How sustainable is road transport in Gauteng, South Africa? An analysis of the R59 from the perspective of traffic volumes and vehicle loading.

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Mini-dissertation submitted in partial fulfillment for the degree Masters of Science in Environmental Management

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ANTI-PLAGIARISM DECLARATION

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Abstract

The transport of freight or goods by truck (heavy vehicles) is a worldwide phenomenon. In South Africa an increase in the number of heavy vehicles, the number of axles the trucks have, as well as, an increase in the mass of goods carried by trucks has taken place. During the 1930's until the 1980's, the transport of freight by government owned railways was favoured over road freight transport, until transport deregulation started in the 1980's. Deregulation focussed only on the technical and safety aspects of trucking, ignoring critical issues such the impact of trucking on freight costs; road infrastructure and negative environmental impacts. Excessive growth of road transport begs the question: how sustainable is road transport in South Africa? This study sought to determine this by undertaking an in-depth study of one important road in Gauteng, namely the R59, which links Vanderbijlpark/Vereeniging, Meyersdal, Alberton and Johannesburg. The study documents the current traffic characteristics and road usage for the R59 for the years 2004 - 2013, creating, for the first time, a traffic baseline data against which future increases or impacts can be measured.

The study made use of data supplied by Gautrans and was collected by seven traffic counting stations along the Gauteng stretch of road. Six of these are secondary stations (which are operational for one week only during a year), and one is a permanent station (operated all year). The study posits that the pavement of this road is an asphalt mix, with an original design life of 20 years. The road was partly rehabilitated and resurfaced in 1996 – 1997 and in 2005 – 2006. The study shows a steady increase in traffic volumes overtime with some vehicles consistently speeding. There is a surprisingly large urban commute of people travelling from Vanderbijlpark/Vereeniging north to work and back each day. The proposed future tolling of the route will have a serious negative impact on these commuters. The R59 is also a key trucking route, carrying a significant number of long heavy trucks, and overloading is a chronic problem. This overloading is leading to visible pavement damage, in the form of cracking, formation of potholes and bleeding. The study demonstrates that the road was under-designed for the current traffic type; it is under-maintained and under-managed. The study calls for better and more consistent rehabilitation, alongside active traffic management - controlling overloading by having a manned weighbridge and imposing hefty fines on those breaking the law - if the road is to be sustainably managed into the future.

DECLARATION

I declare that "How sustainable is road transport in Gauteng, South Africa? An analysis of the R59 from the perspective of traffic volumes and vehicle loading" has not been submitted for any degree or examination at any other university, and that all sources I have used or quoted have been indicated and acknowledged by completed references. I therefore declare that I have endeavored to avoid plagiarism and I have made all possible effort to present ideas and material in my own words.

Yvette Michelle Terblans

Signed

Date: June 2015

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Abbreviations

ADT: Average Daily Traffic.

ADTT: Average Daily Heavy Traffic.

APT: Accelerated Pavement Testing

ASPASA: Aggregate and Sand Producers Association of South Africa.

CSIR: Council for Scientific and Industrial Research.

DoT: Department of Transport.

E80: Daily Equivalent 80 kN axle loads.

GDP: Gross Domestic Produce

GHG emissions: Green house gas emissions

GSM: Global System for Mobile Communications

HiMA: High Modulus Asphalt

HSWIM: High Speed Weigh-In-Motion

NEMA: National Environmental Management Act

PM: Particulate matter

RAP: Recycled asphalt pavements

RFQS: Road Freight Quality System

SANRAL: South African National Road Agency Limited

SABITA: Southern African Bitumen Association.

TCC: Traffic Control Centres

TRH16: Technical recommendations for highways number 16 of 1991. Traffic Loading for Pavement and Rehabilitation design. Committee of State Road Authorities.

WIM: Weigh in motion.

Definitions

E80: The concept of cumulative equivalent standard (80 kN ≈ 8 165 kg ≈ 18 000 lbs) single axles (E S As or E80s) was developed to simplify the assessment of the actual traffic loading over the life of the pavement.

Average Daily Traffic (ADT): This is the total number of all vehicles observed in each direction as well as road total during the actual period monitored divided by the total number of hours monitored multiplied by twenty-four.

Average Daily Heavy Traffic (ADTT): The sum of the average number of heavy vehicles observed during each normal day of the week divided by seven.

Asphalt / Bitumen: The terms bitumen and asphalt are mostly interchangeable, except where asphalt is used as an abbreviation for asphalt concrete. It is a sticky, black and highly viscous liquid or semi-solid form of petroleum.

Axle: Device or set of devices, whether continuous across the width of a vehicle or not, about which the wheels of that vehicle rotate and which is so placed that, when the vehicle is travelling straight ahead, the vertical centre-lines of such wheels would be in one vertical plane at right angles to the longitudinal centre-line of such vehicle.

Axle unit: Set of two or more parallel axles of such vehicle that are so interconnected as to form a unit.

Axle mass limits: Permissible maximum mass of an axle or an axle unit.

B Climate Type (Dry Climates): The most obvious feature of this category of the Köppen Climate Classification System, is that potential evapotranspiration exceeds precipitation. These Köppen climate types extend from 20 to 35° North and South of the equator and in large continental regions of the mid-latitudes often surrounded by mountains.

Directional Split: The percentage of the 7-day ADT per direction.

The estimated average E80's per heavy vehicle: The assumptions on which the average number of axles per truck, truck mass and the E80 per truck for Non-Weigh-in-Motion traffic counting stations has been determined by taking the average of all the values determined from the WIM stations.

GDP: Gross Domestic Produce. The monetary value of all the finished goods and services produced within a country's borders in a specific time period, though GDP is usually calculated on an annual basis. It includes all of private and public consumption, government outlays, investments and exports less imports that occur within a defined territory.

Night traffic: Traffic observed between 18h00 and 06h00.

Overloading: Exceeding the permissible limits in terms of the freight vehicle length, width, height, gross weight or axle weight by freight vehicles operating on public roads.

Permanent Station: A permanent station is one where continuous traffic observations are made.

Primary road network: Network of tolled and non-tolled highways that links all the major population centres in South Africa. The primary road network corresponds with national roads which are defined as roads and routes declared a national road by the South African National Roads Agency Limited and National Roads Act, Act 7 of 1998, as amended.

SANRAL Classification of Motor Vehicles

- **Class 1:** Light vehicles: Light vehicles are motor vehicles, other than heavy vehicles as defined above, with or without a trailer, and include motorcycles, motor tricycles and motor cars.
- **Class 2:** Medium heavy vehicles: Medium heavy vehicles are heavy vehicles, as defined above, with two axles.
- **Class 3:** Large heavy vehicles: Large heavy vehicles are heavy vehicles, as defined above, with three or four axles.
- **Class 4:** Extra large heavy vehicles: Extra large heavy vehicles are heavy vehicles, as defined above, with five or more axles.

Secondary road network: Public roads not proclaimed as national roads or those identified as part of the primary road network, which typically are the roads of regional or provincial importance.

Secondary Station: A secondary station is one where traffic observations are made on a sample basis for at least 168 consecutive hours

Self-regulation: A voluntary system by which an organisation or industry deals with its own compliance and disciplinary problems, and thereby complements the conventional regulatory enforcement.

Station: A station is an installation on a road which enables the collection of data, examples are permanent stations and secondary stations.

Tertiary roads: Public roads, other than primary or secondary roads. These roads typically connect the residential roads to higher classes of roads and can vary from wide urban streets to rural roads. Such roads would typically fall under the jurisdiction of the municipalities.

The National Road Transport Act 93 of 1996, Regulation 240: The carrying capacity of the roads:

Regulation 240 (1) determines that no person may use a vehicle or a combination of vehicles (with pneumatic tyres) on public roads if –

- any wheel mass load exceeds 3 850 kg on a steering axle and 4 000 kg on non-steering axles;
- the mass load of a single axle with two or three wheels exceeds 7 700 kg on a steering axle and 8 000 on axles other than steering axles;
- the axle mass load of a single axle with four wheels exceeds 10 200kg on a refuse removal vehicle, breakdown truck, bus train or a bus or 9 000 kg on other vehicles not mentioned in sub paragraph (i) to (iv) of regulation 240 (I) (c);
- the axle mass load of a two-axle unit with two or three wheels fitted per axle exceeds 15 400 kg on a steering axle and 16 000 kg on non-steering axles;
- the axle mass load of a two-axle unit with four wheels fitted per axle exceeds 20 400 kg on a refuse removal vehicle or a breakdown vehicle or 18 000 kg on other vehicles;
- the axle mass load of a three-axle unit with three or more wheels fitted per axle exceeds 23 100 kg on a steering axle and 24 000 kg on axles other than steering axles;

- the axle mass load of a three or more axle unit with four wheels per axle exceeds 24 000 kg.
- Regulation 365A, which is also known as the "bridge formula", limits the concentration of axle loads over any given distance and is defined as follows: P = 2 100 L + 18 000 where P is the permissible load in kilograms and L is the distance in metres between the centres of the extreme axles of any group of axles and/or axle units.
- South Africa's latest axle load regulations compare favourably with those of most other countries. The maximum GCM, is, however, considerably greater than the corresponding limit in many other countries (CSIR, 1997).

Transport corridor: A major regional transportation route linking several economic centres, countries and ports and along which a significant proportion of regional and international imports and exports are carried by various transport modes. From an economic perspective, the function of a corridor is to promote trade and economic growth by providing more efficient transport and logistic services.

TRH16: Technical recommendation for highways 16: Structural design for of flexible pavements for interurban and rural roads.

Truck (Heavy vehicle) Split % (Short : Medium : Long)

This is the percentage of trucks in each direction as well as road total, which fall into each of the following categories :

- A short truck is typically a rigid-chassis two-axle vehicle designed for transport of goods, or a bus with at least one axle with four wheels;
- A medium truck is typically a truck-tractor, plus semi-trailer combination; and
- A long truck is typically a combination of a truck-tractor plus a semi-trailer and a full trailer.

The indicated split is established from the combination of measurements of vehicle length and chassis height as follows:

- A vehicle shorter than 4.6m is always regarded as a light vehicle, not a truck.
- A vehicle between 4,6 and 11,0m long is classified as a short truck if the signal indicating the chassis height is "high" (if this signal is "medium" or "low") the vehicle is considered to be a long light vehicle e.g. a car towing a caravan.

- ➢ A vehicle between 11,0 and 16,8m long is classified as a medium truck, irrespective of the chassis height.
- ➢ A vehicle longer than 16,8m is classified as a long truck, irrespective of the chassis height.

Vehicle Classifications and Definitions

"Abnormal vehicle" means a motor vehicle exceeding the legal dimensions as described in the Road Traffic Act, 1996 (Act No. 93 of 1996), as amended, or in any other law.
"**Axle**" means a device or set of devices, whether continuous across the width of the vehicle or not, about which the wheels of the vehicle rotate and which is so placed that, when the vehicle is travelling straight ahead, the vertical centre-lines of such wheels are in one vertical plane at right angles to the longitudinal centre-line of such vehicle. Axle shall also include an axle that is lifted and of which the wheels are not in contact with the road surface.
"**Heavy axle**" means an axle the wheels of which are fitted with tyres of a size (bead seat diameter) greater than 406,4 millimetres (16 inches), or an axle with more than two (2) wheels irrespective of tyre size, but excluding any axle of a motorcycle, a motor tricycle or a motor car.
"**Heavy vehicle**" means a motor vehicle with at least one heavy axle and/or any vehicle which is principally designed or adapted for the conveyance of persons exceeding sixteen (16) in number.
"**Light delivery vehicle**" means a motor vehicle designed or adapted for the conveyance of persons and freight with no heavy axle as defined in paragraph 1.3 above.
"**Light vehicle**" means a motor vehicle, other than a heavy vehicle.
"**Motor car**" means a motor vehicle, other than a motorcycle or a motor tricycle, designed or adapted solely or principally for the conveyance of persons not exceeding sixteen (16) in number, but excluding any vehicle with an axle with more than two (2) wheels irrespective of tyre size.
"**Motorcycle**" means a motor vehicle that has two wheels and includes any such vehicle having a side-car attached thereto.
"**Motor tricycle**" means a motor vehicle, other than a motorcycle with a side-car, which has three wheels and which is designed to be driven by means of the type of controls usually fitted to a motorcycle.
"**Motor vehicle**" means an entity comprising of one or more mechanically/electrically powered units with or without any trailer(s) physically joined by means of tow bars, tow ropes or mechanical articulation, and includes, inter alia: (a) a motorcycle; (b) a motor tricycle; (c) a motor car; (d) a vehicle which has pedals and a mechanically/electrically powered unit as an integral part thereof or attached thereto and which is designed or adapted to be propelled by means of either such pedals or such mechanical/electrical unit or both; and (e) a light delivery vehicle (a bakkie).
"**Trailer**" means a vehicle which is not self-propelled and which is designed or adapted to be drawn by a motor vehicle but does not include a side-car attached to a motorcycle.

Weigh in motion (WIM) devices: Weighing devices that are designed to capture and record heavy vehicle axle weights and gross vehicle weights as they drive over a sensor. Unlike the static weigh stations, such devices do not require the vehicles to stop, making them much more efficient.

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Chapter 1: Introduction

1.1. Introduction

This study sought to determine the state of road transport on the Gauteng leg of the R59 freeway. The R59 is a key road in Gauteng's transport network linking people and commercial enterprises between the cities of Vereeniging/Vanderbijlpark and Johannesburg. The road, however, displays evidence of being in a state of disrepair and rehabilitation is a perennial problem, generating concerns that users are not using the road in a sustainable manner. A key aspect of road transport sustainability is the impact of traffic on a road surface (officially known as a pavement). The impact of traffic is largely determined by the characteristics of the traffic using it, namely: traffic volumes and traffic loading. Both traffic volumes and traffic loading impact negatively on a road surface and lead to pavement damage, if not managed or if the road is not well maintained. Of the two, however, loading has the greatest effect: continuous overloading leads to pavement distress and eventually premature pavement failure. This shortens pavement lifetime and rehabilitation of the road would be required. In particular, there needs to be close alignment between what a road is designed to carry and what it is actually carrying. But, importantly, not only must traffic use be matched with road design, but use of the road (in terms of volumes and loading) must also be managed, as rehabilitation has financial and traffic inconvenience implications. Good management of a road can mitigate road damage. However, management of a road requires both knowledge of the road design specifications and the characteristics of the traffic using the road. In the case of the R59 this is not available, thus, this study sought to determine what they are and then make recommendations as to what is needed to manage the road better.

1.2. Background

For much of South Africa's history, rail was the major mode of the transportation of freight, for both technological and political reasons. For example, restrictions on commercial road haulage legislated by the Motor Carrier Transportation Act (No 39 of 1930), stipulated that grain (and other commodities) could not be transported by road other than by farmers, local authorities and government departments (Mitchell, 2006). Post World War Two, as incomes rose, things changed and subsequently road haulage rates increased. By the mid 1980's the National Transport Policy Study (1986) indicated that there was an urgent need to deregulate and privatise transport, especially freight transport. As a result, permits were relaxed and the emphasis was shifted to the regulation of safety, through the Road Freight Quality System (RFQS), rather than on controlling what commodity could be transported on which particular transportation mode. However, although some elements are in operation, the RFQS as a whole was never implemented and even the ones implemented are not strictly enforced (Mitchell 2006, DoT, 1986, DoT, 1996, DoT, 1999). The unmanaged deregulation of the freight industry resulted in a massive shift in freight haulage from rail to road, such that by 2007, some 87% of all land freight tonnage was carried by road (Ittmann, 2008). Much of this freight is dominated by Fast Moving Consumer Goods (FMCG), which include personal care items, packaged food and beverages, household care items, wine, spirits and tobacco (Bala & Kumar, 2011). Not only did the number of trucks on the road increase, however, so do did their size, in terms of axle number, as well as tonnage. Furthermore, many are overloaded, despite regulation of truck mass by the Road Traffic Act (Act No. 93 of 1996) and the associated Road Traffic Regulations. The Automobile Association of South Africa (AA, 2001) has estimates that some 15% to 20% of all trucks are overloaded (by five tonnes on average) and this is causing some R650 million worth of damage to South Africa’s roads on annual basis. The consequences for the country is increasing road damage, increasing road maintenance costs, increased greenhouse gas emissions and road congestion. Thus, the freight logistics system is now viewed as a key constraint to the country’s growth aspirations (Van Eeden & Havenga, 2010). Importantly, the structural imbalance between road and rail freight transport is a key contributor to the problem with most long-haul transport captured by road, despite the suitability of rail for high-density, long-distance freight. Roads should rather serve as a feeder and distribution service at corridor end points (Van Eeden & Havenga, 2010). While this may be a long term solution, currently not much investment by the state is being made into rail transport, partly because the real cost of excessive numbers of large, overloaded heavy vehicles on specific roads is not well documented. This study, therefore, undertook to partially fill this gap by examining the Gauteng section of R59.

1.3. The R59 freeway

The R59 is a regional route that originates in Hertzogville in the Free State and ends in Alberton, Gauteng. The Gauteng leg of the R59 freeway (also known as the Sybrand van Niekerk freeway) was constructed more or less 30 years ago as a supplementary route to the road which links Alberton to Vereeniging Road, the K89. This study focuses only on the Gauteng leg of the route, both the north and south corridors (from South Rand road, Johannesburg, through Alberton, past Meyerton, Vereeniging and Vanderbijlpark in the Emfuleni Local Municipality (situated in the south of Gauteng), to the Free State border (R 59 Corridor Development Plan, 2010). The Gauteng leg of the R59 comprises three sections, the P156/1, which runs from Alberton to Klipriver, after which it becomes the P156/2 to Vereeniging. The section between Vereeniging and the Free State border is referred to as the P202/1, after which the section on the Free State side of the border to Sasolburg is referred to as the P202/2.

1.4. R59 development corridor

The route (see Figure 1.1) is a strategic one, with significant numbers of passengers and goods transported via it. It is also an important non tolled alternative to the N1 toll road (Emfuleni Local Municipality, undated). In addition, it is proposed that the R59 becomes a 'development corridor' or designated economic node (see Figure 1.2). Such a development will result in significantly more traffic using the R59, which would need to be upgraded to cope. Thus, this study also seeks to serve as a base line study which can be used to determine what the needs of the road are and how best this upgrading can be done.

Currently there is already existing public and private investment in the Meyerton section of the R59. Thus, any changes to the area would have to ensure that there is no or minimal impact to existing businesses. Furthermore the development of vacant stands should be encouraged as this would make optimum use of the existing infrastructure. A number of plans are being considered which include: the CBD Revitalisation Project; the Residential Development Plan and the Golf Park Development Plan. In addition to this, due to the fact that he Klipriver/Nampak/Everite section is situated at the gateway to the corridor it has enormous development potential, as it is closely positioned to the Johannesburg and Ekurhuleni complexes. The nature, character and standard of development along this corridor, will mainly be determined by the successful completion of the three initial projects i.e. the Heineken, Graceview and Klipriver Industrial Park which have been initiated and undertaken. Coinciding with this industrial development, is the implementation of residential developments in the neighbouring areas to the west of the Klipriver. Currently there are about 10 800 existing housing units in the Midvaal area, which can be increased by an additional 28 696 units as a result of the development. Currently heavy industries/noxious industries along this corridor are situated to the southern region and include the Samancor area and surrounds. The central and northern parts of the corridor have been set aside for commercial and light industrial developments in a business park type of setting. The proposed development of this corridor is expected to significantly increase traffic volumes along the Gauteng section of the R59 (R 59 Corridor Development Plan, 2010).

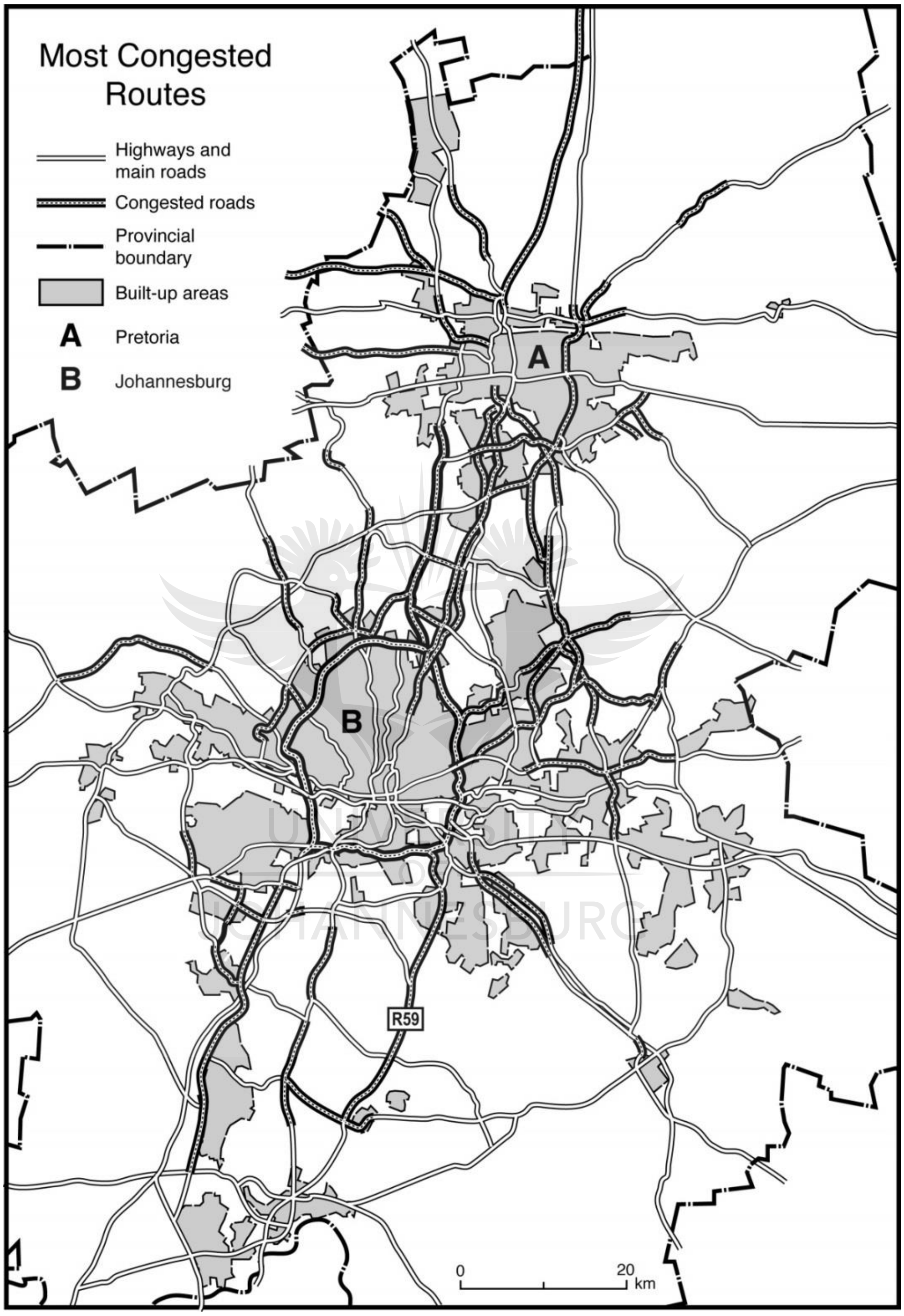

Figure 1.1: Most congested routes in Gauteng

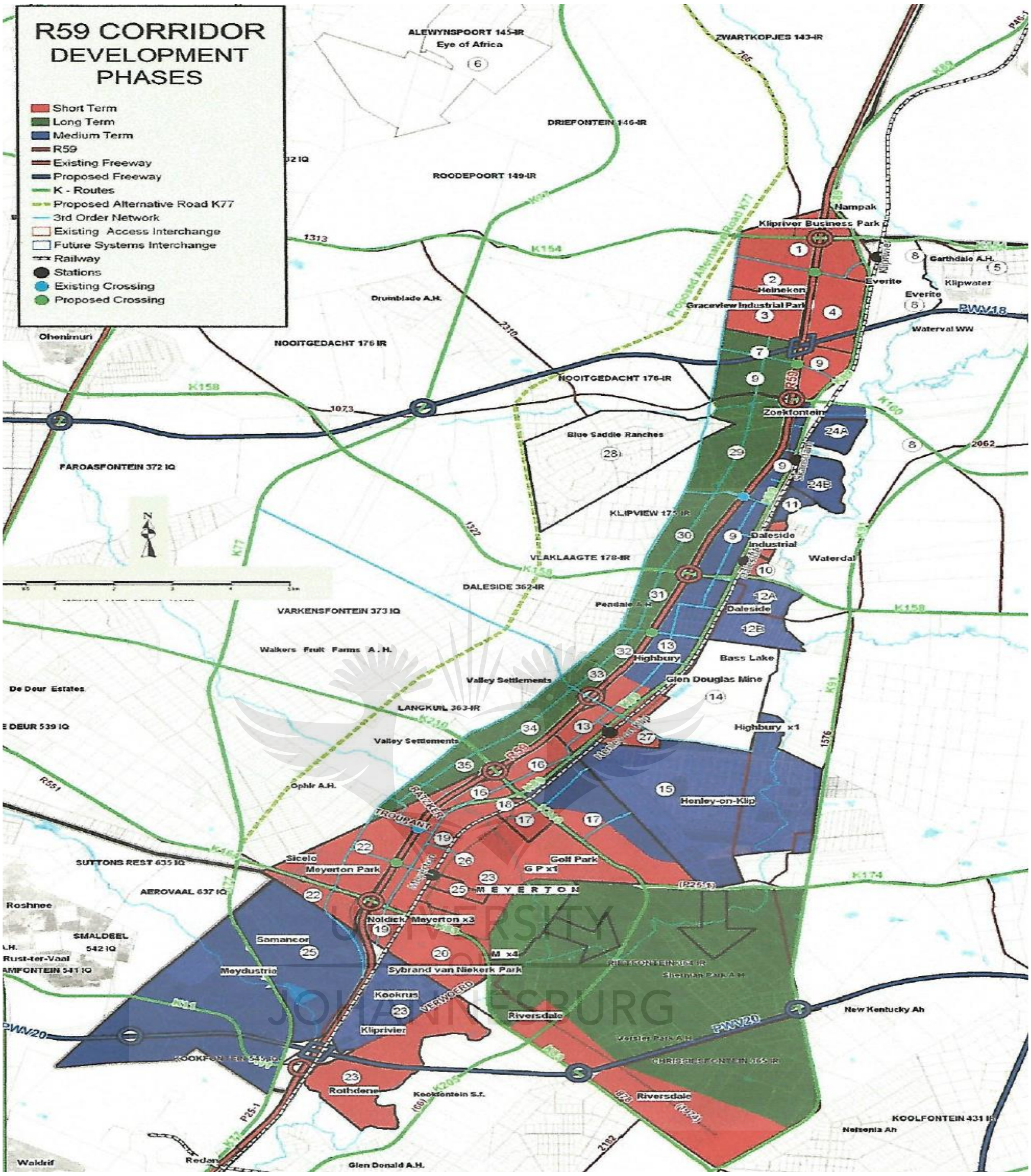

Figure 1.2: R59 Proposed Development Corridor (source: R 59 Corridor Development Plan, 2010: 45).

1.5. Purpose and rationale of this study

This study is important because the underlying causes of poor road quality need to be identified. Continually addressing road surface and road system problems is not financially sustainable for the municipalities or province of Gauteng. Furthermore, poor quality road surfaces negatively impact on the sediment load of the rain run-off. This aggravates the erosive qualities of the run-off and results in the sedimentation of storm water drains and rivers. In some cases, run-off is impaired and roads become flooded, causing traffic hazards and increasing vehicle accidents. Thus, policy makers need to know what is causing road damage, how road damage is occurring, as well as, when, in order to develop informed transport policies for the province. The purpose of this study was to analyse traffic data from 2004 to 2013, from the various counting stations on the Gauteng leg of the R59 to determine:

- Traffic volumes and types using the road between the years 2004 and 2013.
- Traffic load on the road pavement.
- Heavy vehicle usage (split) on the road.
- The classification of the road according to the heavy vehicle composition found on it.
- The extent of overloading of heavy vehicles using the road.
- The road surface quality by documenting the manifestation of road distress: cracking, surface deformation, integration and surface defects.
- To build a base line traffic data set against which future increases/impacts can be measured.

1.6. Research Aims

The main aim of this study was to determine the impact of traffic and trucking on the quality of the road surface of the R59 in Gauteng, as it is a important regional route which connects Johannesburg and Ekurhuleni to the Vaal Triangle. The route already experiences high traffic volumes and is home to heavy industrial activities, such as large-scale manufacturing, warehousing and commercial activities. The decision to promote the route as development corridor will result in traffic volumes rising substantially, especially heavy vehicles, as the result of manufacturers, such as the Dutch brewer, Heineken's Sedibeng brewery are expected to set up in the area (R59 Corridor Development Plan, 2010). It is expected, therefore, that heavy vehicle volumes, in particular, will increase. Thus, this study seeks to determine the current extent to which heavy vehicle transport is impacting on the R59's Midvaal Corridor road surface quality.

1.7. Research questions

Research Question 1: What are the characteristics of the heavy vehicles using the road in terms of weight, overloading, axle number and vehicle split in terms of short, medium and long heavy vehicle types?

Research Question 2: What are the traffic volumes on the road, in terms of the annual daily traffic, the annual heavy daily traffic and the night traffic between 2004 and 2013?

Research Question 3: What is the speed profile on the road?

Research Question 4: What is the classification of the R59 in terms of heavy vehicles?

Research Question 5: Can manifestations of road distress: cracking, surface deformation, integration and surface defects be found on the R59?

1.8. Methodology

Data Acquisition

To undertake this study, data on the R59 had to be obtained. To do this, it had to be determined under which road authority's jurisdiction the road falls. As the Gauteng leg of the R59 is an "R", road, it is a regional or provincial road. Thus, it falls under the jurisdiction of Gautrans. The researcher, therefore, approached Gautrans with a request for access to the data on the road. However, all Gautrans traffic data is filed under P numbers. Thus, the P number of the road had to be determined. This was done by ground truthing, i.e., driving the route and noting the numbers from the relevant roadside markers. From this, it was determined that the Gauteng leg of the R59 is, P156/1, P156/2 and P202/1. Traffic data is recorded by Gautrans in yearbooks. Thus, Gautrans supplied the following Yearbooks: 2004 – 2007 and 2009 – 2013. Gautrans has seven counting stations and data is presented in the yearbooks under each counting station.

Once the year books were obtained, the specific parameters required to answer the research questions had to be extracted from them. These parameters were the average daily traffic (ADT), the average daily heavy traffic (ADHT), the night traffic (NT), the percentage truck split (light, medium, heavy trucks), the E80/HV data (weight), the average number of axles per heavy vehicle, the average mass per heavy vehicle, the peak flow patterns and, lastly, the speed profile on the road.

Once the data had been extracted from each yearbook for each station, it was then tabulated to allow for comparisons to be made and an overall picture of the traffic on the road to be built. This process was time consuming because each yearbook used a different layout and so often hundreds of different pages had to be examined to extract the numerous variables for each counting station and for each year. Thereafter the data had to be cleaned and cross-checked. This took approximately three months to complete and check These detailed tables can be found in the appendices.

Data Analysis

The data obtained for each parameter was consolidated as follows; e.g. all the average daily traffic values for each counting station in a specific year, after which this number was averaged to obtain the value for the specific year. This was done for all the parameters except the E80/HV. The average daily traffic, average daily heavy traffic, night traffic, percentage truck split, average number of axles per heavy vehicle and average mass per heavy vehicle were compared for each year to determine trends (in both the north and south directions) during the period under which the road was studied. The E80/HV data for the permanent WIM station only, was used, as only this data can be considered accurate enough – such data for the other stations are all estimates.

The average annual GDP was determined as well as the average diesel price (Department of Energy) from 2004 to 2014 this was compared to the truck split, which was obtained from the yearbooks. This was used to determine if the economy and the diesel price affected the use and number of heavy vehicles on the R59. The truck split data was then used to classify the road. Two methods were used, firstly one proposed by Bosman (1988), which is used by the provincial government (see TRH16, 1991) and secondly, a more recent method (also proposed by Bosman) the Bosman 2006 system. Using Bosman (1988) roads are classified as a L1, L2, S1 or an S2 roads. Using the Bosman (2006) method roads can classified as an S, M or H road. To determine the extent to which trucks using the road are overloaded or not, the E80/HV and the mass of a heavy vehicle must be correlated with the number of axles the heavy vehicle has. That is, there are pre-determined E80/HV weights per axle. The mass of the vehicle is also predetermined per axles. For this study, the E80/HV values and weight of the heavy trucks (determined by the permanent WIM station 0087) was compared to what values are used in the Bosman (1988) and Bosman (2006). The study also compared the data to what the legal mass of a heavy vehicle (as per guidelines set out in The National Road Transport Act 93 of 1996, Regulation 240). Comparing the data year-on-year, the study was also able to determine the pattern of overloading over the period of study.

Overall, the combination of the average daily traffic, average daily heavy traffic and night traffic were used to determine traffic volumes trends for the period, 2004 – 2013. The yearbooks also contained data that enabled peak traffic flow for a typical week to be determined. This data was then represented graphically to establish traffic flow patterns, both for the week and for the weekends. Lastly, a speed profile of the road could be established using average speeds of vehicles for the section of the road under study.

1.8.1 Traffic counting on roads

Traffic Event Loggers (TEL's) are used to gather traffic information on roads. Inductive loops which are installed underneath the road surface send signals to the TEL. Information which is recorded by the TEL's are: exact time of departure (to the nearest tenth of a second), speed (to the nearest km/h), length (to the nearest tenth of a meter), chassis height (low, medium, high) and the lane number, for every single vehicle. The speed of each vehicle is calculated from the time at which the front of the vehicle arrives at the first and second loops, and the length of the vehicle is calculated from the time the second loop is occupied Gautrans Yearbook, 2007:3).

Where traffic counting stations are equipped with loops only, the vehicle classification is deducted from the vehicle length and the chassis height. This allows a distinction to be made among five types of vehicles, i.e., short light vehicles (cars, LDVs), long light vehicles (e.g. a car towing a caravan, short trucks (single chassis units with two or three axles), medium trucks (articulated units consisting of a truck tractor and semi-trailer) and long trucks (usually a truck-tractor plus a semi-trailer and full trailer combination), (Gautrans Yearbook, 2007:4). The collected data is summarized at various intervals ranging from 5 minutes to 1 hour intervals, depending on the requirements, and stored in the TEL's memory. The data from permanent stations are, where possible, retrieved using a computer connected to the TEL by means of a telephone line or through the GSM network utilizing modems. From the raw data, extensive information on traffic counts, speeds, headways, flows, quality of service and estimated loading can be determined. When a traffic counting station is equipped with axle sensors in addition to loops, the vehicle classification is deducted from the vehicle length and the chassis height and axle spacing. This allows the additional distinction of vehicles into various class schemes, typically the SANRAL Vehicle Classification Scheme (See Abbreviations and definitions). Traffic stations, which have Weigh-in-Motion (WIM) sensors in addition to loops, provide the same vehicle distinction capabilities as stations equipped with axle sensors. In this instance, the masses of axles are estimated from the dynamic masses by the WIM sensors, which are in turn added to the vehicle data recorded.

1.8.2. Road network classification

Bosman proposed a method in which the major roads in South Africa are classified according to the HV composition (Bosman 1988). The Bosman Method was adopted across South Africa in the TRH16 (1991) document (TRH Technical Recommendations for Highways, published by the Committee of State Road Authorities) as it enables roads to be compared to one another in a consistent manner. According to the Bosman Method, there are two main classes in terms of HV traffic, i.e. L and S roads, depending on the composition of the heavy vehicles found on them. L roads carry predominantly shorter heavy vehicles, with two and three axles, whereas S roads carry longer heavy vehicles. These classes were subsequently subdivided into two sub-classes each. Firstly, light classes which carry heavy vehicles with 2-, 3- and 4-axles, and secondly, heavy classes, where roads carry 5-, 6-, 7- and 8-axle HVs (Bosman, 1988: 79 - 91). The guidelines according to this method are:

1. **L1** roads: on which two axle heavy vehicles > 70% of total heavy vehicles
2. **L2** roads: on which 55% < two axle heavy vehicles ≤ 70% of total heavy vehicles
3. **S1** roads: on which 35% < two axle heavy vehicles ≤ 55% of total heavy vehicles
4. **S2** roads: on which two axle heavy vehicle < 35% of total heavy vehicles

More recently Bosman undertook to determine whether the above method was still relevant in current times. In order to affect this, data from the TCCs on the N3 and N4 and from the non-TCC and WIM's on some of the national roads was used. In general it was found that the heavier HVs (5- to 8-axle HVs) increased and that the lighter HVs also carried more freight. It is thus proposed now that the major roads in South Africa could be classified into three classes, namely (Bosman, 2006):

1. **Low** HV roads (L-Roads), on which 2-axle HVs comprise more than 55 per cent of the HVs;

2. **Medium** HV roads (M-Roads), roads on which 2-axle HVs are more than 35 per cent, but less than 55 per cent of the HVs; and
3. **High** HV roads (H-Roads), roads on which the composition of 2-axle HVs are equal to or less than 35 per cent of the HVs.

The average composition on these three types of roads is shown in Table 1.1.

Table 1.1: HV composition on low, medium and high HV roads as measured at the 45 WIM sites (source: Bosman, 2006).

Axles/HV	**HV Composition (%)**		
	Low	**Medium**	**High**
2 Axle	56	41	29
3 Axle	13	10	9
4 Axle	6	5	5
5 Axle	8	9	8
6 Axle	10	14	10
7 Axle	7	21	30

The significance of road classification on the R59, in this case, is that it enables the planners and designers, (Gautrans and contractors), to transfer measured heavy vehicle characteristics from one road class to another. For example if a section of road, which is classified as a High HV road, is to be rebuilt then the HV compositions in Table 1.1 and E80values/HV in Table 1.2 (refer section on pavement loading) can be used which could save the cost of an axle mass survey (Bosman, 2006).

1.8.3. Determining of overloading

1.8.3.1. Pavement loading

Equivalent standard axle (E80)

To today the equivalent standard axle load concept is still applied to most pavement designs in South Africa. The concept of the standard axle load is be applied as follows; a standard axle load of 80 kN (or 8.2 t) is commonly used and the damage caused by the actual spectrum of axle loads is estimated in E80s (Bosman, 2006). Hence E80/HV values are used to determine whether heavy vehicles on a road are overloaded. The number of axles per heavy vehicle on the road determines what the E80/HV value must be, see Table 1.2. If this value is higher, overloading is present on the road. E80/HV values were obtained from Gautrans Yearbooks. Due to the fact that the design value for the road could not be obtained, these values were compared to values obtained from literature. Literature values from two sources were used, firstly from the TRH 16 (1991) document which deals with traffic loading for pavement and rehabilitation design and secondly from Bosman, (2006). The values from these two sources compare quite favourably (Bosman, 2006).

