Vehicle Emissions Control Strategy and Action Plan

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ICLEI Local Governments for Sustainability AFRICA

Report prepared for the City of Johannesburg, Transport Department: Air Quality Unit

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This Vehicle Emissions Control Strategy and Action Plan is compiled on behalf of the City of Johannesburg's Environment and Infrastructure Services Department, and in consultation with the National Department of Transport, Department of Environment, Fisheries and Forestry, Provincial Department of Transport, Gauteng Department of Agriculture and Rural Development, City of Johannesburg Transport Department, City of Johannesburg Development Planning, City of Johannesburg Environment and Infrastructure Services Department, and Johannesburg Roads Association

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List of acronyms

AQMP	Air Quality Management Plan
CBD	Central Business District
CH_4	Methane
CO	Carbon monoxide
CoJ	City of Johannesburg
DoT	Department of Transport
EEA	European Environmental Agency
eNATIS	Electronic National Administration Transport Information System
ESS	Environmental Sustainability Strategy
GDS	Growth and Development Strategy
HOV	High Occupancy Vehicles
JRA	Johannesburg Roads Association
NAAMSA	National Association of Automobile Manufacturers
NAAQS	Nations Ambient Air Quality Standards
NO_2	Nitrogen dioxide
NOx	Oxides of Nitrogen
PM_{10}	Particulate Matter with an aerodynamic diameter ≤ 10 µm
$PM_{2.5}$	Particulate matter with an aerodynamic diameter ≤ 2.5 µm
SO_2	Sulphur di-oxide
SUV	Sport Utility Vehicles
TOD	Transit Oriented Development
VECS	Vehicle Emissions Control Strategy
VOC	Volatile Organic Compounds

1. INTRODUCTION

1.1. Background

The City of Johannesburg (CoJ) has recently completed the review of their 2003 Air Quality Management Plan (AQMP). The 2019 AQMP identifies four critical sources of air pollution that contribute negatively to air quality within the City which includes, mining, vehicle emissions, domestic fuel burning and industrial emissions. The City of Johannesburg is one of the cities with the highest traffic volumes and congestion in the country. Vehicles, traffic and congestion play a significant role in reduced air quality and currently no plan is in place to manage vehicle emissions within the city. The draft AQMP proposed the development of vehicle emissions control strategy that will provide a holistic approach to deal with transport emissions. In response, ICLEI Africa is supporting the CoJ to develop the Vehicle Emissions Control Strategy (VECS) and action plan which constitutes short-medium and long term actions that aim to control and mitigate the contribution of vehicles on poor air quality. The development of this VECS and action plan was through the following major stages:

i. Conducting an analysis on the status quo of air quality and vehicle emissions in the City of Johannesburg. This included a comprehensive overview of interventions implemented nationally and globally as well as a legal review of South African legislation pertaining to vehicle emissions and air quality. To this effect, a status quo report as well as the legal review document were developed and should hence be consulted for further details.
ii. Conducting a vehicle emissions scenario modelling exercise to inform intervention prioritization based on impact. Also, a modelling report was developed to this effect and should be consulted for more details.
iii. And finally, developing a Vehicle Emissions Control Strategy and Action Plan, which includes various interventions, barriers and solutions to implementation of control actions, and alignment of actions to existing strategies. This was developed based on the findings of the status quo report, the modelling report as well as the legal review.

The proposed Vehicles Emissions Control Strategy and Action Plan resonates with national and the CoJ's broader sustainable development agenda depicted in the National Development Plan, Growth and Development Strategy (GDS): Joburg 2040, CoJ Integrated Development Plan (2020/21 review) and CoJ Environmental Sustainability Strategy and Action Plan (2019), amongst others and highlighted section 2 of this document.

1.2. The purpose and focus of this report

The purpose of this report is to consolidate the research and activities done to date on air quality and vehicle emissions through this programme. This includes extracting relevant information from the desktop studies that were done through the *Vehicle Emissions Control Strategy: Status Quo* report that provides an overview of the main causes and aggressors of

vehicle emissions in the city along with a review of related policies and strategies that aim to manage and reduce vehicle emissions.

Further, it provides the deliberations on transport emissions scenario modelling on selected interventions and the outcomes of their impact on reducing vehicle emissions and improving air quality. In doing so, it provides a basis for the prioritization of interventions by their level of impact. These are then aligned to existing policies and strategies, analysed according to the level of investment and time required, as well as barriers and enablers to implementation.

Lastly, the report provides an action plan that was co-developed with stakeholders from a number of departments within CoJ and from other tiers of government. The action plan plots the implementation of control actions in the short- medium and long-term.

1.3. Aligning to existing commitments, strategies and policies

1.3.1. The City of Johannesburg Air Quality Management Plan

The development of the VECS and Action Plan is mostly motivated by the City's air quality management plan as detailed below.

AQMP Vision

A significant component of air pollution in Johannesburg is derived from vehicle emissions. This is due to a sprawling urban area and spatial form, and increasing migration as people from other provinces, and other African countries, move to Johannesburg, the economic hub of Southern Africa. The result is that vehicle emission are set to rise as the city sees an increase in vehicle activity. The 2003 AQMP vision statement highlights that in order to achieve optimum air quality management, it is important to adopt a coordinated approach to the control of air pollution and the sustainable development of the built environment and transportation within the City (CoJ, 2003).

The CoJ has compiled two comprehensive Air Quality Management Plans (AQMP), one in 2003 and the other in 2019. Both highlight vehicle tailpipe emissions as one of the most significant emerging air pollution issues in Johannesburg. The 2003 AQMP had anticipated that the increase in vehicle traffic (volumes) and congestion rates would elevate the concentration of NOx, CO and O_3 measured within the city. Due to the lack of available localized air quality data when compiling the 2003 AQMP, the recommendations focused on enhancing the understanding of contributors to poor air quality.

The establishment of the air quality monitoring network in 2004 and the data gathered from this allowed the 2019 AQMP to take on a more technical and evidence-based approach,

leading to a better understanding of the status of air quality in Johannesburg and finding solutions from cross-sector collaboration accordingly. However, the data received from the air quality monitoring network remains limited due to the lack of air quality monitoring stations available to measure air quality attributed to vehicle emissions.

The visions statement for the current AQMP, and to which this strategy and action plan aims to align with, is to:

"…achieve acceptable air quality levels in the City of Johannesburg. This can be defined as air quality levels that; comply with National Ambient Air Quality Standards (NAAQS), supports liveable, sustainable and resilient communities, and is odourless, tasteless and looks clear".

Fulfilling the AQMP

The AQMP (2019) articulated that the manifestation of the vision, mission and objectives were hindered by a number of gaps and limitations in the air quality management system. It therefore put together the following recommendations to improve air quality monitoring:

- Scheduled maintenance occurs more frequently as this will limit the number of non-operational monitoring stations and improve data recovery.
- Consolidate management system documentation. Further, applying an international standard such as ISO 17025:2005 as well as the draft requirements in the Norms and Standards for Air Quality Monitoring to management system documentation.
- Develop a Standard Operating Procedure for data management to ensure consistency of data processing and validation.
- Emphasis needs to be placed on understanding the traceability requirements of the measurements and this should feed through to procedures on calibration and criteria for the selection of service providers and supplies calibration relevant materials.
- Develop a consolidated approach for planning and training of technical staff to ensure the required skills are available.
- The micro-siting of some stations need to be evaluated and impedances to the airflow addressed.

Also, data disaggregation for reporting on vehicle emissions and the continued evaluation of vehicle emissions has been lacking. To this end, it would be valuable to establish a dedicated vehicle emissions monitoring programme to respond to these challenges as well as ascertain whether interventions

implemented are effective in reducing vehicle emissions. This will also provide opportunities to involve other external stakeholders such as academia for future assessment studies.

Furthermore, vehicle emissions inventory plays an important role in providing an up to date overview of the emissions sources within the CoJ such that management may be directed and modelling may be appropriately informed regarding source characteristics and magnitude of emissions. Emission inventories enable cities to track changes in emissions, identify emission trends and direct the implementation of mitigation measures.

The Environmental Governance Cycle, indicated in Figure 1.1, is the lens and approach that the CoJ intends to take in order to implement its air quality management goals. The cycle highlights overarching activities necessary to manage and improve air quality, as well as research and information required to inform this cycle.

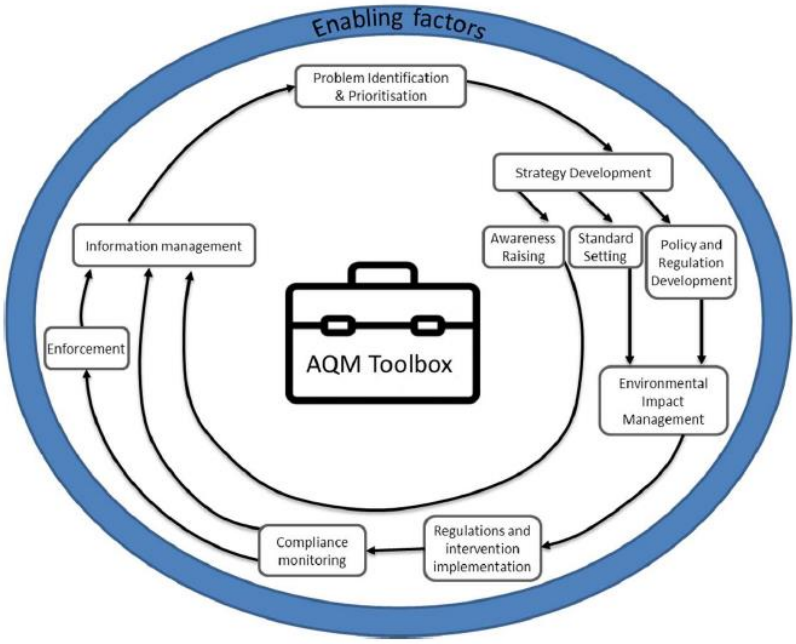


Figure 1.1: The Environmental Governance Cycle (source AQMP, 2019)

In order to fulfil the AQMP, enabling factors and air quality management tools such as air quality monitoring play a critical role in facilitating the application of the environmental governance cycle.

1.3.2. Existing strategies, policies and plans

South Africa has made commitments under the Paris Agreement to reduce Green House gas emissions to between 398 and 618 MT CO_2e by 2030. The transport sector remains a significant contributor to South African emission statistics. As of 05 June 2019, the South African government announced the

implementation of carbon tax of 9 cents per litre and 10 cents per litre on petrol and diesel, respectively, as a step towards achieving these emission targets (Kumalo, 2019). Table 1.1 below is a summary of existing policies in South Africa that support the reduction of vehicle emissions.

Table 1.1: Existing policies and plans supporting the reduction of vehicle emissions in South Africa

Key documents for vehicle emissions	
National strategies	
The Green Transport Strategy (2018-2050)	The Green Transport Strategy (GTS) is South Africa's governmental guidance document that provides pathways to decarbonize the country's transport sector. The Strategy proposes interventions that aim to improve the conditions of existing vehicles on the road, as well as New vehicle fuel-efficiency standards, which are equivalent to CO_2 emission standards, and one of the pillar programs of the GTS action plan.
City level strategies These strategies outline sustainable approaches to achieving better air quality, lower pollution levels, improved city planning and traffic management with the overarching goal of becoming a smarter greener and more resilient city as urbanization grows.	
Growth and Development Strategy: Joburg 2040	The GDS 2040 envisions a city that is resilient, sustainable and liveable, thereby requiring the CoJ to align, integrate, institutionalize and strengthen its climate change action across sectors. This strategy provides the overarching strategic vision for the City, identifying priorities and key challenges, growth targets, and a broad vision for the future City. This strategy forms the basis for future growth and considers long term strategies and growth priorities that ensures future development and action plans reduce harm to the environment, manages scarce resources and provides services efficiently that are supported by appropriate infrastructure networks. Further, it aims to promote energy efficiency and reduce carbon emissions while stimulating a green economy and protecting the most vulnerable segments of society. This is further highlighted in the GDS's principle 4 that aims to ensure resource security and environmental sustainability committing the CoJ to transition to a low carbon economy to achieve healthy urban environments and environmental sustainability where transport plays a significant role in achieving this. It looks to implementing smart infrastructure that aids the management of scarce resources and uses technology effectively for data collection, monitoring, evaluation and integration. In addition, local governments should play an active role in instigating close communication and collaboration with various role-players to ensure the collective action of mandates and development plans. Some key aspects of this strategy assess transport by proposing the future development of public transport and encouraging behaviour change to move people from private car use to public transport and non-motorized transport. This is done with the perspective that spatial planning and enhanced public transport will play central role in encouraging these shifts. Further, the City of Johannesburg's commitment to Climate Change Mitigation and Adaptation is clearly defined in the Growth and Development Strategy 2040 (GDS).

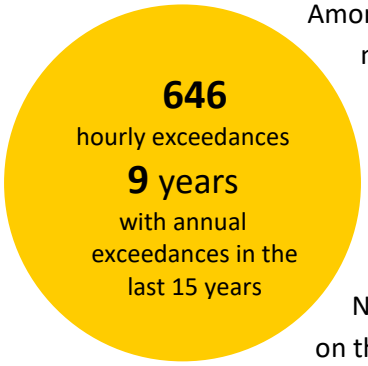
Environmental Sustainability Strategy (ESS) and Action Plan (2019)	The ESS forms the basis to ratify and institutionalise environmental sustainability more strongly into the COJ's sustainable development agenda and makes it a collective responsibility across mandates. It identifies key environmental issues and sets strategic objectives and actionable steps that respond to these. The ESS is the overarching environmental sustainability strategy by which sectoral policies, strategies and plans are required to use as a reference point to inform and drive sustainability within their domain, influencing programmes and subsequent projects. Sector plans should report progress on their sustainability objectives against this strategy The ESS identifies rapid urbanisation and informality, and CoJ as a major contributor to GHG emissions as key environmental challenges, both of which relate to transportation infrastructure and services. It further states that regular updates to GHG inventory for the CoJ must be actioned.
Climate Change Strategic Framework, City of Johannesburg (CCSF-CoJ, 2015)	The Climate Change Strategic Framework acknowledges current and past work in a coherent framework that provides a structured approach towards detailed strategies and action plans for mitigation and adaptation. In this framework, the transport sector is identified as a major consumer of energy and the largest contributor to GHG emissions. While the transportation sector is critical for economic growth and development of the city, the Framework notes the potential impact that climate change can have on infrastructure in the future and that this should be considered when planning transport infrastructure. The document further recognizes that transportation in the city also encompasses the relationship between the concepts of sustainable human settlements and mobility. As such, there is a strong focus on transit-oriented development (ToDs) and the promotion of public transport and access to mobility in support of resilience and sustainable development. A flagship project is the Rea Vaya bus rapid transit system offering fast, safe and affordable public transport on a network of bus routes across Johannesburg.
Integrated Transport Network Plan (2013-2018)	The Integrated Transport Network Plan for the City of Johannesburg is comprised of a Strategic Integrated Transport Framework for a 5-year period (2013-2018), as well as an overarching transportation plan for the city. The aim of the framework is to highlight the status quo and give an overview of some of the major developments and shortcomings of the transport sector in the previous decade and to outline the City's objectives and vision for its transport system and the strategies which it intends to pursue to achieve them. A high-level spatial network was developed which shows the main corridors and routes for public transport, freight and cycling and walking. The Plan is structured in nine thrusts of transport development. The City's approach to reducing and controlling traffic growth is to focus on mobility for people and goods, not vehicles per se. It puts forward a number of interventions and approaches for improving the transport sector in the City, and in turn reducing vehicle emissions.
Corridors of Freedom (2013), incorporated into the Spatial Development Framework (2016)	The City of Johannesburg's flagship project *Corridors of Freedom (CoF),* launched in 2013, strongly advocated for Transit Orientated Development (TOD) that visualized the re-spatializing of the CoJ for socio-spatial equality. The TOD development approach aims to create urban densification areas through mixed-use development that focused on ease of movement and reducing the economic and spatial disparity caused by apartheid urban planning policies. Further, high intensity mixed land uses would include housing, economic and social infrastructure, all within walking distance of a

	transit station or within a transit corridor. The plan is comprehensive in its understanding of TOD and considers socially inclusive and environmentally sustainable transport and city planning solutions that encourage greater use of public transport and non-motorized transport. Although no longer an official strategy, its principles have been incorporated into the CoJ's Spatial Development Framework (CoJ, 2016) that continues to propel TOD into future spatial development plans, focused on creating an urban form that is compact resulting in a city that is energy efficient, provides residents with greater access, promotes social cohesion and creates a vibrant urban environment.
The National Household Travel Survey (2013)	The National Household Travel Survey (2013) conducted by Stats SA found that the average travel time between home and work for commuters making use of public transport is 59 minutes. More than 1.3 million South Africans spend more than two hours a day travelling to and from their places of residence. To this can be added at least 30 minutes per trip spent on walking towards a station and stop and waiting for the bus or train to arrive.

1.4. The origin and impact of key vehicle pollutants

There are a number of pollutants that are produced through fuel combustion in vehicle engines. The origin and impacts of the pollutants are discussed below.

a) Nitrogen Oxide



Among the air pollutants petrol and diesel engines emit are oxides of nitrogen—NO and NO_2, generically abbreviated as NOx. Nitrogen oxides have harmful direct effects on human health, and indirect effects through the damage they do to agricultural crops and ecosystems.

The amount of NOx formed during combustion varies with peak combustion temperature: as temperature rises, so does the rate of NOx formation. Combustion temperature tends to increase as the load on the engine increases—for example, when accelerating rapidly or driving uphill. Diesel cars will sometimes feature lower combustion temperatures than gasoline engines because the air-fuel mixture of diesel combustion contains a higher proportion of air. Some of the oxygen will act as a heat sink, and the engine therefore will produce less NOx in all operating modes than petrol engines do. NO_2 is present in areas where there's high volumes of traffic, particularly where there's a lot of movement to get in and out of areas of main economic activity, such as highways (N3, N1, M2, M1).

b) Carbon monoxide

14
8-hour exceedances in 2014

Carbon monoxide is an odourless and colourless gas. CO in the air is inhaled by the lungs and transmitted into the bloodstream. It binds to haemoglobin and inhibits its capacity to transfer oxygen. Depending on CO concentration in the air, as thus leading to asphyxiation, this can affect the function of different organs, resulting in impaired concentration, slow reflexes, and confusion.

Carbon monoxide results from incomplete combustion and is determined by the air/fuel mixture where there is less excess air. The generation of CO can be caused especially at the time of starting instantaneous acceleration of engine where a sufficient mixture of air to fuel is are required (Faiz et al. 1996).

c) Particulate matter

329
daily exceedances
9 years
of annual exceedances in the last 15 years

Particulate matter emissions in the exhaust gas are resulted from the combustion process. They may originate from the accumulation of very small particles of partly burned fuel, partly burned lube oil, ash content of fuel oil, and cylinder lube oil or sulphates and water (Demers and Walters 1999; Maricq 2007). Most particulate matters result from incomplete combustion of the hydrocarbons in the fuel and lube oil and can be attributed to poor engine maintenance (Reşitoğlu, Altinişik and Keskin, 2015).

$PM_{2.5}$ can penetrate the lung barrier and enter the blood system. Chronic exposure to particles contributes to the risk of developing cardiovascular and respiratory diseases, as well as of lung cancer. Particles with a diameter of 10 microns or less, (≤ PM10) can penetrate and lodge deep inside the lungs, the even more health-damaging particles are those with a diameter of 2.5 microns or less.

2. STATUS QUO OF VEHICLE FLEET AND VEHICLE EMISSIONS IN THE CITY OF JOHANNESBURG

2.1. Air Quality in the City of Johannesburg

The transport sector in the City of Johannesburg accounts for around 40% of emissions in the city. Greenhouse Gas Emissions Inventories taken for 2007 and 2014 show that, although the City's emissions have reduced by 5.3% between 2007 and 2014 (from around 27.2 million tCO_2-eq in 2007), there has been a considerable increase in emissions in the transport sector, up by 26%. This is predominantly attributed to road transport and the reliance on private vehicles.

The state of ambient air quality in the City, as summarised in the Air Quality Management Plan (CoJ, 2019) and in Table 2.1, indicate that a number of air pollutants, in relation to the National Ambient Air Quality Standards (NAAQS), are above standards. Traffic sites Buccleuch and Delta Park experience the largest exceedances of NO_2 and O_3, respectively, and these directly correlate to traffic volumes and vehicle emissions.

Table 2.1: Summary of CoJ's ambient air pollutant concentrations

Pollutants	Summary of ambient concentrations
Sulphur dioxide (SO_2)	Ambient concentrations of SO_2 are relatively low in the CoJ, with occasional exceedances of the limit value of the ambient standards, but there are no exceedances of the allowed frequency of exceedances.
Nitrogen dioxide (NO_2)	Concentrations are high surrounding the major highways and traffic zones. The largest number of exceedances in the areas where the Buccleuch and Newtown monitoring stations are situated.
Particulate Matter (PM_{10})	Concentrations of PM_{10} are generally highest at the station located within low-income areas. Concentrations frequently exceed the daily and annual ambient standards at these stations.
Particulate Matter ($PM_{2.5}$)	There are only data available from the Buccleuch station for the period 2004 to 2015. There are, however, exceedances of the daily and annual ambient standards during these years.
Carbon Monoxide (CO)	Ambient concentrations of CO are relatively low throughout the CoJ.
Ozone (O_3)	Ambient concentrations are relatively high within the vicinity of the Delta Park station, with a number of exceedances of the 8-hour running average ambient standard.
Benzene (C_6H_6)	A limited amount of data for the ambient concentrations of benzene was only available from the Buccleuch monitoring station.
Lead (Pb)	Ambient concentrations of lead have decreased significantly throughout the country and are no longer monitored in most ambient monitoring networks.

2.2. Determinants of vehicle emissions in the road transport sector and status quo at the City of Johannesburg

Vehicle emission are determined by a number of factors, amongst which are the characteristics of traffic, vehicle types and type of road intersections, age of a vehicle, and condition of its engine, type and condition of emission control equipment, engine characteristics, vehicle maintenance, and weight amongst others. Engine size also affects the functioning of emission control equipment (Beydoun, 2004). Also, the fuel quality has a direct effect on the vehicular exhaust emission (Perry and Gee, 1995). All these factors have an influence on the type and composition of vehicle emissions.

Over the years, the CoJ has experienced an increase in vehicles on the road, as indicated in Figure 2.1. Up to 5% of vehicles are unregistered, making up a significant proportion of vehicles that are undocumented. This means there's less information available on them in terms of age, maintenance and resultant vehicle emissions.

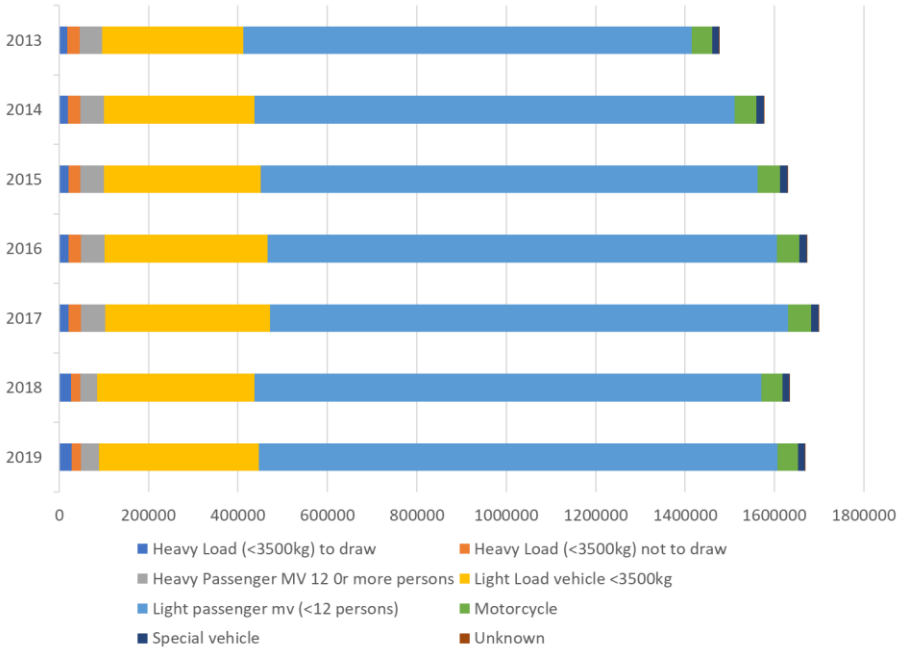


Figure 2.1: Vehicle registrations in CoJ (E-Natis, 2019)

The following section summarises **vehicle** and **traffic** aspects that have an impact on vehicle emissions which will form the basis for interventions modelling and selection.

2.2.1. High Emitters

High emitters are vehicles that contribute to total vehicle parc emissions far out of proportion to their numbers (Stone, 2009). They are very often older vehicles that have not been maintained properly or vehicles that continue to operate despite major malfunctioning of their emissions control systems.

In the developed world, high emitting vehicles may account for up to 10% of the total vehicle parc and yet, contribute more than 50% of the emissions of vehicles on the road. In comparison, the number of high emitters in the South African parc likely exceed 10%, indicating that the proportion of emissions that high emitters account for could be considerably higher than these estimates.

2.2.2. Fleet composition

The type of vehicles on the road influence the quantity and composition of emissions from those vehicles. The emissions from vehicles differ due to the fuel used, fuel efficiency of the vehicle, weight of the vehicle, maintenance of the vehicle as well as any fuel additives or additional catalytic converters fitted to the vehicle. Table 2.2 below shows the composition of e-NaTIS data on registered vehicles (2019) in Johannesburg registering station, Gauteng.

Table 2.2: Vehicle composition and age for Johannesburg (e-Natis data, 2019)[1]

Vehicle type	Total nº registered at licensing centre	Average age	Fuel type			
			Petrol	Diesel	Other fuels	"None and unknown"
Passenger vehicles (motor cars and station wagons)	1238283	15.39	81.77%	15.50%	0.25%	2.49%
LCV (panel vans, other light load and light trailers with GVM <= 3500kg	445722	17.08	28.65%	20.74%	0.68%	49.90%
Buses, bus trains and midi-buses	7173	13.28	5.57%	94.33%	0%	0.10%
HLVs (heavy load trucks and trailers above 3500kg)	53097	14.1	2.94%	63.89%	0.06%	33.12%
Minibus	52686	19.28	71.02%	28.64%	2.00%	0.31%
Motorcycles, Quadricycles, Tricycles	51514	12.88	97.84%	0.50%	0.19%	1.46%
Caravans and other self-propelled	17808	18.44	13.10%	50.31%	1.01%	35.57%

2.2.3. Age of vehicles

The use of older vehicles combined with poor maintenance and monitoring procedures can contribute to a higher proportion of high emitter vehicles on the road. A TransUnion report (2018) showed that

- The data on table 2.2 represents vehicles registered in the Johannesburg registering station and does not include vehicles registered in other stations in Gauteng province
- *None* and *unknown* refer to what was written under fuel type for some of the registered vehicles as per the eNATIS database, and represents quite a significant percentage
- Other fuels, though very little, represents fuels such as paraffin, steam, solar and electricity

the used-vehicle market outweighs the new car market in South Africa by more than 2:1 and offers a better price increase average, making used vehicles the most viable option for most car buyers in the country (TransUnion, 2018).

An analysis of vehicle registration data was conducted for 2019 over a period of 18 month in Gauteng using available data from the e-NaTIS database. From this analysis it was observed that there is a higher proportion of used vehicles being registered in Gauteng over this period, (see Figure 2.2), with the trend extending several years in the past. While there are no clear indicators of the year, make and model of the used vehicles because of inconsistencies in the way that the data is captured, the re-registration of used vehicles indicates that the vehicle parc for Gauteng is indeed aging, and subsequently decreasing in fuel efficiency. An alternative to completely removing old vehicles from the road is the retrofitting and regular maintenance of vehicles to ensure that engines are maintained to reduce vehicle emissions.

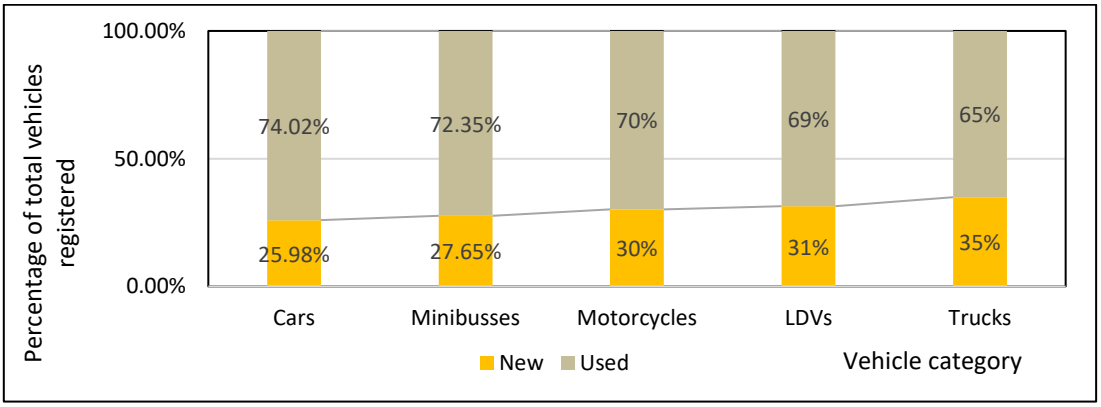


Figure 2.2: Average proportion of new and used vehicles for Gauteng (e-Natis, 2019)

Vehicle age is another important determinant of emissions from road transport. As demonstrated in Figure 2.3, over 50% of the vehicles in the eNATIS database registered under Johannesburg registering station are less than 10 years of age, with about 17% of the vehicles older than 20 years.