Table 1.2: Comparison of average E80 values (source Bosman, 2006)

Axles/HV	Individual axle method	TRH16 (1991) Recommendation
2-Axles	0.78	0.70
3-Axles	1.24	1.70
4-Axles	1.54	1.80
5-Axles	2.46	2.20
6-Axles	3.76	3.50
7-Axles	4.64	4.40

However it should be noted that the calculations of E80 values are based on data collected on roads with high HV traffic, i.e. H-Roads and that these values may not apply directly to L- and M-Roads. This can only be confirmed once the WIM data from the non-TCC and WIM sites has been analysed.

1.8.3.2. Legal mass

The damaging effect on a road caused by heavy vehicles is a function of the load carried by each heavy vehicle axle (CSIR, Roads and Transport Technology, 1997). The permissible legal mass per heavy vehicle on a road is related to the number axles of the heavy vehicle. Guidelines on the permissible mass per axles on roads to control overloading are stated in The National Road Transport Act 93 of 1996, Regulation 240: The carrying capacity of the roads. According to this regulation the mass load on axles and axle units is limited in agreement with the limited carrying capacity of the road. The purpose of this regulation of the Act is to prevent the premature deterioration of roads due to overloading by heavy vehicles, hence ultimately, the protection of roads.

These restrictions on axle loads have been summarized by The CSIR, in the Roads and Transport Technology, document of 1997. This summary states that for a specific number of axles per heavy vehicle the load is not permitted to exceed a specific mass in kilograms, as shown below in Table 1.3.

Table 1.3: Maximum permissible legal mass per number of axles (source: CSIR, 1997)

Axle type per vehicle	**Maximum legal mass (kg)**
Single wheel load	4000
Single axle (two wheels, steering)	7700
Single axle (two wheels, non-steering)	8000
Single axle (four wheels)	9000
Tandem axle* (two wheels per axle)	16000
Tandem axle (four wheels per axle)	18000
Tridem axle**	24000

*Tandem axle = 2 axle unit, **Tridem axle = 3 axle unit

In addition to this, the Gross Combination Mass (GCM) of any combination of heavy vehicles, i.e. truck-tractor and trailers combinations, is limited to 56 000 kg, (CSIR, Roads and Transport Technology, (1997).

According to the CSIR, the influence of light vehicles such as cars and light commercial vehicles compared to heavy vehicles, have a relatively insignificant impact on the structure of a road surface of pavement (CSIR, Roads and Transport Technology, (1997). Hence the contribution of these vehicle types to structural damage of a road pavement by traffic is ignored in this study.

1.9. Shortcomings of the study

In undertaking this study a number of problems were encountered. Firstly, the original design data for the road could not be obtained, rather inferred from other documents obtained from Gautrans. Nor was the design criteria used for the rehabilitation of the road in both 1996 and

2006 available. Some information was obtained for the section between Ring Road interchange and the PAN interchange (Vereeniging region) but this information could not be used for the entire road, as it is not clear if this pertains to the entire road or not. Secondly, the secondary counting stations were not all operational for the same period of time for the years that traffic counts were done. Traffic counts were also not carried out by Gautrans consistently every year, thus there are significant gaps in the data.

1.10. Chapter Outline

This study is divided into different chapters:

Chapter 2 presents an overview of pavement properties, sustainability, sustainable pavements and sustainable road freight transport internationally. Chapter 3 presents an overview of the sustainability of road freight transport in South Africa. Chapter 4 presents the data extracted from the Gautrans yearbooks, followed by a discussion of the patterns and trends observed from this data. Discussions are presented for a number of years on traffic volumes such as the patterns of the average daily traffic, average daily heavy traffic, and night traffic. The truck split data (in percentage) was used to classify the road into a L1, L2, S1 or S2 road, using guidelines from the TRH16 (1991) document or a L, M or H road using guidelines from Bosman (2006). The heavy vehicle data such as pavement loading, (E80/HV) is discussed in terms of overloading. In combination with this the number of axles per heavy vehicle and the mass per heavy vehicle is also evaluated in order to determine overloading of heavy vehicles. Directional flow patterns for traffic (all traffic and heavy vehicle traffic) for a typical week during a year are presented. Lastly trends in the light/heavy variations are shown. Chapter 5 presents conclusions drawn from this study as well as recommendations.

1.11. Conclusion

The number of heavy vehicles transporting freight via roads in South Africa has increased dramatically since the deregulation and privatisation of transport, especially freight transport. In light of this it has been seen that with the increase in the number of heavy vehicles on the road, there has been an increase in their size, in terms of axle number, as well as tonnage. With this the problem of overloading has become an issue, despite regulation of heavy vehicle mass by the Road Traffic Act (Act No. 93 of 1996) and the associated Road Traffic Regulations. The degree of overloaded trucks on specific roads is not well documented. This has led to the current study, the aim of which is to partially fill this gap by examining the Gauteng section of R59. This route is furthermore being promoted as development corridor which will result in traffic volumes rising substantially, especially heavy vehicle volumes, as manufacturers are expected to set up in the area. Hence knowledge of the traffic composition on the road is needed in order to determine what the effect of this development would be on the road. This study will now turn to an examination of the international literature.

Chapter 2: Road freight transport and sustainability – An international perspective

2.1. Introduction

It is accepted that the transport of freight via road has a negative impact on road surfaces. It reduces the lifespan of a road and/or increases the frequency of road maintenance both of which have financial and environmental implications. In particular, questions concerning sustainability come to the fore. Thus, there is considerable interest in defining, measuring and implementing sustainability within the fields of transportation planning and transport infrastructure (Kassens, 2009). The notion of sustainable transportation emanates from the concept of sustainable development and sustainable cities and with this in mind, this chapter will first briefly explore sustainability, then sustainable development and sustainable cities before taking a more in-depth look at sustainable transportation, with an in-depth look at sustainable pavements or road surfaces.

2.2. Sustainability

The concept of sustainability is one that has become increasingly important throughout the world. It encapsulates the need to achieve a future in which non-renewable resources are available for use by future generations. This requires effective long-term, strategic decision-making (Victoria Transport Policy Institute, 2013). Management of these human impacts is required if ecological integrity and functioning is to be preserved (Pahl-Wost, 2007). One way to reduce impacts is for human consumption patterns to be managed down and/or re-directed. Thus, a critical aspect of sustainability is demand side management (Daly, 1990). However, economic efficiency is also considered an aspect of sustainability, as other goals, such as eradicating poverty will not be met if money cannot be re-directed to them. It has thus become necessary to manage the distribution of resources, to achieve a situation where social and distributional needs are met, in a manner which is fair and to ensure public participation and democratic policy formation (Victoria Transport Policy Institute, 2013).

2.3. Sustainable Development

The most widely used definition of sustainable development is from the Brundtland Commission, which states that “sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Jeon & Amekudzi, 2005, p. 31 & WCED, 1987, p. 157). This is a broader definition than that of economics, where sustainability is defined in a narrow way focusing on guaranteeing the consumption possibilities of future generations (Arrow, et al, 2004). Hence in order to achieve sustainability, it is imperative that human activities must be of an integrated nature and that comprehensive planning between sectors, jurisdictions and groups must be essential. This has led to an important change in the manner in which existing institutions address complex, long-term problems, which until recently has been in poorly suited ways (Victoria Transport Policy Institute, 2013). As the notion of sustainable development grew to become an international priority, emphasis has turned to the concept of sustainable cities.

2.4. Sustainable cities

Emerging out of the notion of Sustainable Development is that of an 'eco-city' or sustainable city, first coined in Richard Register (Register, 1987). An eco-city is one which operates in a manner where negative human impacts on the biophysical environment are significantly reduced and/or mitigated. Such cities focus on minimizing inputs of energy, water and food, and outputs such as waste in the form of heat, air pollution and pollution. Sustainable cities thus ensure that the quality of life of residents is far more superior compared to that in unsustainable cities, due to the fact that these cities have low ecological impacts, are economically sustainable and are socially just. Critically such cities do produce more waste than what natural systems can process however the ecological footprint of the city is small (Rai, 2012). Striving to achieve a sustainable city is an essential feature of environmental management, as more than 50% of the world's total population is urbanized and this is expected to increase to 70% by the middle of the twenty first century (Banister, 2005). However, in order to achieve sustainable urban communities, knowledge of the interconnectedness of economy, society, and environment is necessary (Rai, 2012). According to Kenworthy (2006) the development of an eco-city or sustainable city is closely related to sustainable urban development and transportation systems. This embodies the notion of sustainable transport networks, which encompass modes of transport, transport systems and transport planning (Jeon & Amekudzi, 2005 & Litman, 2008). According to this model an eco-city should contain well developed public transport modes which connect high density city centres with areas which surround these city centres. Furthermore a safe and high quality infrastructure for walking and cycling is required. Increases in the use of motor vehicle transport should be controlled by minimising the expansion of road capacity. Such a city is more sustainable because it promotes social equity and inclusiveness; will reduce costs (especially transport costs) and enables the built and natural environment to exist in a more harmonious manner by reducing urban boundary creep.

2.5. Sustainable Transport

Transportation plays a major role in economic and social development, as transport facilitates access to markets, employment, health and education, social services and trade (Lucas, 2011). Economic development is strongly facilitated by good spatial planning and infrastructure capacity, thus, advancing economies are intimately linked to transport (Proost & Van Dender, 2010). Thus, transport is intimately linked to quality of life. In a typical city, road transport dominates as the most common way in which people and goods move around. For goods, this will mean transportation in a truck. Transportation of goods by truck has several advantages. One of which is "door to door" delivery. It is also fast, flexible as it does not rely on schedules (in the way that train or air transport does) and reduces the cost of loading and unloading, fits in well with modern day packaging and load size (Novatech Cargo, 2010). This is despite road freight being less fuel efficient than rail or ship (Proost & Van Dender, 2010).

In terms of progressing towards achieving sustainable development it has become evident that transportation remains a challenge (Goldman & Gorham, 2006). This is due to the fact that factors such as social, technical, and economic systems are included within a transportation system. These factors complicate measures aimed at addressing concerns comprehensively. Urgent attention needs to be paid to the transportation sector, as it consumes resources, destroys habitats, is complicit in atmospheric carbon loading and can seriously hinder economic efficiencies and social justice (Goldman & Gorham, 2006). Furthermore, in addition to consuming large quantities of energy in particular oil, motor vehicles are also responsible for the emission of pollutants such as carbon dioxide and nitrogen oxide as well as generating noise. It has become evident that the adverse impacts of transport systems are externalized, i.e. the advantages of mobility apply to a small number of individuals only, whereas the costs are borne by society as a whole. Thus, there is an urgent need for a sustainable transport or a sustainable mobility agenda (Litman, 2008).

According to European Union Council of Ministers of Transport and the Centre for Sustainable Transportation (CST), a transport system is sustainable when the minimum requirements of access can be carried out in a safe manner, which is consistent with human and ecosystem health. Such a transport system will also strive for the advancement of equity within and between successive generations. Also, it should be affordable, operate fairly and efficiently, offer a choice of transport modes, and support a competitive economy, as well as offer balanced regional development. A sustainable transportation system will also limit emissions and waste, use renewable resources and minimize impacts on land and reduce the generation of noise (Schafer, 1998; Jeon, & Amekudzi 2005, Gilbert et al., 2003). See Table 2.1 on why sustainable transport is a crucial aspect of sustainable development.

Table 2.1: Why support sustainable transportation? (source: UN ESCAP, 2002: 16).

Economic aims	Ecological aims	Social aims
Provide infrastructure for sound economic development and employment	Improve health and safety in transport	Guarantee transport services and access for all social groups
Allow for cheap, fast and high-volume transport	Reduce pollution on local, regional and global level; contribute to climate stabilisation	Focus on transport for the (urban) poor
Reduce congestion	Reduce land take	Improve methods of addressing transport problems of the poor
Strengthen rural-urban interlinkages	Integrate environmental and economic dimensions in transport planning and development	Protect poor against adverse changes in transport policies
Create sound financial basis for public transport	Develop an environmentally sensitive strategic framework	Ensure democratic participation in transport policy decision-making
Allow for different transport options		
Raise revenue for infrastructure and transport facilities set-up, operation and maintenance		

2.6. Pavements (road surfaces)

A pavement is an artificial surface that is laid over the ground to facilitate travel. Although the correct engineering term is pavement, the word mostly used is road. The two main categories of pavements are flexible and rigid pavements. Road construction is a costly exercise and good road design is required to achieve the most cost-effective road while optimizing the level of service provided to road users. However, these goals may frequently be in conflict. For example, the most cost-effective option may be to place a low-cost surfacing on a given segment of pavement on an annual basis. This however, will cause massive service disruptions to traffic unless the road is used infrequently. A frequently used road could perhaps be built with a concrete or "perpetual" asphalt pavement, but although this will be more cost effective in the long run, upfront funding constraints may mean that such a road is not built (South Carolina Department of Transport, 2008). According to Johannessen (2008), the ability of a road to support any given load is dependent upon: (1) the magnitude of the load; (2) how often the load is applied; (3) the supporting power of the soil underneath and (4) the type and thickness of the pavement structure. Thus, the amount and type of traffic must be considered when a road is built, along with weather conditions and how much maintenance is possible over the life of the road.

2.6.1. Flexible pavements

Flexible pavements are composed of aggregate (sand, gravel, or crushed stone) and asphalt (bituminous and mineral aggregate mix) material. A typical flexible pavement consists of four layers (see Figure 2.1). The four layers are: (a) The top or surface layer which is normally asphalt; (b) The base layer, an unbound layer of un-stabilized aggregates, however, stabilizing agents such as asphalt, Portland cement, or another stabilizing agent, could also be employed to stabilize the aggregate base; (c) The sub-base, which mainly consists of a local aggregate material; and (d) the subgrade or foundation. Cement or lime can also be used to stabilize the top part of the subgrade. The typical structural design of this type of pavement can be described as a number of layers where material quality declines with depth (Russel & Lenz, 2011).

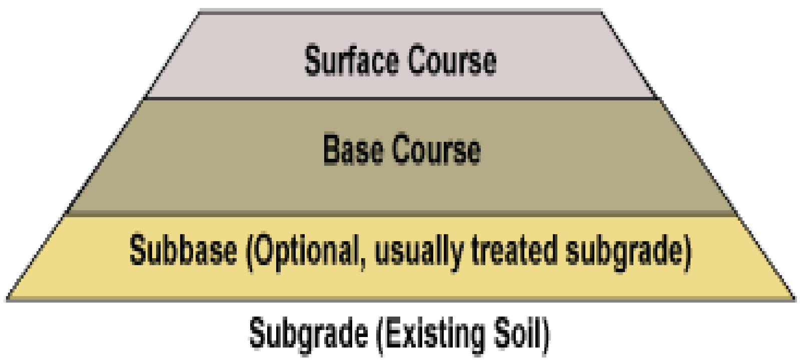

Figure 2.1: Typical flexible pavement layers (source: Russel & Lenz, 2011: 2-11).

2.6.2. Rigid pavements

Rigid pavements are used for major highways as they are designed to withstand all-weather conditions, are long lasting and can carry high-speed traffic. Rigid pavements consist of a concrete slab, of which the thickness is between 10-30 cm (see Figure 2.2) (Hjort, Haraldsson & Jansen, 2008; Russel & Lenz, 2011).

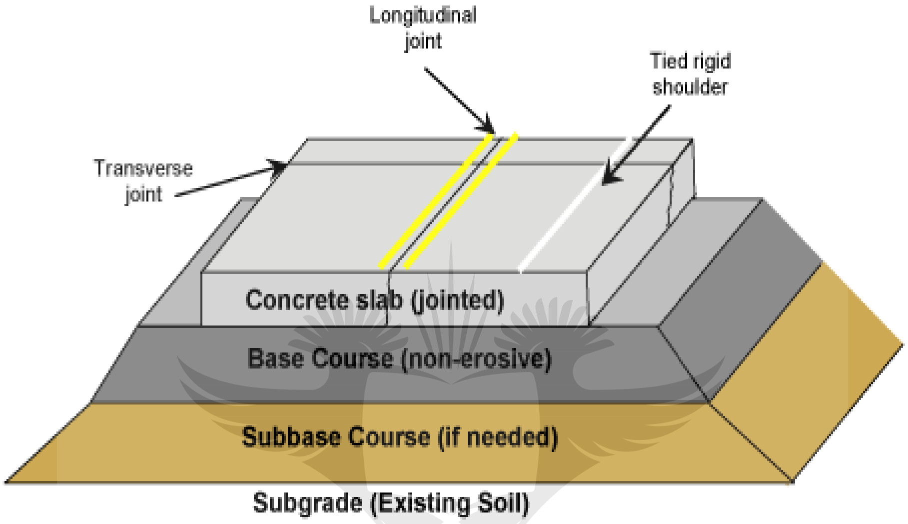

Figure 2.2: Typical section for a rigid pavement (source: Russel & Lenz, 2011: 2-13).

2.7. Sustainable pavements

Sustainable pavements play an important role in achieving sustainable transport. The provision and maintenance of a reliable and sustainable infrastructure is a priority for all countries. Roads are of central economic importance with pavement structures consuming up to 60% of resources allocated for the provision and management of the road infrastructure. A sustainable pavement can be defined as one where the use of natural resources is minimized, energy consumption, GHG emissions and pollution (air, water, earth, noise, etc.) is reduced, health, safety and risk prevention is improved and a high level of user comfort and safety is achieved. Roads can improve their sustainability by minimising the amount of energy used during their construction and minimising waste production (Gambatese & Rajendran. 2005). Improved technology, better construction and rehabilitation methods, as well as optimized pavement selection based on life-cycle cost analysis can also improve pavement lifetime (Lane, Kazmierowski & Alkins, 2008). Economically, sustainable pavements will result in savings at all levels. Better maintenance will lead to longer pavement lifespans, reduces disruptions of the road users' trips, reduces travel costs and lowers maintenance costs (Oliveira, 2009).

2.7.1. Concrete pavements and sustainability

The most defining feature of concrete pavements is that they have a lifespan of up to 40 years without needing significant repair or rehabilitation. However, best-practice guidelines on sustainability practices are not readily available to pavement design engineers, specifiers, and constructors (Tayabji & Taylor, 2010). Additionally, Portland cement, used in the making of concrete pavements, contributes considerably to GHG emissions, partly due to the pyroprocessing that is required and partially due to the calcination of limestone, although new manufacturing techniques lowered the carbon footprint of the product (Van Dam, Taylor, Fick, Gress, Van Geem & Lorenz, 2012). Despite this concrete pavements have some positive sustainable features: (1) Endurance or long life spans with minimal future maintenance and so are economical; (2) Safe - drag is minimized, vehicles experience more fuel efficiency; better surface visibility and higher skid resistance; (3) They are fully recyclable; (4) Concrete pavements have no or little adverse effect on the surrounding environment; (5) Minimal traffic disruption during construction and maintenance activities and (6) Aesthetically pleasing (Van Dam et. al., 2012).

2.7.2. Asphalt pavements and sustainability

Asphalt is a more environmentally friendly pavement construction material from a manufacturing, construction, rehabilitation and recycling point of view (Kriech et. al., 2004; Towsend & Brantley, 1998). This is because they have low energy requirements and emit less greenhouse gases (Gambatese & Rajendran, 2005). The asphalt industry is also well known for their recycling, re-using up to 70 million tons of its own product every year. Asphalt is relatively easy and simple to maintain and produces less noise than a cement pavement (Newcomb & Scofield, 2004). Storm water is easier to manage with porous asphalt (Jackson, 2003).

2.8. Impacts of road transport

Road traffic (be it passenger vehicles or heavy vehicles) has negative environmental impacts which includes greenhouse gas emissions (GHG), other air pollutants, noise pollution, loss of natural infrastructure and biodiversity (Delucchi, 2000; Fürst, Oberhofer & Stöglehner, 2014).

Pollutants such as air pollution and noise pollution can be measured as units per tonne of goods transported. This is because the volume and mass of goods, as well as the distance they must be transported determines the extent of the environmental stress. The overall degree of environmental stress can be expressed by multiplying the quantity of goods by distance transported and mass. The nature of the receiving environment also determines the overall environmental impact (Hecht, 1997; Van Essen, 2008; Oberhofer & Dieplinger, 2014).

One of the biggest challenges facing the world is the emission of greenhouse gasses, especially carbon dioxide. There are also growing concerns around the negative effects vehicle emissions have on human health, such as asthma and elevated blood lead levels. The pollutants of greatest concern are particulate matter (PM_{10}, $PM_{2.5}$); nitrogen oxides (NOx); sulphur oxide (SO_2); ozone (O_3); volatile organic compounds (VOC) and heavy metals Heavy-duty diesel vehicles (HDDV) contribute disproportionally to emissions of nitrogen oxides (NO_x) and particulate matter (PM) (Huai, et. al., 2005). Furthermore, transport-related air pollution also impacts negatively on the biosphere, soil, water, buildings and materials (Lena, et. al., 2002; Maibach, et al., 2008). Pollutants seep into the surface and groundwater, causing eutrophication and acidification (Cloern, Krantz, & Hogan, 2013). In addition to this, gaseous emissions of sulphur dioxide and nitrogen oxide lead to acid rain. Human health is, furthermore, negatively affected by traffic noise, in the form of annoyance, sleep disturbance, and an increase in hypertension and cardiovascular diseases (Den Boer & Schroten, 2008).

2.9. Causes of gaseous emissions in transport

Emissions caused by the transport industry are the result of numerous activities. Firstly, there is the use of fossil fuels, which generates emissions hydrocarbons, as well as other compounds. Air pollution is generated by vehicle emissions and the evaporation of fuel during re-fuelling as well as from the vehicle fuel system (EPA, 2014). Secondly the production of petroleum fuel also generates air pollution, greenhouse gases (GHG) in particular (LCC, 2009). Thirdly, vehicle production, maintenance and disposal generate GHG emissions. The production and disposal of vehicles accounts for roughly 10 to 16% each of the GHG emissions, maintenance is responsible for the rest (Hill et. al., 2011). Lastly, transport related infrastructure, maintenance and adjustments also generate air pollution (British Columbia: Ministry of Transport and Infrastructure, 2011).

2.10. Impact of freight transport on pavement surfaces

Flexible and rigid pavements rely on different mechanisms to transmit load. Rigid pavements are 'stiffer' than flexible pavements and report very low load deflections over a large area. Flexible pavements display localized load deformation as the load is distributed over a small surface area (see Figure 2.3). When the load is removed, the layers rebound, although not fully, so over time distortion builds up. This is the primary reasons rigid pavements have a design life of 30 to 40 years whereas flexible ones have a design life of between 15 and 20 years, although high quality construction material can increase this (Hjort, Haraldsson & Jansen, 2008).

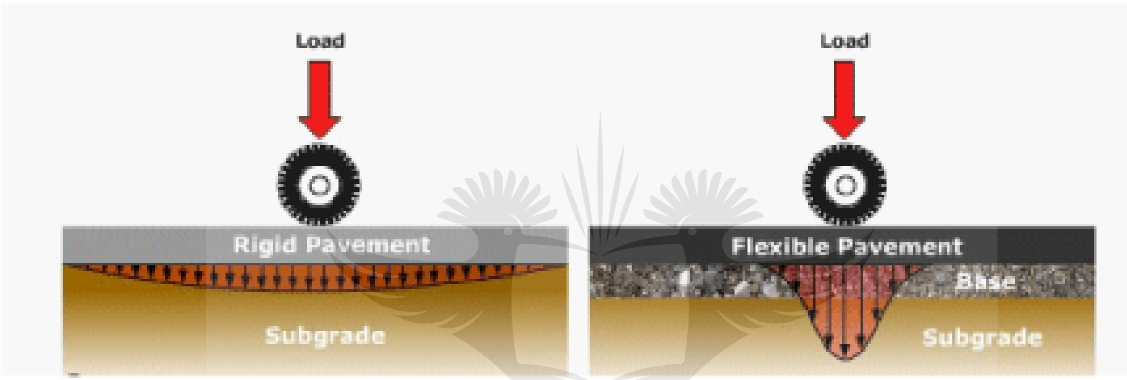

Figure 2.3: The load distribution for a flexible and rigid pavement (source: Russel & Lenz, 2011: 2-16).

Road pavements are designed with a certain load bearing capacity in mind. The load bearing capacity of a pavement determines the traffic volumes it can cope with over a defined period. However, road surface wear is also influenced by the properties of vehicles that use it. This truck loading (axle weight, axle configuration, mass of goods carried, degree of overloading); tyre type; tyre pressure and truck suspension (Al-Qadi, et. al., 2005; Hjort, Haraldsson & Jansen, 2008). However, to establish the specific deterioration of a road pavement due to traffic, heavy vehicles must be weighed individually (Roeun & Mony, 2007).

Two types of load forces interact between a road surface and a vehicle. Firstly the static vehicle load which is a result of vehicle weight and the vehicle payload. Secondly, there is dynamic load, which is a result of the vibrations of the vehicle itself. The dynamic load changes due to it being a function of two parameters, vehicle speed and road unevenness (Hjort, Haraldsson & Jansen, 2008). The sum of the two loads is the instantaneous tyre force (Pable, Gawture, &

Seshu, 2007). As loads vary by type and weight of the vehicles, traffic loads are usually converted into standard axle loads for design purposes. The different axle types are single, tandem and tri-axles (see Table 2.2) (Johannessen, 2008).

Table 2.2: Different Axle types (adapted from Roeun & Mony, 2007: 3).

Axle type	Definition of axle type	Axle load (tonnes)
Single axle	Single axle with 2 wheels in front, more than 1.8 m spacing from other axles.	6
Single axle	A single axle with 4 wheels.	10
Double axle	Two axles, more than 1.8 m spacing, 4 wheels in front.	11
Tandem axle	Two axles, less than 1.8 m spacing between the axles, 8 wheels, often the suspension works to share the load equally between the axles.	19
Tri axle	Three axles, relatively short longitudinal distance between the axles, 12 wheels (often the suspension works to share the load equally between the axles.	24

If maximum loads are exceeded, then extensive damage to the road and its structures occurs. In such instances there is a reduction of the life expectancy of the road. More and more tri and quad axle heavy vehicles now ply our roads, leading to an increase in the size and weight of heavy vehicles. This poses serious challenges for road authorities in terms of managing and servicing the road networks, and providing serviceable networks for users (Taramoeroa & de Pont, 2008).

Wide-base single tyres for heavy vehicles are good for fuel efficiency, allow the range of the payload carried to be expanded, improves vehicle operation, brake performance, there is decreased maintenance and overall costs are saved. However, wide-base tyres cause a significant increase in pavement damage as there is less contact between the road surface and the tyre i.e. the tyre footprint is smaller (Al-Qadi, Yoo, Elseifi & Janajreh, 2005). This increases road wear as wide-single tyres inflict additional scuffing forces on road surfaces (Hjort, Haraldsson & Jansen, 2008). Thus, restrictions on the use of wide-base axle configurations are necessary (Taramoeroa & de Pont 2008). The suspension system of vehicles has a strong impact on how vehicles interact with the road as it affects vehicle vibration and stability (Baviskar, Bhamre & Sarode, 2013). Good suspension reduces vertical vibrations and decreases dynamic axle loads (Hjort, Haraldsson & Jansen, 2008). Thus, suspension is an essential consideration if dynamic pavement load is to be minimized (Sun, 2002).

2.11. Pavement distress and deterioration

The deterioration of a pavement is a process by which distress (defects) develops and eventually leads to the degradation of the pavement. This is due to the combined effects of traffic loading and environmental conditions (Adlinge & Gupta, 2009). The rate at which pavement distress occurs varies over time as it is also a function of the materials used and the design life of the pavement (Hjort, Haraldsson & Jansen, 2008). Pavement failure negatively impacts on user experience (Adlinge & Gupta, 2009). In addition, pavement deterioration can occur on a new road which, because it is new, attracts a lot of traffic, but if it was not designed for such volumes then fatigue failure occurs. Poor road shoulder provision can also lead to edge failure. If drainage factors were not taken into account, then during rain events, water enters the pavement from the sides and top and the top layer later detaches from the lower layers. Poor construction techniques can also cause pavement failure. Furthermore, environmental effects such as high temperatures or frost, can contribute to pavement damage. A combination of heavy vehicle wheel loads and high temperatures can be devastating for asphalt pavements (Gillespie, et. al, 1993).

2.11.1. Cracking

The most common types of cracking found in pavements are (Adlinge & Gupta, 2009:11):

Fatigue cracking (alligator cracking): This is caused by failure of the surface layer or base layer due to material fatigue induced by excessive loading. The cracks lead to disintegration of the surface, with potholes being the result. Drainage problems can aggravate the situation (see Figure 2.4) (Adlinge & Gupta, 2009:11 & Walker, 2002:11).

Figure 2.4. Fatigue cracking on the road surface (source: Walker, 2002:11).

Surface cracking: This is cracking in the bituminous material found at the surface of the pavement, due to material fatigue caused excessive shear loading, although the age of the bituminous material will also play an important role (Hjort, Haraldsson & Jansen, 2008:13).

Longitudinal cracking: With this type of cracking, visible long cracks, parallel to the centre line of the road way occur (see Figure 2.5). The causes of these are multiple: Frost heaving; joint failure; overloading. The cause of the crack must determine the repair or else multiple parallel cracks can form, known as deterioration (Adlinge & Gupta, 2009:12 & Walker 2002:9).

Figure 2.5: Longitudinal cracking on the road surface (source: Walker, 2002:9).

Transverse Cracking: Transverse cracks form at roughly right angles to the centre line of the road. They are usually regularly spaced, wide apart, begin as hairline/narrow cracks, and widen over time. If not properly sealed and maintained, additional cracks develop, parallel to the initial crack. The reasons for transverse cracking are similar to those for longitudinal cracking, although thermal issues can lead to low-temperature cracking if the asphalt is too hard, this is referred to as thermal cracking (see Figure 2.6) (Adlinge & Gupta, 2009:12 & Walker, 2002:7).

Figure 2.6: Transverse cracking on the road surface (source: Walker, 2002: 7).

Block cracking: Block cracking is used to describe an interconnected series of cracks that divides the pavement into irregular pieces (see Figure 2.7.). This can occur if there is a lack of compaction during construction or that the construction mix used was old, too dry the aggregate mix was too fine or absorptive aggregates were used (Adlinge & Gupta, 2009:12 & Walker, 2002:10).

Figure 2.7.: Block cracking on the road surface (source: Walker, 2002:10).

Slippage cracking: Slippage cracks are half-moon shaped cracks with both ends pointed towards the oncoming vehicles (see Figure 2.8). The horizontal forces generated by use create them. They are a consequence of poor bonding between the top and bottom layers or a lack of a tack coat (Adlinge & Gupta, 2009:12 & Walker, 2002:8).

Figure 2.8.: Slippage cracking on the road surface (source: Walker, 2002:8).

Reflective cracking: Reflective cracking occurs on the top bituminous layers as a result of cracks or joints in lower layers (see Figure 2.9) (Adlinge & Gupta, 2009:12 & Walker, 2002:8).

Figure 2.9.: Reflective cracking on the road surface (source: Walker, 2002:8).

Edge cracking: Edge cracks usually begin as crescent shapes at the edge of the pavement and then expand until they resemble alligator cracking. This occurs when weak material is used to construct the shoulder of the road surface or excess moisture has accumulated here. Heavy traffic using the verge (to overtake for example) or vegetation growing along the edge can also lead to edge cracking (see Figure 2.10) (Adlinge & Gupta, 2009:13).

Figure 2.10.: Edge cracking on the road surface (source: Walker, 2002:11).

2.11.2. Surface deformation

Pavement deformation occurs if one or more of the surface layers are weak, which can usually be ascribed to movement after construction. Surface deformations are manifested as rutting, corrugations, shoving, depressions and swells. These deformations pose a safety risk. (Adlinge & Gupta, 2009:13 & Walker, 2002:5).

Rutting: When clear wheel paths are visible on a road surface, this is known as rutting. Ruts can have a width of several decimetres and a length of tens to thousands of metres. Rutting is normally the result of failure of one or more of the pavement layers. Narrow ruts are a sign of permanent deformation of bituminous layers caused by compaction or shearing stresses. A wide rut is indicative of a subgrade failure (see Figure 2.11) (Adlinge & Gupta, 2009:13 & Walker, 2002:5).

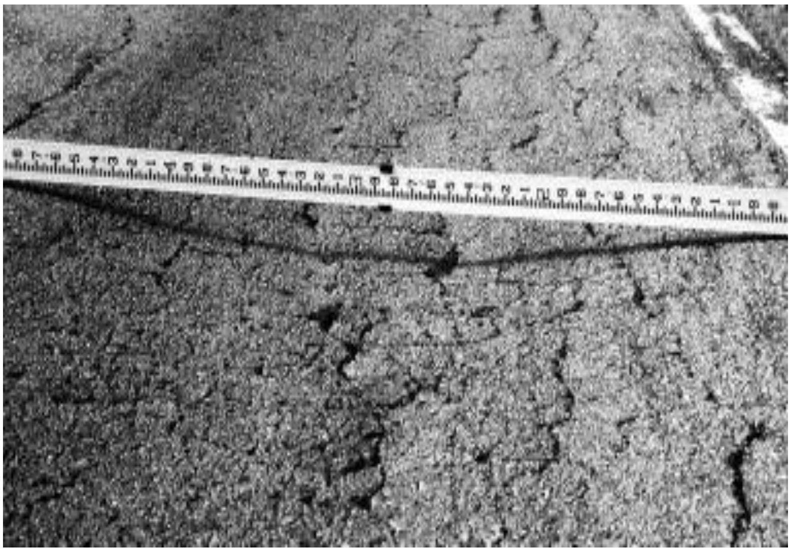

Figure 2.11: Secondary rutting of a road surface (source: Walker, 2002:5).

Corrugation, Shoving & Delamination: Distortion of a pavement surface so that it resembles a washboard is known as corrugation. Corrugation results from instability of the construction material. Shoving is the result of a plastic-like movement in surface layer creating localized bulging of the pavement. If too much asphalt cement, too much fine aggregate, or rounded or smooth textured coarse aggregates are used then corrugation and shoving results. Road surfaces are particularly vulnerable in spots where vehicles accelerate or decelerate. When sections of the surface layer detaches from the under layer, delamination occurs. This is usually a result of using an unstable build mix or slippage between layers due to poor construction or water damage. However, vehicle acceleration and deceleration can also cause it, especially of heavy vehicles (see Figure 2.12) (Adlinge & Gupta, 2009:13 & Walker, 2002:6).

Figure: 2.12: Corrugation, Shoving and Delamination of a road surface (source Walker, 2002:6).

Depressions: These are small, localized bowl-shaped areas that also contain cracks. Depressions lead to road surface roughness, making driving conditions dangerous and enabling water to pool on the surface. Movement of pavement layers below the surface layer may be the cause (see Figure 2.13) (Adlinge & Gupta, 2009:13).

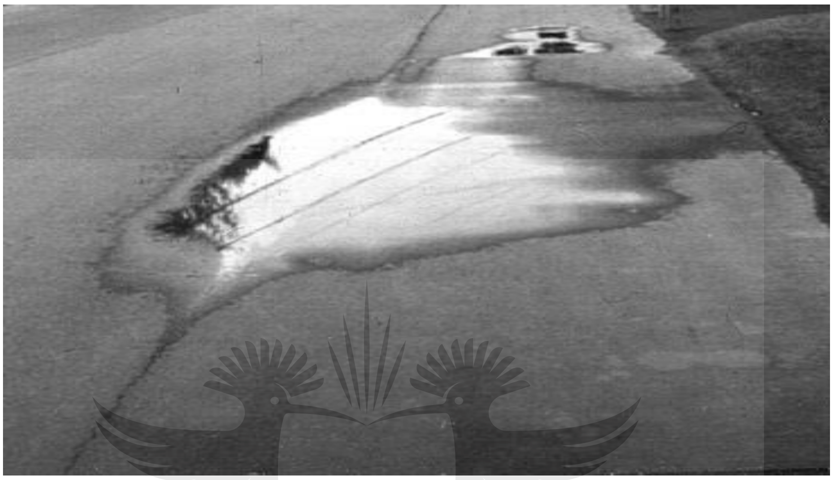

Figure 2.13: Depressions of a road surface (source: Walker, 2002:6).

Swell: A swell is a localized upward bulge resulting from the expansion of the supporting layers beneath the surface layer. Frost heaving, highly plastic clays in the subgrades or the presence of moisture, are the main causes (see Figure 2.14) (Adlinge & Gupta, 2009:14).

Figure 2.14: Swell of a road surface (source: Walker, 2002:6).

Disintegration: Disintegration is the gradual breaking up of the pavement into small, loose pieces. Complete reconstruction of a pavement becomes necessary if disintegration is not addressed in its early stages. The two main types of disintegration are potholes and patches (Adlinge & Gupta, 2009:14).

Potholes: Potholes are bowl-shaped holes, similar to depressions, found in the road surface. Potholes represent a localised collapse of the pavement due to structural defects, or frost action. Loading is not necessarily the cause of potholes, but the mismatch between loading and pavement design is. Potholes start small and become larger and the process is enhanced by the presence of water. Thus, poor road drainage can be a cause as well. When repaired the root cause must be addressed. If not, the pothole will simply appear again (see Figure 2.15) (Adlinge & Gupta, 2009:14 & Walker, 2002:13).

Figure: 2.15: Pothole in road (source: Walker, 2002:13).

Patches: These are found when a road surface has been repaired using the removed and replace system. However, the patch needs to be to the same standard as the rest of the road surface otherwise it too will fail. When a patche fails, then the failure spreads to the surrounding pavement (see Figure 2.16). (Adlinge & Gupta, 2009:14 & Walker, 2002:12).

Figure: 2.16: Patches on road (source: Walker, 2002:12).

2.11.3. Surface defects

Defects in the surface layer of a pavement are called surface defects. The most common types of surface distress are ravelling, bleeding and polishing (Adlinge & Gupta, 2009).

Ravelling: Here material is lost from the road surface, caused by the failure of the bond between the aggregate and the binder. This can be a result of road fatigue (age), use (number of shear loadings) and cold weather (freezing temperatures). Often it is a consequence of inferior quality materials or construction techniques. In the initial stages, fine aggregate breaks loose, resulting in small rough patches. As the disintegration progresses, larger aggregates begin to break loose, leading to bigger rough surfaces. Traffic and freezing weather lead to an increase in the rate at which ravelling takes place (see Figure 2.17) (Adlinge & Gupta, 2009:14 & Walker 2002:4).

Figure 2.17: Ravelling of a road surface (source: Walker, 2002:4).

Roughness: A number of factors can result in a road surface becoming rough. This includes rutting, cracking, potholes and unevenness (Adlinge & Gupta, 2009:10).