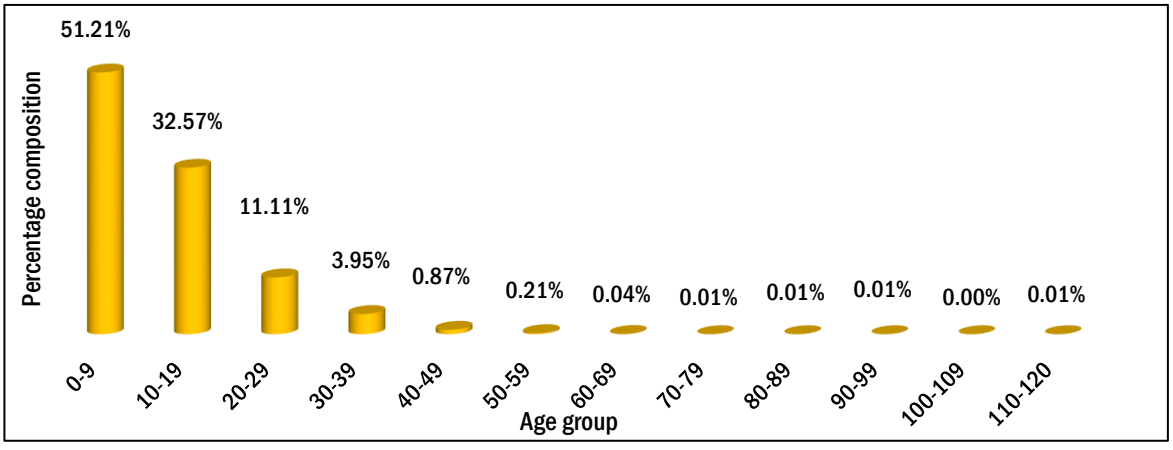


Figure 2.3: Vehicle categorisation in Johannesburg by age group

2.2.4. Fuel efficiency

With regard to fuel use, about 17% of all passenger vehicles in SA are sold with a diesel engine. Sales of diesel vehicles are heavily focused on the SUV segment. Volkswagen and Toyota are the highest sellers of diesel vehicles in absolute terms; Daimler and BMW have the highest share of diesel vehicles sales compared to all other manufacturers.

Average CO_2 emissions of new passenger cars in South Africa, tested under the NEDC test cycle, was 148 gCO_2/km in 2015. The equivalent metric in terms of fuel consumption is 6.3 L/100 km. Disaggregating the data by fuel shows that diesel passenger vehicles emit about 14.4% more CO_2 per km than the average gasoline vehicle; this is explained by a much wider use of diesel engines in SUVs, which are on average the heaviest and highest rated power vehicles in the fleet. South Africa's passenger car fleet average CO_2 emissions are about 21% higher than EU's fleet average emissions of 121 g/km. This large difference is highlighted by the fact that SA's fleet is 5% lighter than the European fleet. Comparing CO_2 emissions performance by manufacturer shows a significant gap between the European and South African models. Toyota presents the highest CO_2 gap between regional fleets of 43%, which is partially explained by an SUV preference in South Africa and also by reduced access to highly efficient vehicle technologies.

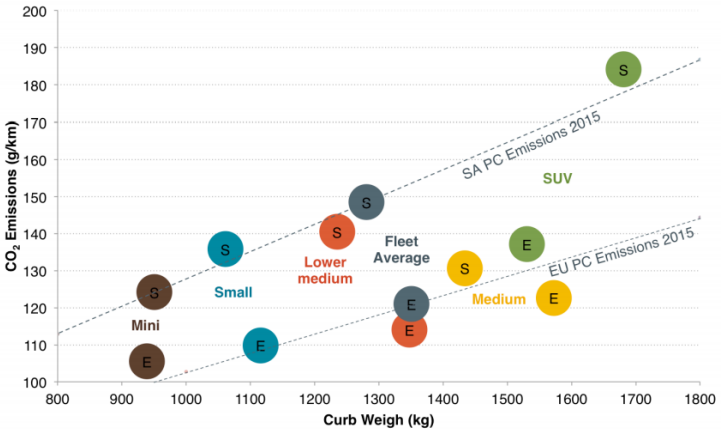


Figure 2.4 Average new vehicle sales-weighted CO_2 emissions as a function of curb weight by segment of passenger vehicles– all fuels (ICCT, 2015) S – South Africa; E – Europe

2.2.5. Fuel Types

The gaseous and particulate emissions from motor vehicles, particularly petrol fuelled vehicles, are a major source of impacts from transport. Diesel light vehicles typically produce in the region of 10% less CO_2 than petrol fuelled equivalents; however in some recent passenger car models from the South African market, vehicle size generally has a much greater impact on emissions. This is because larger vehicles will consume more energy when accelerating because of their higher mass and in certain cases, are less aerodynamic and have more rolling resistance due to bigger tyres (Reşitoğlu, Altinişik and Keskin, 2015).

Diesel engines are extensively used in freight and heavy vehicle use compared to gasoline engines on account of their low-operating costs, energy efficiency, high durability and reliability. However they have a significant impact upon environmental pollution problems worldwide. Moreover, diesel

exhaust gas contains higher amount of particulate matter and NOx emissions that are responsible for severe environmental and health problems (Reşitoğlu, Altinişik and Keskin, 2015).

Gasoline vehicles are the main consumer choice among South African consumers, with 82.9% of the new vehicle market. Diesel is the second largest fuel option, taking 16.9% of sales. Sales of advanced fuel-efficient vehicles, such as hybrids, had a very small market share in 2015, with 0.1% or 512 units. Only 79 electric vehicles were sold in SA in the period studied by the ICCT (2015).

2.2.6. Maintenance

The correct maintenance of a vehicle can drastically reduce fuel consumption and emissions, regardless of fuel type. In a petrol vehicle, this includes tuning the engine correctly (4% efficiency gains), frequently replacing air filters (10% gains), having the correct tyre pressure (3% gains) and using the correct motor oil (1-2% gains) (Vanderschuren et al., 2008). There is little data on the condition of vehicles on the road. While most new vehicles are guaranteed to be serviced for at least 3 years after purchase, the used-vehicle market is potentially less well maintained. This is particularly true for older vehicles bought by individuals that are financially unable to maintain their vehicles. As a proxy for maintenance data, the number of used vehicle sales and the age of these vehicles can give an indication that there is a significant percentage of older vehicles on the road that are more likely to be poorly maintained. There is potential to incentivize vehicle maintenance through policies that involve rebates on licensing or administration fees when these measures are taken out on a registered vehicle

2.2.7. Vehicle emissions related to traffic/congestion

Steady growth in the number of vehicles has put environmental stress on urban centres in various forms, particularly causing poor air quality. The severity of the problem arises when the traffic flow is interrupted and the delays and start–stops occur frequently. These phenomena are regularly observed at traffic intersections, junctions, and at signalized roadways. As a result, queuing of vehicles, stopped-delay at the signals, rates of traffic flow in various idle, acceleration, deceleration, and cruise driving modes often occur. These traffic related characteristics, combined with road and vehicle characteristics, raise emissions at traffic intersections (Pandian, Gokhale and Ghoshal, 2009).

In the City of Johannesburg, Nitrogen dioxide maximums closely coincide with the City highways (N3, N1, M2, M1) and the CBD being particularly high along the Eastern Bypass, the M2 and main entry road to the south of the inner city, and the section of the N1 between the Beyers Naude off-ramp and the interchange with the Eastern Bypass. The zones of maximums thus coincide closely with the areas of high vehicle activity being particularly high at roadway sections noted by the iGoli 2010 Traffic Study to be problematic in terms of congestion (City of Johannesburg, 2003).

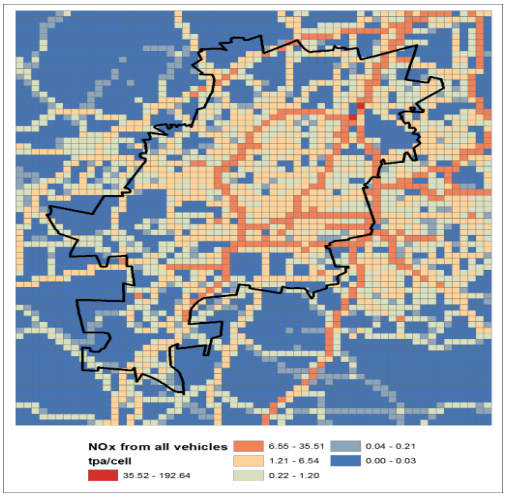


Figure 2.5: NOx emissions in CoJ (CoJ, 2016)

Further, air quality monitoring outputs as set out in the AQMP indicate that the traffic sites (Buccleuch , Newtown and Delta Park) display the same distinct diurnal and seasonal profiles, where peaks in NO, NO_2, NO_X, O_3, PM_{10} and CO occur in the mornings and evenings and during the colder winter months (June, July and August). This pattern coincides with the increased traffic volumes during the peak morning and early evening traffic periods that occur at approximately the same times, approximately 06h00 in the morning and 18h00 in the evening. A further distinct signal, which is indicative of traffic flows, is that the same pattern that occurs in the weekday profiles of NO, NO_2, NO_X, PM_{10} and CO, except for O_3, display a decrease in the concentrations on Saturday and Sunday, when there is generally fewer people commuting to work and thereby less vehicular traffic.

2.3. Air Quality Monitoring in the City of Johannesburg

The City of Johannesburg's Air Quality Monitoring Plan states that the purpose of the monitoring (CoJ, 2015) is "to determine the ambient concentrations of criteria pollutants within the city, in comparison with the National Ambient Air Quality Standards in order to assist the city with the following:

I. Making informed decisions regarding the measures required to human health and the environment
II. Provide air quality information for strategic and policy development by the city and municipal owned entities and
III. To assess the effectiveness of policy and strategic interventions on trends in air quality"

CoJ's ambient air quality monitoring network was first established in 2004. Six monitoring stations were initially set up in Alexandra, Buccleuch, Delta Park, Jabavu, Newtown and Orange Farm. Expansions of the network occurred in 2009 and 2015, with the inclusion of the Diepsloot and Ivory Park stations and then the mobile station in Davidsonville, respectively. The monitoring network, initially a total of nine stations, now consists of a total of eight stations after Newtown was shut down. A summary of monitoring stations is listed in Table 2.3 below as well as on Figure 2.6. Each monitoring

station captures the types of pollutants that are expected to be of concern according to the location of each station.

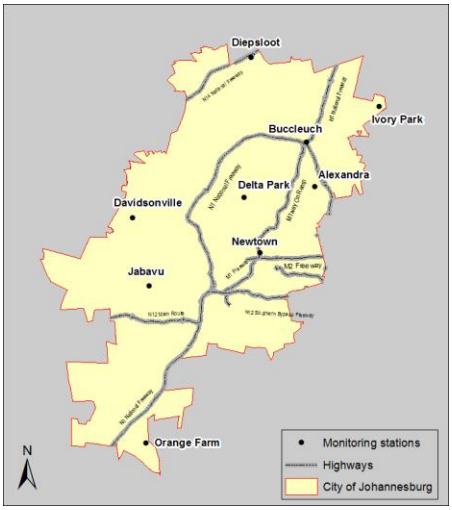


Figure 2.6: Position of Air Quality monitoring stations in relation to CoJ main roads

Although air monitoring stations are well distributed throughout the city, there is a greater focus on capturing the air quality near low income communities where domestic burning of fuels is a major contributor to air pollution in the city. Buccleuch and Delta Park are earmarked as traffic sites, with Buccleuch being the main station that captures vehicle emissions given that it is in the middle of a well-trafficked intersection. With the closure of Newtown and only two remaining stations available for air quality monitoring related to traffic, there is a gap in the monitoring of vehicle emissions. An increase in the number of monitoring stations along major traffic routes would be useful to increase the understanding of air quality related to vehicle emissions.

Table 2.3 : Air Quality Monitoring Stations in the City of Johannesburg

Monitoring station	Co-ordinates	Location Rationale	Parameters Measured	Status 2015	Status 2020
Buccleuch	**Latitude:** 26^{0}02'42.7"S **Longitude:** 28^{0}05'56.6"E Altitude: 1513m	The station is located at the intersection of N1, N3 and M1. It is meant to measure the effects of vehicle emission on ambient air quality in the area.	PM_{10}, $PM_{2.5}$, SO_2, NOx, O_3, Meteorology	Not operational due to power problems	Operational
Alexandra	**Latitude:** 26^{0}06'24.5"S **Longitude:** 28^{0}06'36.8"E Altitude: 1522m	The station was sited to measure the effect of emissions from domestic fuel burning on ambient air quality in the area. A significant proportion of households in the area, use coal and biomass for space heating and cooking purposes.	PM_{10}, SO_2 (Open path analyser), meteorology	Not operational – has been shut down since 2010	Operational
Delta Park	**Latitude:** 26^{0}07'30.0"S **Longitude:** 28^{0}00'31.0"E Altitude: 1587m	This station was intended to be used as a background urban station and is located with the Delta Park Environmental Centre. This station is not exposed to any direct emissions from air pollution sources, however, measured concentrations at this station compare well with the rest of the stations. The station is therefore no longer representative of the background concentrations.	All instruments have been removed, previously measurements of O_3, NO_X, PM_{10}, Meteorology	Not operation – station has been shut down	Temporal shut down
Orange Farm	**Latitude:** 26^{0}28'48.0"S **Longitude:** 27^{0}52'01.2"E Altitude: 1571m	The station was sited to measure the effect of emissions from domestic fuel burning and other sources, on ambient air quality in the area. A significant proportion of households in the area, use coal and biomass for space heating and cooking purposes.	PM_{10}, SO_2, O_3 Meteorology	Operational	Station has been shut down
Jabavu	**Latitude:** 26^{0}15'10.8"S **Longitude:** 27^{0}52'19.2"E **Altitude:** 1624m	The station is located in Soweto, Jabavu and was also sited to measure the effect of emissions from domestic fuel burning and other sources, on ambient air quality in the area. A significant proportion of households in the area, use coal and biomass for space heating and cooking purposes.	PM_{10}, SO_2, O_3 Meteorology	Operational	Operational
Diepsloot	**Latitude:** 25^{0}55'19.2"S **Longitude:** 28^{0}01'08.4"E **Altitude:** 1439m	The station was also sited to measure the effect of emissions from domestic fuel burning and other sources on ambient air quality in the area. A significant proportion of households in the area, use coal and biomass for heating and cooking purposes.	PM_{10}, SO_2, Meteorology	Operational	Operational
Ivory Park	**Latitude:** 25^{0}59'34.8"S **Longitude:** 28^{0}12'14.4"E **Altitude:** 1566m	The station was sited to measure emissions from domestic fuel burning. A significant proportion of households in the area, use coal for heating and cooking purposes.	PM_{10}, SO_2, Meteorology	Operational	Operational
Davidsonville	**Latitude:** 26°09'16.13"S **Longitude:** 27°50'52.7"E **Altitude:** 1697m	This is a mobile station that is located in Davidsonville Roodepoort, the station is located to assess community exposure to dust from mine tailings	PM_{10}, Meteorology	Operational	Operations

3. VEHICLE EMISSIONS ESTIMATION AND SCENARIO MODELLING FOR THE CITY OF JOHANNESBURG

In order to develop a vehicle emissions control strategy and action plan, it is important to estimate the current emissions occurring as a result of using vehicles in the city. In the case of the CoJ, this was done using the COPERT vehicle emissions modelling tool. The development of the COPERT tool is coordinated by the European Environment Agency (EEA), in the framework of the activities of the European Topic Centre for Air Pollution and Climate Change Mitigation. The tool was developed for official road transport emission inventory preparation in EEA member countries; it is also applicable to all relevant research, scientific and academic applications. The motor vehicle situation in South Africa is very similar to that of Europe. This is also supported by studies carried out, which depict similarities in emission factors between the South African vehicle fleet and those used in the COPERT tool for calculating emissions in the road transport sector[i], hence the use of the tool in this work.