Bleeding: Bleeding occurs normally under hot weather conditions, as the asphalt becomes more liquid and pressure from the weight of the vehicles forces the asphalt to the surface (see Figure 2.18) (Adlinge & Gupta, 2009:15). It is usually caused by incorrect mixing of the asphalt, using asphalt with a viscosity that is too low or a seal coat which is too heavy, or applied incorrectly. Such damage makes a road surface slippery when wet and skidding becomes a real possibility.

Figure 2.18: Bleeding of a road surface (source: US Department of Transport, 2003:26)

Polishing: This occurs when the aggregate of the pavement surface is worn out by use. It is dangerous due to low friction (see Figure 2.19) (Walker, 2002:4).

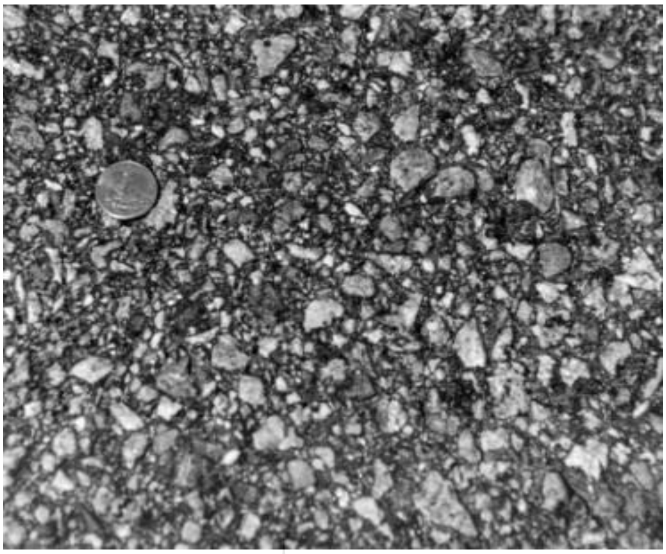

Figure 2.19: Polishing of a road surface (source: Walker, 2002:4).

2.12. Costs and transport policy

Damage to road surfaces by transport users us not usually captured directly in markets for motor vehicles or heavy vehicles, motor fuel, or motor-vehicle operations. Thus, as they are hidden, they are often overlooked in terms of ways to reduce transportation costs. Rather, then, estimated costs should be determined and then prices should be adjusted (fuel, vehicles, tolls) to reflect real costs (Delucchi, 2000). Internal costs are those, which originate from the provision of a transport infrastructure e.g. the construction of the road and the use of the road (Litman, 2009). Both users and the taxpaying public are usually responsible for carrying these costs. External costs include the costs associated with congestion, road accidents, gaseous emissions and noise pollution. Even in countries, which apply the ‘user pays principle’ strictly, seldom insists that road users carry all these external costs. That is, ‘user pays principle’ is usually applied to internal costs only. Consequently few are aware of the real costs of road transportation, due to misleading impression, the negative environmental and social effects are compounded.

2.13. Possible solutions to achieving more sustainable pavements

For a sustainable road network, pavements and their design are important. Thus, consideration of pavement types with respect to energy consumption during manufacture and construction is necessary. Asphalt pavements are more environmentally friendly than concrete pavements (Gambatese & Rajendran, 2005). During the manufacture and construction of a reinforced concrete pavement, energy is primarily consumed during the manufacturing of cement and reinforcing steel. For asphalt pavements, the majority of energy is consumed during mixing, drying of aggregates and the production of asphalt. Thus, asphalt pavements use less energy. Concrete pavements, however only require limited, periodic maintenance and repair measures, whereas an asphalt pavement requires periodic rehabilitation or strengthening in the form of overlays. Initially, however, construction of asphalt pavements is cheaper. Waste generated from cement roadways occurs during extraction and production of cement and aggregates. For asphalt, the extraction and production of aggregates produce the majority of waste. The amount of waste generated is greater for cement than for asphalt.

2.14. Improvement measures in road freight transportation

Factors that contribute towards smoother traffic flow are the synchronisation of traffic lights and reduced speed limits. These lead to a reduction in fuel consumption and reduce carbon dioxide emissions (per kilometre travelled). Unfortunately, for long haul road freight transport, these types of measures have only a small reduction potential. Better are improved logistics. According to Pischinger & Hausbergerm (1998) and Bates et. al., (2001) better logistics, better organisation, co-ordination and route planning can reduce the number of kilometres driven, thus reducing fuel consumption, usually by a factor of 10 to 20 percent.

2.15. Conclusion

The transportation sector has proven to be particularly difficult territory for the advancement of sustainable development, partly due to its complexity. Urgent attention, however, needs to be paid to the transportation sector as it consumes resources, destroys habitats, causes atmospheric pollution and can generate economic inefficiencies and hinder the achievement of social justice. Sustainable road transport means minimising environmental, social and economic costs. A sustainable transport system is one that is affordable, efficient, offers modal choice, supports a competitive economy and balanced regional development. Pavements or road surfaces are an important facet in attaining sustainable transport. Pavements need to be cost-effective, designed for appropriate use, operating conditions and take environmental impact reduction into consideration. This will include optimal use of natural and man-made resources, construction that causes negligible environmental damage to the environment, such as minimal waste and energy consumption. Freight transport has a specific impact on road surfaces due to differences in wheel loads, number and location of axles, types of suspensions and tyres. Thus, special care needs to be taken when designing a road surface for freight traffic. One of the challenges is that heavy vehicles can have a significantly damaging effect on pavements. To mitigate for this, maximum axle load has to be enforced to prevent fatigue damage. When not, then fatigue damage manifests itself as cracking, surface deformation, rutting, potholes and bleeding of the road surface. A damaged road surface is unsustainable as it increases the costs of transportation. This is both directly, for the road users and indirectly, for the agents responsible for road maintenance and for those who ultimately pay logistical costs (end consumers). Additionally, there are costs associated, with increased congestion, road accidents, gaseous emissions and noise, most of these costs are not borne by road users alone. To this end, design alone is not sufficient; attention needs to be paid to road maintenance and repair. For long haul road freight transport, these types of measures do not have a large reduction potential. Rather emphasis should be placed on better logistics, such as better logistic organisation; better co-ordination between all transport operators and better route planning.

Chapter 3: Transport: The South African context

3.1. Introduction

The South African road network is widespread and consists of both primary and secondary roads. This road infrastructure, serves as an important driver of socioeconomic development in the country. However, there are a numerous concerns regarding South Africa's road infrastructure as the road network is in a poor state of repair (Henderson, 2014). Part of the problem is the artificial shortening of the design life of pavements due to unanticipated traffic volumes and vehicle overloading. As building long-lasting, durable pavements is expensive it may well be that the South African road network was always under engineered. This chapter demonstrates that in part, heavy road traffic volumes, overloading and a long term under investment in roads is a legacy issue. More recently, new problems have emerged such as a decline in the availability of asphalt and significant cost increases thereof (De Beer, 2007). There is also the issue of poor road management. While the World Bank (amongst others) found that South Africa made significant progress in the field of road network management during the 1980s and 1990s, the quality of road network management has deteriorated since then (Mitchell, 2009). This may be a symptom of limited financial resources. Sustainable solutions unique to South African conditions need to be developed in order to optimize the road network (De Beer, 2007).

3.2. Transport deregulation

Real competition between rail and road for business began in the 1930's. During this time road transportation grew rapidly at the expense of rail transport and it seemed that road transport would dominate the transport industry. This led to a government intervention in the form of a permit system, which was enforced by the Motor Transport Carrier Act, Act No. 39 of 1930. This permit system favoured the transport of freight by government owned railways over road freight transport (Van der Mescht, 2006). However, incremental deregulation of the freight industry commenced with the Road Transport Act (Act No. 74 of 1977) and all regulation ceased upon the promulgation of the Transport Deregulation Act (Act No. 80 of 1988) and the Road Traffic Act (Act No. 29 of 1989) (Stander & Pienaar, 2002; Van der Mescht, 2006). This led to subsequent low investment in rail (with resultant poor service delivery) and the failure to develop an integrated alternative to road transport. Worse is that economic deregulation only focussed on technical and safety aspects, ignoring critical issues such as high freight costs; road infrastructure challenges including costly damage to roads and negative environmental impacts (Havenga, et. al., 2011). Thus, there is little holistic management of where freight is hauled to and the nature of the freight, which is moved (Stander & Pienaar 2002).

Consequently, roads, with a resultant excessive growth in heavy road transport vehicles, now dominate the freight transport. According to the CSIR's Fifth Annual State of Logistics Survey for South Africa (2008), in the order of 1.6 billion tonnes of freight was transported. Of this about 1.4 billion tonnes (or 88%) was moved by road, over a distance of 178 km. This equates to 245 billion tonne/km of freight by road in 2007. Part of the problem is the overloading of heavy vehicles. Such vehicles are slow, hold up traffic, are a danger on the road (such as if their brakes fail) and damage the pavements (Stander & Pienaar, 2005). Little will change, however until rail is able to compete with road on service delivery (Jorgensen, 2004). Currently, rail can only compete on distance – transporting on average a distance of 629 km (Ittmann & King, 2008). Such a situation is unsustainable and calls for intermodal solutions. To this end, a study was carried out on possible intermodal solutions in South Africa (Havenga, et. al., 2011). It was found that an intermodal transport system needs at least two different modes of transport to be used in an integrated manner. It was suggested that three intermodal terminals are created connecting the three major industrial hubs in South Africa (Gauteng, Durban and Cape Town). If undertaken it could lead to a reduction transport costs along the Cape-Gauteng and Natal-Gauteng corridors by about 42% (Havenga, et. al., 2011).

3.3. Transport corridors in South Africa

Gauteng is the economic hub of South Africa and is connected to various regions in Southern Africa via seven primary transport corridors (see Figure 3.1.). These corridors are the KwaZulu-Natal–Gauteng Corridor; the Western Cape–Gauteng Corridor; the two SADC corridors (Gauteng-Beitbridge and Gauteng-Maputo); the Gauteng-Lobatse-Walvis Bay Corridor; the Port Elizabeth-Gauteng Corridor and the East London-Gauteng Corridor (DoT, 2005). These corridors dominate the Southern African region and have shown unprecedented growth in demand. Demand is such that growth rates have exceeded the estimates of Moving South Africa's 20-year projections some 16 years earlier than expected. Of these, the largest growth in mass (tonnes) has been for the KwaZulu-Natal–Gauteng Corridor and the Western Cape–Gauteng Corridor. Between 2010 and 2012, the increase in tonne/km on these two corridors was roughly 20% (Viljoen, 2012). Due to this mismatch between expected and actual demand, these transport corridors are now lacking the necessary infrastructure required to cope with the impact of heavy freight transport. While some of the rise in in demand can be attributed to economic and population growth, it is also partly due to the rail system being inefficient, unreliable and prone to theft (De Beer, 2007; Ittman, 2008). Consequently, there is a high growth of heavy vehicles, some of which are overloaded, using secondary networks not designed and maintained to support a high volume of heavy vehicle traffic (DoT, 2005).

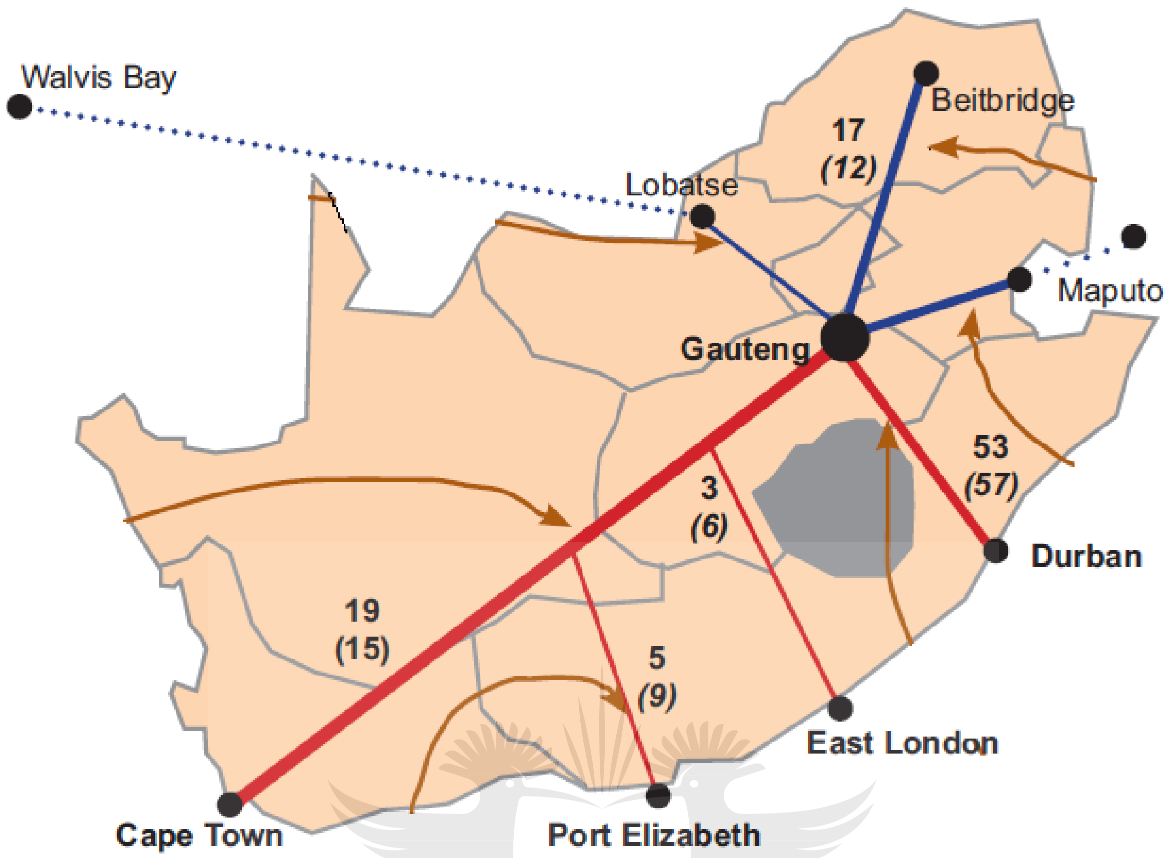

Figure 3.1: Road and rail transport corridors in South Africa (source: DoT, 2005: 34)

3.4. South Africa's road network

Upon considering the condition the primary road infrastructure of South compared to the county's secondary network (the provincial road infrastructures) a clear contrast can be observed. In essence this can be contributed to the contrasting maintenance of the road networks. The South African National Roads Agency Limited (SANRAL) is responsible for the upkeep of the primary road infrastructure. The upkeep of provincial road infrastructure is the responsibility of provincial authorities. Most provinces lack the budget to maintain and service their road network, and consequently there has been a marked deterioration in road surface conditions (Viljoen, 2012; Henderson, 2014). In addition, there is a chronic shortage of skilled personnel (road engineers) (Mitchell, 2013).

3.4.1. Challenges facing South Africa's road network

The South African road network covers around 754 600 km, with roughly 60 % of it in a bad state of repair (Budget review, 2012). This is way below international benchmarks, which state that no more than 10 percent of a road network should be classified as being in a bad state of repair at any one time. Deteriorating road conditions manifest themselves as potholes and crumbling road pavements. Such conditions impact negatively on logistics operations and increase the cost of doing business. For example, vehicles travelling on poor roads experience increased vibrations, which then results in structural damage to vehicles and increased vehicle maintenance and repair costs (Singh et al., 1991; Jarimopas et al., 2005; Steyn et al., 2012). It was estimated in 2009 that bad road conditions cost motorists (including heavy hauliers) approximately R20-billion due to an increase in fuel consumption vehicle repair costs and tyre wear (Steyn, et. al., 2011). The rapidly deteriorating network can be attributed to numerous factors. The main three contributing factors are: (a) “insufficient funding for road maintenance” (Mitchel, 2013: 103); (b) “ineffective law enforcement with respect to vehicle overloading” (DoT, 2011: 3) and (c) “significant increases in road freight volumes” (as a result of general economic factors as well as the favouring of road over rail freight) (DoT, 2011:1). However various other factors in particular high rainfall can also have an effect on the rate of deterioration of South Africa’s roads.

3.4.1.1. Insufficient funding

Due to financial restraints, South Africa’s roads are often poorly managed and badly maintained (Heggie & Vickers, 1998). The cost of repair of South Africa’s roads is estimated to be in the range of R100 billion to R149 billion (Viljoen, 2011). Most of this is due to the provincial road maintenance backlog. Furthermore the expenditure then required for the on-going maintenance of these roads is about R120 000 per kilometre or R 32 billion per annum. Despite this, the actual budget is roughly R8 billion. Thus, financial resources have to be used creatively and carefully if the roads are to remain in a good state of repair. This will involve: (1) a realistic (not a wish list) determination of the optimal sum of funds required; (2) managing competing demands from the fiscus for funds; and (3) efficient use of the available funds [such as hiring competent consultants and contractors; quality control of repair work and keeping overhead administrative costs low] (Mitchell, 2013).

3.4.1.2. Skills Shortage

South Africa is also facing a major skills shortage, particularly in the fields of civil and road engineering. This shortage has the potential to negatively impact the much needed road development in the country (South African Government News Agency, 2010; Mitchell, 2013).

It has been reported by The Institute of Municipal Engineering SA (IMESA) that in January 2013, that there was no professional engineer on the staff establishment of at least one Metro authority. In the KwaZulu-Natal Roads Authority, the number of professional road engineers employed is 90% less than the number employed 50 years ago, when the workload was considerably less. Compounding this is that not all of the CEO's of provincial road authorities are registered professional road engineers. This situation is of grave concern for the long term sustainability of the road network. The result of a shortage of qualified technical and professional staff results in indecisive or poor decision making, poor work procedures, political micro-management, lack of good governance, a deteriorating and eventually crumbling road network; high accident and death rates, as well as, high vehicle operating costs (South African Government News Agency, 2010). Although the private sector can help to address some of these problems, without adequate expertise and experience in the various road authority directorates, to provide leadership and strategic planning, achieving the long-term sustainability of the road network will not occur (Mitchell, 2013).

3.4.1.3. Overloading

The overloading of heavy vehicles has been singled out as one of the most important contributors to road damage, as overloaded heavy vehicles directly damage the pavement (Bosman, 2006). This damage to the road infrastructure amounts to billions of rand, annually. In order to demonstrate the magnitude of the problem statistics obtained from the KwaZulu-Natal Department of Transport's weighbridges for 2008 are used as illustration. During 2008, 5-axle articulated trucks, with a single drive axle and a tridem axle unit on semi-trailers, were the most likely vehicles to be overloaded. The consequence of overloading was that total combination mass of these particular heavy vehicles were more than five times the legal mass. The analysis of overloading data obtained from the WIM stations is presented in Table 3.1. From this table it can be seen that for example, on a road classified as a Low HV Road (using the Bosman, 2006 method) approximately 9 per cent of the trucks could be overloaded. Furthermore it is indicated that regular weighing of 2-, 5-, 6- and 7-axle HVs is required if overloading is to be curtailed (Bosman, 2006).

Table 3.1: Overloaded HVS on low, medium and high HV roads (source: Bosman, 2006)**.**

Road Class	Percentage of HV class that is overloaded							Overall overloading as a percentage
	2-Axle	**3-Axle**	**4-Axle**	**5-Axle**	**6-Axle**	**7-Axle**	**8-Axle**	
Low	**28**	16,5	7	17	13,5	12,5	2	9
Med	**21.5**	6	6	11	16	**33.5**	3	12.5
High	**23**	6	6.5	13	17.5	**31**	4	7.5

Bold indicates severe overloading

A major consequence of overloading heavy vehicles, for hauliers (ironically) is that they are only causing future difficulties for themselves. In addition to risking, being penalised, by law enforcement they are destroying the road network that keeps them in business (CSIR, 1997). Furthermore, a serious factor leading to the rapid deterioration of the South African road network is ineffective law enforcement with respect to vehicle overloading. Due to numerous reasons the control of overloading by heavy vehicles is at present still being carried out on an ad hoc basis in the country (CSIR, 1997). The most common reason for this is that the expenditure associated with the capital and operation of these permanent weighing stations overload control facilities) are high. The static weighbridges are also operated randomly by many road authorities (especially provincial) and in these cases not all heavy vehicles are weighed, but only those which visually seem to be overloaded (Bosman, 2006). Failure on the part of law enforcement to address overloading results in the continued overloading of heavy vehicles by hauliers. In order to control overloading practices certain measures have been put in place, such as the user pay principle on toll roads (CSIR, 1997). This has however, simply shifted the problem to secondary and tertiary roads, which are now being used by heavy vehicle hauliers to avoid paying the tolls (DoT, 2011). These roads are now experiencing traffic loads for which they were not designed, with the result that rapid deterioration of road is taking place (DoT, 2011).

The National Road Transport Act 93 of 1996, Regulation No 240, sets the legal weight limits for heavy vehicles on South African roads. This regulation gives the so-called carrying capacity of the roads and provides guidelines for the mass of heavy vehicles. This regulation of the Act is to prevent the premature deterioration of roads due to overloading by heavy vehicles, hence ultimately, the protection of roads. The subsections of this regulation are:

Regulation 240 (1) of the Road Traffic Act (Act No. 93 of 1996), states that no vehicle or a combination of vehicles (with pneumatic tyres) may be operated on public roads if the legally prescribed mass load per axle type (including number of axles) is exceed. These guidelines are summarised in table 3.2

Furthermore “Regulation 365A”, which is also known as the “bridge formula”, restricts the load or mass per axle irrespective of the distance travelled. The bridge formula is defined as”

$P = 2\,100\,L + 18\,000$,
where P = the permissible load in kilograms,
L is the distance in metres between the centres of the extreme axles of any group of axles and/or axle units.

It has been established that the latest axle load regulations employed in South Africa are on par with what is enforced in most other countries. The only major concern is the limit of the maximum Gross Combination Mass which is significantly higher than in numerous other countries in the world (CSIR, 1997).

Table 3.2: Legal permissible mass per number of axles (source: Compiled from Regulation 240 (1) of the Road Traffic Act (Act No. 93 of 1996)

Number of axles or axle type	Legal maximum mass (kg)
wheel mass load on a steering axle	3850

wheel mass load on a non-steering axle	4000
single axle with two or three wheels on a steering axle	7700
single axle with two or three wheels on any other than a steering axle	8000
single axle with four wheels on a refuse removal vehicle, breakdown truck, bus train or a bus	10200
single axle with four wheels on other vehicles	9000
two-axle unit with two or three wheels fitted per axle on a steering axles	15400
two-axle unit with two or three wheels fitted per axle on a non-steering axles	16000
two-axle unit with four wheels fitted per axle on a refuse removal or breakdown vehicle	20400
two-axle unit with four wheels fitted per axle on other vehicles	18000
three-axle unit with three or more wheels fitted per axle on a steering axle	23100
three-axle unit with three or more wheels fitted per axle on axles other than a steering axle	24000
Three or more axle unit with four wheels per axle	24000

3.4.1.4. High traffic volumes

During the past two decades road use patterns in South Africa have developed in unexpected ways. It is generally believed that this is due to the declining state of the rail network, which could in part be attributed to the reduction in maintenance of the rail network and the decline of the availability of trains except along the main routes. This creates a negative feedback loop, where by companies cease to use the rail network, rail income declines, less money is available for trains and maintenance and so on. Thus, South Africa's rail network needs attention (Automobile Association, 2014). As goods are now transported by road, there are high traffic volumes on South African roads, which include an increase in road freight. It has been estimated that this increase is around 4 percent per annum on both the major networks and also the minor or secondary road networks (De Beer, Fischer & Kannemeyer, 2004). The road network is, therefore, under tremendous stress. Due to this increase in the traffic volume on the country's road network, programmes are being undertaken to add more lanes to roads, in order to better cope with the traffic volumes. This has however, only lead to further increases in traffic volumes instead of the desired reduction on the roads.

3.4.1.5. Road safety issues

Poor road safety associated with driver fatigue, ill health and poor driving habits leads to accidents. In spite of attempts to introduce more stringent law enforcement by authorities this situation prevails (Nordengen & Oberholtzer, 2006). Many vehicles display various degrees of un-roadworthiness. This is often the result of inadequate vehicle maintenance. However, drivers travelling at high speeds and/or driving drunk are also concerns in terms of non-compliance to safety (Daily Maverick, 2015). It has been reported that motorists exceeding the speed limits on roads is increasing. Speeding not only contributes to road accidents but also to the severity of these. Many reasons exists for speeding, however of the most important are the performance of vehicles, road conditions which include the geometry and structure of pavements, lack of law enforcement and the fact that drivers generally have a misconception of the fact that speeding is not dangerous (Bester & Geldenhuys, 2007). Public transport can address some of these issues, as this will lead to fewer vehicles on the roads. In "The Road Freight Strategy for South Africa" document solutions are proposed through which intermodal transport systems can be adopted (DoT. 2011).

3.4.1.6. Storm water management and rainfall

Higher than normal rainfall can often completely destroy a road. Changes in climate, e.g. higher rainfall and temperatures, have become a serious concern with regards to pavement sustainability, as pavements are not necessarily designed to withstand these changes. Surface damage to asphalt pavements has been seen to be a consequence of higher temperatures. However, more severe structural damage is a result of higher rainfall. Concrete pavements on the other hand have been seen to be less severely impacted by water, but higher temperatures can lead to expansion beyond the capacity of the joints (Willway, et. al., 2008).

One way of dealing with the problem of increased rainfall is to provide adequate drainage systems. Hence, an effective storm water management system is required. In many large South African cities, these storm water systems fall under the jurisdiction of the municipal roads department. However, these departments are financially constrained, lack skills and manpower. It has therefore become evident that maintenance and cleaning of the storm water infrastructure in conjunction with that of the road infrastructure is not adequate. This leads to the deterioration of roads as a result of increased traffic volumes and heavy rainfall. Thus, South Africa's municipal storm water system is in need of significant capital investment and maintenance (Fisher-Jeffes & Armitage, 2012).

3.4.1.7. Asphalt availability

In terms of preserving the environment, asphalt pavements are the most desirable as they are cheaper and completely recyclable. Construction of such pavements will also help sustain the local hot mix asphalt and road construction industry, creating job opportunities and business opportunities. However, South Africa is facing an asphalt shortage (Cokayne, 2013). This is placing significant strain on road projects (Esterhuizen, (2012). Hence alternative technologies, such as High-modulus asphalt (HiMA) technology and ultra-thin continuously reinforced concrete pavements are required (Nkgapele, et. al., 2012, Denneman, et. al., 2011a, & Denneman, et. al., 2011b). In addition, the design life of heavily-trafficked roads needs to be extended to decrease the need for maintenance and minimise delays for road users (CSIR Built Environment, 2013). Importantly, such pavements are less able to cope with the wear and tear associated with heavy use and overloading.

3.4.2. Costs of Road Freight Transport

Currently the road freight industry is externalising some costs to the taxpayer. If there was better transparency and accountability with respect to these costs, perhaps the inefficiencies of road freight transport would be addressed. For example, operators of heavy vehicles are not paying for all the costs associated with damaging the road network, increasing congestion, exhaust fumes, noise and the like, at least not directly. By externalising such costs onto the South African fiscus and communities, transport prices seem cheaper than they really are (DoT, 2005; Jorgensen, 2009). But, in the long term the cost to society is great as there are serious economic consequences to the deteriorating road conditions in South Africa. Firstly, the declining quality secondary and tertiary roads is increasing the costs of doing business for the freight companies by at least R625 million. This can be attributed to increased fuel consumption, tyre wear and tear, additional maintenance and repairs required caused by using such roads. Most certainly some of this will be passed on to consumers. Secondly, poor road conditions increase the frequency of fatal accidents, as it has been established that road related factors lead to between 5 and 15% of fatal road accidents. The cost of this is mainly borne by the state, the road accident fund, individuals and insurance/medical aid companies. It has been estimated that for 2010/2011, the total cost of fatal road accidents which can be attributed to appalling road conditions was between R207 million and R621 million. The sad truth of this is that the deaths of hundreds of people could have been averted, if the road network had been regularly maintained to ensure an acceptable state of repair (Viljoen, 2012; Henderson, 2014).

3.5. Roads and sustainable development in South Africa

In South Africa, the concept of sustainability is encapsulated in the National Environmental Management Act (Act 107 of 1998). This Act serves as a guideline for actions in sectors such as transport, which have an impact upon the environment. However, progress in the urban transport sector towards achieving sustainability has been unsatisfactory. The reasons for this are: (i) In transport planning, environmental assessments are always not regarded as an integral part of the process; (ii) When environmental assessment plans are reviewed, this may be done by a junior government official whose skills are not sufficiently well developed to make the best decision; (iii) Environmental impact mitigation is perceived to be a costly exercise (Kane 2004).

All of this is especially true for the road transport industry, which is the dominant mode of transport in South Africa and produces the greatest environmental impacts of all transport modes. The environmental impacts that road transport has can be classified into two categories. First level impacts are the result of physical transport and can be attributed to the propulsion of the vehicle. Second level impacts are the consequence of all the elements which are necessary to enable transportation. These are impacts, which result from the energy supply, infrastructure supply, vehicle supply, and maintenance operations (Lane & Vanderschuren, 2011).

One aspect of managing down the negative social, environmental and economic impacts of road transport is making the pavements more durable, less prone to fatigue and one that reduces vehicle drag. Such a road is more environmentally, socially and economically sustainable than one which is not (Henderson, 2014). This is an aspect of road network management. There are specific environmental issues, which must be considered during the design and construction of road infrastructure in order to promote sustainability. For example, roads must be designed to facilitate improved energy efficiency and to reduce vehicle emissions. Better use of construction materials will reduce waste. Roads should be designed to minimize maintenance and consider lifetime road user costs. The report on pavement type selection by Freeme, Otte & Mitchell (1980) still has value in that they argue that minimizing impact is an integral part of road design. They call for innovative approaches to road pavement construction, such as pavements that reduce "energy usage" pavements; as well as suggesting that pavements are recycled and use is made of indigenous pavement materials. Importantly is the need to have much longer pavement design lives (Mitchel, 2013). Mitchell (2013) found that South Africa needs better road institutional arrangements. This includes reducing the number of road administrative units; improving (and optimising) the road programme delivery; better road administration, equitable distribution of resources and service delivery and, preferably, the involvement of multiple stakeholders, not just the government.

Various stakeholders[1], such as SANRAL, have made commitments to work towards achieving sustainability in the road transport sector (eProp Commercial Property News. 2013). The Department of Transport, in a document entitled the "Road Freight Strategy for South Africa" has proposed solutions through which improved integration of road transport with other transport modes can be structured (DoT, 2011, p.i). Strategic initiatives have been identified to address issues in the short, medium and long term. These initiatives include (DoT, 2011, p.i):

- **Road infrastructure maintenance and funding**: Adequate road network infrastructure management must take place in a systematic manner and should be applicable to the entire South African road network, with the availability of adequate financial resources.

[1] Stakeholders include the Department of Transport (DoT), South African National Roads Agency Ltd (SANRAL) the Council for Industrial and Scientific Research (CSIR), Southern African Bitumen Association (Sabita), Aggregate and Sand Producers Association of South Africa (ASPASA).

- **Measures to control overloading**: A number of measures need to be adopted to ensure reduce the overloading of heavy vehicles. These measures need to incorporate some form of inspection on a national level, the utilisation of mobile technologies, administrative enforcement approaches, credible deterrents and data intelligence. This can be achieved by load monitoring at the consignee weighbridges. The primary purpose of the weighing would be to monitor the payload of each vehicle at the origin. The success of this to a great extent will depend on active involvement of the consignees and consignors.
- **Stakeholders self-regulate and ensure road safety**: Responsible operator behaviour needs to be encouraged, through which the prevention of road damage and improved road safety can be achieved. The introduction of more stringent penalties and consequences for breaking the law is required, along with incentives for good-performance and data intelligence.

The various roles played by the numerous stakeholders in the sector will now be elaborated upon.

3.5.1. SANRAL

SANRAL has identified a number of fields into which research is necessary if the road network is to become more sustainable (De Beer, 2007). These areas include: (1) the improved efficiency of roads; (2) better infrastructure design and delivery; (3) more cost effective road construction techniques; (4) installation of performance-related design systems; (5) acquisition of more durable, cost effective materials, requiring less frequent maintenance; and (6) the protection of non-renewable sources of road construction material. Research is also needed in order to quantify and minimise risk support, decision-support systems development, life-cycle costs optimisation in South African, new and advanced methodologies for Accelerated Pavement Testing (APT) and intelligent transportation systems (ITS) (De Beer, 2007, p.2).

3.5.2. CSIR

The CSIR in conjunction with SANRAL and other road authorities are currently researching ways to enhance the performance of South Africa' road infrastructure. Through this research programme it is hoped to achieve: (1) the development of an advanced road pavement materials design platform; (2) the development of road pavement materials with better functional performance; (3) the development of advanced road pavement design methods; (4) enhanced understanding of tyre inflation pressures and tyre contact stresses on pavements and (5) the development of a new Accelerated Pavement Testing (APT) platform, with the aim of simulating the effects of high-speed traffic loading, with accurate dynamic loading effects and advanced wireless instrumentation, to monitor the road pavement response to traffic loading. This programme should significantly improve performance of South Africa's road system, in the long term. Included in this would be more economical ways of road construction, more sustainable pavements, efficacy of design techniques and road safety and less traffic congestion (De Beer, 2007, p.2).

3.5.3. SABITA

The Southern African Bitumen Association (Sabita) has also become involved in achieving sustainable pavements in South Africa. As asphalt is is one of the few industrial materials that can 100 percent be recycled, Sabita has been involved in developing procedures and industry standards for the recycling of asphalt pavements (Distin, undated). These measures are aimed at ensuring the sustainability of the asphalt road construction industry in South Africa. However, the supply of asphalt is limited, making the future availability uncertain. in future asphalt could be obtained from the following sources: (a) integrating recycled asphalt pavements (RAP) in new asphalt mixes; (b) re-use of existing materials through bitumen; and (c) incorporating other materials usually classified as waste into hot mix asphalt (e.g. steel slag, rubber from scrapped tyres, cellulose fibres and glass), all of which have been identified as having the required engineering properties deemed necessary for use in fresh asphalt mixes (Dustin, undated).

3.5.4. ASPASA

The Aggregate and Sand Producers Association of South Africa (ASPASA) has indicated that it is committed to sustainability by reporting on its triple bottom line. Like Sabita, ASPASA, has made a commitment to ensure that transport systems would be provided which are not only, satisfactory and efficient, but would have the absolute minimum environmental impact on natural resources. The Aggregate and Sand Producers, has stated that in order to obtain effective sustainability, all stakeholders should be committed to achieving it. In order to provide an equitable, enabling environment for sustainability the necessary controls and regulations to should be enforced. Currently one of the key focus areas for ASPASA is the management of greenhouse gas emissions, which are a result of road construction and transport industries (Chappat & Bilal, 2003). In the case of new pavements or road surfaces, it has been determined that the construction reinforced concrete surfaces leads to more pollution than bitumen surfaces. It is recognised now that during rehabilitation, bitumen that is recycled on site is by far the most energy efficient process and emits the least amount of greenhouse gases.

3.6. Conclusion

In order to increase productivity, social development and growth, an effective road infrastructure is required. Unlike in developed countries expensive road pavement solutions are not an option. Therefore, uniquely South African solutions have to be developed and validated to optimise the use of limited resources. The country is currently facing road freight challenges such as low levels of maintenance, poor road conditions, rising freight costs and major skills shortage, particularly in the civil and roads engineering field. Various stakeholders have become involved to work towards achieving sustainable pavements. Specific initiatives have been identified by stakeholders, such as more economical road construction, optimisation of design techniques to increase efficacy of road construction and ensure less congestion during construction. With the aim of regulating the heavy vehicle industry, particularly with respect to overloading, the Department of Transport's National Overload Control Strategy was implemented in the timber industry with the aim of determining whether it would be feasible to introduce a form of self-regulation. The ability to be able to screen the loading of heavy vehicles at the origin and/or destination of the trip, based on information volunteered by operators is deemed to be important in order to markedly improve the issues of heavy vehicle overloading (and in cases under-loading). This initiative would be conducive in enabling significant time and cost saving in the trucking industry, as well as improved the logistics of road freight transport. To conclude, in order for South Africa to achieve sustainability of roads some aspects need to be addressed. It has become imperative that there are appropriate institutional arrangements for the execution of the roads programme. Sound management of the road network is required, with the aim of facilitating the achievement of sustainability of roads. There is a dire need for sustainable and adequate resources, with the emphasis on finances and personnel. Lastly, during the construction and maintenance phases of roads, the preservation of the environment is imperative. The study will now turn directly to the R59 and present the findings of the research.

Chapter 4: Results and discussion

4.1. Introduction

In this chapter, the data obtained from the Gautrans yearbooks are presented and examined in order to determine the impact of traffic and trucking on the quality of the pavement surface of the R59 Gauteng for both the northerly direction (from Vereeniging to Alberton) and the southerly direction (from Alberton to Vereeniging) (see Figure 4.1). The chapter uses the data to determine changes in traffic volumes, in terms of Average Daily Traffic, Average Daily Heavy Traffic as well as Night traffic on the road between the years 2004 to 2013. The chapter also explores the heavy vehicle data in order to obtain insight into overloading and, thus, possible pavement damage. In this chapter all data used from the identified counting stations along the Gauteng leg of the R59 are presented in an abridged form in tables and where possible in graphs. Additional data can be found in the Appendix. The chapter is structured as follows: Information on the counting stations is presented, e.g. number, name, description, pavement section on which it is located, the type (permanent or secondary) and distance between the two points which is monitored by it. The data which were extracted from the yearbooks for the different counting stations are presented in tables and in some cases graphs. The data are discussed under the headings:

(i) Average daily traffic, average daily heavy traffic and night traffic
(ii) Pavement classification from percentage truck split
(iii) Traffic loading and overloading
(iv) The effects of overloading
(v) Peak traffic flows
(vi) Speed profile

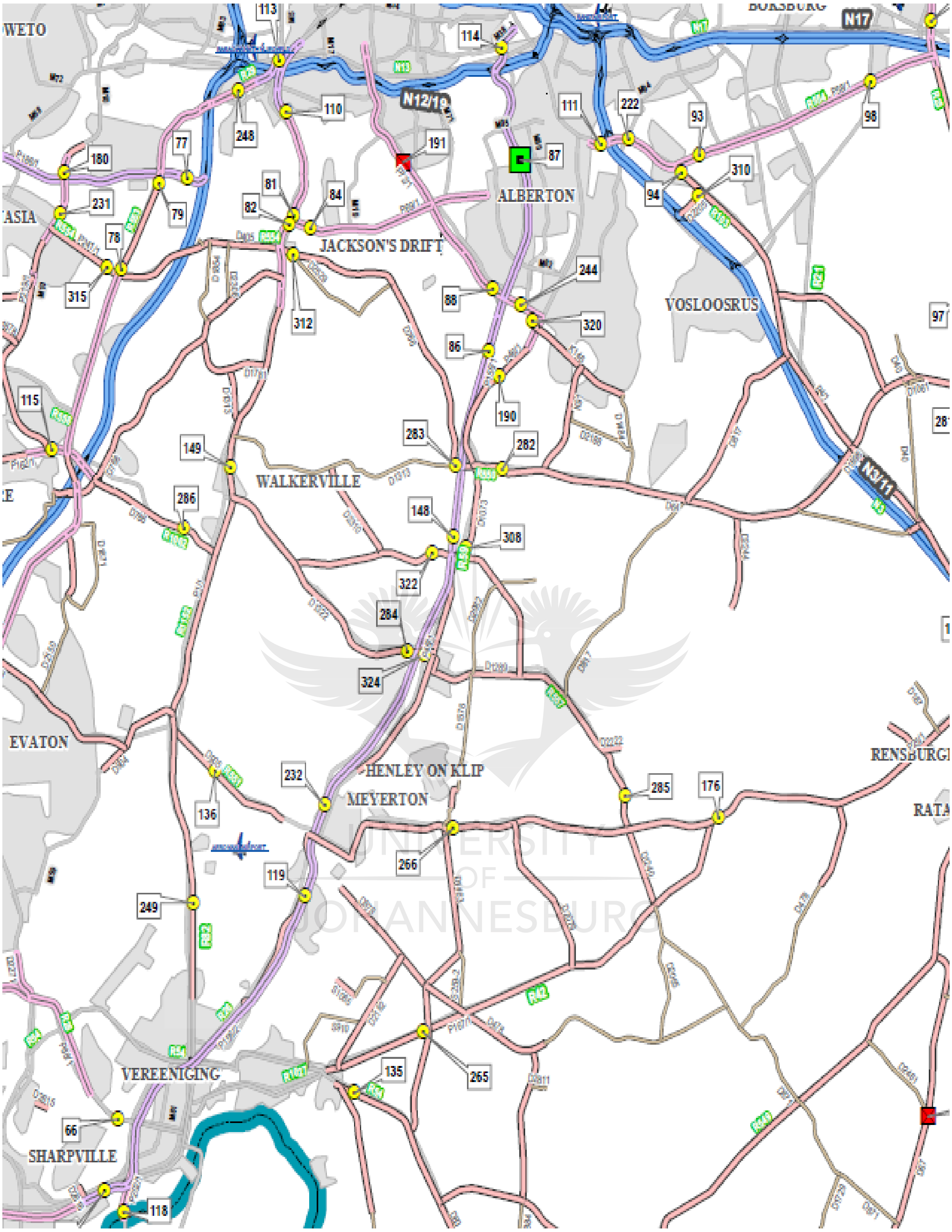

Figure 4.1: Counting Stations along the R59 freeway (source: Gautrans yearbook, 2013).

4.2. Design specifications and maintenance of the R59

Although the actual specifications of the road could not be established (due to some Gautrans documents being inaccessible or irretrievable, due to curatorship issues), the documents which Gautrans was able to supply allowed for the following deductions to be made: The pavement design of the R59 is an asphalt mix design for a B climatic zone (i.e. Dry Climate Type). The asphalt mix pavement design of the R 59 most likely contained a subgrade; an aggregate base – where the aggregates are most likely andesite (with nominal sizes ranging from 9.5 and 9.6); gravel; river or mine sand. The filler material is most likely 1% Portland cement. Lastly, most likely a binder and an asphalt aggregate surface layer would have been added (DoT and Public Works, 1996, DoT and Public Works, 1997).

The study also found that rehabilitation of sections of the R59 had been undertaken twice: (1) once in 1996 -1997 and then again (2) in 2005 – 2006. During the first period of 1996 – 1997 rehabilitation of approximately 9.0 km of road, from the Ring road interchange to the PAN interchange, occurred. Additionally, there was pre-treatment and asphalt overlay of approximately 23 km of road from the Klipriver road interchange to the Johan le Roux road interchange. During the second period, resurfacing occurred between Meyerton and the Free State border (the Vaal River); repairing and resealing along the Sedibeng 21 [P156/1 / P202/1] section and along the Sedibeng 24 [P156/2] section also took place (DoT & Public Works, 2005, DoT & Public Works, 1997).

4.3. Information from Counting Stations on the R59

In this section, the relevant counting stations along the R59 are described in terms of name, site number, geographic location and type of station. The entire distance of the road under study is 65.7 kms. This information is shown in Table 4.1 and Figure 4.1. The survey information for each counting station is summarised in Table 4.2. It is important to note that data is missing due to traffic surveys being conducted sporadically. Additionally, the survey periods were not always the same. Thus, direct comparisons are not always possible, although patterns are discernible. Such gaps in the data must be noted not only as a short coming of the study but also of how roads in South Africa are managed. It was found that record keeping was not extensive, not long term and seldom meticulous.

Table 4.1: Information for each Counting Station (source: Gautrans Yearbook 2007)

Counting Station	Name	Description	Pavement & Section	Type
0114	South Crest	Between N12/18 & South Rand Rd (M38)	P156/1	Secondary
0087	**Alberton WIM (BL) Northbound**	Between Michelle Ave & Swartkoppies I/C (M95 – P69/1	P156/1	**Permanent HSWIM**
0086	R59 Brackendowns	Between P72/1 (556) & D64 (R550)	P156/1	Secondary
0148	Klipview AH	Between D64 (R550) & D1322 (R557 Randvaal Rd)	P156/2	Secondary
0232	R59 Meyerton	Between D905 (R551 Johan le Roux) & Meyer Str I/C	P 156/2	Secondary
0119	Meyerdustria	Between D1566 (551 Verwoerd Rd) & P25/1 (R551)	P156/2	Secondary
0118	R59 Vaal River	Between P156/2 (R42) & Vaal River	P202/1	Secondary

Bold: Indicates the permanent counting station

Data on traffic volumes, heavy vehicle split, traffic loading and directional flow patterns were extracted from the Gautrans Yearbooks for the years 2004 to 2013 (Gauteng Yearbook 2004 – 2007, 2009 – 2013). The data from the various counting stations are presented as consolidated data, i.e. the data from each station per annum, for each category e.g. average daily traffic was summed and an average for a specific year was obtained, this enabled comparisons over the years under study.

Table 4.2: Counting Stations surveyed from 2004 to 2013

Station	0086	0087	0114	0118	0119	0148	0232
Survey period							
2004	29/09 – 11/10	Not surveyed	11/03 – 22/03	03/09 – 09/09	02/09 – 09/09	16/06 – 26/06	Not surveyed
2005	Not surveyed	**07/10/ - 31/12**	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed
2006	Not surveyed	**01/01/ - 31/12**	Not surveyed	Not surveyed	Not surveyed	Not surveyed	Not surveyed
2007	17/10 – 25/10	**01/01 – 31/12**	Not surveyed	26/09 – 08/10	25/10 – 02/11	01/01 – 31/12	25/10 - 02/11
2009	Not surveyed	**13/08 – 31/12**	Not surveyed	Not surveyed	30/10 – 09/11	18/09 - 16/09	08/09 – 16/09
2010	23/03 – 01/04	**01.01 – 31/12**	11/11 – 29/11	28/09 – 07/10/	Not surveyed	11/05 – 19/05	20/10 – 28/10
2011	21/11 – 29/11	**01/01 31/12**	01/01 – 31/12	24/11 – 01/12	06/10 - 14/10	04/10 – 13/10	06/10 – 11/10
2012	Not surveyed	**01/01 – 14/02**	01/01 – 31/03	Not surveyed	Not surveyed	Not surveyed	Not surveyed
2013	Not surveyed	Not surveyed	30/06 – 31/07	Not surveyed	23/08 - 30/08	23/08 – 30/08	Not surveyed

Note: 53% of the stations were not surveyed during periods 2004 and 2013. **Bold** indicates the permanent counting station

4.4. Analysis of data from counting stations along the R59

4.4.1. Average daily traffic, Average daily heavy traffic and night traffic

The trends in the average daily traffic, average daily heavy traffic and night traffic were analysed by using the averages for the counting stations for each year, affording an overview of the entire pavement over the study period. The analysis is shown in Table 4.3 below as well as Figures 4.2 and 4.3.

The average daily traffic shows an overall increase of 22% between 2004 and 2013 or an average of 2.4% per year (see Figure 4.2). The average daily heavy traffic shows an overall increase of 19% over this period, or 2.1% per year; whereas the night traffic shows a 16% increase or 1.8% per year (see Figure 4.3). Hence, it can be said, that traffic volumes on the road have increased over time, with an overall, combined increase of traffic, trucks and night traffic of 2.1% per year.

Table 4.3: Average daily traffic, Average daily heavy traffic and night for the period 2004 to 2013 on the R59 from counting stations 0114 to 0118

Year	Average daily traffic	Average daily heavy traffic	Night Traffic
2004	27 186	3 550	2 758
2007	36 682	**5 271**	4 222
2009	**40 293**	4 819	**6 929**
2010	36 569	4 523	**6 741**
2011	36 735	**5 291**	6 585
2012	**41 985**	3 313	5 700
2013	34 808	4 376	3 297
Average	36 323	4 449	5 176

Note: Bold indicates the 'peak' traffic years.

However, careful examination of the data indicates that there was a decrease of nine percent in the average daily traffic between the year 2009 and 2011. This decrease is likely due to the economic recession. The 5% decrease for the same period for night traffic can also be attributed to the recession (Hofmeyer, 2009). The average daily heavy traffic data shows a decrease (of 14%) ahead of the decline in the daily average traffic, but also a recovery ahead of the daily average traffic. As heavy vehicles are used to transport freight, economic upturns or downturns will affect heavy vehicles volumes on the road (Hofmeyer, 2009). Thus, the pattern of heavy vehicle use of the R59 could be used as a proxy economic indicator. A decline in trucking volumes may predict a future economic downturn and an uptick in heavy vehicle traffic may predict an increase in economic activity in the future.

The data shows that between 2012 and 2013 there was a 17% reduction in the average daily traffic and a 42% reduction in night traffic. The average daily heavy traffic on the other hand showed an increase of 24%. This significant difference could be explained by a change in the data collection system and methods. That is, the 2012 Gautrans Yearbook recorded data for the first quarter only. Thus, 2012 data was only collected for a short period, not the whole year, and only obtained from two stations (one of which was the permanent one) (see Table 4.2.). This was due to the awarding of a new tender. The tender process, however, took time, and consequently minimal 2012 data exists (personal communication with Pierre van Heerden, Gautrans, 07/08/2014). That is, for three quarters of the 2012 no tender was in place at all, which is why there is so little data for that year. Secondly, in 2013 no data from the permanent station was collected. Thus, 2012 and 2013 data could be different to all other years prior, due to methodological differences. An explanation for the methodological differences is that a different company carried out the 2013 survey. That is, in 2012, TES Trust collected the data, whereas in 2013, Mikros Traffic Monitoring collected the data.

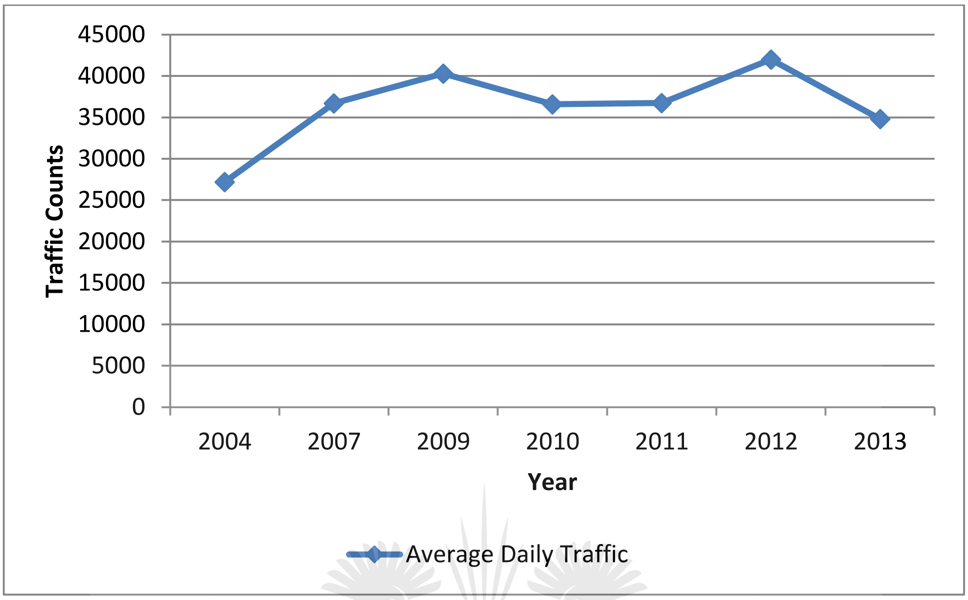

Figure 4.2: Average daily traffic for the years 2004 – 2013

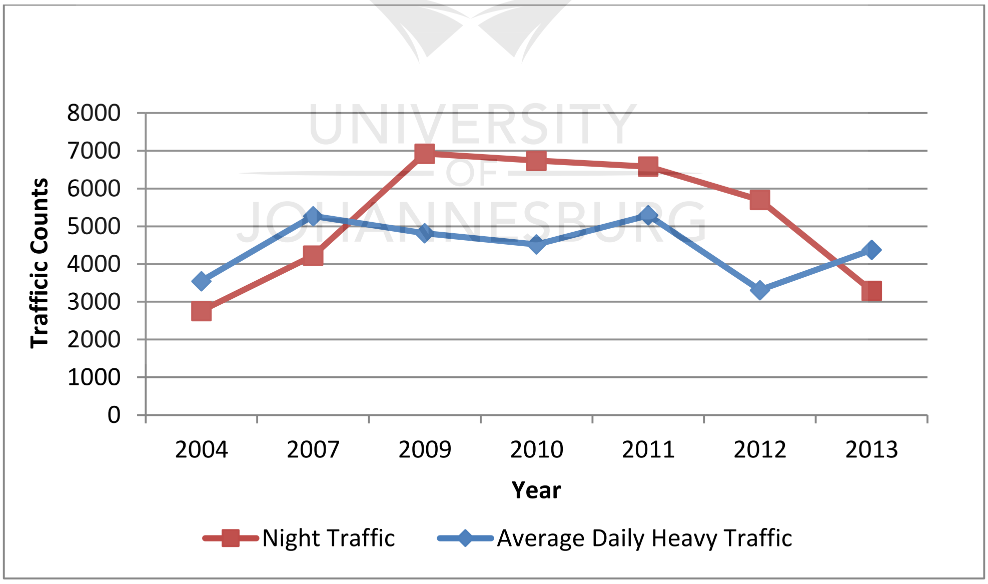

Figure 4.3: Average daily heavy traffic and night traffic for the years 2004 – 2013

4.4.2. Average data from 2004 – 2013 per counting station

To understand the nature of the traffic on the section of the R59 under study, data from all traffic stations must be viewed collectively, for the entire section from Alberton to the Free

State border (see Figure 4.1). The traffic counting stations are listed here in a north-south order, as previously shown (see Table 4.1). The Average Daily Traffic, the Average Daily Heavy Traffic and Night Traffic volumes collected from all the stations along the R59 were compared to determine geographical flows (see Table 4.4). Average values were calculated for each station to facilitate the comparison (see Figure 4.4.).

Table 4.4: Average values for each counting station for the period 2004 - 2013

Counting Station	**0114**	**0087**	**0086**	**0148**	**0232**	**0119**	**0118**
Location	South Crest	Alberton	Brakendowns	Klipview	Meyerton	Meyerdustria	Vaalriver
Average daily traffic	28 435	**56 665**	37 704	37 860	33 938	33 960	16 055
Average daily heavy traffic	2 510	**4 234**	4 926	5 573	5 880	5 781	3 072
Night traffic	4492	**6453**	6092	5 763	6253	3630	2497

Note: Stations are listed from North to South 0114 to 0118.

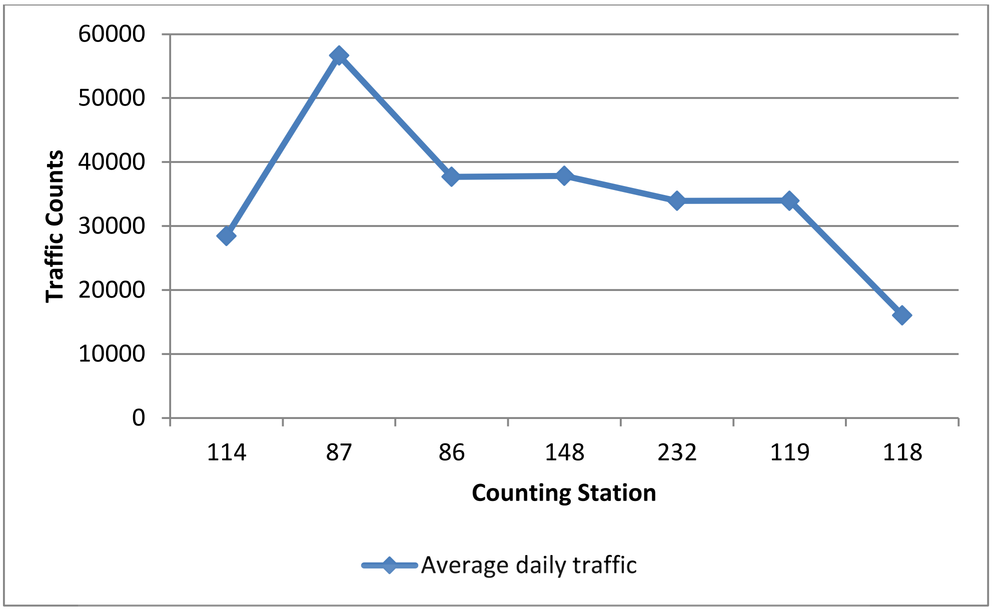

Figure 4.4: Average daily traffic.

The following observations were made: There is a 50 % increase in the average daily traffic between counting stations 0114 and 0087, the volume of traffic stays constant thereafter until counting station 0119, there after it drops significantly (by 53 %) at counting station 0118. The sharp increase at counting station 0087 is most likely due to this counting station being a permanent counting station. It collects data all year round, seven days a week so the data collected by this station is more accurate than any other station along this section of the road. Data from the other stations are collected for short periods of time, and are thus less accurate. The sharp decrease seen at station 0118 could be due to this station being located on the border between Gauteng and the Free State. The majority of the traffic on this leg of the R59 flows from Vanderbijlpark and Vereeniging northwards to Johannesburg and vice versa. That is, little traffic is originating in the Free State or travelling to the Free State on this road. Thus, people are commuting to Johannesburg (and beyond) from Vanderbijlpark and Vereeniging, and heavy vehicles are moving from and Vanderbijlpark and Vereeniging/Johannesburg (and beyond).

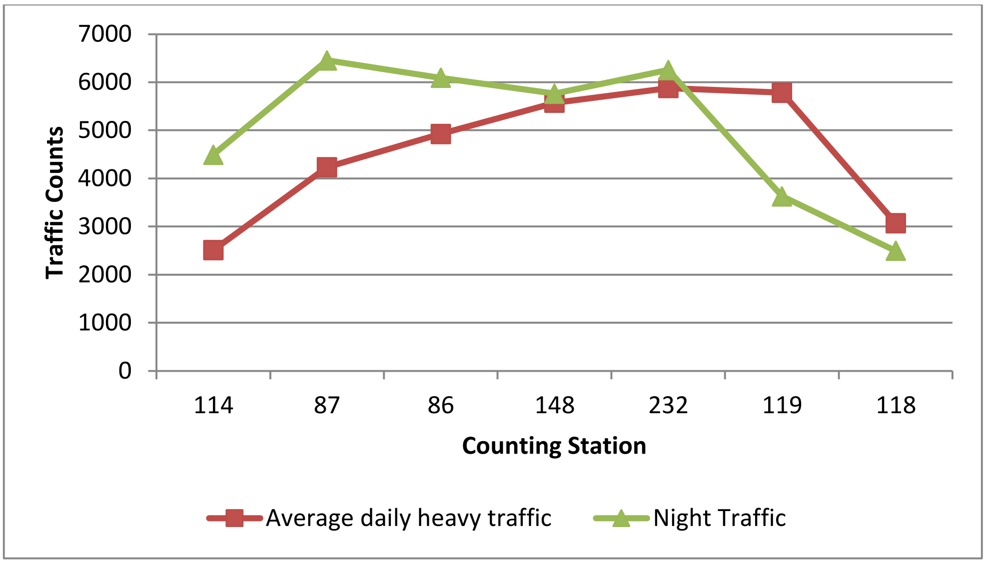

Figure 4.5: Average daily heavy traffic and night traffic for each station

The data for the Average Night Traffic shows a similar pattern for that of the Average Daily Traffic (see Figure 4.5). Once again there is a sharp increase at the permanent counting station 0087 (+45%). Overall night traffic is associated with the towns of Alberton and Meyerton area. The other counting stations along the R59 are either more remote or not near a residential area. The data for the Average Daily Heavy Traffic shows that, from north to south, there is a steady increase in heavy vehicles. This suggests that as the main industrial areas on this route are situated in the Vanderbijlpark/Vereeniging area, the heavy vehicles are moving freight between the industrial areas. Thus, heavy vehicles are clustered in industrial areas. Much of the heavy traffic using the road either exits or enters the road at Klipview, Meyerton and/or Meyerdustria. Thus, Meyerton and its industrial area, is a major source of heavy traffic for this section of the R59. As already discussed, heavy vehicle traffic may be a proxy for economic activity. That is, when economic activity is on the rise, there are more heavy vehicles on the road and vice versa. What this data suggests is that economic activity involves trading or movement of goods between various industries, for which heavy trucks are required.

4.5. Pavement classification from percentage truck split

Internationally, pavements are classified according to the composition of heavy vehicles using them. This classification is annotated as a percentage and is known as the percentage truck split (i.e. the percentage of short heavy vehicles: medium heavy vehicles: long heavy vehicles). Below details how the heavy vehicles are classified:

- **A short heavy vehicle** (typically) has a rigid chassis with two-axles and is between 4.6 m and 11.0 m long.
- **A medium heavy vehicle** (typically a horse-plus-semi-trailer combination) most often has three or four axles and is between 11 m and 16.8 m long.
- **A long heavy vehicle** (typically a combination of a horse, a semi-trailer and a full trailer) most frequently has five or more axles and is longer than 16.8 m. Some have up to seven axles.

Thus, if one knows what the percentage truck split is, the pavement can be classified, using methods by the provincial government (TRH16, 1991), who made use of Bosman (1988) or the Bosman (2006) method. Bosman (1988) classified the major roads in South Africa in terms of the HV composition. He proposed two main classes, namely roads carrying light-HV traffic and roads carrying heavy-HV traffic. Each class was later subdivided into two sub-classes. The light-HV classes carry mainly 2-, 3- and 4-axles heavy vehicles and the heavy-HV classes carry mainly 5-, 6-, 7- and 8-axle heavy vehicles.

The Bosman (1998)/ TRH16, 1991 guidelines are:

- If two axle heavy vehicles constitute more than 70 per cent of the truck split, then the road is classified as a L1 road.
- If two axle heavy vehicles constitute between 55 per cent and 70 per cent of the truck split, then the road is classified as a L2 road.
- If two axle heavy vehicles constitute between 35 per cent and 55 per cent of the truck split, then the road is classified as a S1 road.
- If two axle heavy vehicles constitute less than 35 per cent of the truck split, then the road is classified as a S2 road.

More recently Bosman's (2006) method represents an updating of the Bosman (1988) method. This was done using the data from the Traffic control centres (TCC) on the N3 and N4 and from the non-TCC WIMs. In general it was found that the heavier trucks (5- to 8-axle heavy vehicles) have increased in number and that the lighter heavy vehicles now carry more freight weight. Thus, the revised method, known as the Bosman (2006) method classifies South African roads into three classes, namely:

- If short heavy vehicles constitute more than 55 per cent of the truck split, then the road is classified as a **Low Heavy Vehicle Road** or L Road;

- If short heavy vehicles constitute between 35 and 55 per cent of the truck split, then the road is classified as a **Medium Heavy Vehicle Road** or M Road;
- If short heavy vehicles constitute less than 35 per cent of the truck split, then the road is classified as a **High Heavy Vehicle Road** or H Road.

Using this system and the R59 truck data to classify the road will provide important information to Gautrans and its civil engineers when rehabilitation of the road occurs. In particular, costly axle mass surveys are no longer required. Table 4.5 shows the results of the classification of the R59. Both the Bosman (1988) and (2006) methods show that the road must be classified as an S2 or H road or a S1 or M road. This indicates that the road carries many long heavy vehicles and on this basis, it should be considered that the R 59 should not be asphalt, but a concrete pavement due to the load it must carry.

Table 4.5: Classification of the R59 from 2004 to 2013

Year	**Percentage Truck split**			**Classification of road**	
	Short	**Medium**	**Long**	**TRH16 (1991) Bosman (1988)**	**Bosman (2006)**
2004	32	33	35	S2	H
2007	24	32	44	S2	H
2009	28	14	58	S2	H
2010	37	17	47	S1	M
2011	40	13	46	S1	M
2012	42	21	37	S1	M
2013	36	24	39	S1	M

Note: For 2012 and 2013 the road is at the limit of the M classification, very close to an H road.

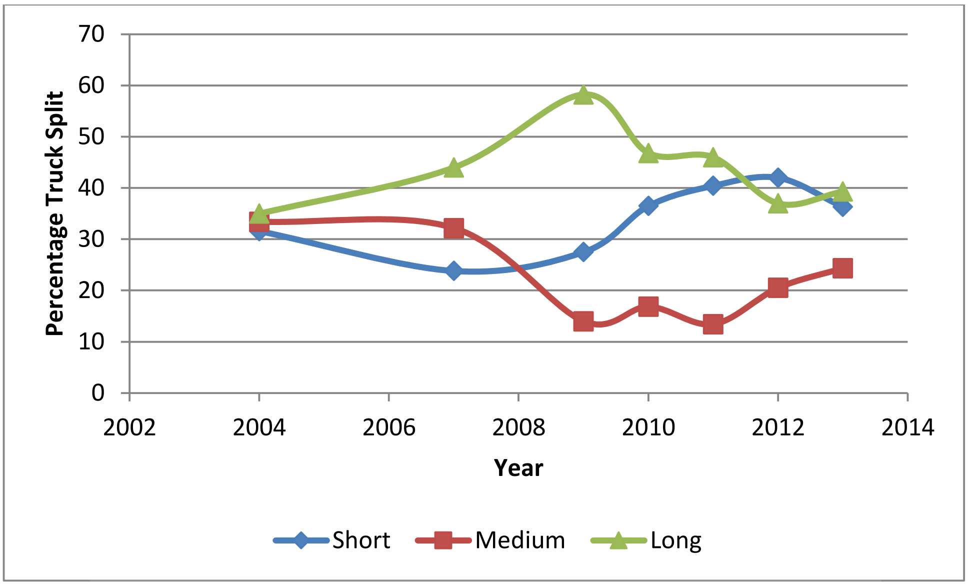

Figure 4.6: Percentage Truck Split for the period 2004 to 2013 on the R59 from counting stations 0114 to 0118

From Figure 4.7 it is evident that there is an increase in the percentage of long heavy vehicles on the road between 2004 – 2009, followed by a decline, between 2009 – 2013. This decline coincides with an increase the percentage of short and medium heavy vehicles during the same time period. The shift from medium to short and long heavy vehicles could be linked to the price of diesel and the economy. For example, if there are fewer goods to be moved, as a consequence of poor economic growth then companies may elect to use short heavy vehicles. They could also opt to consolidate loads into one medium heavy vehicle to reduce the number of trips required. The data indicates that the recession of post 2009 created an incentive to shift to cheaper vehicles such as short heavy trucks at the expensive of long heavy vehicles. This implies that companies had both fewer goods to transport and needed to save money on fuel. As the economy starts to recover in 2012 onwards, the split is beginning to return to the pattern of truck split found in 2004. Thus, truck split may be a function of economic demand and cost of diesel.

4.5. Relationship between truck split, economy and diesel price.

As was mentioned above the data indicates that there is a relationship between truck split on the R59 and the changes in the economy and the price of fuel. Figure 4.7 indicates the percentage of medium trucks on the R59 correlated against the growth in the GDP (as a percentage) from 2004 to 2013. A direct relationship exists between these two parameters i.e.

as the annual GDP decreases so does the use of medium heavy vehicles. The R^2 value of these two parameters is 0.33.

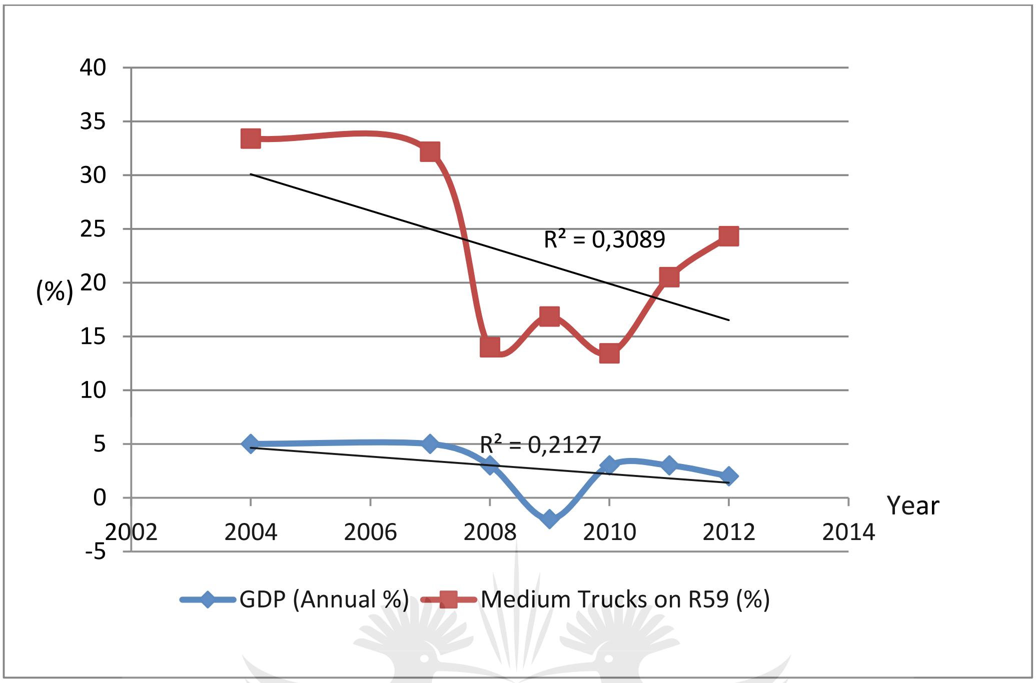

Figure 4.7: Medium heavy vehicles on the R59 versus the annual GDP

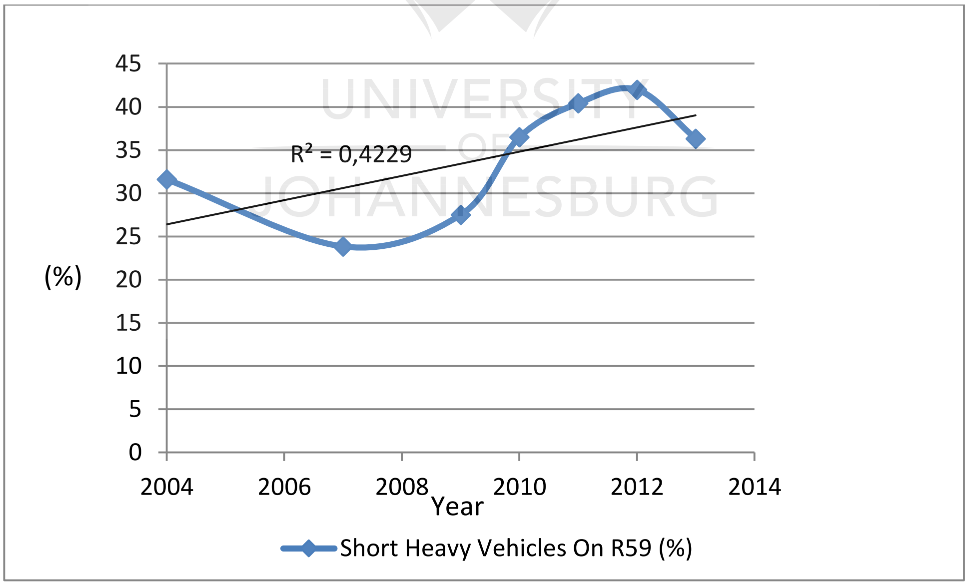

Figure 4.8: Short heavy vehicles (%) on the R59

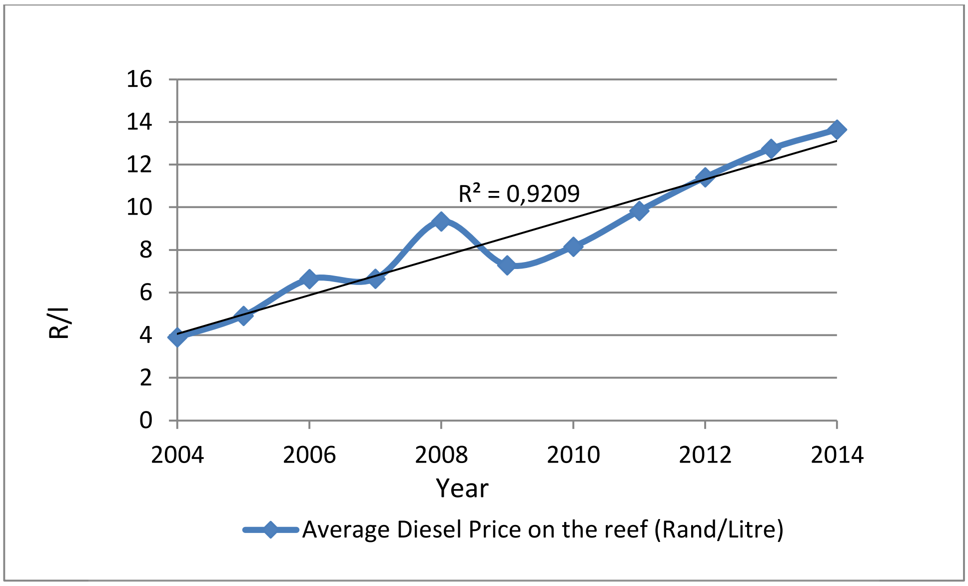

Figure 4.9: Average Diesel Price on the reef (R/L)

It also seems that the number of small heavy vehicles on the R59 is directly influenced by diesel price (Figure 4.8 and 4.9). As the diesel price increases companies choose to use smaller more economical vehicles. The R^2 value of these two parameters is 0.42. There appears to be a correlation between long heavy vehicles and the GDP, the R^2 value is 0.5, the relationship is inversely proportional. This is to be expected; in times when the economy is not doing well companies will choose smaller, more economical vehicles. Other correlations were also attempted, such as long heavy vehicles versus diesel price, no real relationship could be found in these cases. The R^2 value when long heavy vehicles were compared to the diesel price no relationship could be found, the R^2 value was 0.012. Short heavy vehicles showed no relationship with the GDP, their goodness of fit had a value of 0.0009. It should be noted here that this does not necessarily mean that relationships do not exist, but the absence of them may be due to the missing data.

4.6. Overloading on the road

4.6.1 Determination of overloading using E80/HV related to the number of axles

E80/HV is a measure of the loading (the amount of stress that the heavy vehicle places on the pavement) of the vehicle on the pavement. A pavement is built with a particular E80/HV value in mind. Unfortunately, this E80/HV value for the Gauteng leg of the R59 could not be obtained. Thus, the design of the road can only be determined using E80/HV values available, making the design specifications to be an estimate. However, only WIM stations measure E80/HV values directly, so only values from station 0087 (WIM station) were used in this study to calculate the design specifications of the road retroactively. The E80/HV data was available for the years between 2005 – 2007 and 2009 - 2012. The E80/HV values were then compared to the values given in the TRH16 document (1991) and Bosman (2006) to determine overloading (see Table 4.6.)

Table 4.6: Heavy vehicle data for the period 2004 to 2012 on the R59 from counting station 0087

Year	Number of Axles per heavy vehicle	Actual E80/HV	E80/HV (Individual Axle Method)	E80/HV (TRH16 (1991) recommendation)	Overloaded/ Not overloaded
2005	5.0	3.0	2.5	2.2	Overloaded
2006	5.0	3.0	2.5	2.2	Overloaded
2007	3.5	2.1	1.4	1.8	Overloaded
2009	4.8	1.4	2.0	2.0	Not overloaded
2010	4.6	0.99	2.0	2.0	Not overloaded
2011	4.6	1.4	2.0	2.0	Not overloaded
2012	4.6	1.2	2.0	2.0	Not overloaded

From the data (Table 4.6) it is evident that overloading on the section of the R59 under study was present for 2005, 2006 and 2007. This appears to not be the case for 2009 to 2012. However, this may be due to challenges experienced at the permanent station (0087) from 2009 onward. The WIM station 0087 was no operational for a period between 2009 and 2012 and only reinstated in July 2009. It was however, Gautrans then found that the northbound feeder had to be replaced. The WIM station was then only re-commissioned on 13th of August 2009. Furthermore, the northbound WIM sensor failed on the 1st October 2009 and was only replaced in January of 2010. Additionally, it was found that the southbound WIM sensor was not calibrated prior to commissioning and so subsequently had to be replaced. Hence overloading data was only collected for a short period during 2009 (Gautrans Yearbook, 2009). In March 2011, the WIM station 0087 was rebuilt. The southbound WIM bending plate was replaced on the 4th October 2011 (Gautrans yearbook, 2011). Thus data for 2011 is not continuous. Lastly, as previously stated, 2012 data is only for a short period due to the challenges associated with the tender process (Gautrans Yearbook, 2012). Hence there was not sufficient information on the E80/HV for that year. Thus, data from the permanent station from 2009 onwards may not give a true reflection of the state of overloading on the road.

4.6.2. Determination of overloading using mass related to average number of axles

Overloading can also be determined by comparing the average number of axles per heavy vehicle to the mass of the heavy vehicle. This allows one to determine whether the mass of a heavy vehicle exceeds the legal mass (as stated in The National Road Transport Act 93 of 1996) or not. Thus, the average number of axles as well as, the average mass per heavy vehicle was extracted from the counting stations data. A comparison of the masses to the legal masses is shown in Table 4.7. The legal mass for a heavy vehicle with three or more axles is 24 000 kg. Hence, it is seen that trucks exceeded their legally permitted mass (i.e. were overloaded) for all years except 2011 and 2012.

Table 4.7: Average number of axles and mass per heavy vehicle for the period 2004 to 2013

Year	Average Number of Axles per heavy vehicle	Mass per heavy vehicle (Tonnes)	Legal Mass (Tonnes)	Overloaded/ not overloaded
2004	4.8	24.2	24	Overloaded
2005	5	29	24	Overloaded
2006	5	29	24	Overloaded
2007	5.2	29.4	24	Overloaded
2009	5.2	27.6	24	Overloaded
2010	4.8	27.7	24	Overloaded
2011	5	24	24	Not overloaded
2012	5	24	24	Not overloaded
2013	4.3	26.5	24	Overloaded

The above findings show that medium and long heavy vehicles with 4 or more axles are the ones which are overloaded. In order to confirm this finding the direct overloading data from the permanent counting station (0087) was examined. These results are shown and discussed in the following section.