The modelling work had three main parts: the first part entailed estimating vehicle emissions for the baseline scenario, with 2019 being the base year (as far as possible) since 2019 was the most recent year with the most available data required; the second part was scenario modelling, which entailed modelling the impact of various interventions and comparing to the baseline scenario; and the third part analysed traffic patterns for a number of congested routes in CoJ.

A detailed modelling report has been developed, which provides details on the objective, methodology, challenges, assumptions and findings of the vehicles emissions modelling work for CoJ, The following sections provide a summary of the data needs/sources and key findings from the modelling work.

3.1. Data requirements and data sources for vehicle emissions modelling

The COPERT tool requires a wide range of input data, amongst which are: fuel specifications; fuel consumption; vehicle type, count, category, age; driving speed; vehicle mileage; ambient temperature and relative humidity among others. Sourcing data needed for this task was one of the most challenging phases of the work. Major sources of data included eNATIS (for vehicle count and vehicle specification data), OutScraper (vehicle driving speed), TomTom (congestion rates in the city), SANRAL (vehicle categories and speed on some routes in the city; South African Bureau of Standards (petrol and diesel specifications) and other peer reviewed articles. In areas lacking data, informed assumptions were made, based on stakeholder consultations and peer-reviewed literature. Details on the data requirements, data sources, and challenges encountered in gathering the data needed have been presented on Table 6.1 Annex A of this document. Table 3.1 below is a summary of the data requirements and sources used for vehicle emissions estimation and modelling using the COPERT tool.

Table 3.1: Summary for data requirements and data sources used for CoJ vehicle emissions modelling

Data	Source
Vehicle stock data	• eNATIS database
Traffic data	• Outscrapper • Tom Tom
Traffic volume	• SANRAL vehicle counting stations
Fuel specifications	• South African Bureau of Standards
Environmental conditions	• Accu Weather Website

3.2. Baseline emissions from the road transport sector of CoJ

Outlined below is a summary of the quantity and composition of vehicle emissions in CoJ as a function of vehicle category and pollutant type. These are based on results of baseline emissions from using the COPERT vehicle emissions modelling tool.

3.2.1. Baseline emissions as a function of fuel type used

The quantity and composition of these emissions are a result of a combination of factors. If an engine is 100% efficient, the major products of combustion will be CO_2 and water. However, engines are inherently inefficient, hence products of incomplete combustion are present, for instance, CO and VOCs in petrol engines and CO and VOCs and smoke in diesel engines. Table 3.2 below provides a summary of the quantity and composition of emissions as per the different pollutants. These has also been disaggregated by fuel type used.

Table 3.2: Summary of the amounts of emissions by pollutant type and the percentage contribution from each fuel

Pollutant	Total (tonnes)	% from Diesel	% from Petrol
CO	50223.7	7%	93%
NO_x	36021.1	78%	22%
NO_2	8190.1	96%	4%
NMVOC	7142.8	3%	97%
SO_2	2384.9	62%	38%
PM_{10}	2332.4	68%	32%
Pb	1627.5	66%	34%
$PM_{2.5}$	1416.0	70%	30%
NH_3	1009.1	36%	64%
N_2O	497.6	85%	15%
CH_4	383.9	10%	90%

The emission of CO and NO_x are predominant. Also, the emission of CO, is mostly from petrol-fuelled vehicles. It is also worth noting that 73% of the vehicles in the eNATIS vehicle stock for the CoJ are petrol fuelled vehicles. With CO most often being emitted as the result of incomplete combustion in petrol engines, the dominance of CO particularly from petrol engines is not surprising. On the other hand, the emission of NOx is principally from diesel engines.

3.2.2. Vehicle Emissions as a function of vehicle category:

Figure 3.1 below illustrates the emission of the various pollutants as a function of the respective vehicle categories. As expected, passenger vehicles are contributing the highest to the emissions. This is mainly because the vehicle fleet in the CoJ is dominated by passenger vehicles which account for about 60% of the total vehicle fleet. Hence, any intervention that would reduce the number of passenger vehicles in the CoJ will contribute highly to a reduction in the quantity of emissions and consequently improve the air quality of the city. It is worth noting that minibuses were merged under passenger vehicles for input into the COPERT tool due to limitations of the tool.

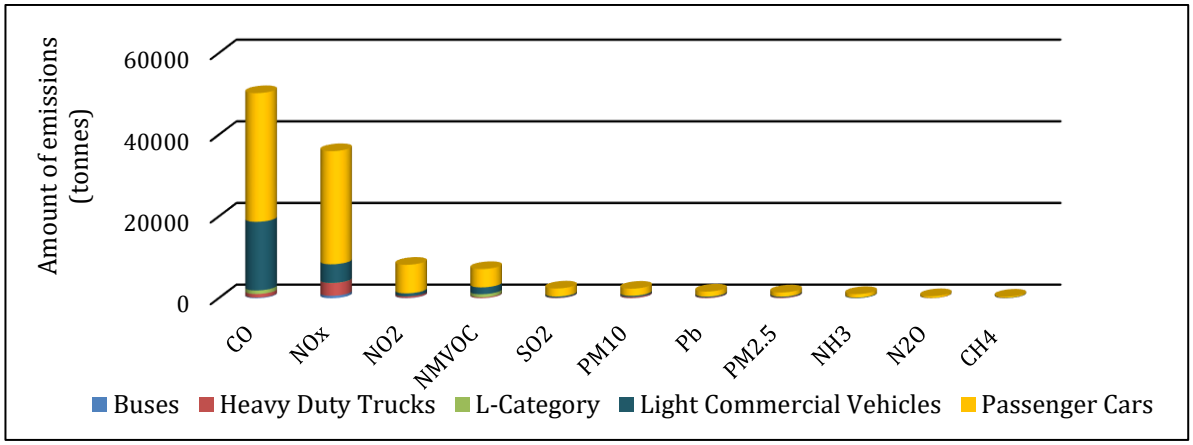


Figure 3.1: Emissions by vehicle category

3.3. Scenario modelling results

As part of the scoping phase of this programme, research done for the *Vehicle Emissions Control Strategy: Status Quo report*, provides a broad understanding of the potential interventions that could be implemented. This was sourced from existing strategies and case studies from other cities. In addition, a benchmarking research section extracted empirical impacts of vehicle emissions interventions in terms of improving air quality through decreasing traffic, lengths of trips, increasing public transport and improving the types of vehicles on the road. The findings of the scoping phase have been detailed in the Status Quo report and should therefore be read in conjunction with this Vehicle Emissions Control Strategy and action plan.

A select number of interventions, presented in Table 3.3 were identified as those that have the potential to have the most significant impact on reducing emissions and improving air quality. These scenarios were later modelled for the CoJ using the COPERT tool.

Table 3.3: Interventions selected for vehicle emission scenario modelling for CoJ

Mechanisms	Scenario	Description
Traffic control	Congestion charges	Reducing traffic volumes in certain areas by charging a fee for entering said zones. This was introduced in certain high traffic areas in London. The city reported a 15% reduction in traffic volume and 30% in congestion.
	High Occupancy Vehicle lanes	Prioritizing road space for vehicles that have more than 3 passengers in a vehicle. Employer programmes which aim to encourage the use of alternative transport, such as public or non-motorised transport or car-pooling, to get to work. This could include preferential parking for those carpooling, subsidies for public transport tickets, guaranteed ride home and reduced subsidized parking for single occupancy vehicles.
	Low Emission Zones	Vehicles travelling within low emission zones that do not comply with vehicle emission standards will be charged a fine.
	Decreased daily Mileage	Reducing the kilometres travelled by car through public transport interventions, promoting a transit oriented city and integrating transport and land-use planning to effectively include mixed use development.
Vehicle Emissions	Improved Fuel Efficiency and Fuel grades otherwise referred to as compliance with stricter vehicle emission standards	Promote fuel efficient vehicles by showing benefits thereof, as well as improving the quality of fuel purchased and sold to consumers.
	Reduction in the number of high emitters	High emitters are older vehicles that have high mileage and are usually poorly maintained. This requires further targeted interventions that look at environmental performance and emissions testing on existing vehicles through maintenance programmes/incentives and roadworthy testing.

Table 3.4 provides a summary of the input data used in the COPERT vehicle emissions tool to model the impact of various interventions as per the defined scenarios.

Table 3.4: Intervention scenario modelling inputs

	Scenario	Interventions
1	Decreased daily mileage	• vehicle mileage for all vehicle categories were reduced by 10%
2	Congestion charges	• 10% reduction in mileage across all vehicle categories • 10% reduction in passenger vehicles • 5% addition in buses
3	High occupancy vehicle lanes	• 15% reduction in annual mileage of all vehicles and • 15% reduction in the number of passenger vehicles

4	Optimal low emission zones	• 18% reduction in annual mileage • 20% reduction in passenger vehicles
5	Compliance with stricter vehicle emission standards	• all vehicles were shifted to a more recent vehicle emission standard, and the Euro 6 vehicles were unchanged since EURO 6 is the most recent standard
6	Reduction in high emitters	• 5% reduction in the number of vehicles older than 15 years.

The scenario modelling was done using the COPERT vehicle emissions modelling tool, with the input data same as in the baseline scenario, but with changes in the input data as per each intervention. It is worth noting that modelling social scenarios are not as straight forward as technical interventions. Hence, the different interventions modelled below might not be a perfect representation of what is possible in the real world, but have been designed to match what can practically be done as much as possible. This section of the report assesses the impact of various interventions on the emission of each of the pollutants compared to the baseline scenario.

3.3.1. Summary of interventions and their impacts

Table 3.5 below summarises the impact of each intervention on the emission of each pollutant compared to baseline scenario. The intervention with the most significant effect is the compliance with stricter vehicle emission standards, which has a very significant effect on the reduction of CO, CH4, NMVOC and NOx to a lesser extent. It is recommended that South Africa develops and enforces vehicle emission standards for its vehicle fleet. This needs to go hand in hand with enforcing the Clean Fuels 2 regulations given that the South African Clean Fuels 2 specifications are stricter than the Clean Fuels 1 specifications used for this study. This is because higher EURO stage vehicles (e.g. EURO 6) perform appropriately only with correct fuel specifications, and CF2 would allow for this to happen.

Table 3.5: Comparison of percentage reduction in emissions compared to baseline scenario

	Baseline emissions (Tonnes)	Reduction in high emmitters	Congestion charges	HOV lanes	Compliance with stricter emission reduction standards	Optimal low emission zones	Decreased daily mileage
CH_4	384	15%	16%	24%	44%	29%	10%
CO	50224	15%	16%	23%	52%	28%	10%
N_2O	498	1%	18%	26%	2%	32%	10%
NH_3	1009	2%	18%	26%	6%	32%	10%
NMVOC	7143	13%	14%	21%	49%	26%	8%
NO_x	36021	6%	17%	25%	33%	31%	10%
Pb	1627	3%	17%	25%	0%	30%	10%
PM_{10}	2332	4%	17%	24%	4%	30%	10%
$PM_{2.5}$	1416	4%	16%	24%	6%	30%	10%
SO_2	2385	3%	17%	26%	0%	32%	10%

The impacts of the various scenarios and possibility for implementation in the CoJ have been detailed in the section below.

3.3.2. Decreasing daily mileage[2]

Enhanced city planning that contributes to decreasing the daily mileage was modelled by applying a 10% reduction in annual mileage to the baseline scenario. This intervention shows the least significant impact and **reduces emissions by up to 10%.** Interventions that prioritise decreasing the daily mileage could also have a major impact on improving the quality of life for CoJ residents.

3.3.3. Congestion charges

Implementing this intervention based on current 2019 traffic data shows that **congestion charges could reduce emissions by up to an average 17%** when applying a 10% reduction in mileage, 10% reduction in private passenger vehicles and a 5% addition in buses. The reduction in emissions will vary depending on when and the rate at which congestion charges are implemented. Furthermore, the buy-in and uptake of this intervention will depend on the messaging around it and the quick introduction of alternative means of transport. There may be strong opposition to applying congestion charges, therefore seeking context-specific ways to implement along with a variety of measures are imperative. For example, London exempts hybrid vehicles from the tax, while Milan exempts fuel efficient and lower emission cars, and schemes in Norway offer discounts to lighter vehicles. In Singapore the tax varies according to the time of day and the level of congestion on roads. Implementing congestion charges is a long-term solution as experienced by London who saw reduction of emissions over a 10-year period, therefore reduction in emissions may be realised gradually.

3.3.4. High Occupancy Vehicle Lanes

High Occupancy Vehicle (HOV) Lanes on **average reduces emissions by up to 25%**. Implementing HOV Lanes will require a variety of practical solutions and measures geared towards changing citizen behaviour. For example, employer programmes which aim to encourage the use of alternative transport, such as public or non-motorised transport or car-pooling, to get to work. This could include preferential parking for those carpooling, subsidies for public transport tickets, guaranteed rides home and moving away from subsidized parking for single occupancy vehicles. In one study in the United States, 284 $kgCO_2e$ were reduced per year using a fixed price on vehicle kilometres travelled or 627 $kgCO_2e$ reduced per year in a scheme that varied prices based on peak travel times (Rufolo and Kimpel 2008).

3.3.5. Optimal Low Emission Zones

The results of the scenario modelling show that implementing stricter measures such as applying Optimal Low Emission Zones could have **significant impact by reducing emissions by up to an average 30%**.

[2] The analysis for this programme inadvertently took place over the COVID-19 Lockdown period. It would be interesting to see the results of the Lockdown on traffic volumes and therefore air quality in CoJ. Questions remain as to how much will return to normal post-Lockdown, and how this could impact indicators such as daily mileage and traffic volumes in the long-term.

In such a scenario, vehicles that do not meet vehicle emission standards as stipulated by local government by-laws will be charged a fee. In London, small to medium vehicles entering low emission zones that do not comply with emission standards face charges of around $16 per day. Larger vehicles, such as trucks and buses pay heftier fines upwards of $130. Implemented in stages, the first stage of the plan went into effect in the winter of 2017 and within two years, London saw a drop of around 11,000 vehicles every day from the targeted area.

The monitoring required to track compliance with vehicle standards include scanning of licence plates and cross examination of vehicle databases. Other supporting services include enforcement of fines, providing payment facilities and auctioning permit grants where required. Given the challenges faced by South Africa in enforcing existing schemes such as roadworthiness, tolls, general fines and infractions, this issues around resource and capacity must be fully considered and addressed.

3.3.6. Compliance with stricter vehicle emission standards

The outcomes of the scenario modelling show that complying with stricter vehicle emission standards, which includes improving fuel efficiency has a significant impact on **reducing emissions such as CO, NMVOC, CH4 and the NOx by more than an 30%.** Improving fuel economy can be done through applying strict vehicle efficiency standards, introducing fiscal measures, engaging the market and relevant stakeholders and creating awareness to the cost benefits of fuel efficiency to the consumer. Although a Euro 2 fuel efficiency and vehicle tax has been prescribed by National Government, the enforcement thereof remains a challenge. Systems to measure and monitor vehicle emissions through vehicle emissions testing, as implemented in London and Paris through The Real Urban Emissions Initiative (TRUE), is also important in providing real-world data and tracking outcomes of improving fuel efficiency, and the information captured can be used for information and awareness for consumers.