4.6.3. Direct measuring of overloading

A WIM station measures the weight of heavy vehicles and can, hence, be used to determine overloading. This data was available from the Gautrans Yearbooks for the period 2005 – 2007 and 2009 – 2013. The data is presented in Figure 4.10.

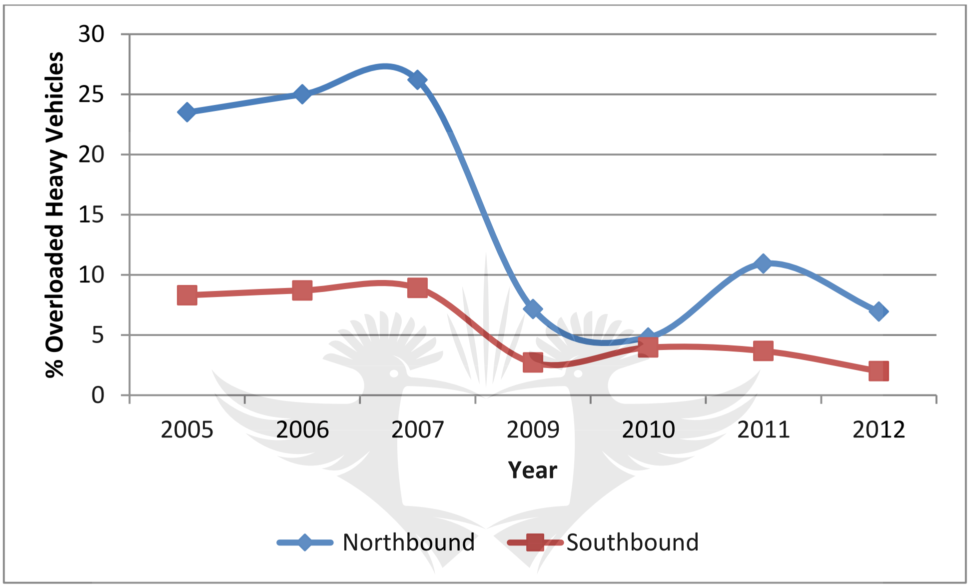

Figure 4.10: Percentage overloaded heavy vehicles on the road for the period 2005 – 2012.

Figure 4.10 shows the overloading pattern for heavy vehicles travelling north and south along the R59 for the section under study. The data reveals firstly that overloading is a typical feature of heavy vehicles on this section of the R59. Secondly, there are two distinct phases in the overloading pattern, although across the board there is more overloading of trucks heading north. More overloading in the northbound direction can be attributed to the transport of freight from the industries in the south (Vereening/Vanderbil park) of the province to the north (Alberton). The first phase is the years 2005 to 2007. In this phase, overloading was, on average 16.3% more for northbound traffic. Typical overloading for northbound trucks for this period was 25%, whereas for southbound trucks it was 8.6%. The second phase occurred from 2009 to 2012. The most significant aspect of the second phase is a dramatic decrease in overall overloading. Typical overloading for northbound trucks was 7.45% and for southbound, 3.1%. For phase one, trucks in both directions were overloaded by 16.8% while for phase two, trucks were overloaded by 5.3% on average. Thus, a decline of 11.5% occurred in the second phase. The massive decrease could be due to the economic recession, but the interruption of data collection at the permanent station for 2009, 2011 and 2012 may be a significant factor where actual overloading was under measured for these years.

In the Gautrans Yearbooks the overloading of heavy vehicles as measured by station 0087 was further broken down to show the percentage of overloading of heavy vehicles per number of axles. This analysed in this study for both the northbound traffic and southbound traffic - in the slow lane (lane 1 northbound and lane 4 southbound). The findings are shown graphically in the yearbooks, 2009 – 2012. The graphs for 2009 are shown below in figures 4.11 and 4.12. The graphs for the remaining years can be found in the Appendix. The graphs for all the years show similar trends.

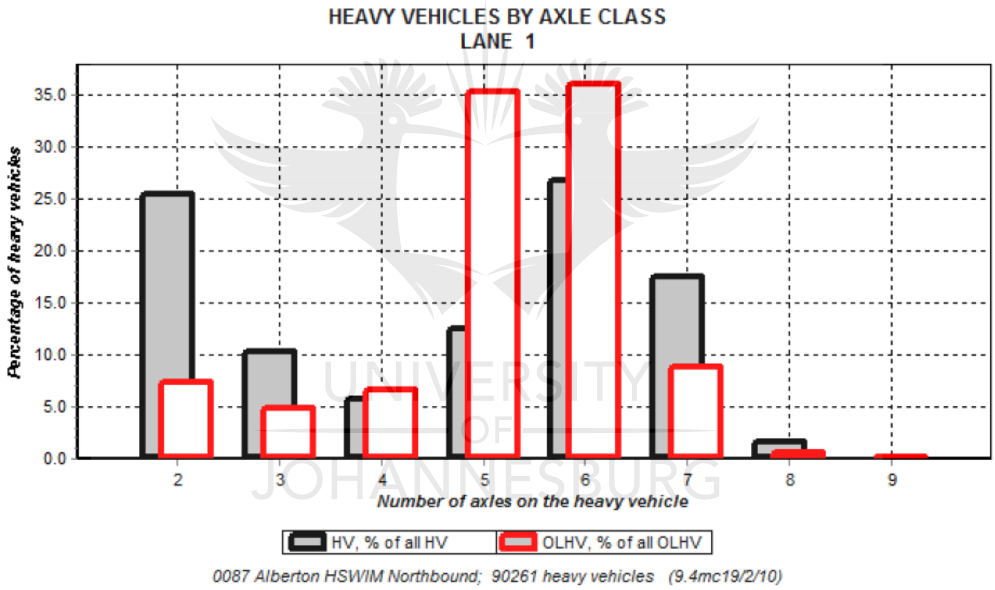

Figure: 4.11: Percentage of heavy vehicles and overloaded heavy vehicles northbound in lane 1 on the R59, 2009

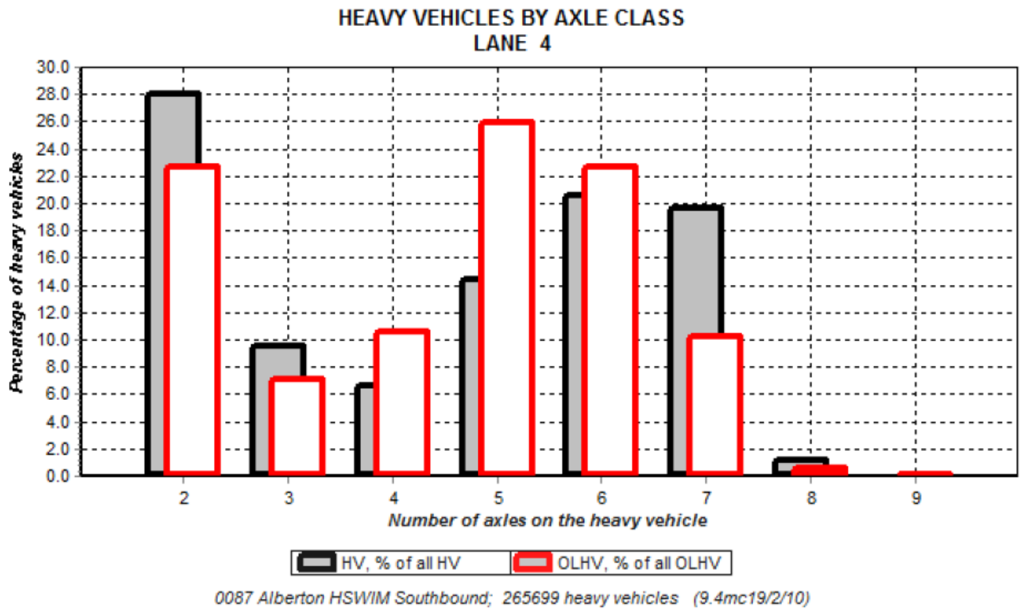

Figure 4.12: Percentage of heavy vehicles and overloaded heavy vehicles southbound in lane 4 on the R59

It is observed that in both directions, for 5 and 6 axle heavy vehicles, there is severe overloaded. Interestingly in the southbound direction there is a large number of over loaded two axle heavy vehicles that are not seen in the northbound direction. There are many non-industrial businesses in the north of Gauteng that supply the south that could potentially use shorter axle trucks for example the food industry, paper and stationery.

4.7. Effects of overloading on the R59

In order to confirm overloading, ground truthing took place and it found evidence of overloading on the R59. Photographic evidence was collected. Although the photographs presented in this study are of single incidents of pavement fatigue, they are representative of patterns of distress found along the entire route - in both the north and southbound direction. Thus, the photographs illustrate the extent of the problem. The distress is currently visible as cracking and the formation of potholes. Fortunately the distress is localised, however if not addressed timeously large scale rehabilitation will be required.

Figure 4.13 shows the beginning of the formation of a pothole on the pavement. Potholes are due to localised collapse of the pavement usually due to structural defects. Loading is not necessary the cause of potholes but rather the mismatch between loading and the design of the pavements. Potholes start small and unless rehabilitated will grow larger. This pothole can still be repaired without removing and replacing this section of the pavement. If it is however left, the ingress of water will accelerate the loss of material, after which patching of this section will be required.

Figure 4.13: Photograph of pothole forming on the R59.

Figure 4.14 shows transverse cracking. Transverse cracking appears at approximately right angles to the centre line of the pavement and is also caused by overloading amongst other things. Before repairs can be made the reasons for the cracking need to be determined. In the photograph the transverse crack can be seen running at a ninety degree angle from the yellow line. This cracking is not very deep and can still be sealed to prevent further cracking and loss of material.

Figure 4.14: Transverse cracking of the pavement.

In Figure 4.15, fatigue or alligator cracking is observed. This type of distress is caused by fatigue of the surface layer or the base layer due to excessive overloading. Fatigue cracking leads to disintegration of the surface with potholes been the result if rehabilitation is not carried out. Bad drainage of the pavement can aggravate this type of distress. These areas are still relatively small and can still be fixed with a patch or area repair. If however left these will become larger and sections of the road will require reclamation or reconstruction.

Figure 4.15: Fatigue cracking along the R59.

Figure 4.16 shows longitudinal cracking of the pavement. Longitudinal cracks form parallel to the centre lines of the road, amongst other reasons they form as a result of over loading. As with transverse cracking, the reason for the cracking must be determined before repairs can take place. Currently the cracking is not all that severe, however if the cracking is not repaired more of these cracks form parallel to each other and the road will begin to disintegrate.

Figure 4.16: Longitudinal cracking found along the R59

Figure 4.17 shows bleeding of the surface of the road. Bleeding occurs under hot weather conditions, as the asphalt becomes more liquid and pressure from the weight of the vehicles forces the asphalt to the surface. The underlying cause of bleeding is the result of the consistency of the asphalt used. If the asphalt has a viscosity that is too low or a seal coat, which is too heavy, it will lead to bleeding. Such damage is a safety concern as the road surface becomes slippery when wet and skidding becomes a real possibility. The application of a new seal coat is needed on sections showing signs of bleeding.

Figure 4.17: Bleeding along the surface of the R59

It is apparent that the overloading that is taking place is damaging the pavement, hence indicating that there is a mis-match between what the pavement was designed for and the current use.

4.8. Peak traffic flows on the R59

The reason that peak hour traffic exists in any major metropolitan area in the world is because the economy and the schooling system requires that people commute to work, or go to school or run errands around the same time every day. The effect of this however is peak hour traffic where traffic congestion is a reality. The R59 is no exception; the graph below (figure 4.18) shows an example of traffic flow over a typical week.

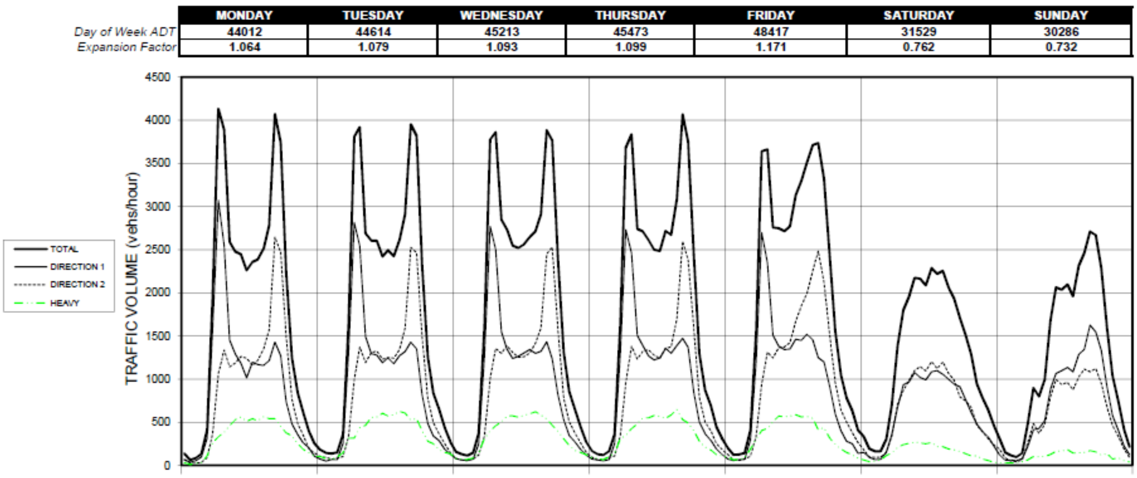

Figure 4.18: Peak traffic flow over a typical week on the R59

The traffic flow shows two distinct peak traffic times, one in the morning and the other in the evening. These peaks show a daily commute from Vanderbijlpark and Vereeniging to Alberton. These destinations can however also be Johannesburg and Pretoria. People are, thus, travelling roughly 120 km per day to get to work. People living in Vanderbijlpark and Vereeniging and travelling north for work may be opting to do this for a variety of reasons: It could be that housing is cheaper in Vanderbijlpark and Vereeniging; it could be they perceive the crime rate to be lower or that they are 'settled' in the Vaal Triangle and their children attend school there but there are few jobs in the Vaal Triangle and they must travel if they want to work.

The Monday morning peak appears to be the highest for the week, with a decline towards Friday mornings. This means fewer people are driving into work on a Friday. They may be on a four day work week or they may elect to work from home that day. In terms of the afternoon peaks, Thursday afternoons show the highest afternoon peak. This could mean that some people leave for work on a Monday morning, stay close to work for four days of the week and then return to Vanderbijlpark and Vereeniging on a Thursday afternoon/evening. The Friday afternoon peak is also lower than for the rest of the week. Peak traffic travelling to the south starts earlier on Fridays, presumably because people start leaving work earlier on a Friday afternoon.

There are fewer vehicles on the roads during the weekend and that there are no rush hour periods, as there are no distinct early morning and late afternoon peak visible. Hence, there is not a daily commute on weekends although people still travel on the road between the south of the province and Johannesburg. On a Sunday afternoon, there is; however a peak in traffic to

Alberton, this is the result of the "weekend warriors" who have a second home on the Vaal to participate in recreational activities, returning from the Vaal.

The volume of heavy vehicles on the road peaks during mid-day and is at its lowest during the evening/night. Heavy vehicles are present in very low volumes during the night. The volume of heavy vehicles is lower on the road on a weekend, most likely because the industries and other suppliers of goods do not distribute goods during weekends. It can thus be stated that South Africa still follows a traditional workweek model with a Monday to Friday Industrial Week.

4.9. Speed profile on the R59

Although speed is one of the factors that least affects pavements with respect to damage, a pavement is still designed with a certain speed in mind. The R59 is a standard South African Highway, with a speed limit is 120 km/hr. Figure 4.19 below is an example of a typical speed curve (Northbound, 2009) generated by the permanent counting station on the R59. Speed curves are found for the north and south bound directions in the Gautrans Yearbooks 2009 – 2012. The pattern of vehicle speed is similar in all the curves. The graph shows that the vast majority of vehicles are traveling within the speed limit. The average speed of all vehicles on the road is 96.6 km/hr, with light vehicles as 97.9 km/hr and heavy vehicles 82.8 km/hr (Gautrans Yearbook, 2009). The majority of vehicles travel between 70 and 120 km/hr. About 8 to 9% of all vehicles travel at 120 km/hr and that there is a small percentage of vehicles travelling at speed between 120 – 140 km/hr, or exceeding the speed limit. Between 8 and 9% of vehicles on the road are observed to travel at speeds of 70 km/hr. A small percentage of vehicles are fairly slow moving between 50 and 60 km/hr, these vehicles could be underpowered, not well serviced, and very old, under maintained and/or un-roadworthy vehicles.

Heavy vehicles travel at significantly lower speeds than other vehicles on the road. The maximum speed at which heavy vehicles travel does not exceed 110 km/hr. The majority of heavy vehicles travel between 60 and 100 km/hr. This is lower than the speeds at which light vehicles travel, which causes dangerous conditions on the road, as traffic travelling at higher speeds, will suddenly encounter slow moving traffic on the road and so will need to slow down rapidly. This may lead to accidents.

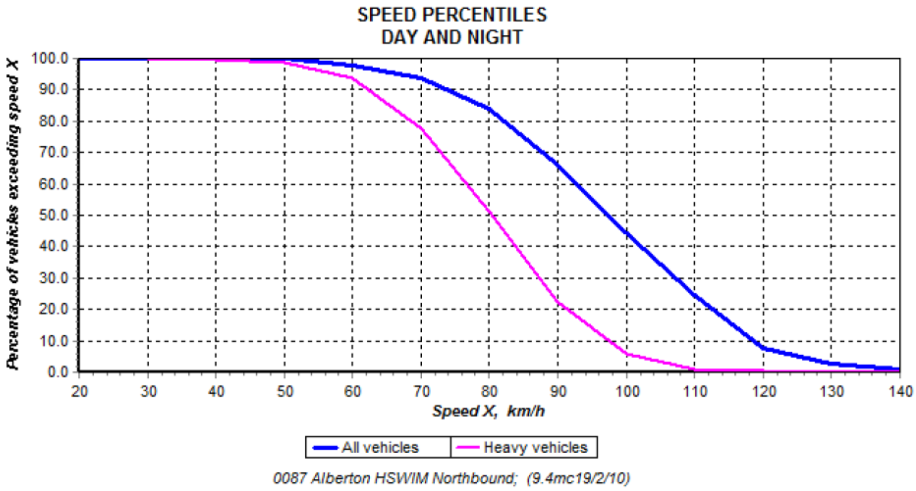

Figure 4:19: Speed curve on the R59, northbound 2009

4.10. Conclusion

Data was extracted from the Gautrans Yearbooks to determine changes in traffic volumes, the impact of traffic and trucking on the quality of the pavement surface of the R59 in Gauteng.

The study showed that the volume of traffic, i.e. average daily traffic, average daily heavy traffic and night traffic increased during the period that the road was under study. These increased traffic volumes on the road contribute to congestion on the road, slowing of traffic and increase the potential for accidents. Of growing concern is the increase in the number of heavy vehicles on the road, as well as the overloading of these heavy vehicles. E80/HV data and the mass per heavy vehicle was correlated to the number of axles and it was found that for almost all the years that the study was conducted overloading was observed. Furthermore, the permanent counting station measured overloading of heavy vehicles on the road for every year. The effects of overloading manifest as cracking of the road, formation of potholes on the road and bleeding of the road surface.

The pavement deterioration shows that the road was most likely under designed for the current traffic loading. This is a result of the fact that the road was built over 30 years ago. At that time the main mode of freight transport was rail. However, when deregulation of transport occurred, freight transport was shifted to road and this shift was not anticipated. The road in all likelihood should have been a concrete pavement and not an asphalt design. The lack of adequate management of traffic characteristics on the road also contributes to the deterioration of the road surface. The road should have at least one weighbridge, where heavy vehicles can be weighed and thus steps can be taken against overloading perpetrators.

Chapter 5: Recommendations and Conclusion

5.1. Introduction

This study explored road transport in Gauteng, from a traffic volume, speed and vehicle-loading viewpoint, with the R59 as a specific case study. This entailed the complication of a traffic data set for the R59, for the years 2004-2013 using unpublished Gautrans Yearbook data. The data was collected by seven counting stations along the Gauteng section of the R59. A detailed description of these counting stations is given in Chapter Four. This data was released by Gautrans specifically for this study. This data is now a baseline dataset against which future increases/decreases in traffic volumes, speeds and overloading can be measured. Once the baseline data set was complied, the following data was then analysed: (1) Traffic volumes and traffic types; (2) heavy vehicle usage both by volume and by axle split and (3) the number of overloaded vehicles. Using this data, the R59 was then classified. The data was used to determine what design strength the road requires. The data also revealed the extent of overloading and, thus, the traffic load on the pavement (road surface). Sections of the road, randomly selected, were subjected to ground truthing whereby indications of road distress were documented to corroborate the traffic volume, speed and overloading data. Lastly, the average annual GDP as well as the average diesel price from 2004 to 2014 was compared against truck split. This was done to determine if the economy and the diesel price affected the number and type of heavy vehicles using the R59. This chapter draws the study to a conclusion by detailing what the answers to the research questions are, summarising the findings and presenting recommendations that emerge from the data analysis.

5.2. The traffic volume and vehicle loading baseline dataset

Research Question 1: What are the characteristics of the heavy vehicles using the road in terms of weight, axle number and vehicle split in terms of short, medium and long heavy vehicle types?

The current traffic data set (see Table 5.1.) indicates that the road currently carries a significant number of heavy vehicles, with 44% of these long heavy vehicles. The baseline data also indicates that the typical heavy vehicle weights 26.8 tonnes, with an average E80/HV of 1.87. No evidence could be found to suggest that the R59 was specifically designed for such trucks, thus, it is likely that pavement distress and damage is occurring. A site investigation demonstrated that this was, indeed, a correct assumption to make. Thus, it can be concluded that the overall classification of the road must be H or long heavy vehicle carrying road.

Table 5.1:Baseline traffic data set

Indicator	
Total number of vehicles per lane per hour:	378
Average mass per heavy vehicle:	26.8 tonnes
Average number of axles per heavy vehicle:	4.8
Average E80/HV:	1.87
Heavy vehicle split: %short:%medium:%long	34% short : 22% medium : 44% long
Overall Road type:	S2 and S1 road*, H and M road#

*S2 road from 2004 to 2009, S1 road from 2010 to 2013.#H road from 20004 to 2009, M road from 2010 to 2013.

Data obtained from the WIM counting station 0087, have shown that overloading was present on the road during the period 2004 to 2013. The use of average estimated values obtained for the period 2004 to 2013, shows that when comparing the mass per heavy vehicle with the legal mass, overloading was present for the entire period.

Research Question 2: What are the traffic volumes on the road, in terms of the annual daily traffic, the annual heavy daily traffic and the night traffic between 2004 and 2013?

The average number of vehicles using the road on a daily basis was 36 322 per day for both North and South directions. Thus, currently the road is carrying 378 vehicles per lane per hour as it is two lanes in each direction. The annual daily traffic increased by 22 per cent between 2004 and 2013, although this was not a steady increase. The data revealed that average daily heavy traffic increased by 19 per cent from 2004 to 2013, although this was not a steady increase. The data also indicates that night traffic increased by 16 percent from 2004 to 2013, which also fluctuates between the years under study.

It should be noted that there were slight differences of approximately one percent in the traffic volumes in the northbound and southbound.

Research Question 3: What is the speed profile of all vehicles and heavy vehicles on the road?

The majority of vehicles travel within the speed limit, that is, between 70 and 120 km/hr. Some vehicles exceed the speed limit < 10%. Roughly 9% of vehicles are slow moving, between 50 and 60 km/hr are on the road. Heavy vehicles travel at significantly lower speeds than other vehicles on the road. According to the curve the maximum speed at which heavy vehicles travel does not exceed 110 km/hr. The majority of heavy vehicles travel between 60 and 100 km/hr.

Research Question 4: What is the classification of the R59 in terms of heavy vehicles?

Using the TRH16 (1991) manual classification, The R59 was an S2 road between 2004 and 2009, after which it was a S1 road (2010 to 2013). This is because the R59 carried more long heavy vehicles from 2004 to 2009 and then more short heavy vehicles dominated the traffic from 2010 onwards. If Bosman's (2006) method is used, the road was an H road until 2009 after which it was an M road from 2010 to 2013, as it carried fewer heavy vehicles than an H road.

Research Question 5: Can manifestations of road distress: cracking, surface deformation, integration and surface defects be found on the R59?

During the ground truthing exercise, numerous incidents of pavement distress could be observed. Photographs of the different types of pavement distress discovered are shown in Chapter 4. The types of distress observed included:

- **Cracking:** transverse cracking, longitudinal cracking, fatigue (or Alligator) cracking and block cracking.
- **Bleeding:** The bleeding in the pavement was mostly seen in the slow lane along most of this section of the road.
- **Disintegration:** In sections where fatigue cracking was observed, disintegration of the road in the form of potholes was taking place.

5.3. Summary of the findings

The average daily traffic, average daily heavy traffic and night traffic all showed an increase between 2004 and 2013. The typical traffic volume is 378 per lane per hour in both directions.

A study of the truck split data indicates that long heavy vehicles dominate the R59. On this basis, the study classifies the R59 as an S road or H road. That is, the typical truck on the road had 4.8 axles and weighed 26.8 tonnes. It was only possible to use E80/HV data obtained from the permanent WIM station. This data, however, confirmed that overloading is a permanent feature of the road. The impact of this overloading was clearly visible on the surface of the road. The pavement showed signs of distress in the form of cracking, bleeding and the formation of potholes. Furthermore, a relationship between truck split on the R59 and the changes in the economy and the price of diesel fuel exists, the percentage of medium trucks on the R59 correlated positively against the growth in the GDP (as a percentage) from 2004 to 2013. Thus, there is a relationship between these two parameters, i.e. as the annual GDP decreases so the use of medium heavy vehicles declines. It also seems that the number of small heavy vehicles on the R59 is directly influenced by diesel price. Therefore, as the diesel price increases, companies opt for smaller vehicles that are more economical. There is also a correlation between long heavy vehicles and the GDP, (R^2 = 0.5) the relationship is inversely proportional. When the GDP goes down i.e. during bad economic times the use of long heavy vehicles increases, companies are possibly opting to make fewer trips by putting their freight together in one load and in this way save fuel.

5.4. Discussion

The majority of South African roads were not designed to carry the number of heavy vehicles as well as the mass of the freight that they now carry (Van der Mescht, 2006). In the 1930's to the 1980's the majority of goods were moved via rail, suggests that past road engineers would not have designed main routes to carry the number of heavy vehicles that they now do (Havenga, et. al. , 2011). With the increase in road freight comes an increase in road damage, environmental pollution, safety issues and social problems such as traffic jams from slow moving traffic. It is clear that South Africa needs a multi modal transport system to efficiently move freight around the country. However, for this to occur, the rail system would have to be upgraded considerably and would cost vast amounts of money. To this end the road network is deteriorating resulting in unnecessary costs for repairs. The R59 is a good example of this phenomenon, having not been designed for the number of heavy vehicles that it now carries; the damage to the pavement is evident.

The pavement design of the Gauteng leg of the R59 is an asphalt mix design. It can thus be assumed that this pavement would be designed with a lifetime of 20 years. Unfortunately the original design specifications of the road could not be obtained. It was however seen from documents from Gautrans that an asphalt overlay of approximately 23km was placed on the section of the road P156/1 and /2, from Klipriver road interchange to Johan le Roux interchange was in 1996 (DoT, 1996). In 1996 – 1997, rehabilitation of approximately 9.0 km of the road P156/2, between Ring Road Interchange and PAN interchange was carried out (DoT, 1996). In 2005 – 2006**,** resurfacing took place from Meyerton to the Free State border [P156/2 & P202/1]; repairing and resealing along the Sedibeng 21 [P156/1 / P202/1] section and along the Sedibeng 24 [P156/2] section (DoT, 2005). This indicates that in the past there appears to have been a mismatch between what the road was designed for and what the traffic characteristics, in particular the traffic loading on the road, are. Hence trends in the data extracted from the yearbooks indicate that there is a mis-match between the design and current usage, as such a mis-match manifests itself in the form of road damage.

Traffic volumes on this section of the R59 have increased from 2004 to 2013. Thus, over the past decade the road is increasingly being used. This is despite the economic recession of 2009, during which time the volume of traffic on the road decreased for a while. Heavy vehicles are present on the road in increasing numbers. It was determined that overloading of these heavy vehicles on the road is taking place. The surface of this road was inspected and photographed. Damage is evident on the road surface, in the form of cracking, formation of potholes and bleeding. This indicates that maintenance is needed ten years after the previous rehabilitation. Hence, it can be deduced that there is a mismatch between what the road was designed for and what it is being used for. Further aggravating these issues is insufficient funding for road maintenance, severe lack of skills such as civil engineers and asphalt shortages making asphalt more expensive.

5.5. Recommendations

5.5.1. Mitigation of the impacts of heavy vehicles on the road surface

The single most significant mitigation measure, to reduce pavement distress would be to exercise better load control of long heavy vehicles. This will have to include stricter law enforcement of legal heavy vehicle mass per number of axles. This can be done by erecting an additional permanent traffic counting and weighing station. It is recommended that this station is erected between or between Vereeninging and Sasolburg or Vereeniging and Meyerton. It is also recommended that a manned weighbridge is erected on both the north and south sides of the R59. This weighbridge will enable the weighing and monitoring of heavy vehicles on an on-going basis. When overloading is found, steps can be taken immediately against perpetrators and the surface of the road can be protected against damage, also, the categorisation of the road, as an S2 and/or H means that this categorisation must influence maintenance decisions going forward. That is, rehabilitation takes the strength requirements associated with heavy vehicle usage into account.

5.5.2. Improved data quality

It is also recommended that data collection is improved. This can be done by:

1) Align the collection of data by secondary stations to specific times of the year so that data can be easily compared year-on-year. This will enable better comparisons of data, as traffic characteristics may vary during different times of the year.

2) Conduct a survey at every temporary station every year in order to eliminate the huge gaps in the data and provide a clearer picture of annual variations along this section of the road.

3) Add an additional HSWIM permanent station, in order to obtain data all year round and not for a short period of time per year only. This way a clearer traffic profile along this section of the road can be obtained and the data from the permanent stations can be compared.

4) Ensure that the call for tenders are sent out timeously to prevent the loss of data.

5.6. Conclusion

This study has shown that the number of vehicles on the Gauteng leg of the R59 has been increasing during the period, 2004 – 2013. The characteristics of heavy vehicles on the road on the other hand are of growing concern. Overloading of heavy vehicles is evident when examining the mass of heavy vehicles and the E80/HV in relation to the number of axles. The effects of this overloading are clearly visible on the road surface and are manifested as cracks, bleeding and potholes. A baseline traffic data set was built against which future increases and mitigation can be compared. From this it is evident that further increases in traffic characteristics of heavy vehicles in terms of overloading, will accelerate damage of the pavement and hence shorten the lifetime of the road. It also suggests that measures are needed to control the current overloading of heavy vehicles. Lastly, the study shows that the damage on the road means that rehabilitation of the road surface is needed. This has financial implications for Gautrans, who now needs to budget for this rehabilitation, as well as for other road users who will be negatively affected by the poor state of the road.

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Appendices 1 - 8: Traffic flow patterns obtained from Gautrans Yearbooks

Overview

The document is divided into appendices. In each appendix the characteristics of an individual counting station is presented. The information includes, (i) the period during which the surveying took place for the years under study, (ii) the traffic data which was extracted from the yearbook is presented in tables, (iii) lastly graphs of the traffic flow patterns for one week during a year, as well as light/heavy variations are shown.

Appendix 1: Secondary Counting Station 0086 – Brackendowns

Table A1.1: Surveying of station 0086

Year	Requested period	Number of hours	Actual period	Number of hours
2004	01/01 – 31/12	8784	29/09 11/10	282
2007	01/01 – 31/12	8760	17/10 – 25/10	190
2010	Not given	Not given	23/03 – 01/04	280
2011	Not given	Not given	21/11 – 29/11	189

Table A1.2: Traffic counts for counting Station 0086

Year	ADT	ADDT	AWDT	Truck split %Short : % Medium : %Long	E80/HV	No, Axles	Tonnes	Night traffic (AV)	% Night traffic (HV)
2004	33249	4224 (12.7%)		29:33:38	2	5	24	3691 (11.1%)	—
2007	37736	5343 (14.2%)		29:29:42	1.8	5	29	4038 (10.7%)	—
2010	39183	4411 (11.3%)	43288	27:22:52	1.8	5.2	30.3	8307 (21.2%)	1345 (35.5%)
2011	40648	5726 (14.1%)	44517	41:08:51	Not given	Not given	Not given	8333 (20.5%)	1620 (28.3%)

Note: Data was not recorded for the years 2002, 2003, 2005, 2006, 2008, 2009, 2012 and 2013. No % OLHV data was recorded at all.