Air quality monitoring again plays a crucial role in understanding the impact interventions have on air quality. In a study on HOV Lanes in Atlanta, Georgia, in the United States, a lack of data on air quality before and after the intervention led the research team to assume two findings, one that suggested a 5% decrease in emissions and the other a 17% increase in emissions (Xu *et al.*, 2017).

3.3.7. Reduction in high emitters

This intervention aims to scrap older vehicles in the vehicle fleet, given that older vehicles are less efficient in fuel conversion and more polluting. The results show that applying a 5% reduction in the number of vehicles older than 15 years, could achieve a reduction of 6% of NOx and 15% of CO.

The scrapping of older vehicles may not be possible given the social and economic impacts of doing so. This intervention is also likely to be met with opposition, non-registration of vehicles and negative socio-economic impacts on citizens who can only afford older vehicles. This intervention should be considered among a variety of strategies to reduce emissions from older vehicles. For example, in response to China's growing traffic volume and annual emissions of NOx being 1.33 times higher than the norm at about 128,000 tons, a variety of measures where implemented such as improving the environmental performance of vehicles, controlling the number of vehicle licenses for private use and

implementing a 'public transport first' policy led to a reduction of CO by 30%, reduction in HC by 50% and reduction in NOx by 50%. One of the measures included **strengthening the monitoring and maintenance of current-use vehicles** and promoting the elimination of old vehicles.

3.4. Summary of priority actions in terms of emission reduction potential

In terms of emission reduction potentials, the list below presents the different scenarios in order of percentage reduction in emissions across pollutants, listed from the scenario with the highest impact to that with the least impact.

1. Compliance with stricter emission reduction standards
2. Then optimal low emission zones
3. High occupancy vehicle lanes
4. Congestion charges
5. Reduction in high emitters
6. Decreased daily mileage

3.5. Mandate mapping for implementation of interventions

Improving air quality in the City of Johannesburg requires vertical and horizontal integration as implementing interventions cuts across various sectors. To improve air quality through transport planning interventions requires mandated departments and relevant stakeholders to be involved in influencing the uptake and buy-in of interventions and driving the implementation thereof.

As part of the project, a legal review was conducted of all pertinent legislation and roles and responsibilities for air quality management and the control of vehicle emissions in the City. This includes:

- An overview of the regulatory landscape applicable to air quality management and control of harmful emissions by municipalities;
- An outline of laws specific to the control of vehicle emissions that apply to the City of Johannesburg; and
- A discussion of the legal mandates, roles and responsibilities of stakeholders in air quality management and control of vehicle emissions.

For the full mandate mapping and legal review, refer to Annexure C. The section below endeavours to assign roles and responsibilities and indicate which legislation is activated and applies to the different interventions.

Table 3.6 below is a summary of the various departments needed to implement the various actions modelled through the scenario modelling exercise. The relevant policies and legislations supporting the implementation of these interventions have also been mapped out.

Table 3.6: Summary of roles and policies relating to the implementation of the various modelled interventions within the CoJ

Category	Interventions	Who is responsible?	Relevant strategies	Legislation support
TRAFFIC (TRAVEL DEMAND MANAGEMENT)				
Regulations	**Congestion charges** • Identify areas where congestion charges should be applied. • Stipulate the fine payable for entering specified zone. • Monitor vehicles that enter specified zones • Vehicle monitoring	CoJ Transport; JRA; CoJ Development Planning	Green Transport Strategy	• National Environmental Management Act: Air Quality Act ○ AQA allows municipalities to make local emission standards in respect of harmful substances or mixtures of substances from mobile sources, for example, vehicles (AQA, section 11(1)(b)). ○ Setting stricter standards requires a consultative process. ○ By-laws must be phased in. • The National Air Quality Management Framework • Local Government: Municipal Systems Act, 32 of 2000 (Systems Act). • The City of Johannesburg Air Pollution Control by-law ○ Setting own air pollution by-laws to regulate vehicle emissions
Traffic calming	**High Occupancy Vehicle lanes** • Supporting dedicated lanes/road infrastructure for vehicles transporting more than 3 passengers. • Encourage use of alternative transport or carpooling by providing preferential parking, subsidies for public transport tickets. • Staggering working hours • Park and ride schemes. • Accurate parking charges in the CBD • Compliance	National Dep of Transport; Provincial Dep of Transport; CoJ Transport; JPMD JRA	Green Transport Strategy CoJ Draft Parking Policy	National Road Traffic Act, 93 of 1996 National Road Traffic Regulations, 2000 National Land Transport Act, 5 of 2009 • Land transport planning

Regulations	**Optimal low emission zones**
	• Restrict certain vehicles from entering
	• Setting vehicle emission standards
	• Car-free days/No car zones
	• No car zones: close off some roads to all vehicles
	• Repurpose road space and provide alternative transport options e.g. NMT and buses
	• Vehicle monitoring
		CoJ Transport
		JMPD
		JRA
			Green Transport Strategy
			
			CoJ Draft Parking Policy
				• **The National Air Quality Management Framework**
				• **National Environmental Management Act: Air Quality Act**
				  ○ AQA allows municipalities to make local emission standards in respect of harmful substances or mixtures of substances from mobile sources, for example, vehicles (AQA, section 11(1)(b)).
				  ○ Setting stricter standards requires a consultative process.
				  ○ By-laws must be phased in.
				• **National Road Traffic Act, 93 of 1996**
				• **National Road Traffic Regulations, 2000**
				  ○ Municipalities may make by-laws relating to specific aspects of road traffic control, including among other things, "the use of any public road by traffic in general" (Section 80A (1) (a)).
				  ○ A by-law made under the Act may be made to apply generally throughout the municipality's area of jurisdiction or in a specific part of the municipal area and may also be specific to a category of vehicles or persons.
				• **National Land Transport Act, 5 of 2009**
				  ○ Land transport planning
				  ○ enforcement

	Decreased daily mileage • transit oriented development and mixed use development and land-use planning • One hour walking neighbourhoods • Promoting non-motorised transport	CoJ transport; CoJ Development Planning;	CoJ GDS CoJ SDF CoJ Nodal strategy	• **National Land Transport Act, 5 of 2009** ○ Land transport planning • **Spatial Planning and Land Use Management Act**
VEHICLES				
	Compliance with stricter vehicle emission standards • The enforcement of fuel efficiency standards and vehicle taxes. • Vehicle emissions labelling • Tax on fuel	National Government DOT; Provincial Department of Transport; Department of Mineral	National Transport Policy white paper	Petroleum Products Act, 120 of 1977

	• Incentivize and subsidize fuel efficient vehicles. • Public awareness raising & information sharing on the benefits of fuel efficiency encouragement of driver behaviour change.	resources Department of Energy		
	Reduction of High emitters • Maintenance and Inspection programmes • Roadworthiness testing	Provincial Department of Transport;		National Road Traffic Act, 93 of 1996 National Road Traffic Regulations, 2000 • No vehicle may be operated on a public road, unless it has a certificate of roadworthiness (NRTA Section 42). The requirements of roadworthiness, which include smoke emissions are contained in regulation 138 and Schedule 2 of the National Road Traffic Regulations, 2000 (GNR.225 of 17 March 2000) are based on compliance with the standard SANS 10047 which is incorporated into the regulations by reference. Vehicle examiners, who may be appointed by local authorities, must determine roadworthiness on the basis of compliance with the standard.

4. COJ VEHICLE EMISSIONS CONTROL STRATEGY AND ACTION PLAN

4.1. Vehicle Emission Control Strategy

The transport sector has been identified as one of the key sectors to target in improving air quality in the CoJ. In support, the 2019 AQMP identified four critical sources of air pollution that contribute negatively to air quality within the CoJ, one of which is vehicle emissions. Vehicle emissions play a significant role in reducing air quality by emitting Green House Gases such as Carbon Dioxide (CO_2) and other vehicle pollutants such as particulate matter, Nitrogen Oxide (NOx) and Carbon Monoxide (CO) which have adverse impacts on human and environmental health.

Vehicle characteristics as well as vehicle driving conditions play a significant role in reduced air quality. Therefore a targeted approach with short, medium and long-term outcomes is required to tackle the city's air quality challenges due to vehicle emissions.

4.1.1. Vision

"A low carbon and healthy CoJ that supports liveable, sustainable and resilient communities by improving air quality and providing adequate transport and mobility options"

4.1.2. Mission

To apply a holistic, all-of-society approach to tackling vehicle emissions in CoJ by effectively executing the transition of the CoJ from a car-dominant city to one that values low carbon mobility and transport. To this end, this strategy aims to implement interventions that reduce the reliance on vehicles by investing in public transport and alternative mobility options, shifting travel patterns and encourage positive changes in travel behaviour and vehicle usage.

Table 4.1. : Strategic priorities for reducing vehicle meissions in the city

Strategic priorities	Problem statement and objectives/outcomes
Reduce vehicle emissions by improving vehicle performance and vehicle efficiency through strategies and regulations that aim to improve vehicle characteristics.	The use of second-hand, older vehicles is prevalent in CoJ due to its affordability. With this, there's a high risk that vehicles may be ill-maintained and equipped with outdated technologies reducing vehicle performance and energy efficiency. Objectives: • To improve vehicle functioning by investing in vehicle maintenance programmes. • To introduce regulatory mechanisms that drive vehicle efficiency and vehicle emissions reductions.

Increase the availability of low emission, integrated transport and mobility systems to support the reduction of single use private vehicles and alleviate traffic and congestion challenges.	There is limited transport infrastructure and facilities available that supports alternative modes of transport, and enables a shift away from the reliance on vehicles. Objectives: • Offer citizens affordable and accessible mobility options; • Extend the public transport, walking and cycling network; • To pilot walking and cycling routes in high traffic and other identified congested areas; • Create mixed use neighbourhoods that promote ease of access to amenities and prioritize waking and cycling.
Establish smart data and monitoring systems to track air quality, vehicles characteristics, and traffic volumes and flow.	Currently, vehicles, emissions and traffic data is either, inadequately collected and collated; or there exists limited or no instruments whereby to collect and monitor data in the city. This is problematic as policy and type of interventions required to effect change, along with an understanding of actual impact of policy and interventions is dependent on the data available for analysis. Having a robust data system to capture and record information in a consistent manner is key to making informed, evidence-based decisions and improving air quality in the city. Objectives: • To accurately and consistently capture information on vehicles on the road according to vehicle type, fuel type, age and vehicle make. • To establish a wider network of air quality monitoring stations and traffic monitoring data systems on key roads. • To establish a vehicle emissions monitoring programme that tracks vehicle emissions in the city. • To effectively communicate vehicle emissions reduction and improved air quality in municipal reporting processes.
Formulate and implement awareness raising campaigns that link vehicle emissions to environmental and human health, and climate change.	Across all sectors in the city, there is limited motivation, incentive and/or punitive measure to support the transition to a low carbon, low emissions transport and mobility sector. Walking, cycling and public transport is largely unsafe and stigmatised, and citizens often do not understand the impact that vehicle use has on the environment and their health and wellbeing. Objectives: • To create an understanding of the impacts of increased vehicle use and impart a shared responsibility in tackling challenges around vehicle emissions and air quality. • Introduce CoJ vision and strategies to reduce emissions and improve air quality in the city • Involve the private sector and civil society in enabling the transition to low carbon mobility.

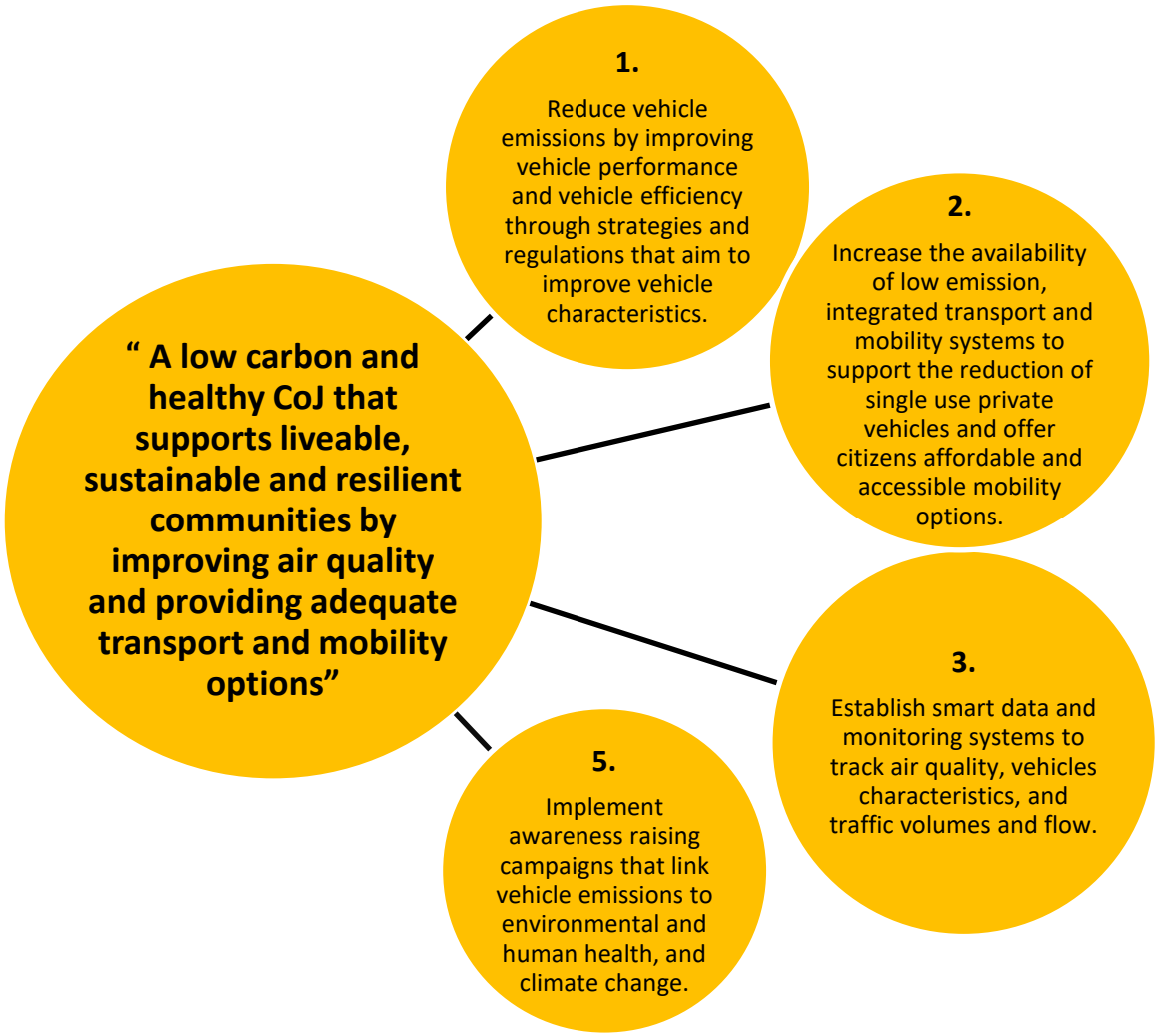


Figure 4.1: CoJ visions and strategic priorities to reduce vehicle emissions in the city and improve air quality

4.2. Vehicle Emissions Action Plan

The purpose of the following section and the Action plan is to operationalize and institutionalize the Vehicle Emissions Control Strategy (VECS).