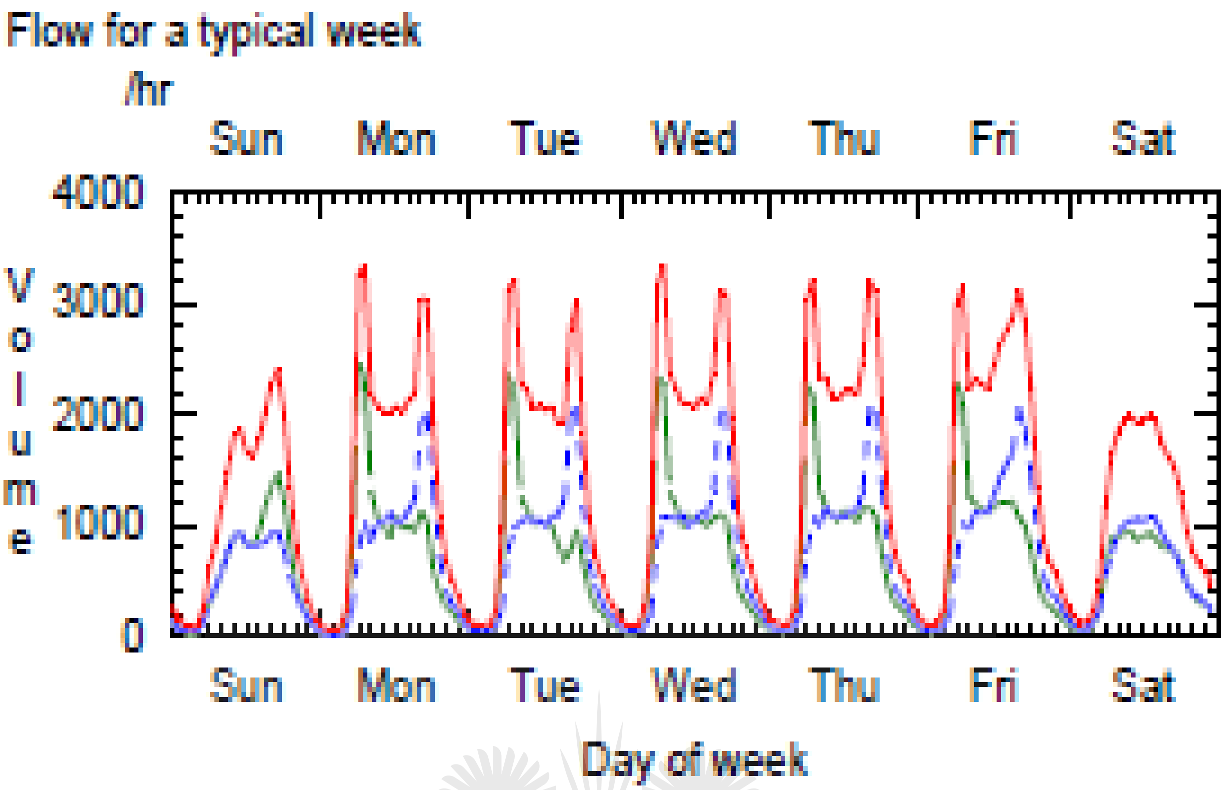


Figure A1.4: Traffic volume for a typical week in 2004

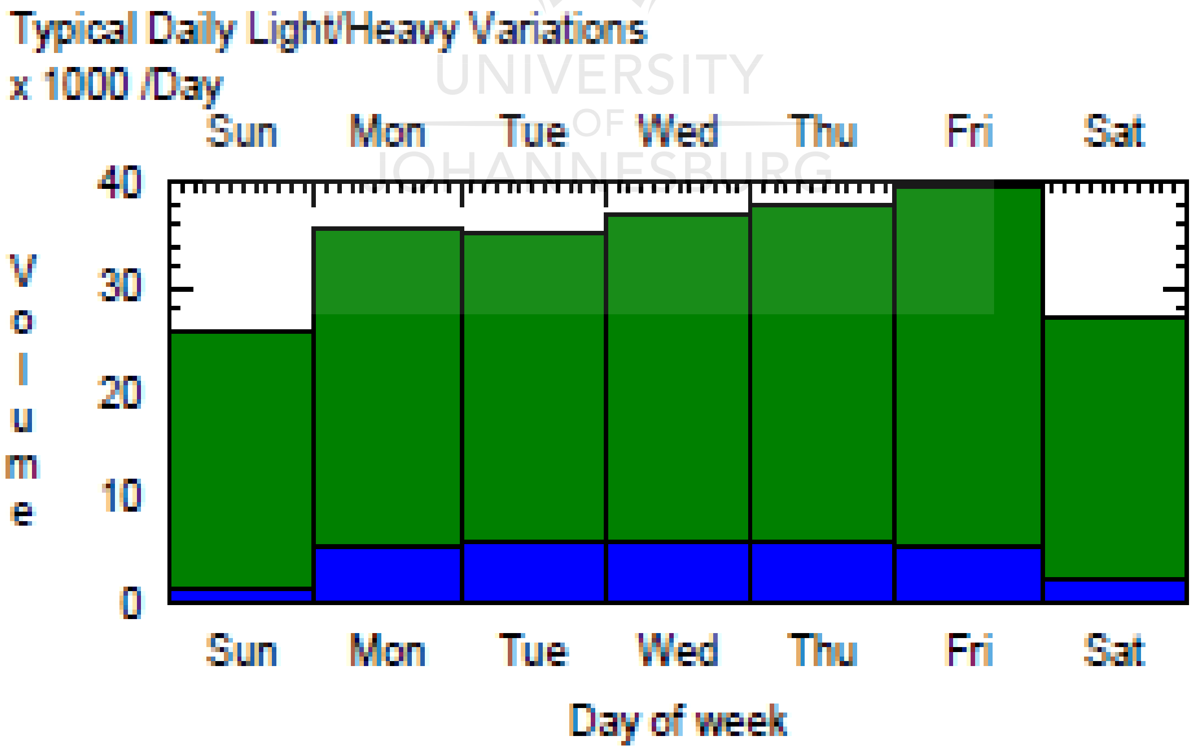


Figure A1.5: Typical daily light/heavy variations in 2004

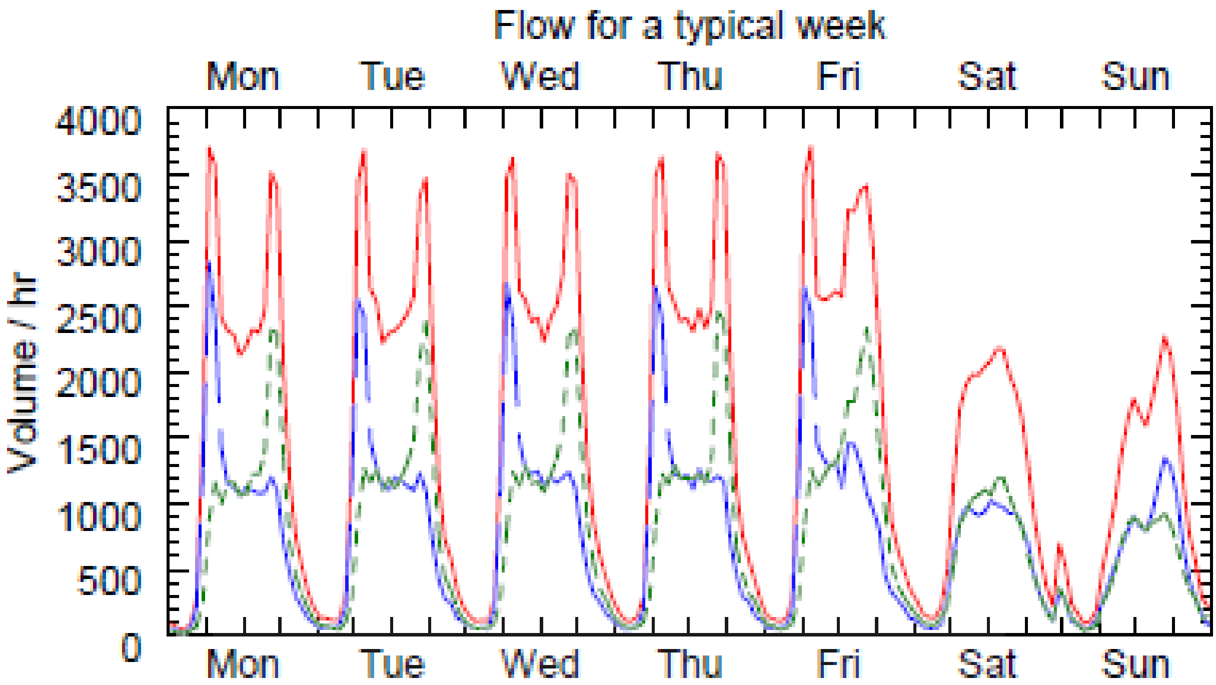


Figure A1.6: Traffic volume for a typical week in 2007

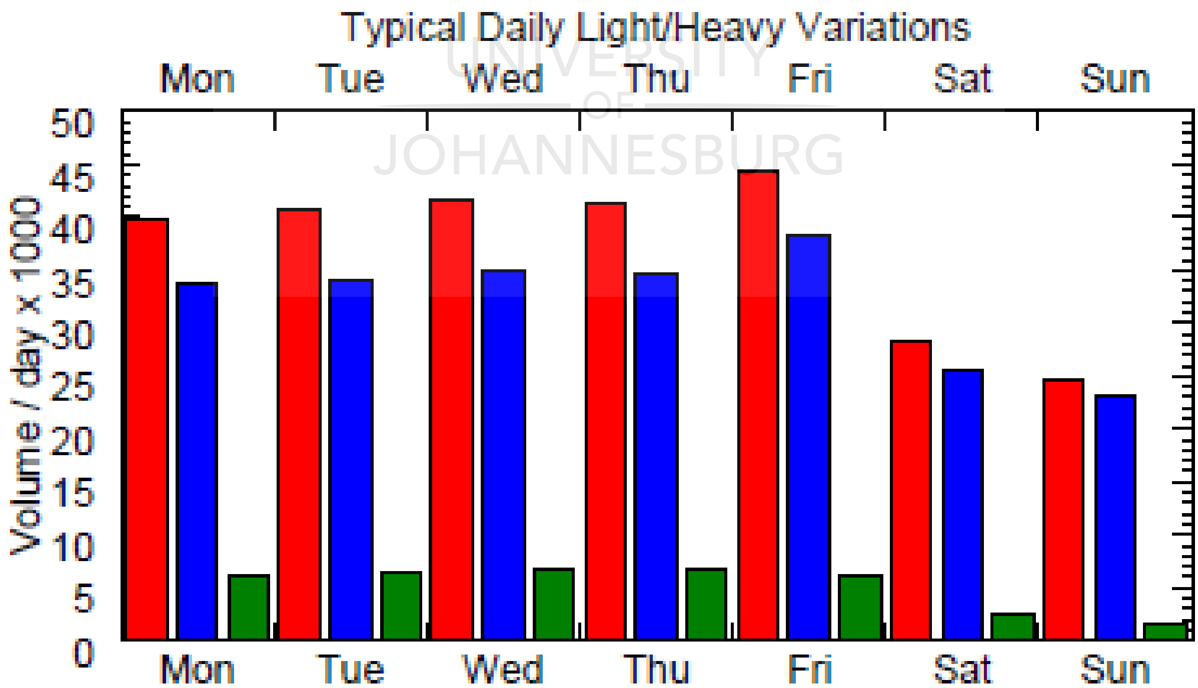
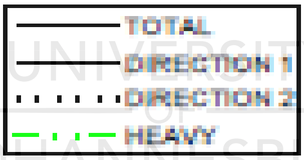
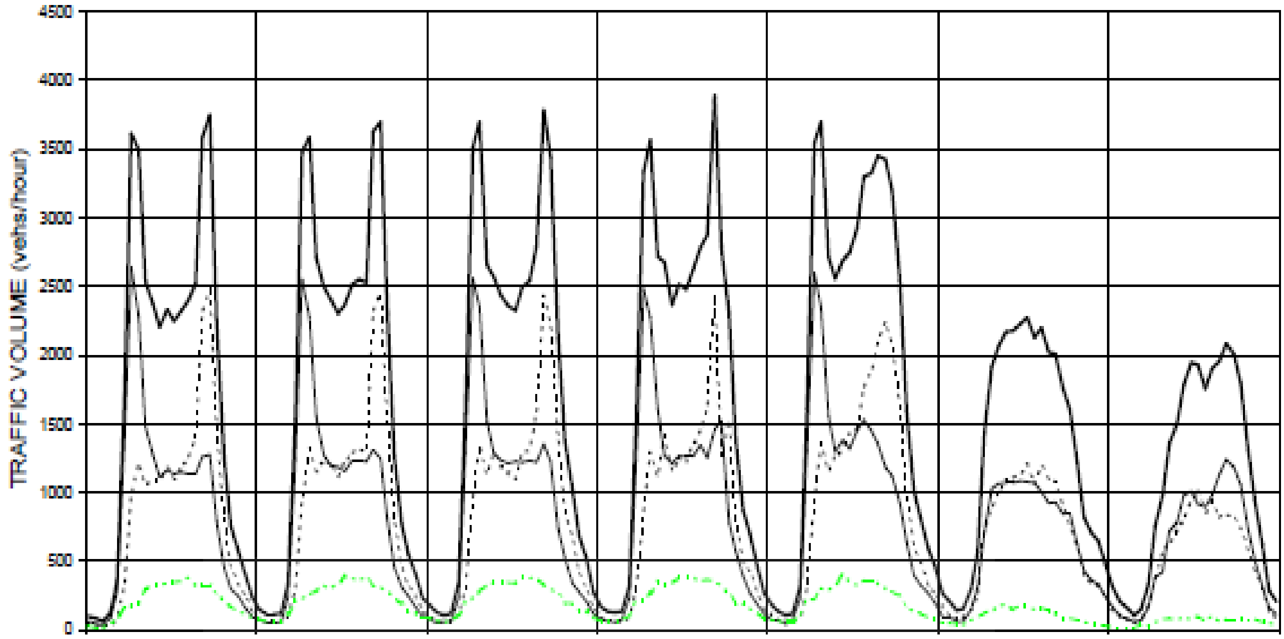


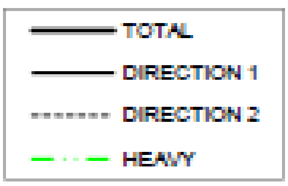
Figure A1.7: Typical daily light/heavy variations in 2007

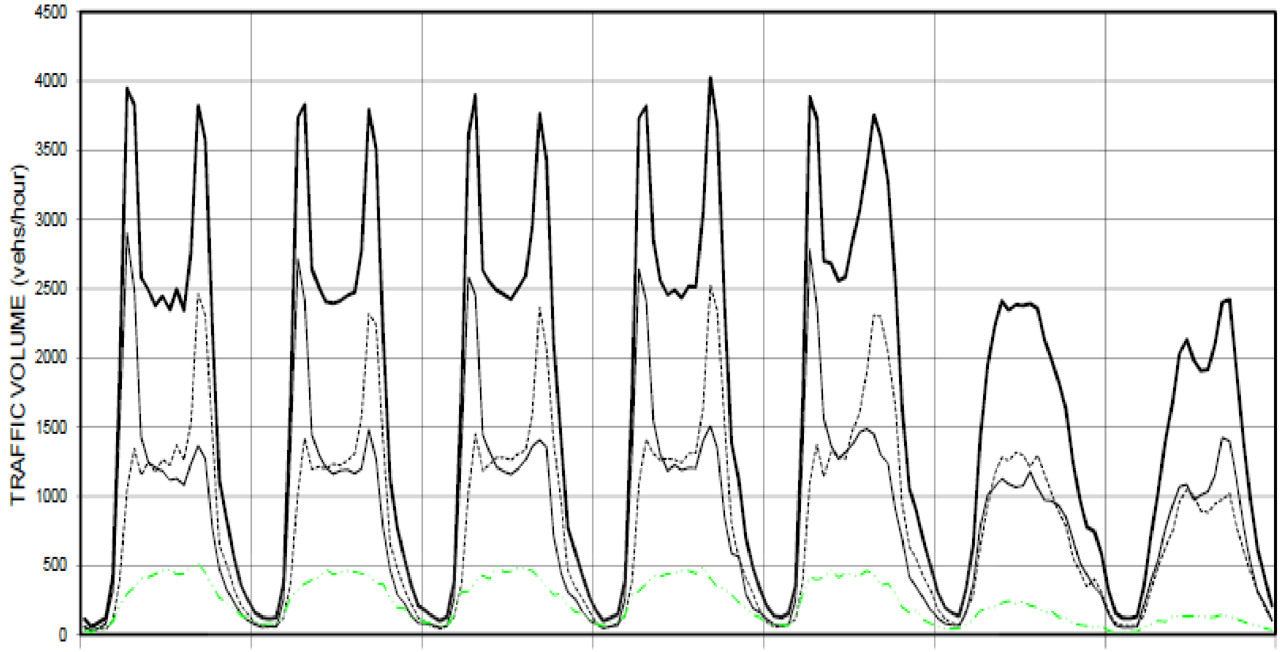

TOTAL
DIRECTION 1
DIRECTION 2
HEAVY



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	41255	42153	42886	42886	47052	31461	28379
Expansion Factor	1.053	1.078	1.097	1.097	1.201	0.803	0.873

Figure A1.8: Traffic Volume for a typical week in 2010





	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	43083	42712	43527	45208	48055	33543	28409
Expansion Factor	1.060	1.051	1.071	1.112	1.182	0.825	0.699

Figure A1.9: Traffic Volume for a typical week in 2011

Appendix 2: Permanent Counting Station 0087 – Alberton WIM (BL)

Table A2.1: Surveying of Station 0087

Year	Requested period	Number of hours	Actual period	Number of hours
2005	01/01 – 31/12	8760	07/10 – 31/12	2050
2006	01/01 – 31/12	8760	01/01 – 31/12	8631
2007	01/01 – 31/12	8760	01/01 – 31/12	8609
2009	01/01 – 31/12	8760	13/08 – 31/12	3102
2010	01/01 – 31/12	8760	01/01 – 31/12	8076
2011	01/01 – 31/12	8760	01/01 – 31/12	8076
2012	01/01 – 31/12	8760	01/01 – 14/02	1080

Table A2.2: Traffic counts for counting Station 0087

Year	ADT	ADDT	% OLHV	Truck split %Short %Medium %Long	E80/HV	No, Axles	Mass Tonnes	Night traffic (AV)
2005	56126	3818 (6.8%)	15.8	10:35:55	3	5	29	6398 (11.4%)
2006	56807	3895 (6.9%)	16.6	10:37:53	3	5	29	6249 (11%)
2007	59407	3997 (6.7%)	17.1	9:44:47	2.1	5.7	33.6	6713 (11.3%)
2009	55905	4090 (7.31%)	9.87	15.2:14.7:70.1	1.4	5.5	23.38	Not given
2010	56872	4547 (7.99%)	8.84	30.15 : 22.65 : 47.15	0.99	Not given	Not given	Not given
2011	56037	4666 (8.33%)	14.6	30.5 : 20.2 : 49.4	1.4	Not given	Not given	Not given
2012	55501	4626 (8.33%)	8.96	32.1:19.8:48.1	1.2			Not given

Note: No data was recorded for the years 2002, 2003, 2004, 2008 and 2013.