4.2.1. Introduction

The VECS action plan is meant to be a flexible document that assists the CoJ to envisage and facilitate the reduction of vehicle emissions to improve air quality and realise the CoJ's Air Quality Management Strategy. The successful implementation of this Action Plan requires a collaborative approach with internal and external stakeholders and this plan provides a basis for the CoJ to coordinate actions between departments, spheres of government and key stakeholders.

The Action Plan responds to desktop research that shows the status quo of vehicle emissions in the CoJ, findings from the scenario modelling presented in section 3 and the VECS visions. All the preceding documents should be read in conjunction with each other.

The Action Plan incorporates:

- Key focus areas for vehicles, traffic and regulations, prioritizes them and relates them to key policies, strategies and legislation.
- Roles and responsibilities of internal and external stakeholders
- Identifies existing and other strategies and projects that are in process and directly relate and align to these interventions.
- Social, economic and environmental impact of actions, and where negative, mitigating actions and considerations.

4.2.2. Enabling factors (CoJ AQMP)

i. Finance

The implementation of the VECS depends on sufficient and adequate funding; therefore the CoJ needs to explore various avenues, both internally and externally, to support the roll-out of the strategy. Further, alternative revenues of income derived from interventions should be explored on the basis of maintaining operations, implementing subsequent phases, providing supporting infrastructure options and as potential subsidies to drive uptake of certain interventions by CoJ citizens.

ii. Information flows – improving the air quality management system

The CoJ must develop and maintain a comprehensive air quality management system as an operational system that develops, improves and maintains the necessary air quality tools. These tools provide the information necessary to understand the state of air quality, to support and measure the impact of decisions and to prioritise problems. These important tools include the following:

- Air quality monitoring
- Spatial and temporal evaluation tools (Dispersion and air quality modelling)

- Emissions inventory
- Impact, risk and/or vulnerability assessments

iii. Communicating internally and with CoJ citizens

Effective education programmes, awareness raising and communications campaigns should be devised and implemented to empower CoJ personnel and citizens alike on air quality in the city, and the impacts that uncontrolled vehicle emissions has on the health and wellbeing of citizens. It needs to elaborate on and show how interventions required to control vehicle emissions can positively impact and benefit citizens in the long-term. The AQMP suggests a two-way communications approach where the CoJ provides information to citizens on the state of air quality through air quality information portal, real time air quality reporting, air quality indicator, emission reduction strategies and actions, and where citizens provide input to the CoJ for example complaints and identifying problems (and possible solutions).

iv. Collaboration

Cross-sectoral collaboration is an important element in ensuring the success of intervention implementation, reducing emissions and improving air quality in the City. The CoJ needs to ensure that stakeholder engagements occur regularly and collaboratively in order to gain support, mobilise resources, further assess and develop actions and interventions, and drive the implementation of interventions put forward in the action plan. Furthermore, collaborative target setting, monitoring and regular review of the actions, planning and implementation is pivotal to ensuring interventions are targeted and contextualised.

v. Innovation, research, and evidence-based decision-making

Although air quality management activities have been ongoing in CoJ since 2003, there are still areas that do not comply with NAAQS. Transport and vehicle emissions has been identified as a priority area to tackle in order to improve air quality in the City. Testing and implementing innovative ideas and using research to provide and improve the knowledge-base can greatly improve air quality management. Engaging research institutions as key stakeholders to facilitate ongoing research, monitoring and evaluation to track emissions, identify problem areas, put forward solution and recommendations can provide CoJ with the evidence to pilot innovative ideas that reduce vehicle emissions in the city.

4.2.3. Action plan

Outlined below is a compilation of an action plan for the implementation of the aforementioned strategic priorities related to the vision of the City of Johannesburg. The corresponding departments responsible for implementing each intervention as well as the alignment of the intervention to a relevant policy and/or strategy have also be identified.

STRATEGIC PRIORITY 1: Enable vehicle efficiency and reduction of vehicle emissions through strategies and regulations that aim to improve vehicle characteristics.				
PROBLEM STATEMENT	**The use of second-hand, older vehicles is prevalent in CoJ due to its affordability. With this, there's a high risk that vehicles may be ill-maintained and equipped with outdated technologies, thus reducing vehicle performance and energy efficiency.**			
OBJECTIVES	• To improve vehicle functioning by establishing vehicle maintenance programmes. • To introduce regulatory mechanisms that drive vehicle efficiency and vehicle emission reductions.			
TARGETS	- Increase the efficiency of older vehicles by 40% through target maintenance and inspection programmes and emissions testing; - Set minimum vehicle emission standards through regulatory mechanisms and existing processes.			
STRATEGIC INTERVENTIONS	**ACTIONS REQUIRED FOR IMPLMENTATION**	**RESPONSIBLE**	**ALIGN TO EXISTING STRATEGIES POLICIES AND PLANS**	**POTENTIAL IMPACT REALISED** SHORT (12-24 MONTHS); MEDIUM (24-48 MONTHS);LONG TERM (48 MONTHS +)
Vehicle roadworthy certificate enforcement	1. Three-yearly test on vehicles that covers roadworthiness.	Department of Transport	Green Transport Strategy **National DoT currently working on a road policy (in cabinet process to be approved- delays because of COVID)**	SHORT

Car Licensing	1. Revise the annual taxation of vehicles based on their emissions through the annual car licensing renewal system. 2. Enforce the requirement to provide an emissions test with car license renewal for car older than 10 years and weighing 5 tons or less.	Provincial Government, Department of Transport ; CoJ Transport, Traffic department & CoJ EISD	Green Transport Strategy CoJ Air Pollution Control By-laws, Chapter 7(16)	SHORT
Congestion charges	1. Develop a context specific regulatory policy on congestion charges for CoJ - Determine emission standards as part of CoJ By-laws - Stipulate the fine payable for entering specified zone. 2. Conduct traffic studies to identify high traffic areas where congestion charges could be applied. 3. Pilot congestion charges in one or more areas. 4. Establish a monitoring system to track vehicles that enter specified zones, and enforce fines and collection of payments.	Provincial Government, Department of Transport CoJ Transport	Green Transport Strategy	MEDIUM

Low Emission Zones	1. Prescribe accepted vehicle emission standard for LEZ and identify vehicle classes that are restricted from entering LEZ's. 2. Assess where alternative transport options, such as dedicated walking and cycling and public infrastructure and public transport, are required within restricted areas and invest in these. 3. Vehicle monitoring - Establish a monitoring system to track vehicles that enter specified zones, and enforce fines and collection of payments. - Investigate, establish and resource mechanisms to enforce compliance.	CoJ transport, CoJ EISD ,JRA and Dev planning	Green Transport Strategy	

Fuel improvement	1. Improve the quality of fuel sold in the country/region to improve the quality of emissions produced by vehicles 2. Set emission standard to Euro 4 or higher and enforce this. 3. Collaborate with national and provincial government to establish fuel efficient vehicle subsidy. 4. Promote the manufacturing and use of vehicles using alternative fuel and energy sources such as hybrids and electric vehicles - Investigate the landscape and market for electric vehicles and produce measures to make the use of these more attractive, convenient and affordable through free bates, subsidies and incentives in the manufacturing industry and consumer market; - Devise an approach and strategy to expand the network of charging stations powered by renewable energy sources.	National Government, Dep of Energy	International benchmarking	LONG

Greening the municipal fleet	1. Set sustainable public procurement standards and technical specifications for greening the municipal fleet 2. Set targets for the procurement of vehicle fleet and include indicators in the IDP. 3. Raise awareness on the benefits of applying sustainability into the procurement process for municipal vehicles 4. Establish monitoring and evaluation systems to understand the impact ito reduced emissions and reduced costs because of sustainable public procurement. Impacts and lessons learned should be communicated and reported on.	CoJ transport and fleet management and supply chain management CoJ EISD	Green Transport Strategy	SHORT - MEDIUM
Inspection and maintenance programmes	1. Implementation of a basic Inspection and Maintenance programme to determine the emissions values of a segment of vehicles; 2. Maintenance free bates: co-design and implement maintenance programmes for older vehicles that are incentivised through rebates or subsidies. 3. Resource the implementation of inspection and maintenance programmes locally; 4. Collaborate with provincial and national government to co-produce the programme and pool resources.	National Government; Department of Transport; CoJ (nationwide)	NRTA regulations	MEDIUM
Introducing car life cycle limits on the road	1. A car with an engine that's covered more than 400 000km must be banned from the road or scrapped. 2. Establish education and awareness raising campaigns on the impacts of older cars on vehicle emissions and pollution to encourage the uptake of car lifecycle limits.	National dep of Transport	Green transport strategy	LONG

Investigate appropriate financial solutions for interventions.	1. Conduct a cost-benefit analysis on various interventions to identify low cost, high impact solutions. 2. Investigate revenue generation, funding sources and operational models for different interventions; 3. Establish a land transport fund to manage revenues and finances - Mandate an appropriate authority to manage revenue and finances in a way that supports the implementation and operation of low carbon transport and mobility solutions.	CoJ Transport Department, JRA		SHORT
STRATEGIC PRIORITY 2: Increase the availability of low emission, integrated transport and mobility systems to support the reduction of single use private vehicles and alleviate traffic and congestion challenges.				
PROBLEM STATEMENT	**There is limited transport infrastructure and facilities available that support alternative modes of transport, and enables a shift away from the reliance on private vehicles. In addition, the spatial form of CoJ is fragmented, increasing vehicle kilometres travelled.**			
OBJECTIVES	• Offer citizens affordable and accessible mobility options; • Extend the public transport, walking and cycling network; • To pilot walking and cycling routes in high traffic and other identified congested areas; • Create mixed use neighbourhoods that promote ease of access to amenities and prioritize waking and cycling.			
TARGETS (2040)	• The use of single occupancy vehicles will be reduced by 60% • Neighbourhoods and high traffic areas are mixed-use and prioritise walking and cycling			
STRATEGIC INTERVENTIONS	**ACTIONS REQUIRED FOR IMPLMENTATION**	**RESPONSIBLE**	**ALIGN TO EXISTING STRATEGIES POLICIES AND PLANS**	**POTENTIAL IMPACT REALISED** SHORT (12-24 MONTHS)

				MEDIUM (24-48 MONTHS) LONG TERM (48 MONTHS +)
Promotion of non-motorised transport	1. Create an extensive network of cycle lanes and pedestrian walkways to re-orient South Africa's towns and cities away from cars towards people. 2. Pilot bicycle pop-up lanes to monitor usage and determine efficacy. This is a low cost solution that can be established immediately and has been piloted by numerous cities globally in response to the Covid-pandemic. 3. Build awareness around NMT as a viable means of transportation through regular promotions, events and campaigns such as SA Transport Month. 4. Partners with local organisations to educate and train citizens on road safety, bike riding, repairs, etc. 5. Develop programmes to encourage the uptake of NMT such as bicycle distribution programmes; 6. Establish a NMT an NMT and cycling strategy as well as an NMT committee that oversees the roll-out of events and campaign and implementation of infrastructure and projects. 7. Re-establish a cycling forum with civil society and businesses to provide input on plans and assist with events and awareness raising.	CoJ; City Transport dep	Green Transport Strategy CoJ NMT framework (developed in 2009- needs to be reviewed) Integrated Transport Network Plan (2013-2018)	SHORT

No-car zones	• Identify areas such as central business districts that can be closed off to cars and apply for the necessary approvals. • Establish regular car-free days by either closing off select streets or whole areas to promote alternative mobility options. • Provide infrastructure and facilities that supports walking and cycling as the preferred mode of transport • Deploy additional metro buses to cater for mobility needs • Reallocate road space for other activities by using approaches such as tactical urbanism and parklets. • Resource enforcement and monitoring of no care zones • Partner and collaborate with relevant stakeholders and conduct regular stakeholder engagement to enable cross sector buy-in and assist with awareness raising and implement no-car zones. *Many of these actions can be piloted first to assess efficacy before implementing it permanently. This must go hand-in-hand with awareness raising campaigns.	JRA, Devevelopment planning, and CoJ transport planning department, CoJ traffic	Green Transport Strategy Strategic Integrated Transport Plan (must be reviewed)	SHORT

Implementing effective parking management	1. Continue with parking studies to ascertain where parking strategies can be applied and finalise the CoJ Parking Management Strategy. 2. Formulate a stakeholder engagement strategy and conduct regular engagement sessions to understand conflicts and the co-creation of solutions with businesses and other affected parties. 3. Repurposing parking areas - Allowing significant areas of urban real estate currently used for parking to be repurposed 4. Discourage car use by increasing cost of parking - Encourage employers to increase the cost of parking provided to employees 5. Increase parking capacity near public transport options - Maximum parking provision limits should be introduced in public transport priority areas in terms of the City's Growth Management Strategy (GMS) - Lower maximum parking requirements should be introduced around upgraded public transport corridors and in the marginalised areas 6. Management of inner-city parking - Lower off-street parking requirements in the inner City and regional nodes as defined by the Consolidated Town Zoning Scheme should be introduced. 7. Make parking available for public transport vehicles near large retail facilities	CoJ Transport, JRA, CoJ Development Planning	Green Transport Strategy Integrated Transport Network Plan CoJ Draft Parking Management Strategy (2019)	SHORT - MEDIUM

	- The designers of shopping malls, other large retail facilities and office parks should be required to make provision for public transport vehicles, metered taxis and decent pedestrian access, as well as shared parking. 8. Implement shared parking - A shared parking concept - where the same parking spaces can be used for different land uses at different times - should be introduced for mixed land-use developments 9. Establish and resource a monitoring systems for parking violations			

Implement city planning and regulations that support sustainable mobility alternatives	1. Changing the zoning to allow mixed-use. - This will allow people to operate home-based enterprises and reduce the need for travel 2. Creating one-hour walking neighbourhoods - The neighbourhood should be the unit of design with most social amenities accessible within an hour's walk.	Green Transport Strategy CoJ Nodal Review Policy (2020) CoJ Spatial Development Framework	CoJ Transport, CoJ development Planning	MEDIUM
High Occupancy Vehicle Lanes (referred to as managed lanes)	1. Introduction and enforcement of high occupancy vehicle lanes on highways - Supporting dedicated lanes and road infrastructure for vehicles transporting more than 3 passengers. - Encourage the use of alternative transport or carpooling by providing preferential parking and subsidies for public transport tickets. - Encourage staggered working hours and work from home schemes. - Investigate and establish park and ride schemes with supporting infrastructure and facilities - Enforce accurate parking charges in the CBD - Enforce compliance through adequate resourcing of traffic enforcing authority and making it part of their mandate. - Continuous monitoring and evaluation of managed lanes to understand efficacy and evaluate lessons learned.	Green Transport Strategy CoJ Draft Parking Management Strategy	National Government; Department of Transport; CoJ transport department	SHORT-MEDIUM

Efficient freight routes, regulations and operations	1. Conduct a study to understanding the impacts of freight of traffic, congestion and vehicle emissions; 2. Establish freight vehicle operation regulations for the low carbon movement of goods and services; 3. Identify different low carbon, low emissions solutions for freight management in the CoJ, for example restricting long-distance freight to rail, with the development of "Green Corridors" in the road network to promote the use of cleaner efficient technologies in the freight industry. 4. Establish and coordinate the Joburg freight forum to co-develop solutions with industry stakeholders.	Spatial Development Framework		
STRATEGIC PRIORITY 3: **Establish smart data and monitoring systems to track air quality, vehicles characteristics, and traffic volumes and flow.**				
PROBLEM STATEMENT	**Currently, vehicles, emissions and traffic data is either, not adequately collected and collated; or there exists limited or no instruments whereby to collect and monitor data in the city. This is problematic as policy and type of interventions required to effect change, along with an understanding of actual impact of policy and interventions is dependent on the data available for analysis. Having a robust data system to capture and record information in a consistent manner is key to making informed, evidence-based decisions and improving air quality in the city.**			
OBJECTIVES	- To accurately and consistently capture information on vehicles on the road according to vehicle type, fuel type, age and vehicle make. - To establish a wider network of air quality monitoring stations and traffic monitoring data systems on key roads. - To establish a vehicle emissions monitoring programme that tracks vehicle emissions in the city.			
TARGETS (2040)	- Vehicle emissions data is aligned with municipal reporting processes - Instruments required for the monitoring of air quality and vehicles is well established - A robust and comprehensive vehicle emissions data management system is established in line with the CoJ's smart city ambitions.			
STRATEGIC INTERVENTIONS	**ACTIONS REQUIRED FOR IMPLMENTATION**	**RESPONSIBLE**	**ALIGN TO EXISTING STRATEGIES POLICIES AND PLANS**	**POTENTIAL IMPACT REALISED** SHORT (12-24 MONTHS) MEDIUM (24-48 MONTHS)

				LONG TERM (48 MONTHS +)
Establish a vehicle information management programme	4. Expand the network of traffic counting stations in CoJ; 2. Formulate a data management strategy for vehicles, vehicle emissions and traffic in the city. - Develop a Standard Operating Procedure for data management to ensure consistency of data processing and validation; 5. Establish a Travel Demand Management programme to understand travel patterns and behaviour in light of COVID impacts; 6. Formulate a technical training programme for personnel managing vehicle and air quality data; 7. Seek partnerships for collaboration on data analysis and evidence-based decision making of applying interventions; 8. Include data reporting indicators on vehicle emissions into municipal reporting processes.	CoJ; City Transport department	Air Quality Management Plan 2019	MEDIUM
Extend the Air Quality Monitoring Network	1. Investigate areas and main roads where this would be most valuable in capturing vehicle emissions related air quality data; 2. Establish a maintenance programme for the upkeep of air quality monitoring stations.			
STRATEGIC PRIORITY 4: Devise and implement awareness raising campaigns that link vehicle emissions to environmental and human health, and climate change.				
PROBLEM STATEMENT	**Across all sectors in the city, there is limited understanding, motivation, incentive and/or punitive measure to support the transition to a low carbon, low emissions transport and mobility sector. Walking, cycling and public transport is largely unsafe and stigmatised, and citizen's often do not understand the impact that vehicle use has on the environment and their health and wellbeing.**			

OBJECTIVES	- To create an understanding of the impacts of increased vehicle use and impart a shared responsibility in tackling challenges around vehicle emissions and air quality. - Introduces CoJ vision and strategies to reduce emissions and improve air quality in the city - Involve the private sector and civil society in enabling the transition to low carbon mobility.			
TARGETS	- Low carbon mobility solutions are widely accepted across society and departments across governments are collaborating and actively driving the implementation thereof.			
STRATEGIC INTERVENTIONS	**ACTIONS REQUIRED FOR IMPLMENTATION**	**RESPONSIBLE**	**ALIGN TO EXISTING STRATEGIES POLICIES AND PLANS**	**POTENTIAL IMPACT REALISED** SHORT (12-24 MONTHS) MEDIUM (24-48 MONTHS) LONG TERM (48 MONTHS +)

Encourage consumers to make informed decisions on vehicle purchases and play a role in effecting vehicle emissions control through behaviour change.	• Behaviour change to promote fuel efficiency
	  ○ Modify driving behaviour using digital apps to improve safety, reduce driving inefficiencies and improve awareness of emissions and vehicle maintenance protocol
	• Establish vehicle information portals
	  ○ The introduction of an information platform for new and used vehicles to calculate emissions. Potential to be integrated into a wider campaign on lowering emissions in the city.
		CoJ; City Transport dep		MEDIUM

Drive awareness raising campaign highlighting the challenges faced due to vehicle emissions, impact on human & environment and	• Formulate a communications and events strategy to communicate impacts of vehicle emissions and CoJ strategy and potential interventions for tackling challenges related to vehicle emissions and air quality; • Establish an events calendar aligned to proposed interventions as a way to shift mindsets and normalise low carbon mobility	CoJ EISD and City Transport dep		

possible interventions proposed by the city.	• Seek key partnerships to collaborate in rolling out communications strategy and events calendar.			

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6. ANNEXURE

Annexure A: Summary of COPERT tool data requirements and sources of data used

Table 6.1: Summary of data requirements, challenges encountered, assumptions and sources of the data used for vehicle emissions modelling for the CoJ using the COPERT tool

Section	Data requirements per sub-section	Challenges	Assumptions	Data sources
Properties				
Environmental information	Minimum temperature; Maximum temperature; humidity	This data was readily available on a monthly resolution as required	None	AccuWeather.com [ii]
Trip characteristics	Trip length [km] & Trip duration [hour]	Information specific to the CoJ not found	The default values of the COPERT tool were used	COPERT vehicle emissions modelling tool
Fuel				
Fuel specifications	• Fame energy content [MJ/kg] • H:C ratio • O:C ratio • Density [kg/m^3] • S [ppm wt] • Pb, Cd, Cu, Cr, Ni, Se, Zn, Mg, As	Some of the specifications for the metals and elements required here were not found in the most recent petrol and diesel specifications purchased from SABS (for instance, H:C ratio, O:C ratio)	Default values of the tool were used where specifications were not available. This should not be a major issue on the accuracy of the modelling results as specifications for most of the elements of interest were available	South African Bureau of Standards (SABS) **SANS 1598:2019** Edition 3.1 for Petrol **SANS 342:2016** Edition 5.1 for diesel

	•	There was also the challenge of which petrol/diesel specification to use as there exist Clean Fuel 1 (CF1) and Clean Fuels 2(CF2) specifications for both petrol and diesel	CF1 specifications were used given that though CF2 specifications are in place, they have not yet been enforced as refineries are not yet producing such fuel grades.	South African Bureau of Standards
		For some fuel specifications, two values were available either for CF1 or for CF2. For instance, the low diesel standard of 50 ppm and the standard specification of 50 ppm	The worst case scenario of 500 ppm for sulphur specifications was used. More details on this can be found on the 'data requirements' section of the modelling report	South African Bureau of Standards
Advanced specifications	<u>For Petrol</u> • E100 [% Vol] • E150 [% Vol] • Aromatics [% Vol] • Olefins[% Vol] <u>For Diesel:</u> • PCS[% Vol] • CN • T95 [^{o}C]	Some of the specifications required were not found in the most recent petrol and diesel specifications purchased from SABS (for instance, CN)	Default values of the tool were used. This should not be a major issue on the accuracy of the modelling results as specifications for most of the elements of interest were available	South African Bureau of Standards

Lubricant specification	Content in species: • S, Pb, Cd, Cu, Cr, Ni, Se, Zn, Hg, As Specifications: • H:C ratio • O:C ratio	These values were not available. From research, there exist a wide range of lubricants in use in South Africa	The default values of the tool was used	COPERT Vehicle Emissions Modelling Tool
Statistical energy consumption (if an energy balance will be performed)	• Total fuel sales in TJ	Fuel consumption data for 2019 in the CoJ was not accessible even after a request to the Ministry of Energy. The explanation was that this data is no longer made public.	No fuel sales data was used and hence, in the COPERT tool, no energy balance was done. An energy balance is not a mandatory requirement in the tool. It serves to enable the COPERT tool to balance the fuel consumed within the city with the vehicle mileage input into the tool in order to have a more accurate vehicle mileage value.	None
Monthly Reid Vapor Pressure	Reid Vapor Pressure for different months [kPa]	Data was not available for the different months but rather a winter and a summer value for the Reid Vapour Pressure	The same winter value was used across the winter (cold) months in South Africa (April to September) and the summer value across the rest of the hotter months	Data from diesel and petrol specifications purchased from the South African Bureau of Standards
Fossil fuel fraction in Biodiesel	• G fossil CO_2/ g Fame [g/g]	Data not available	Default values of the tool were used	COPERT Vehicle Emissions Modelling Tool

	• Fame energy content [MJ/kg]			
Vehicles				
Stock configuration	• Fuel • Segment • Euro standard	Database did not contain enough information (vehicle weight and dimensions) to help in passenger vehicle segmentation (mini, small, medium and large SUV)	Information from a study that referenced NAAMSA data on passenger vehicles segmentation was applied to the vehicle data[iii]. The percentages of the various segments from the different segments was applied to the vehicle stock data for modelling	Data obtained from the eNATIS database through RTMC An assumptions for passenger vehicle segmentation from "South Africa's New Passenger Vehicle Co_2 Emission Standards: Baseline Determination And Benefits Assessment"
		Some data columns contained inconsistent information and a vehicle category was labelled as *other self-propelled*" and contained a mixture of vehicles from different categories. Also, some cells for the year of vehicle registration were left empty	These inconsistencies and gaps accounted for less than 1% of the dataset. The "other self-propelled" vehicle category was left out of the data set used for the model Cells with no year of registration were filtered out of the data set used for modelling.	Data obtained from the eNATIS database through RTMC
Stock and activity data	• Stock [n] • Mean activity [km]	On the eNATIS database, information on the mileage of the vehicles and the	Information for annual vehicle mileage was obtained from a peer reviewed study done in	Assumptions and Methodologies in the South African TIMES (SATIM) Energy Model

	• Lifetime cumulative activity [km]	cumulative vehicle mileage over time was not captured.	South Africa, on assumptions used in the South Africa TIMES energy model[iv] -The lifetime cumulative activity was calculated using an average 4.9% vehicle mileage decay rate compounded annually.	
Circulation activity	Share [%]: Urban peak; Urban off-peak; Rural ;Highway Speed [km/h]: Urban peak; Urban off-peak; Rural ';highway	No documentation found on the percentage of roads that are highway, urban and rural	The assumption is that the highway-urban roads distribution of the roads covered by TomTom users for the CoJ is reflective of the roads in the City and that there are no rural routes within the CoJ.	Data was obtained from TomTom website[v], on the percentage of highways and urban routes within the city of Johannesburg.
Fuel Evaporation data	Vehicle specific properties: • Fuel tank size [L] • Canister size [L] • Fuel injection [%] • Evaporation control [%] Evaporation share [%]	Most of the data needed for this section was not available, but for data on fuel tank size and canister size on the data obtained from the eNATIS database	The default values of the tool was used for data requirements which were not available from the eNATIS database	eNATIS and default values of the COPERT vehicle emissions modelling tool

	Urban peak; Urban off-peak; Urban; Rural; Highway			
Driving conditions	Load [%] Urban peak; Urban off-peak; Rural; Highway Road slope [%] Urban peak; Urban off-peak; Rural; Highway	No information on different load percentages per vehicle category in each of the road splits (highway, urban and rural); same challenge for the average road slope in each of these scenarios	Default values of the tool were used	COPERT vehicle emissions modelling tool
Axles number	• Number of axles	No challenge as data was available	N/A	eNATIS database
SCR usage	• UC as a % of FC (%)	Not available information on this	Default values of the tool were used	COPERT tool
A/C usage	• Vehicles with AC [%]	Not available information on this	Default values of the tool were used	• COPERT tool
Technology share	• First [%] • Second [%]	Not available information on this	Default values of the tool were used	COPERT tool
Blend share and Bifuel share		Not available information on this	Default values of the tool were used	COPERT tool

Annexure B: Analysis of barriers to implementation and mitigating actions of interventions

Table 6.2: Barriers to implementations and mitigation actions, compiled in consultation with stakeholders across government departments.

	Intervention	Description	Category	Barriers to implementation	Mitigating actions
Vehicles	Vehicle roadworthy certificate enforcement	Three-yearly test on vehicles that covers roadworthiness and exhaust emissions	Vehicle maintenance and monitoring	- Implementation should be at local level - Buy-in will be difficult because of affordability - Tax capitalisation programme: scrapping old vehicles, buy-in was a problem - Social concerns outweigh the environment impact - Cost dependant on vehicle class, therefore we require measures to support implementation. - Testing should include environmental aspects	Incentivise the use of cleaner and newer vehicles – need to categorise the age of consumer, identify the audience for awareness around reducing emissions. Communicate how this will benefit consumers- including personal benefits where health is one aspect). Low hanging fruit: aggressively promote the uptake of public transport
	Introducing car life cycle limits on the road	A car with an engine that has covered more than 400 000 km must be banned from the road or scrapped	Vehicle maintenance and monitoring	- May not be feasible in the SA context due to socio-economic challenges. - May result in non-registration of vehicles	
Traffic	No-car zones	Central business districts being closed off for car use, and emphasising walking and cycling as the preferred mode of transport, for use in affordable inner-city housing and businesses	Traffic and city planning	-Requires better public transport corridors as a supplementary services (challenges in terms of budget and roll-out) -infrastructure required to deter movement through no-car zones -Requires stringent enforcement and monitoring (inner-city managed lane study – these are supposed to be managed by infrastructure and JMPD) -Limited capacity within the JMPD -Interruptions from communities	-Political championing is very important -Awareness of actions are very important - Stakeholder by-in; continuous stakeholder engagement, building trust

				-require partnerships to make transport implementation work. -Strategy needs to be better integrated – consider institutional arrangements required to increase collaboration between departments. -NIMBY problem with implementation (locating of rea vaya station was an issue) -Identify key sectors that may be impacted - businesses	
	High Occupancy Vehicle Lanes (referred to as managed lanes)	Introduction and enforcement of high occupancy vehicle lanes on highways	Traffic control and enforcement	-Requires better public transport corridors as a supplementary services (challenges in terms of budget and roll-out) -infrastructure required to deter movement through cordoned off lanes -Requires stringent enforcement and monitoring (inner-city managed lane study – these are supposed to be managed by infrastructure and JMPD) -Limited capacity within the JMPD Park and ride (getting more people to use public transport) – wants to shift modes from vehicles to public transport -proved to be expensive and approached shopping centres where parking is already available. Motorists would have to pay for parking. -Employers pay for parking at offices, therefore people would be reluctant to pay parking at park and ride. -Safety issue (approached discovery to develop an ride-sharing app for carpooling)	-Identified 12 primary rea vaya corridors (integrated corridor management (ICM) – feasibility studies underway for 3 corridors (minimum infrastructure investment for larger returns. William Nichol, orange farm to CBD, Roodepoort - CBD. This will identify challenges and who needs to be involved.

				-Engaged businesses -Cost is an issue for consumer -Soweto (interchange moving from taxi to rea vaya, plus a park and ride. But this is expensive – might stop this services)	
Regulation	Car Licencing	Revise the annual taxation of vehicles based on their emissions through the annual car licensing renewal system.	Vehicle regulation	- Requires capacity, resourcing and technical know-how to measure emissions	
	Congestion charges	Develop a regulatory policy on congestion charges in cities.	Vehicle regulation	-If there's no alternative public transport, what are their options -Requires investigation to see whether it's feasible. City is trying to stay away from what people need to pay for. -Consider for CBD - Could impact business if people can't access the place/area. People may stop going a certain area, eg people moving from CBD to Sandton	CoT launched a programme (Travel Demand Management programme) as a response to COVID to monitor the reduced traffic, engage corporate to continue work from home. Piggy back on how COVID has changed behaviour and further encourage this. Get PT to be reliable, safe and affordable. Engage businesses and necessary stakeholders and citizens. Managing loading bays better – restricting larger vehicles within the CBD (this was considered previously but not investigated further).