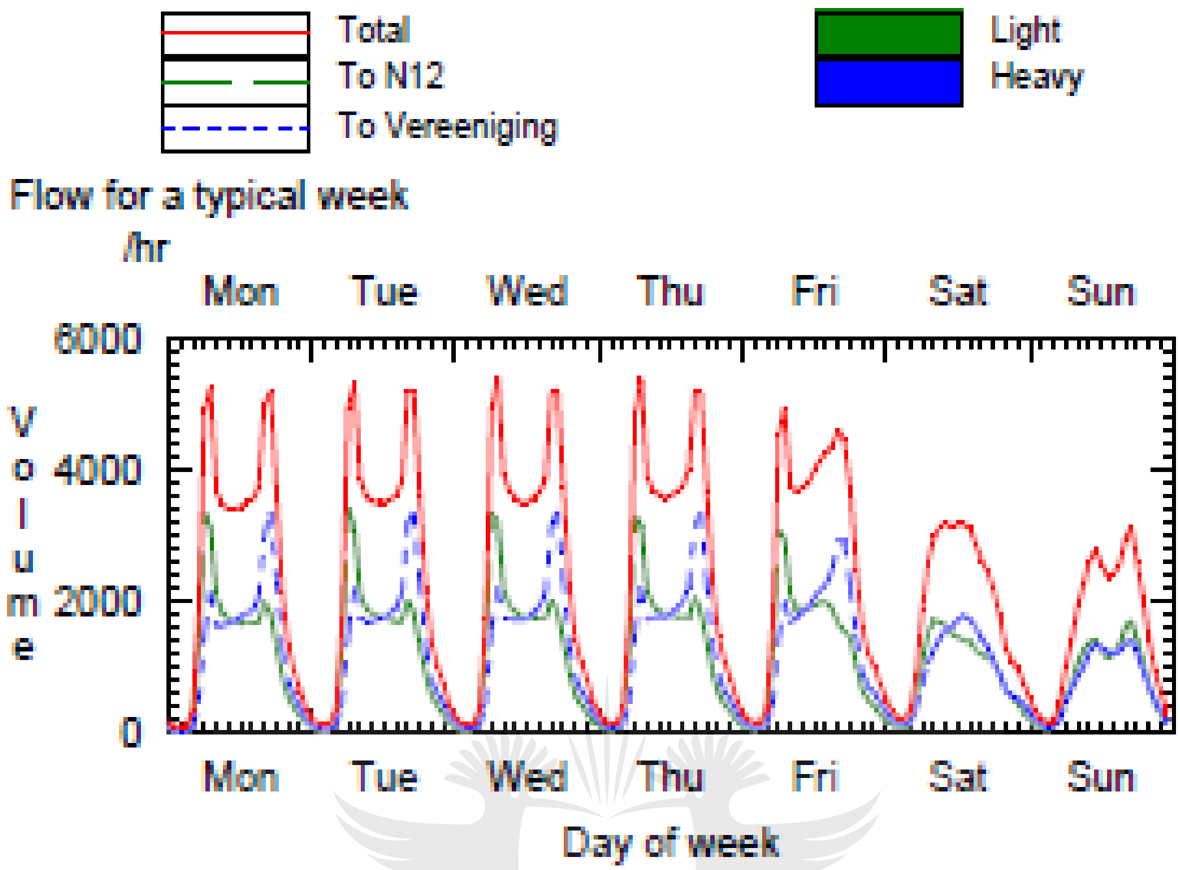


Figure A2.1: Traffic Volume for a typical week in 2005

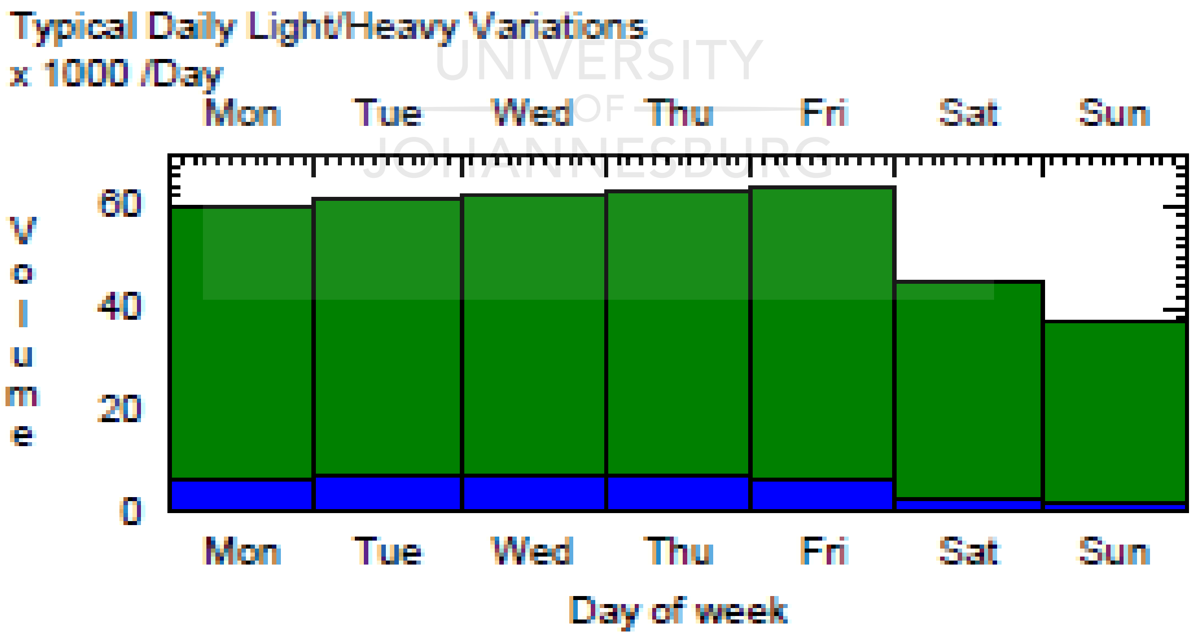


Figure A2.2: Typical daily light/heavy variations in 2005

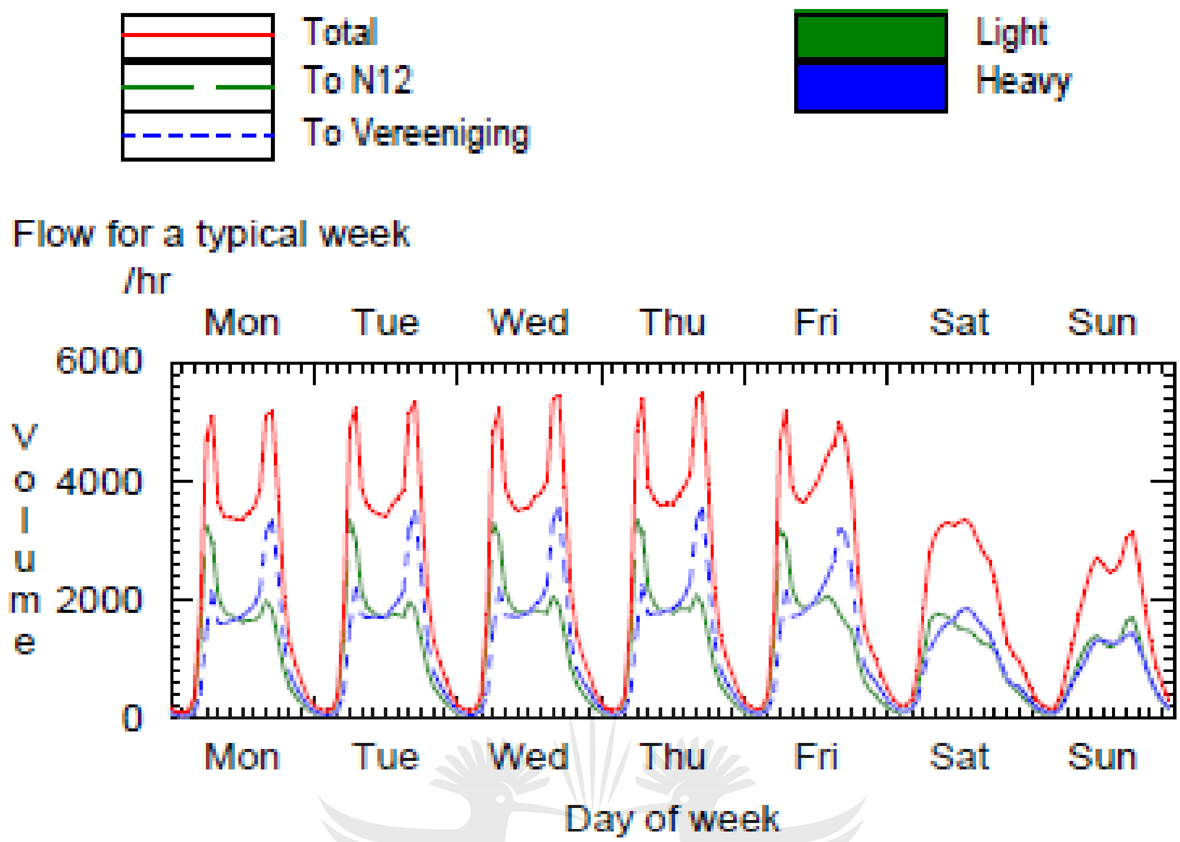


Figure A2.3: Traffic Volume for a typical week in 2006

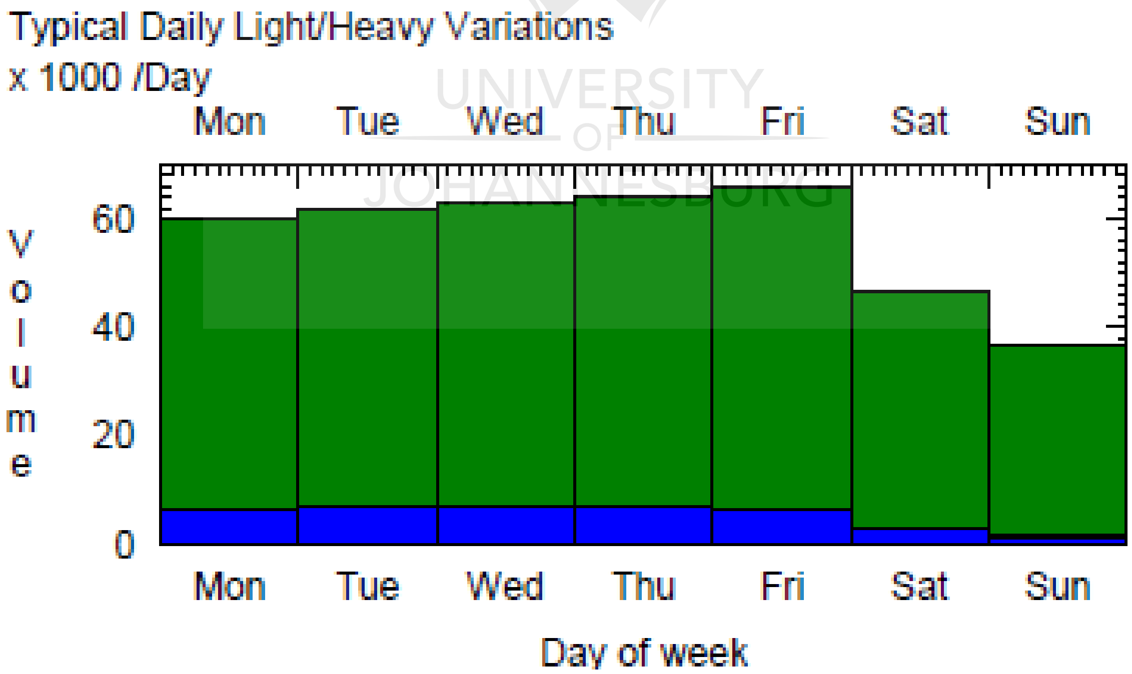


Figure A2.4: Typical daily light/heavy variations in 2006

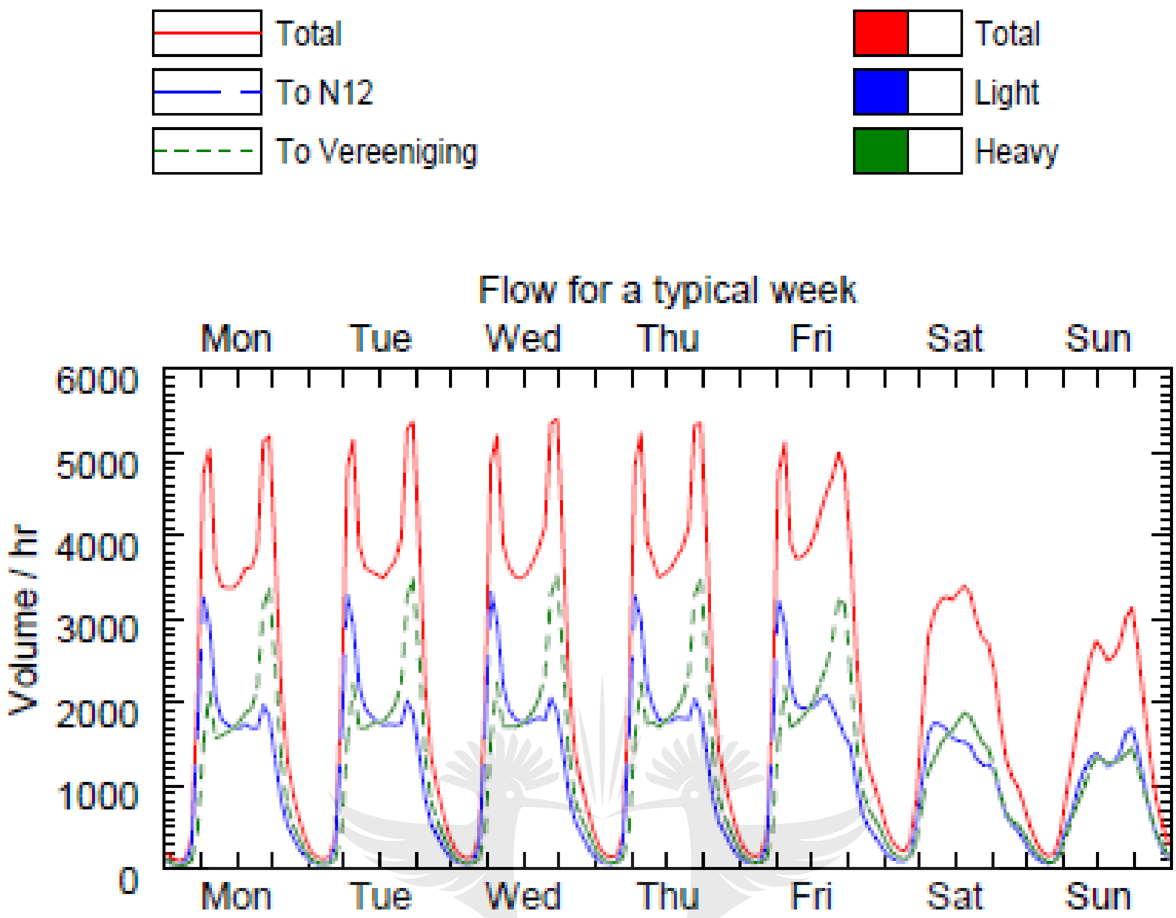


Figure A2.5: Traffic Volume for a typical week in 2007

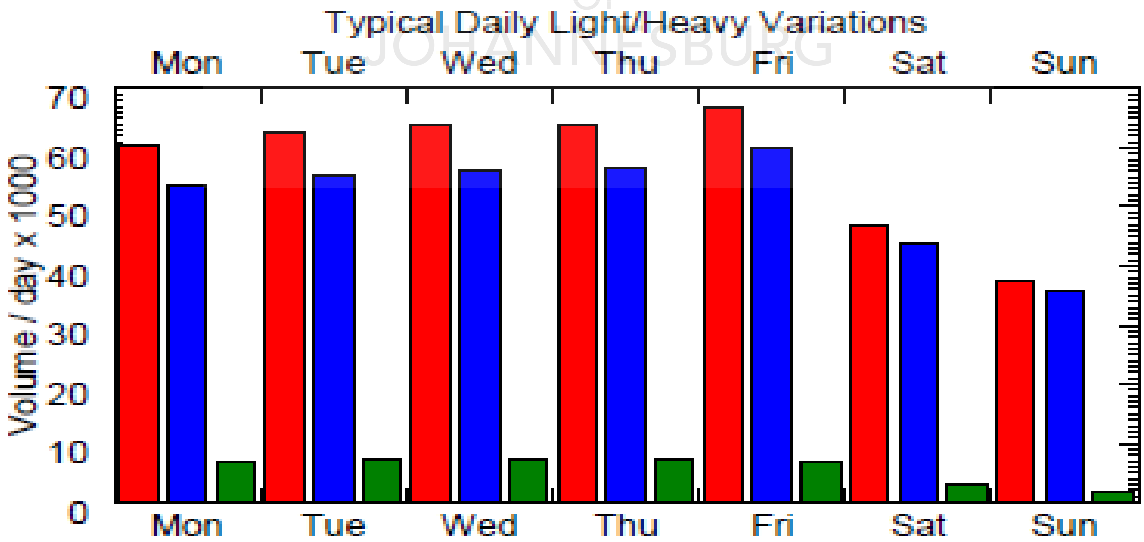


Figure A2.6: Typical daily light/heavy variations in 2007

Overloading patterns at the permanent station

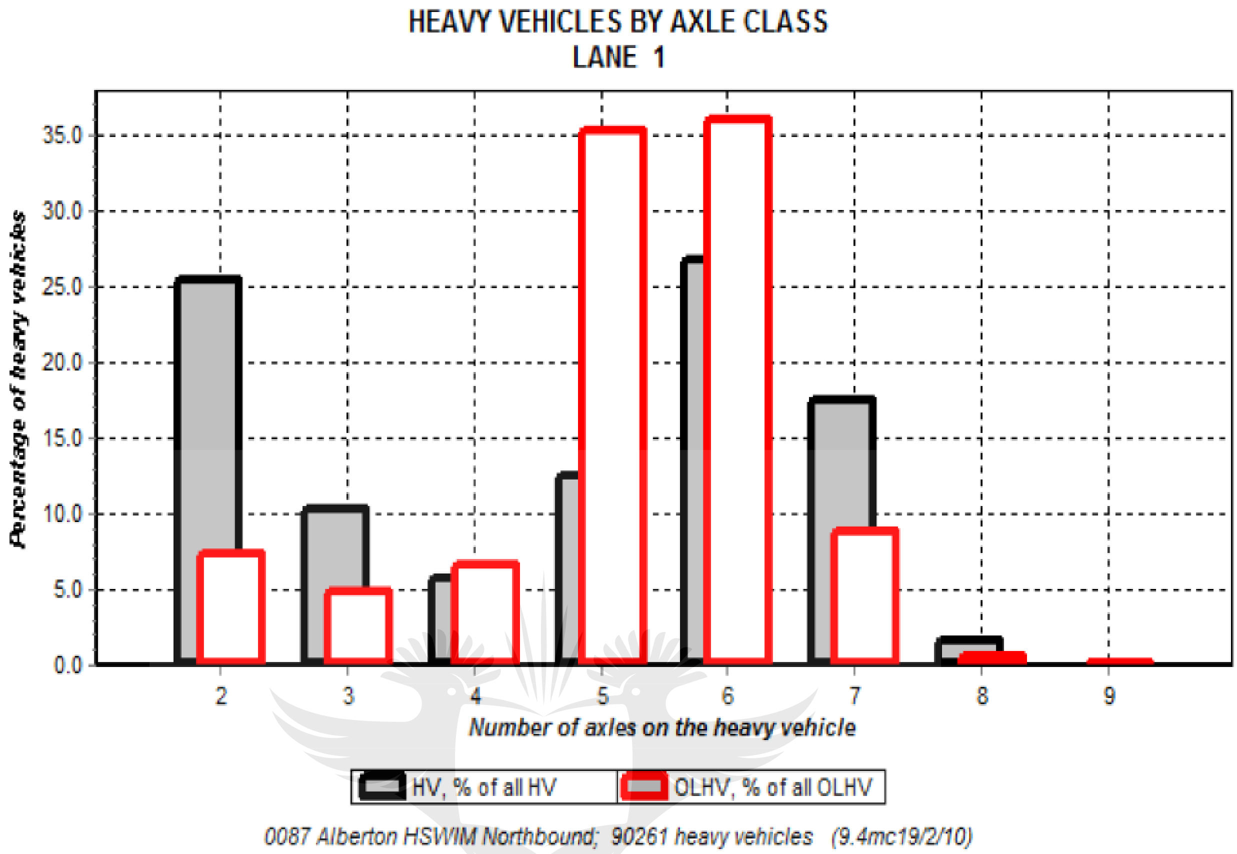


Figure A2.7: Northbound heavy vehicles on the R59, 2009

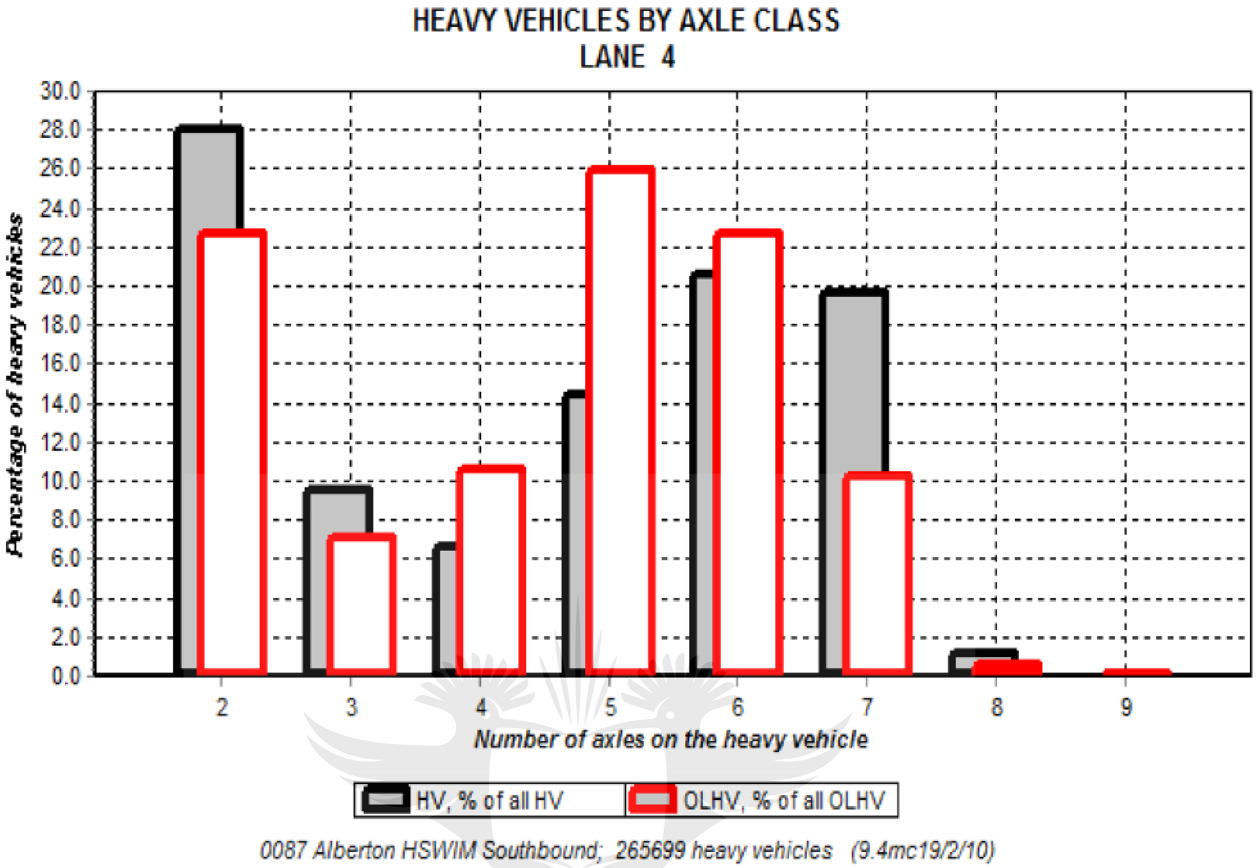


Figure A2.8 Southbound heavy vehicles on the R59, 2009

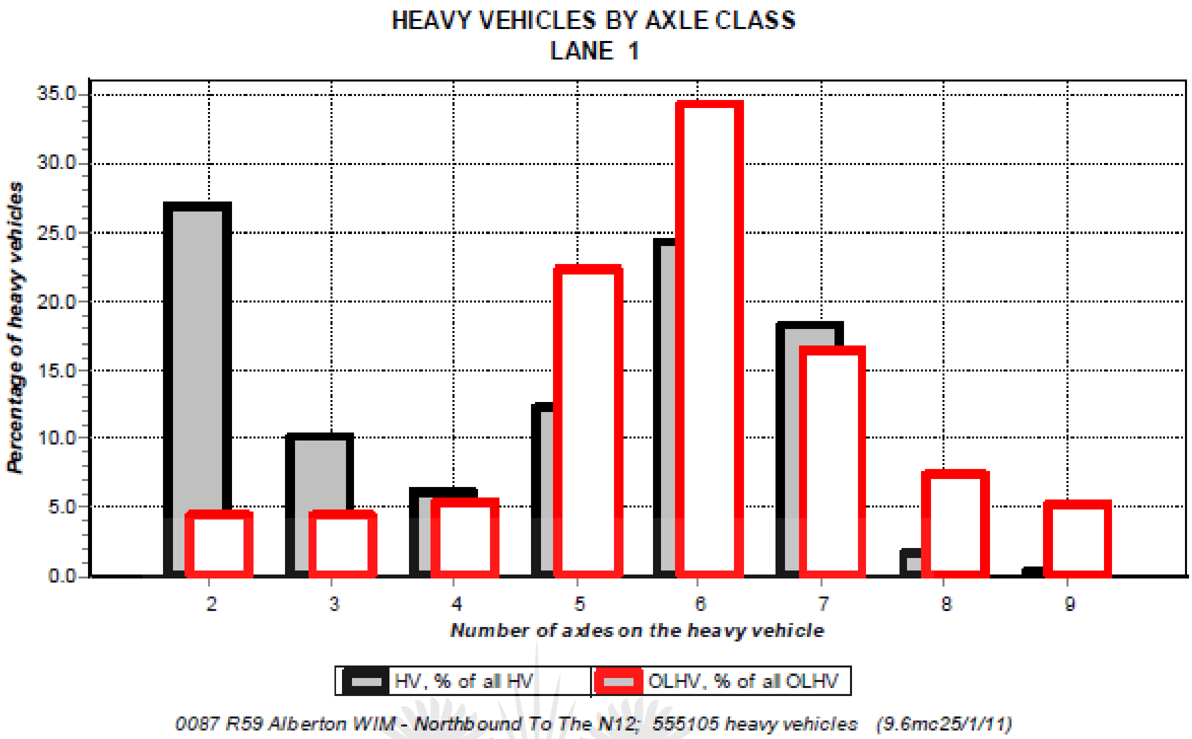


Figure A2.9: Northbound heavy vehicles on the R59, 2010

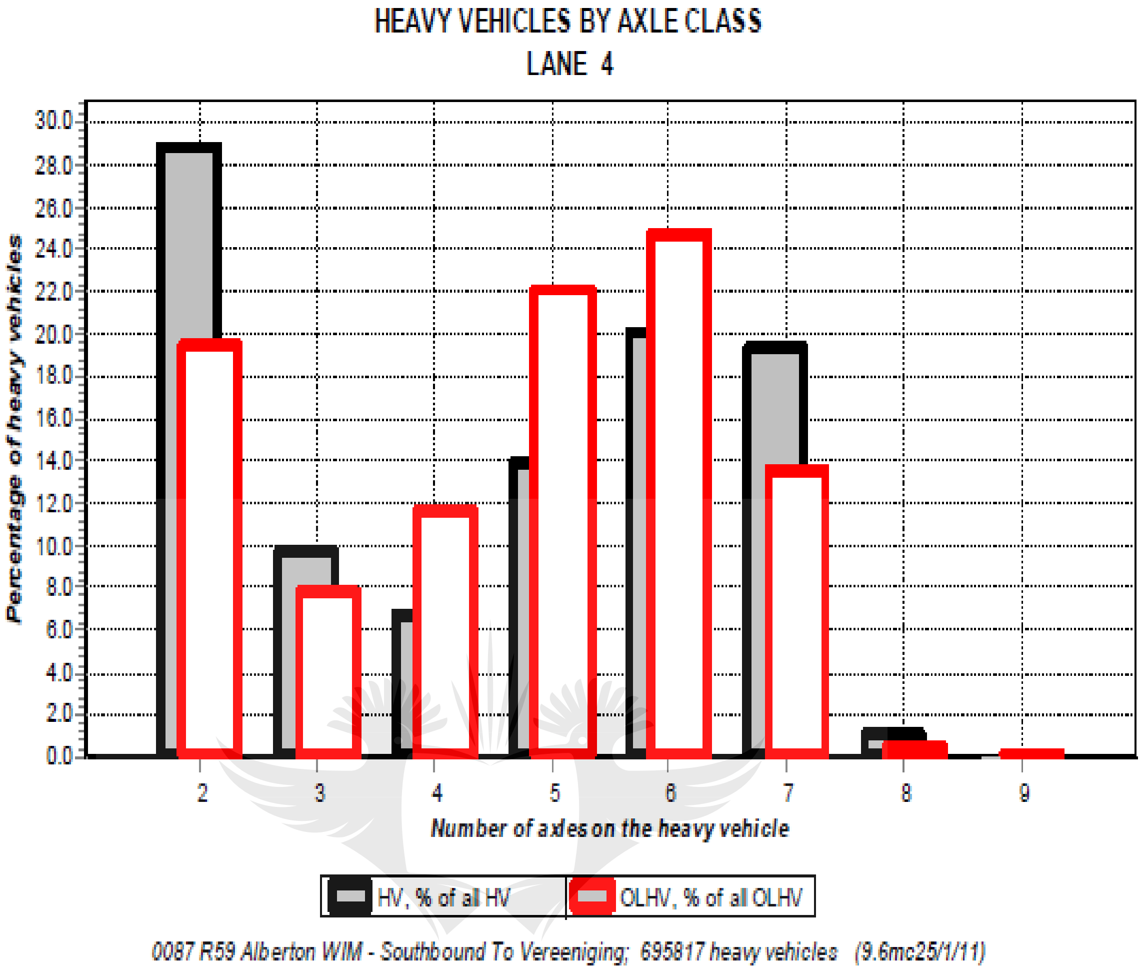


Figure A2.10: Southbound heavy vehicles on the R59, 2010

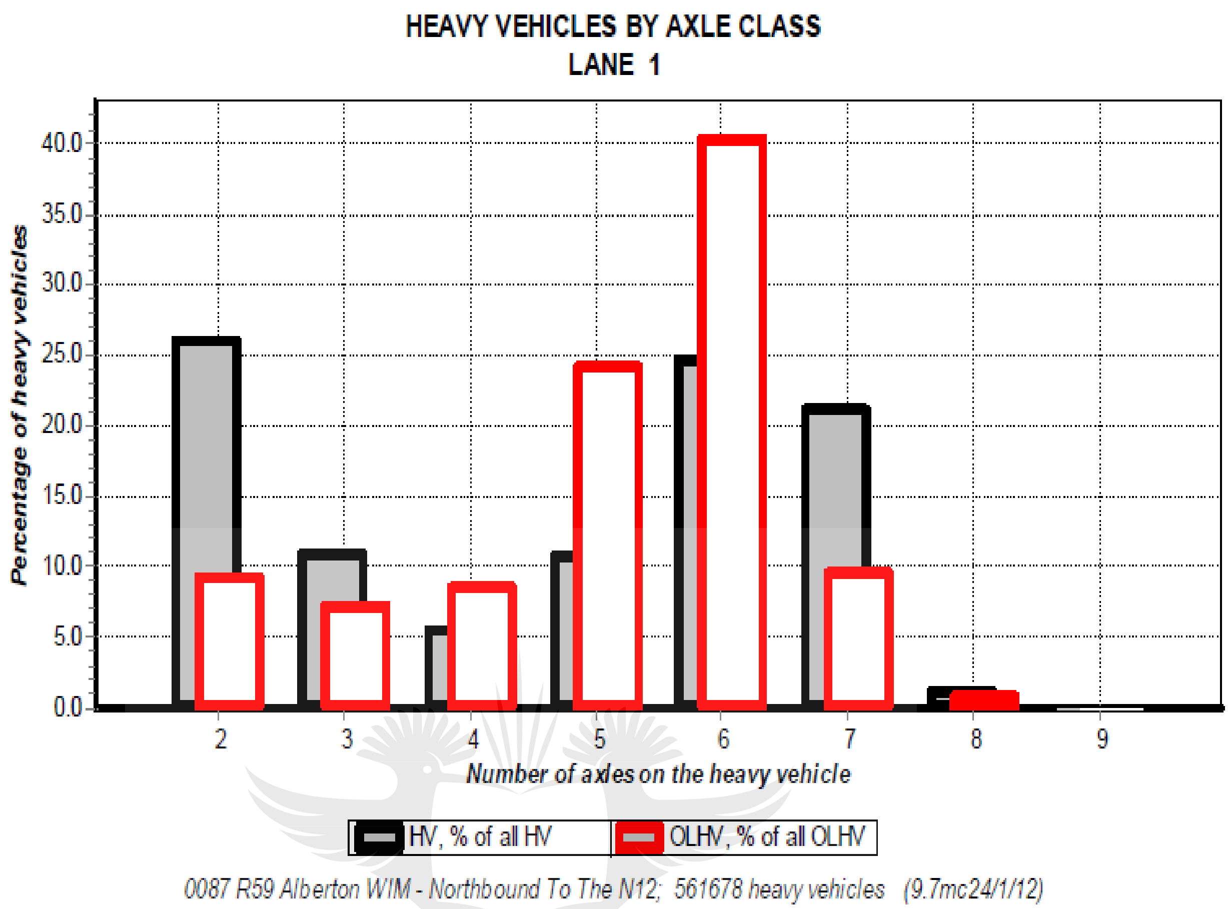


Figure A2.11: Northbound heavy vehicles on the R59, 2011

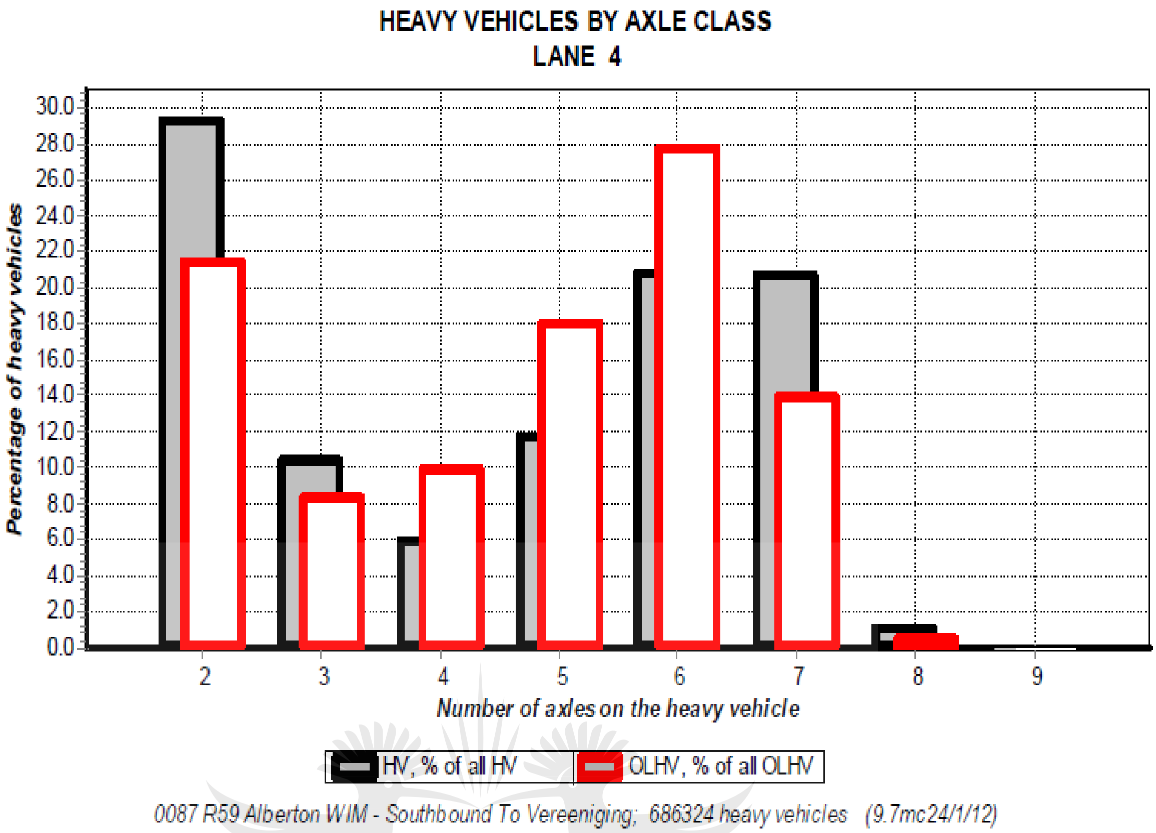


Figure A2.12: Southbound heavy vehicles on the R59, 2011

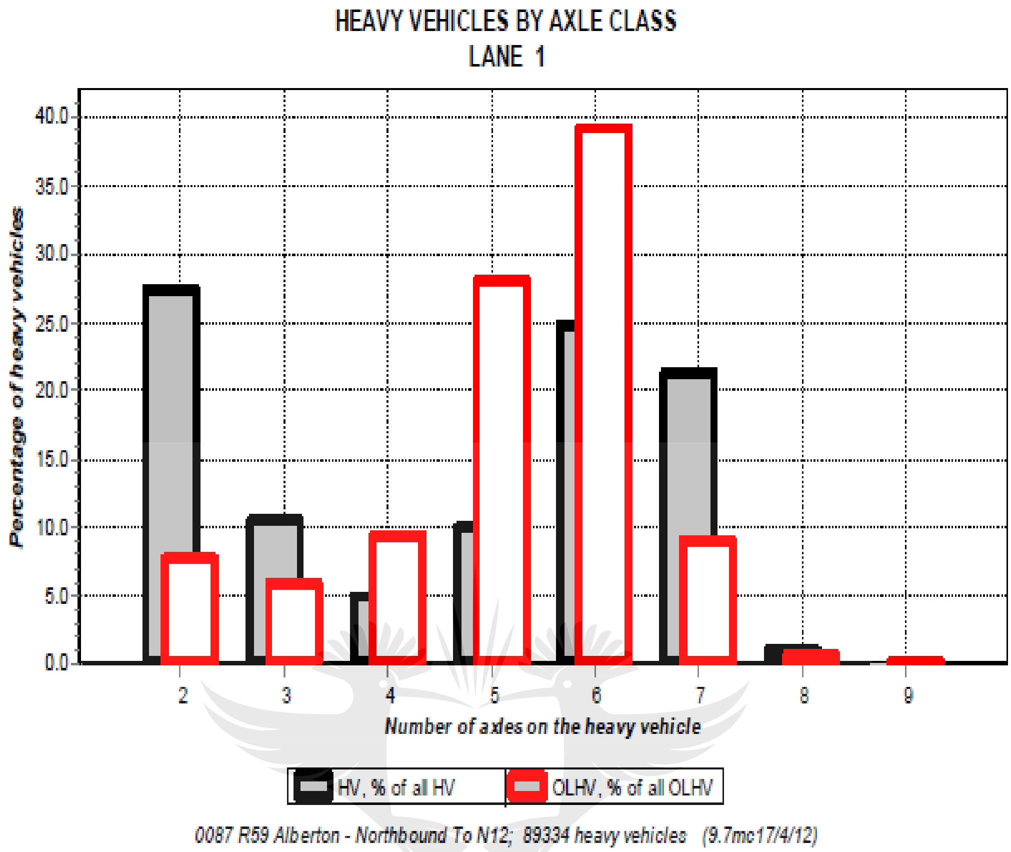


Figure A2.13: Northbound heavy vehicles on the R59, 2012

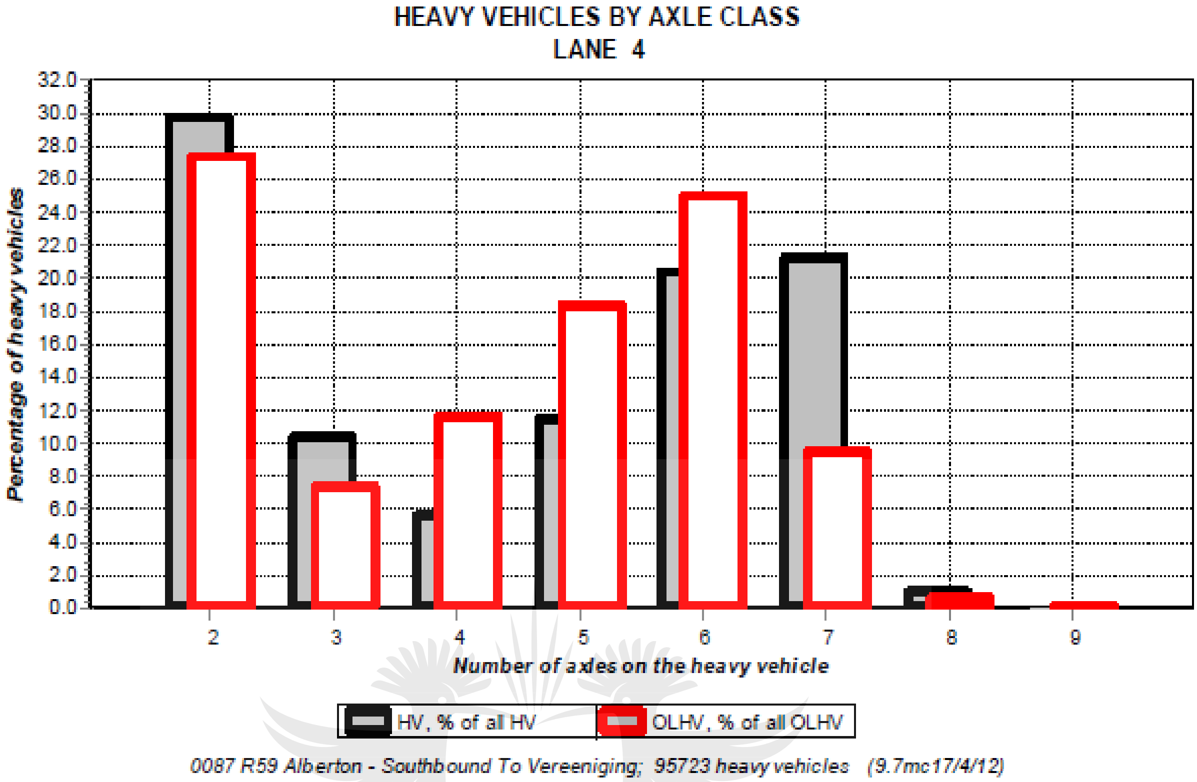


Figure A2.14: Southbound heavy vehicles on the R59, 2012

Appendix 3: Secondary Counting Station 0114 – South Crest

Table A3.1: Surveying of Station 0114

Year	Requested period	Number of hours	Actual period	Number of hours
2004	01/01 – 31/12	8784	11/03 – 22/03	261
2010	01/01 – 31/12	8760	11/11 – 29/11	427
2011	01/01 – 31/12	8760	01/01 – 31/12	6849
2012	01/01/ - 31/12	8760	01/01 – 31/03	2184
2013	01/01/ - 31/07	8760	30/06 – 31/12	716

Table A3.2: Traffic counts for counting Station 0114

Year	ADT	ADDT	AWDT	Truck split %Short %Medium %Long	E80/HV	No, Axles	Tonnes	Night traffic (AV)	Night traffic (HV)
2004	25199	1404 (5.6%)		51:26:23	2	5	24	2268 (9%)	–
2010	32161	4682 (14.6%)	36697	65:18:17	1.2	3.4	19.5	6850 (21.3%)	814 (17.4%)
2011	28586	2662 (9.3%)	32711	60:20:20	—	Not given	Not given	4774 (16.7%)	535 (20.1%)
2012	28469	2000 (7%)	32662	52:22:26	—	Not given		5722 (20.1%)	326 (18.1%)
2013	27760	1800 (6.5%)	—	50:24:26	1.4	4	23.2	2847 (9.9%)	_

Note: Data for the years 2002, 2003, 2005-2009 are missing. No % OLHV data was recorded at all.

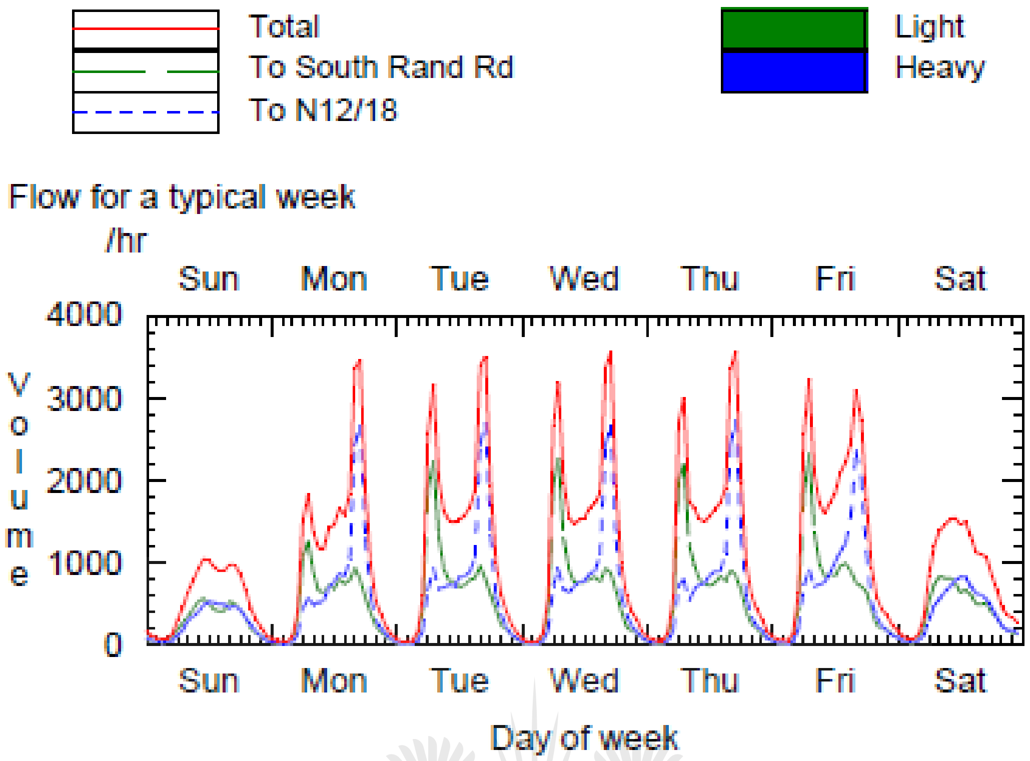


Figure A3.1: Traffic Volume for a typical week in 2004

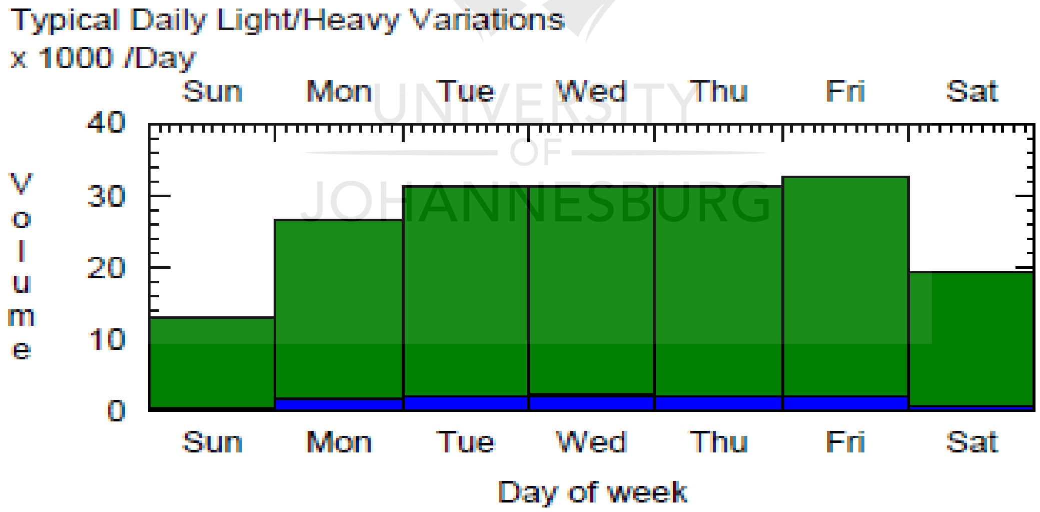
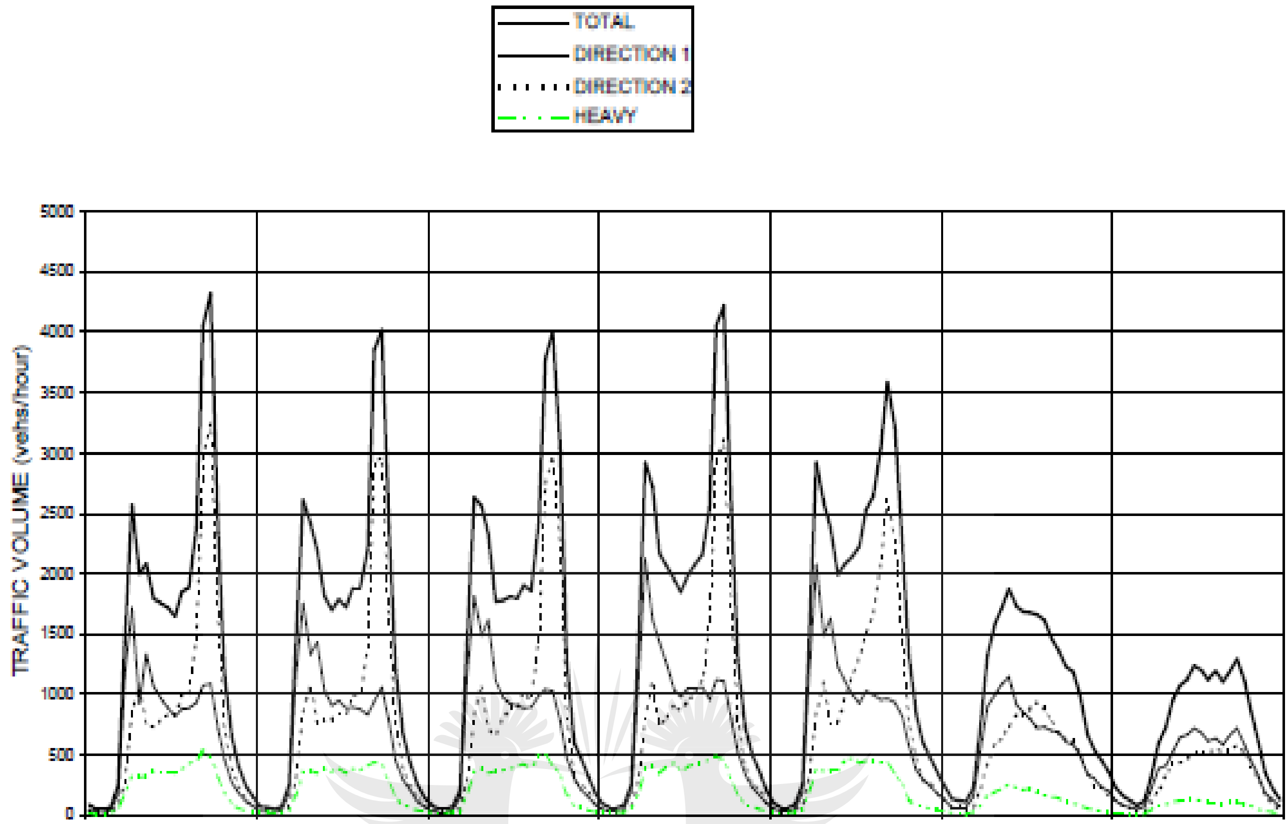
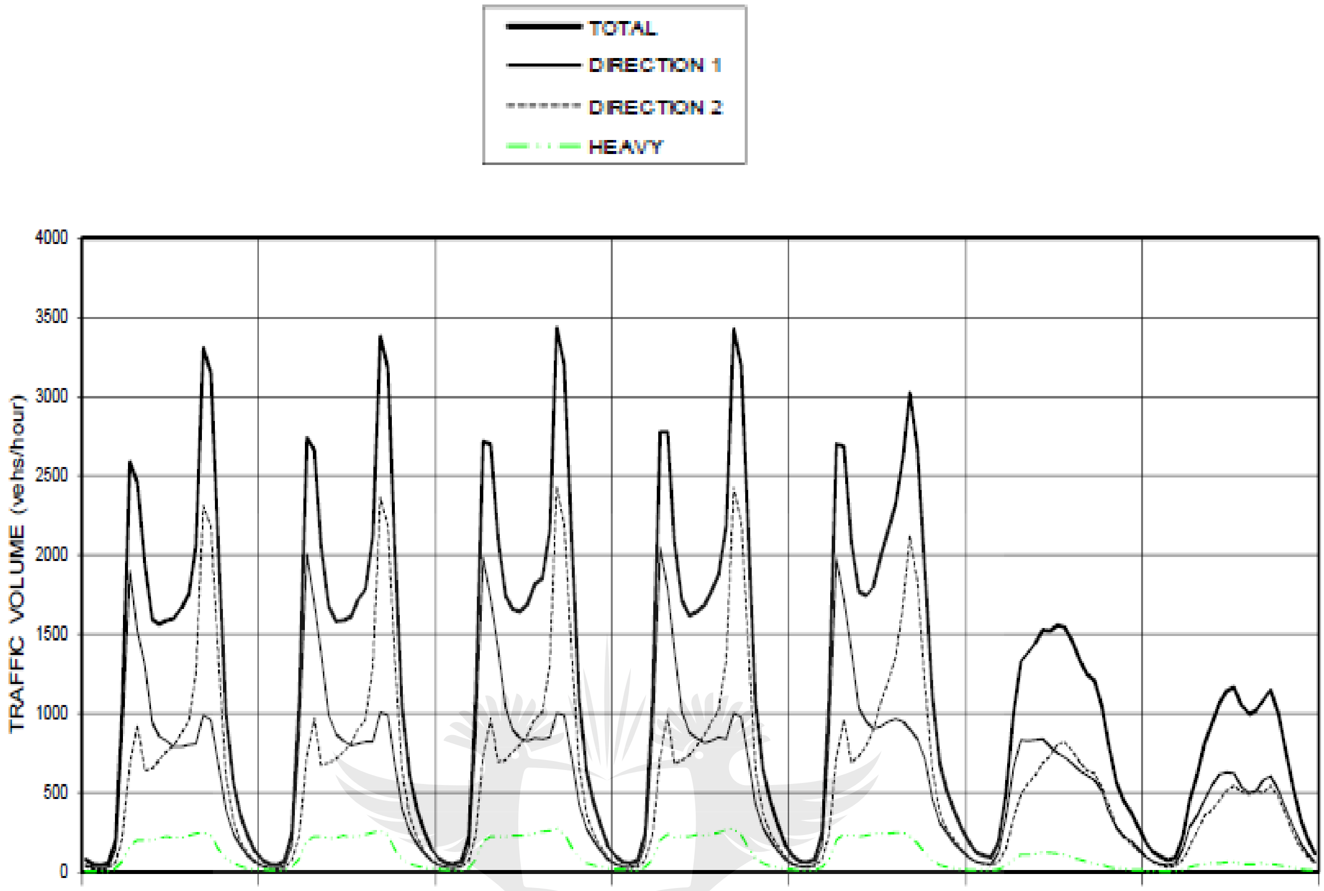


Figure A3.2: Typical daily light/heavy variations in 2004



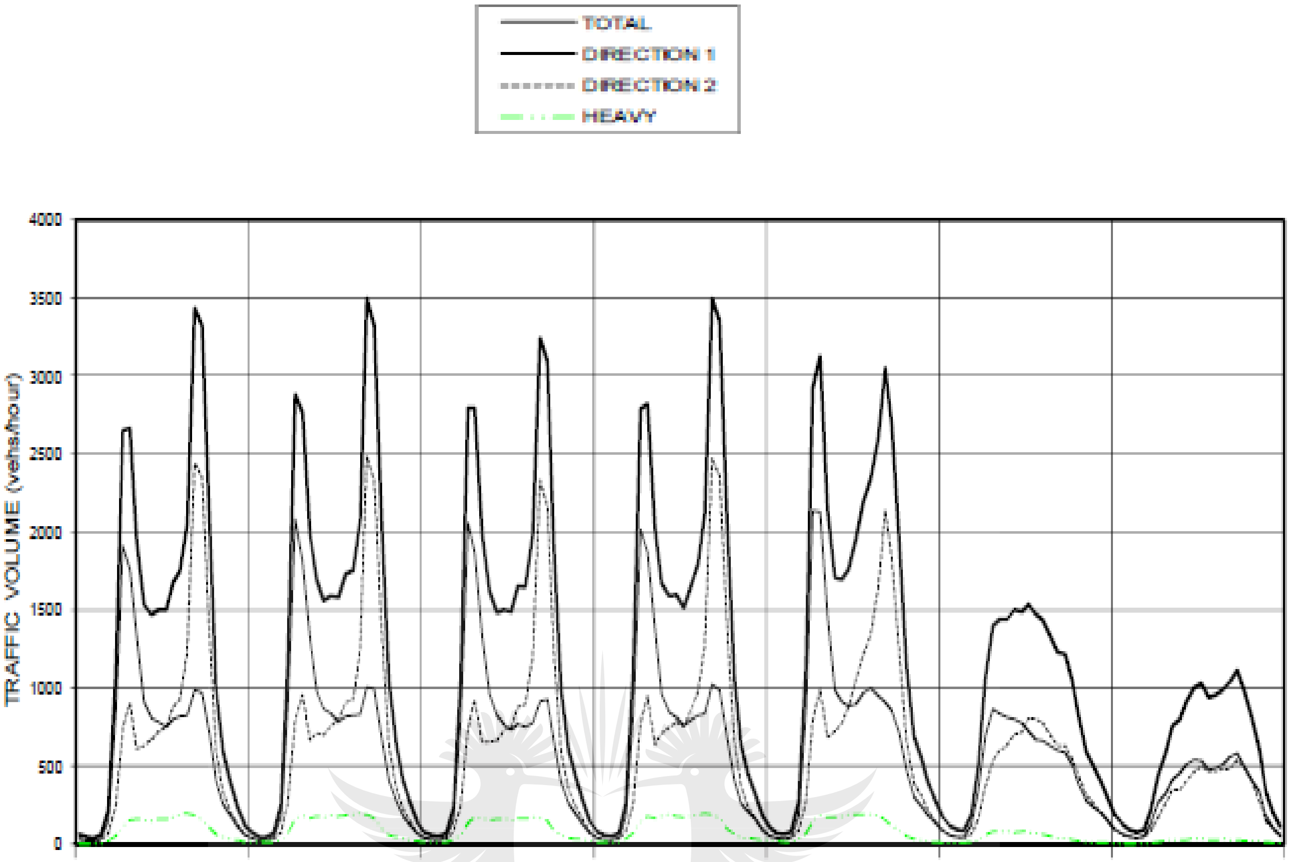
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	34887	36018	38346	38170	38086	24683	17083
Expansion Factor	1.084	1.088	1.130	1.187	1.215	0.784	0.631

Figure A3.3: Traffic Volume for a typical week in 2010



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	31125	32178	33045	33126	34082	21285	15263
Expansion Factor	1.089	1.126	1.156	1.159	1.192	0.745	0.534

Figure A3.4: Traffic Volume for a typical week in 2011



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	31488	32726	31244	32839	35015	21474	14495
Expansion Factor	1.106	1.150	1.097	1.154	1.230	0.754	0.509

Figure A3.5: Traffic Volume for a typical week in 2012

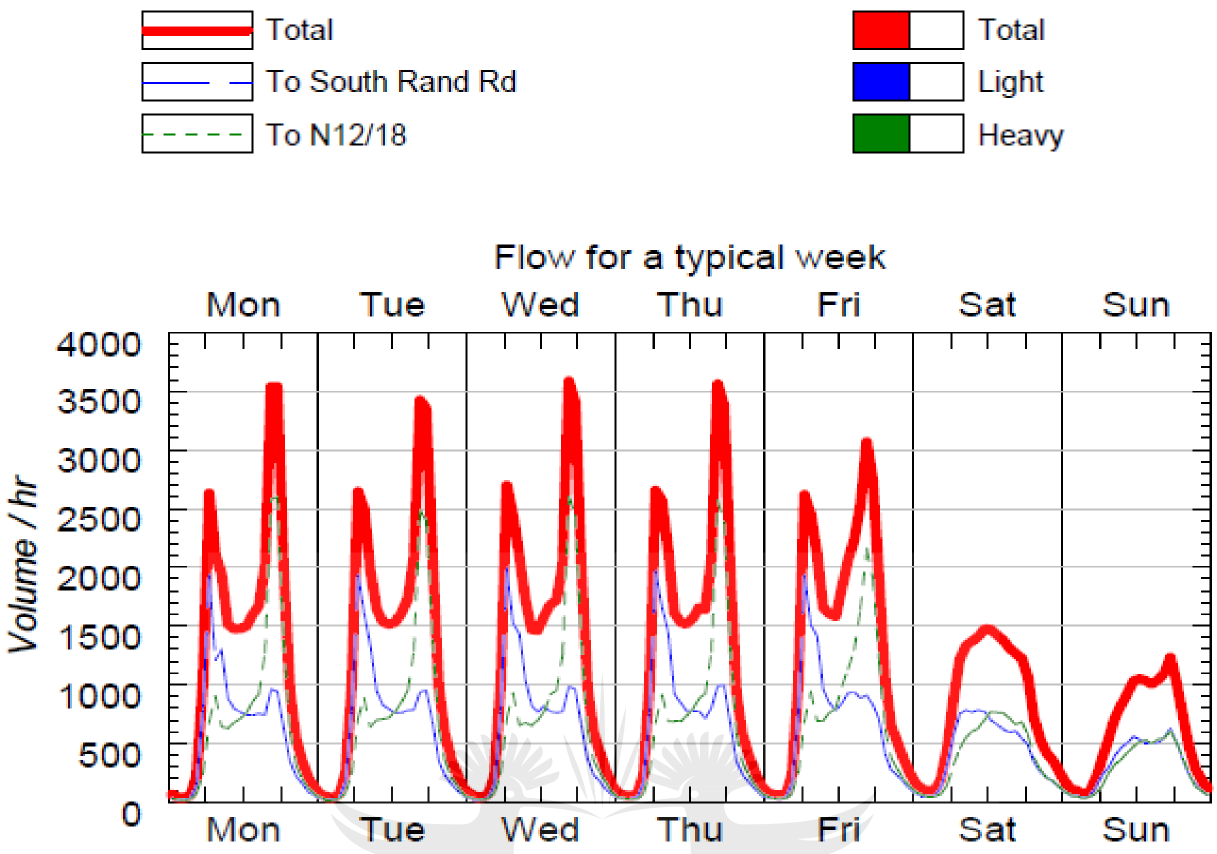


Figure A3.6: Traffic Volume for a typical week in 2013

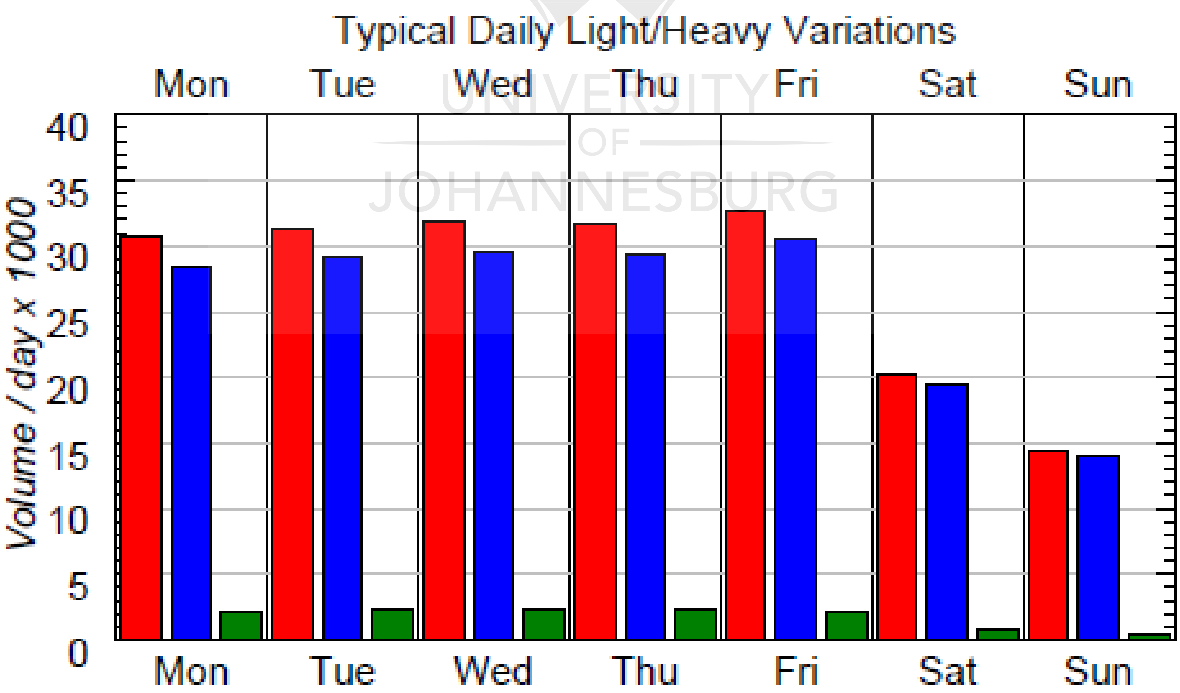


Figure A3.7: Typical daily light/heavy variations in 2013

Appendix 4: Secondary Counting Station 0118 – R59 Vaal River

Table A4.1: Surveying of Station 0118

Year	Requested period	Number of hours	Actual period	Number of hours
2004	01/01 – 31/12	8784	03/09 – 09/09	168
2007	01/01 – 31/12	8784	26/09 - 08/10	287
2010	01/01 – 31/12	8784	28/09 – 07/10	215
2011	01/01 – 31/12	8784	01/01 – 31/12	6849

Table A4.2: Traffic counts for counting Station 0118

Year	ADT	ADDT	AWDT	Truck split %Short %Medium %Long	E80/HV	No, Axles	Tonnes	Night traffic (AV)	Night traffic (HV)
2004	15316	3028 (19.8%)		25:34:41	2	5	25	1807 (11.8%)	
2007	16224	2964 (18.3%)		23:24:53	1.8	5.4	31.1	1996 (12.3%)	
2010	17489	2822 (16.1%)	19369	30:13:57	1.7	5.2	30.1	3533 (20.2%)	861 (30.5%)
2011	18848	3755 (19.9%)	21135	36:15:49	not given	not given	not given	4033 (21.4%)	1070 (28.5%)

Note: No data was recorded for the years 2005, 2006, 2008, 2009, 2012 and 2013. No % OLHV data was recorded at all.