					Limited Budget could stifle implementation. Transport funding comes from national – not in favour of looking at financing models. Discouraged from doing PPP's Barriers to CoJ getting own revenue from interventions (land transport fund- this has not been done, a transport authority can establish this fund). JRA should/ could manage revenue and finances. This needs to be further investigated. Ringfencing of budget and cross-subsidization.
	Low Emission Zones	Identify, plan and execute Low Emission Zones in the CBD and provide mechanisms for enforcement of these areas.	Vehicle regulations	-Could be a political issue; requires political support -Minibus taxis not using this standard – help them to upgrade their vehicles – this requires funding -More thinking into freight and not private vehicles – this is a long-term plan (Initial thoughts around low emissions zones had to do with restricting freight vehicles).	

	Vehicle Efficiency Labelling		Vehicle sales	- Required legislation and buy-in from the economic sector - Introduction of vehicle scrapping scheme- the socio economic conditions might not support such an intervention - Regulation of the second hand vehicle sales/ markets	
	Emissions Taxes **(already in place)**	The introduction and enforcement of emissions taxes based on vehicle make, model and age	Vehicle maintenance and regulations		
Regulation and national policy	Fuel Efficient vehicle subsidy		National policy		
	Fuel improvement	Improve the quality of fuel sold in the country/region to improve the quality of emissions produced by vehicles	Fuel Regulations	National fuel regulation	
	Maintenance free bates	Design and implement maintenance programmes for older vehicles that are incentivised through rebates or subsidies.	NRTA regulations	- Funding mechanisms to support this	
	Inspection and Maintenance Programme	Implementation of a basic Inspection and Maintenance programme to	Vehicle maintenance and regulations	- Lack of approved inspection programme - Inspection standards and systems - Regulation - Funding mechanism	

		determine the emissions values of a segment of vehicles		- Enforcement programme	
Regulations	Greening the municipal fleet	Assess and procure greener vehicles for the municipal fleets		-fleet department who deals with the procurement of municipal vehicles. The City have never pushed in this direction. Engage other departments on this, eg EISD. Alignment of City's strategy and all department plans - There were pilots done in the city to use a specific fuel – but this was not easily accessible.	(for rea vaya) Buses are Euro 5/6, already procuring greener buses. All metro buses will be green. Not ready to go electric
	Include environmental levy to commercial vehicles	Review the current environmental levy on new vehicle CO_2 emissions and expand it to include commercial vehicles to more effectively influence energy efficiency.	Vehicle and traffic regulation		
Planning	Promotion of non-motorised transport	An extensive network of cycle lanes and pedestrian walkways to re-orient South Africa's towns and cities away from cars towards people.	Non-motorised transport	-Number of studies have been done wrt NMT -Political factions come up with their own priorities, which changes with new administrations where there's a likelihood that initial priorities will be scrapped. -Braamfontein has a 20km cycle lane that connects the campuses, but lack of promotion and limited people using this lane means that motorists started using these lanes. -Shifting mind-sets, currently road is seen for vehicles	-promotions and events have been planned to promote this. Also a bike distribution programme (Partnered with Qubeka – distributed schools and to health workers in Alexandra for Chronic dispensing, also donated to waste pickers), building of bike infrastructure (4 pillars that looked at) - Masterplans developed per area – NMT is included in

				-Budget is a concern, costs a lot to implement, how to accommodate everyone with limited funding. -Personal and road safety is a huge problem. There's a disregard for cyclist -Diepsloot has a large cycling community during peak. Fight for road space between taxis, motorists, cyclists and pedestrians. - Cycling forum was established with stakeholders and NGO's – commenting on plans etc. This has been dissolved because of change in political administration.	this (region G transport masterplan – procurement for this is underway) - Need to change the behaviour of motorists on the road – require awareness campaigns. Also a political champion to get on the road and build awareness (also cycle). - Change the mind-set from recreational cycling to commuter cycling. - Re-establish cycling forum was established with stakeholders and NGO's.
Parking, city planning and regulations	Repurposing parking areas	Allowing significant areas of urban real estate currently used for parking to be repurposed	City Planning	Currently parking studies are underway to see which areas it can be applied. -There's been push back from certain areas. It worked well in Braamfontein, but this has not worked in Parkhurst. - Lack of alignment between land use planning and parking management solutions.	
	Discourage car use by increasing cost of parking	Encouraging employers to increase the cost of parking provided to employees	Economic disincentive		
	Increase parking capacity near public transport options	Maximum parking provision limits should be introduced in public transport priority areas in terms of the City's Growth Management	City Planning		

		Strategy (GMS) Lower maximum parking requirements should be introduced around upgraded public transport corridors and in the marginalised areas			
	Management of inner-city parking	Lower off-street parking requirements in the inner City and regional nodes as defined by the Consolidated Town Zoning Scheme should be introduced'	City Planning		
	Make parking available for public transport vehicles near large retail facilities	The designers of shopping malls, other large retail facilities and office parks should be required to make provision for public transport vehicles, metered taxis and decent pedestrian access, as well as shared parking.	City Planning		
	Shared parking	A shared parking concept - where the same parking spaces can be used for	City Planning		

		different land uses at different times - should be introduced for mixed land use developments			
Regulation	Changing the zoning to allow mixed-use.	This will allow people to operate home-based enterprises and reduce the need for travel	City Planning	- Political will and priorities of the political administration - Funding barriers - NIMBYism, with development objections from communities often derailing projects	
	Creating one-hour walking neighbourhoods -	The neighbourhood should be the unit of design – with most social amenities accessible within an hour's walk.	City Planning		
Information and awareness	Behaviour change to promote fuel efficiency	Modify driving behaviour using digital apps to improve safety, reduce driving inefficiencies and improve awareness of emissions and vehicle maintenance protocol	Traffic & consumer behaviour		
	Information platforms – vehicles	The introduction of an information platform for new and used vehicles to calculate emissions. Potential to be integrated into a	Vehicle sales	- Requires a suitable platform to input information and implementation and operational funding to maintain such a platform.	

		wider campaign on lowering emissions in the city			
	Synchronized traffic lights				
Planning	Charging points for electric vehicles	Provide enough infrastructure for the expansion of EV in cities, that is affordable and accessible	Planning and infrastructure	- Since electric vehicles are not yet widespread, it remains unaffordable and the infrastructure required for operations is limited. - Requires cross-government collaboration and funding to action a move towards mainstreaming electric vehicles.	- Proper planning and strategizing is required to encourage the uptake of electric vehicles.
Vehicles	Promote Electric vehicles	Through free bates, subsidies and incentives in the manufacturing industry and consumer market	Vehicle regulations		
Traffic	Freight vehicle operation regulations	Development of regulations to ensure that freight vehicles may only enter urban hubs during off peak hour.	Traffic and freight	- Safety issues if freight is transported at night which requires more security. - Freight implementation plans requires many partnership. Joburg freight forum – but there are always conflicting objectives	
	Long-distance freight shift to rail	Long-distance freight will be restricted to rail, with the development of "Green Corridors" in the road network to promote use of cleaner efficient technologies	Traffic and freight		

Annexure C: Mandate mapping

Transport

National

Institutions	Mandate and Responsibility	Governing Documents
Department of Transport	National transport planning, co-ordination, policy and strategy Co-ordination between provinces, between spheres of government and public entities Assigning functions to the most appropriate sphere of government Capacitating and monitoring provinces and municipalities Co-ordinating transport relations between the Republic and other 5 countries and implementing international agreements Applications for operating licences Regulation of tourism transport and interprovincial road transport Conducting sector research and setting norms and standards	National Land Transport Act, 2009 National Transport Master Plan 2050 Legal Succession to the South African Transport Services Act National Land Transport Strategic Framework National Road Traffic Act, 1996
National Public Transport Regulator	Monitor and oversee public transport in the country Operating licences or accreditation for interprovincial transport, tourist transport services Oversee fares charged for public transport services throughout the country	
South African Rail Commuter Corporation (SARCC)	Operates long-distance passenger rail through Shosholoza Meyl	
TRANSNET	Owner of South Africa's railway, ports and pipelines infrastructure. Assist in lowering the cost of doing business in South Africa; Enable economic growth; and Ensure security of supply by providing appropriate port, rail and pipelines infrastructure in a cost-effective and efficient manner, within acceptable benchmarks.	
Passenger Rail Agency of South Africa (PRASA)	To ensure that, at the request of the Department of Transport or any transport authority, rail commuter services are provided within, to and from the Republic in the public interest.	
Railway Safety Regulator (RSR)	To oversee and promote safe railway operations through appropriate support, monitoring and enforcement	
Road Traffic Management Corporation (RTMC)	To oversee coordination of traffic law enforcement and the implementation of road safety interventions	
Road Traffic Infringement Agency (RTIA)	To promote road traffic quality by providing for a scheme to discourage road traffic contraventions and implement a point demerit system	
Road Accident Fund (RAF)	To compensate users of South African roads for loss or damage caused by the negligent driving of motor vehicles	
South African National Roads Agency Limited (SANRAL)	To maintain, upgrade, manage, administer and finance the national road network	
Cross-Border Road Transport Agency (C-BRTA)	To regulate and promote access to the market by the road transport freight and passenger industry in respect of cross-border road transport	

Transport	Institutions	Mandate and Responsibility	Governing Documents
Sub-national	**Provincial Department of Transport and Public Works**	May publish and implement a provincial land transport policy and strategy Assist municipalities Improve the planning, co-ordination and facilitation of the land transport functions of the province and between municipalities Set standards, performance criteria and related indicators to ensure intermodal and intramodal co-ordination Sourcing international, national, local, private and public funding Co-ordinate transport initiatives with municipalities, and other stakeholders Ensuring that municipalities that lack capacity and resources are capacitated to perform	National Land Transport Act, 2009 Provincial Land Transport Framework
	Provincial Regulator Entity	Monitor and oversee public transport in the province Operating licences for intra-provincial transport	
Municipal	**City of Johannesburg** **Johannesburg Roads Authority**	Developing land transport plans, policy and strategy - incorporates spatial development policies on matters such as densification and infilling as well as development corridors Promulgating municipal by-laws Ensuring co-ordination between departments and agencies in the municipal sphere Financial planning, with due focus on rehabilitation and maintenance of infrastructure Encouraging and promoting the optimal use of the available travel modes Prevent or reduce any adverse impacts of the land transport system on the environment Promoting safety and security in public transport Provision for the needs of special categories of passengers in public transport infrastructure Undertaking functions relating to municipal roads Modally integrated public transport networks and travel corridors Service level planning for passenger rail on a corridor network Integrated ticketing systems Travel demand management measures Freight by road, taking into account freight by rail and port	National Land Transport Act, 2009 Integrated transport plans Freight transport strategy
	Metrorail	To ensure that rail commuter services are provided in the public interest, and to promote rail as the primary mode of mass commuter transportation. Custodianship of all commuter and passenger rail assets such as land in and around stations, infrastructure and rolling stock. PRASA operates commuter rail services through Metrorail.	
	Intermodal planning committee	To co-ordinate public transport between the modes	
Private	**South African National Taxi Council**	To ensure that the Taxi industry is mobilized and speaks in one voice and is organized around a common vision: Regulation, Governance and Control of the Industry; Economic empowerment of industry stakeholders; Transformation and development of the Taxi industry.	IPP Procurement Programme

Air Quality

Institutions

National

Department of Environmental Affairs

- **Mineral Resources**
- **Energy**
- **Health**
- **Water Affairs**
- **Labour**
- **Trade and Industry**
- **Transport**
- **Rural Development and Land Affairs**
- **Provincial and Local government**
- **Human Settlements**
- **Defence**
- **Department of Public Enterprises**

Mandate and Responsibility

National Departments Department of Environmental Affairs (DEA) The Department of Environmental Affairs is responsible for developing the National AQMP as part of its EMP/IEP. Further responsibilities include:

- Review of all other National, Provincial and Municipal AQMPs
- Compilation and review of the department's AQMP.
- Development, implementation and review of priority area AQMPs
- Support to other spheres of government Other National Departments

There are several National departments that have an impact on air quality and, hence, have a responsibility in respect of **managing atmospheric emissions within their jurisdictions** as summarized in the National Framework. The National Framework states: "With regard to specific air quality management responsibilities, National departments that are responsible for preparing an EIP or EMP in terms of Chapter 3 of the NEMA are responsible for:

- **Including an AQMP in their respective plans**
- **Preparing an annual report providing information on progress regarding the implementation of its AQMP**
- **Submitting these plans to DEA for review and then implementation**

The main air quality management goal for other National government departments is:

- to ensure that activities that fall within their jurisdiction do not compromise ambient air quality
- to ensure implementation of the Republic's obligations in respect of international agreements and
- to ensure that their AQMP is coordinated with the National AQMP

Governing Documents

- NEMAQA

Air Quality	Institutions	Mandate and Responsibility	Governing Documents
Sub- National	**Provincial Government** City of Tshwane City of Johannesburg City of Ekurhuleni Lesedi Midvaal Rand West City Merafong City Mogale City	• Monitor compliance with provincial AQM plans • Development of provincial air quality management plan • Intervene if plans are not complied with • Develop provincial guidelines and standards • Develop and enforce provincial regulations act of potential air quality hazards • Ensure and oversee adherence to the information management protocols • Implement air pollution reduction initiatives, promoting the development of voluntary partnerships with stakeholders (in line with the NEMA) • Ensure that local authorities are well resourced and capacitated to fulfil AQM functions • Audit the performance of local authorities in fulfilling their obligations under the national framework of the AQM legislation • Ensure that national information systems and protocols are adhered to and reported according to the national department's requirements • Be responsible for provincial research and development programs in line with the national air quality framework	• NEMAQA
Municipal	**City of Johannesburg**	• Develop an Air Quality Management Plan to ensure that the national ambient air quality standards set in this act are adhered to. • Municipalities are obliged to include an air quality management plan in their Integrated Development Plan • Making by-laws to control vehicle emissions within the municipality, monitoring compliance with laws and standards established by the by-laws and enforcement of by-laws	• Section 15(2) of NEMAQA • Chapter 5 of the Municipal Systems Act

[i] Tirusha Thambiran and Roseanne D. Diab (2011) *Air Pollution and Climate Change Co-benefit Opportunities in the Road Transportation Sector in Durban, South Africa* https://bit.ly/2OeUUDh

[ii] https://www.accuweather.com/

[iii] South Africa's new passenger vehicle co_2 emission standards: Baseline determination and benefits assessment: https://bit.ly/3ejisBv

[iv] Energy Research Centre, Systems Analysis & Planning Group, University of Cape Town(2013) *Assumptions and Methodologies in the South African TIMES (SATIM) Energy Model* University of Cape Town, South Africa. Available online at https://bit.ly/2O5B3Xc

[v] TomTom (2019). Johannesburg historic traffic data. Available online at https://bit.ly/30lR25Z