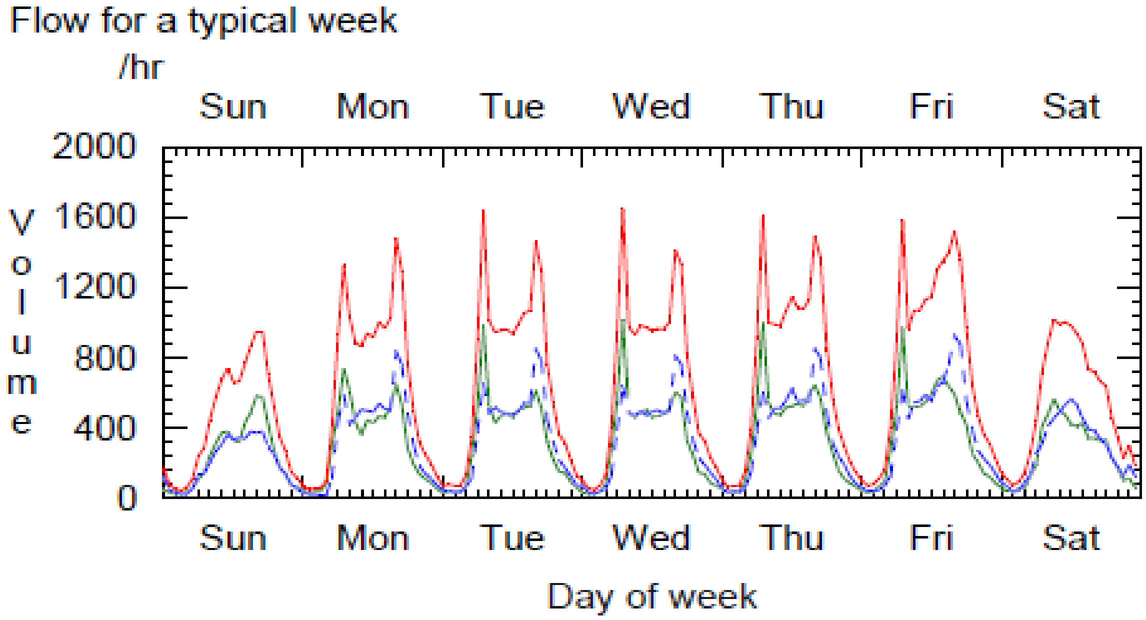


Figure A4.1: Traffic Volume for a typical week in 2004

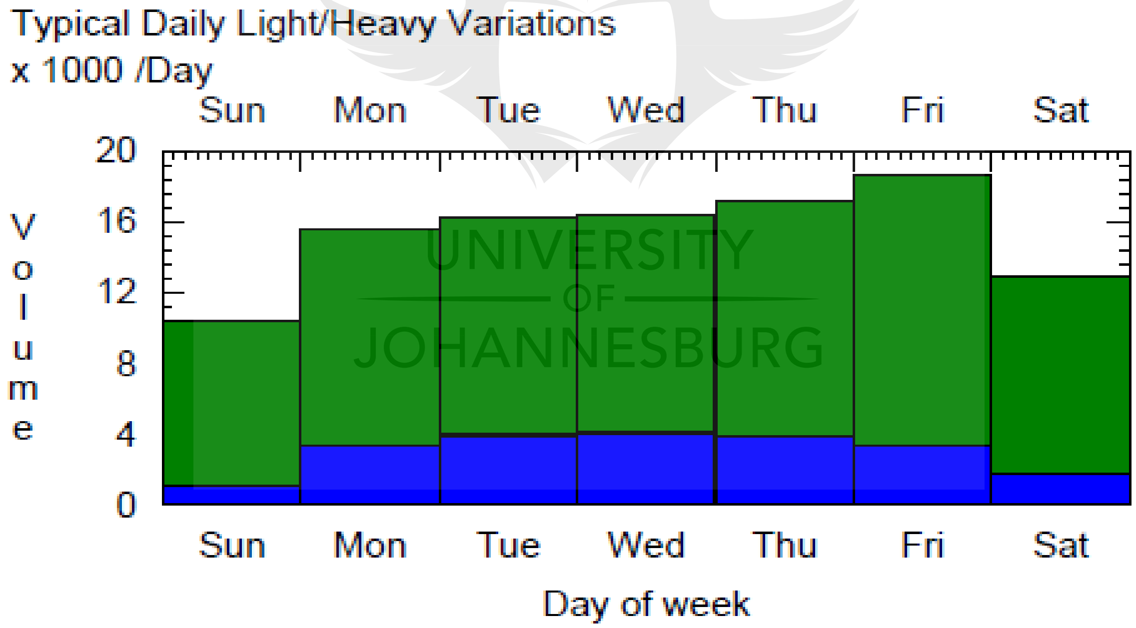


Figure A4.2: Typical daily light/heavy variations in 2004

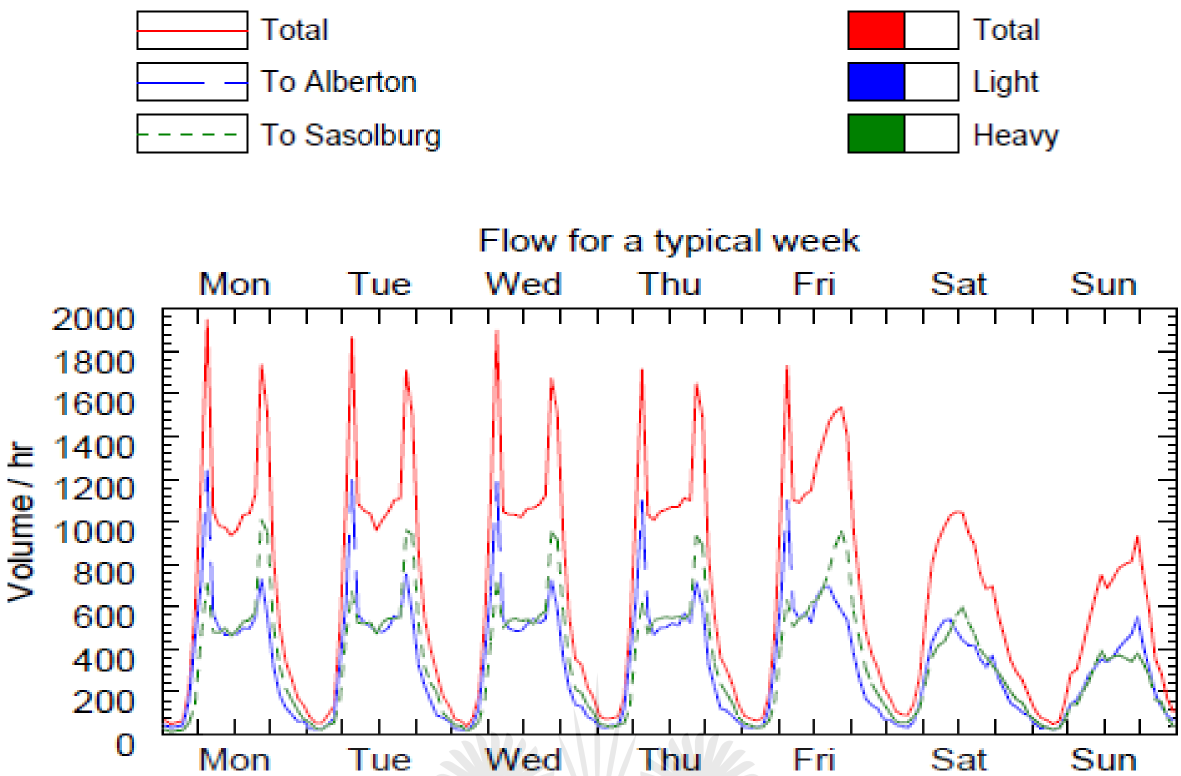


Figure A4.3: Traffic Volume for a typical week in 2007

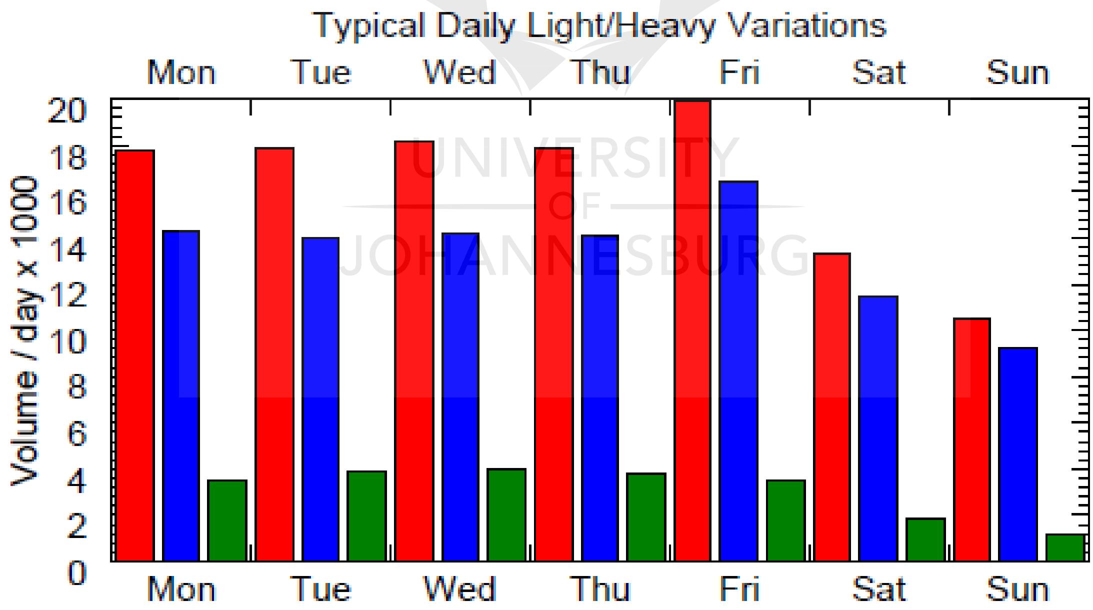
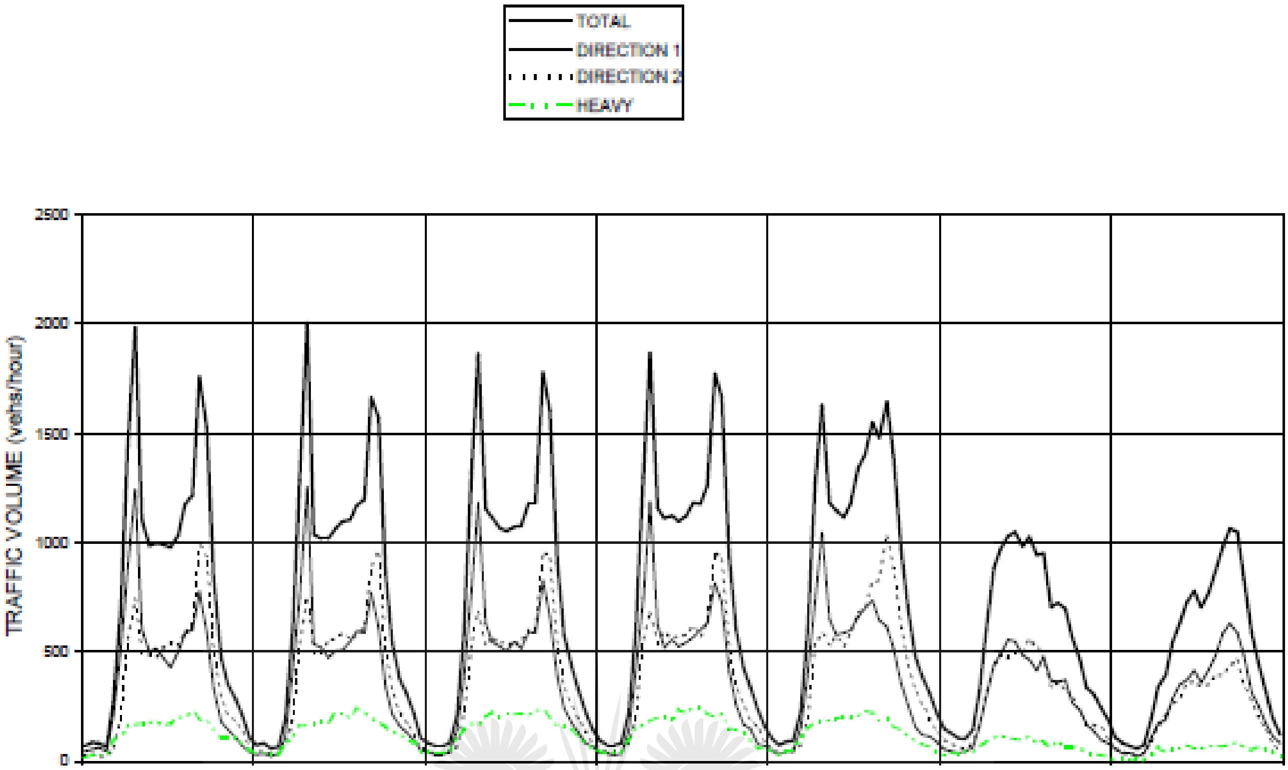
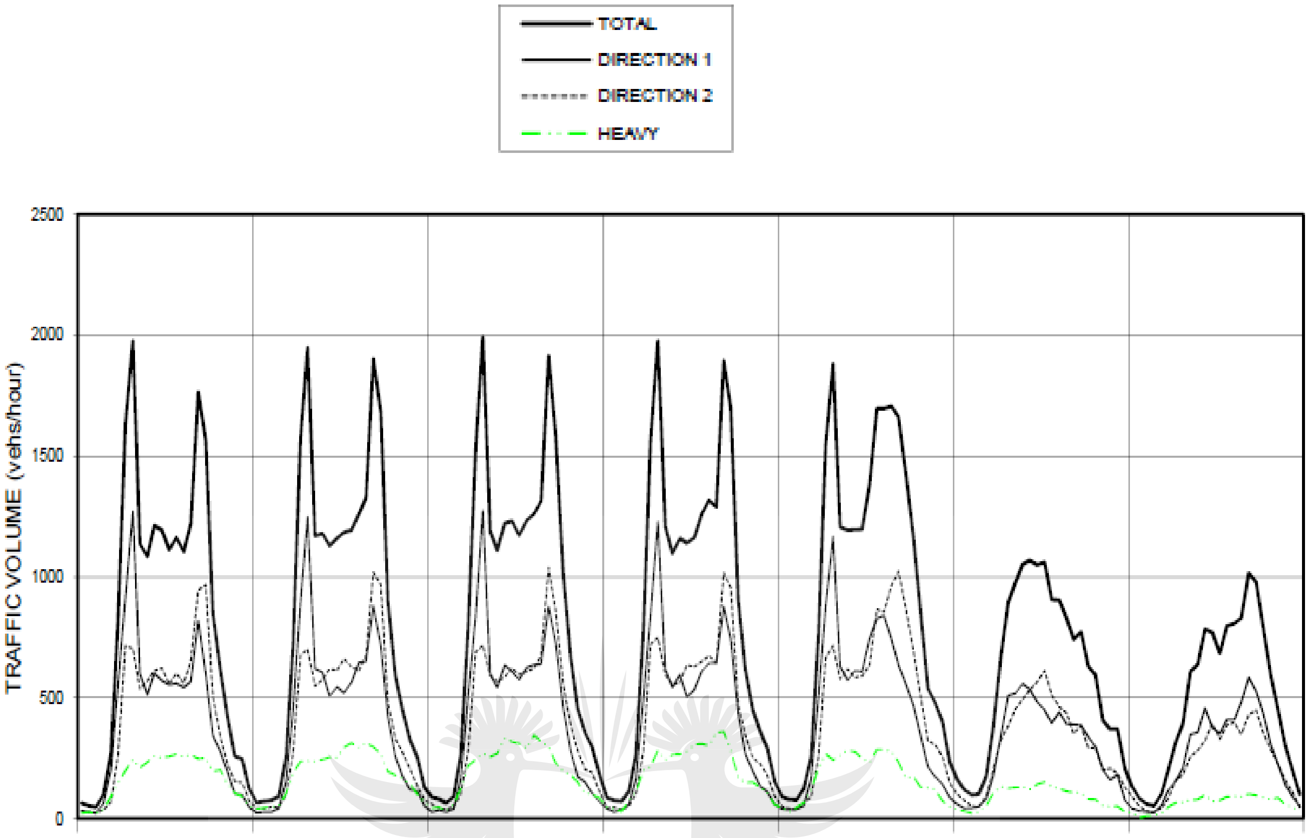


Figure A4.4: Typical daily light/heavy variations in 2007



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	18740	18898	19152	19681	20577	13810	11865
Expansion Factor	1.072	1.069	1.096	1.126	1.177	0.778	0.684

Figure A4.5: Traffic Volume for a typical week in 2010



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	20053	20658	21141	20959	22866	14549	11710
Expansion Factor	1.064	1.096	1.122	1.112	1.213	0.772	0.621

Figure A4.6: Traffic Volume for a typical week in 2011

Appendix 5: Secondary Counting Station 0119 – Meyerdustria

Table A5.1: Surveying of station 0119

Years	Requested period	Number of hours	Actual period	Hours
2007	01/01 – 31/12	8760	25/10 -02/11	188
2009	01/01 – 31/12	8760	30/10 -09/11	239
2011	01/01 – 31/12	8760	06/10 -14/10	191
2013	01/01 – 31/12	8760	23/08 -30/08	168

Table A5.2: Traffic counts for counting Station 0119

Year	ADT	ADDT	AWDT	Truck split %Short %Medium %Long	E80/HV	No, Axles	Tonnes	Night traffic (AV)	Nigh traff (HV
2004	30509	5004 (16.4%)		27:34:39	2	5	24	3112 (10.2%)	
2007	34467	6286 18.2%)		28:32:40	1.8	4.9	29	4033 (11.7%)	
2009	34408	5176 (15%)	38554	31:13:56	1.7	5.2	29.8	7054 (20.5%)	106 (27.3
2011	36457	6656 (18.3%)	40620	38:09:53	Not given	Not given	Not given	7036 (19.3%)	140 (24.9
2013	36015	5663 (15.7%)		28:24:48	1.8	5.1	29.8	3746 (10.4%)	

Note: Data was not recorded for the years 2002, 2003, 2005, 2006, 2008, 2010 and 2012. No % OLHV data was recorded at all.

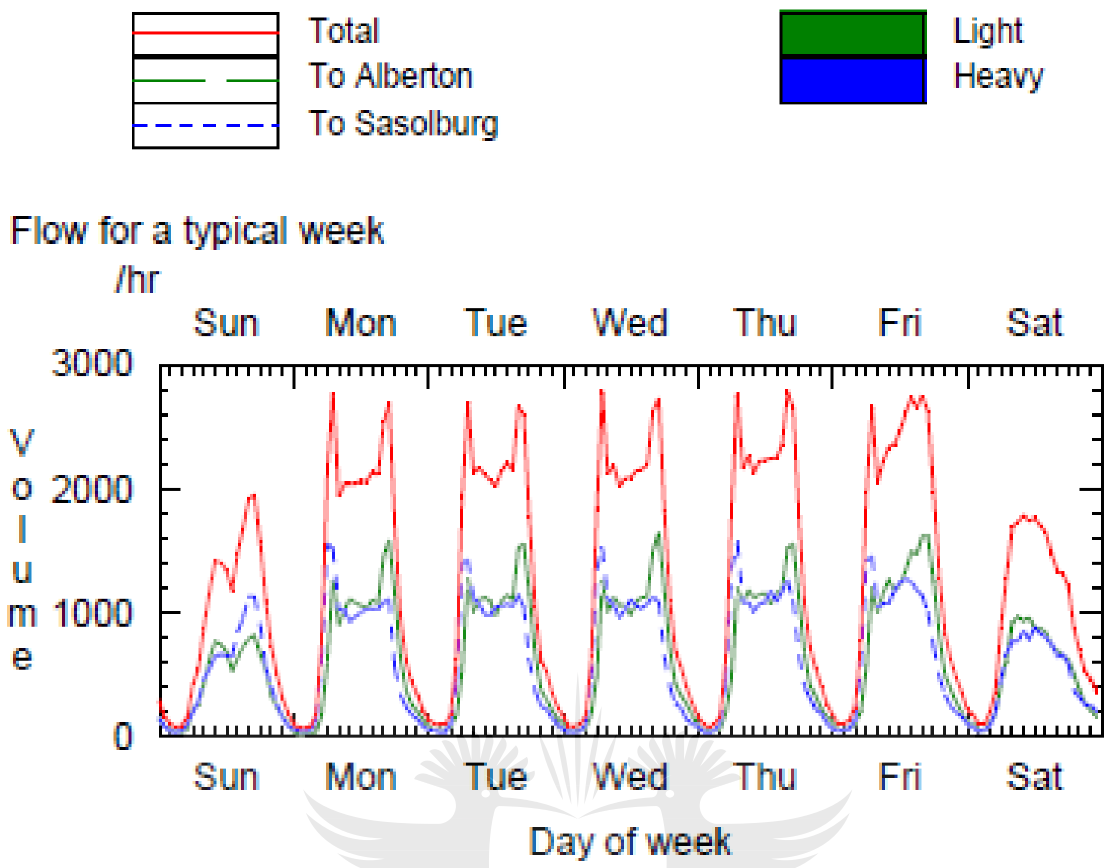


Figure A5.1: Traffic Volume for a typical week in 2004

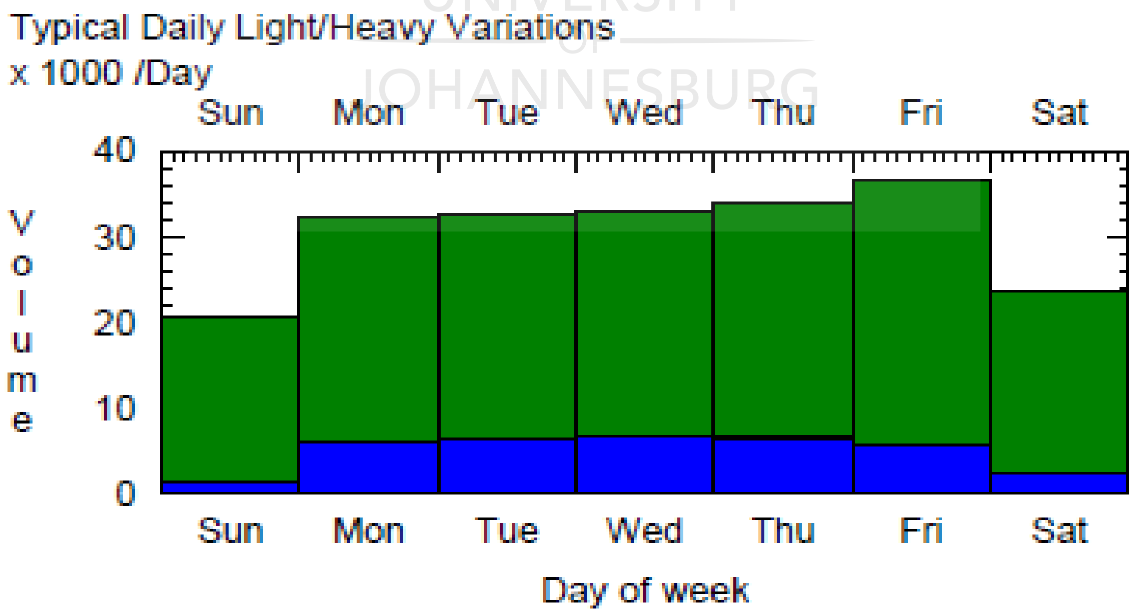


Figure A5.3: Typical daily light/heavy variations in 2004

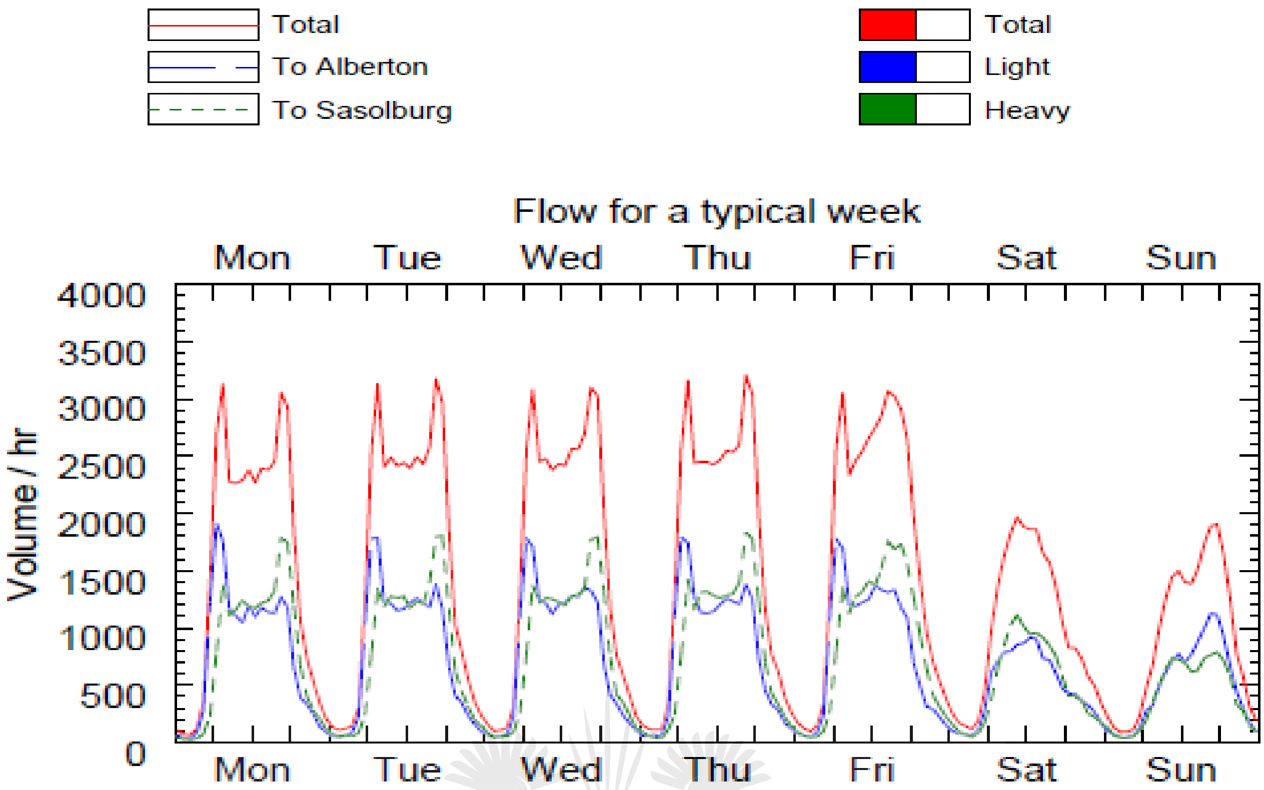


Figure A5.4: Traffic Volume for a typical week in 2007

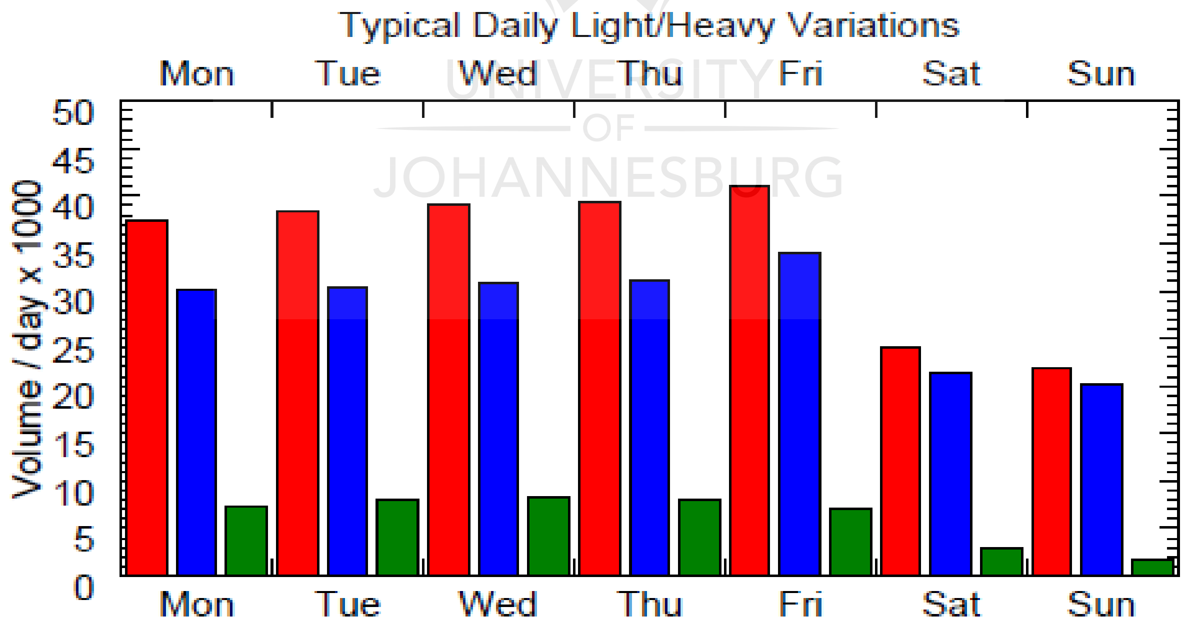
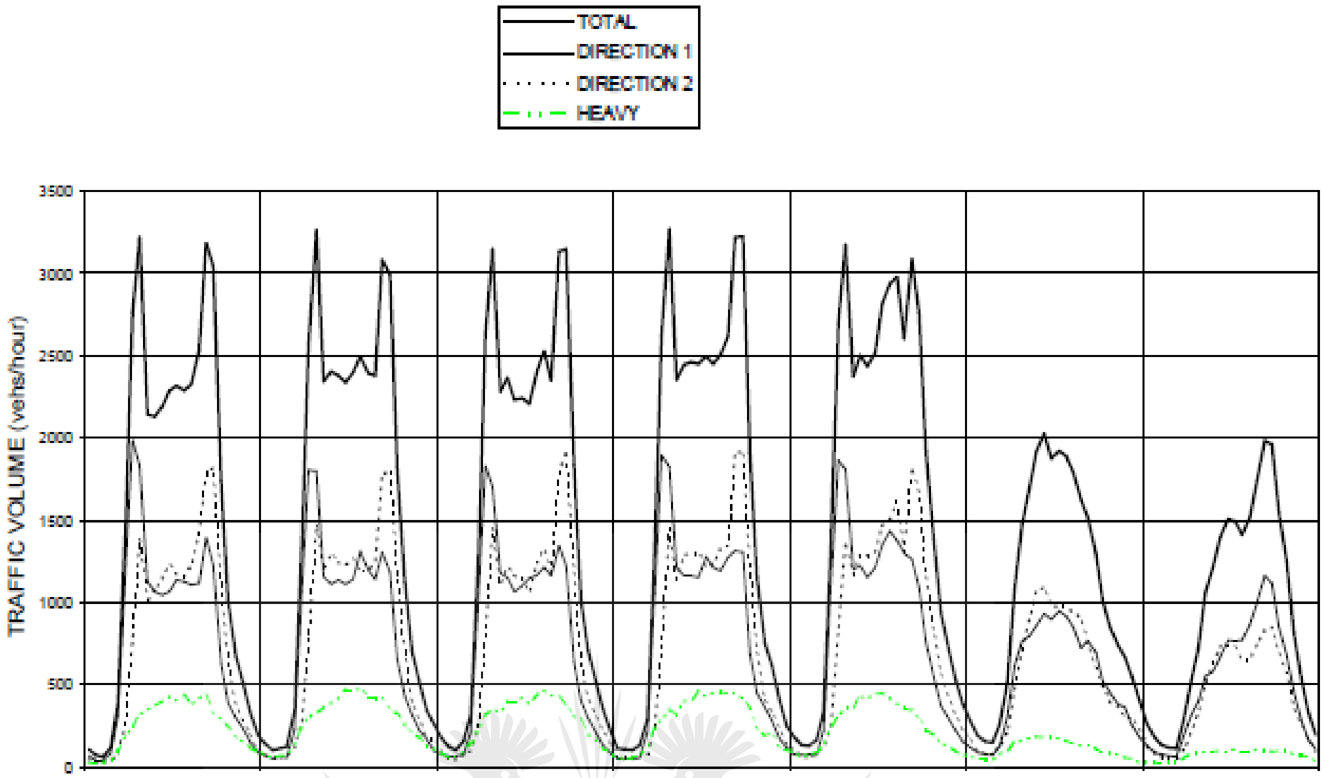
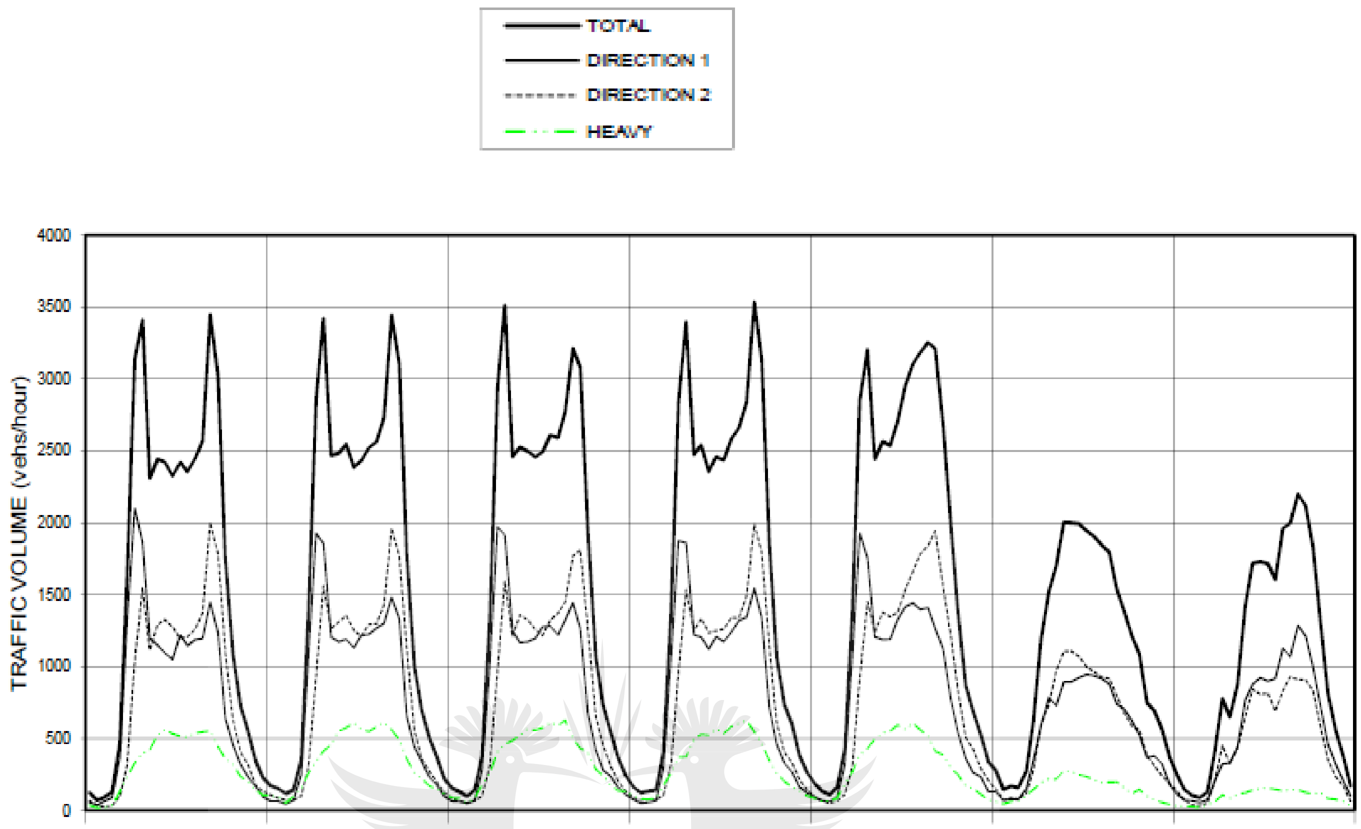


Figure A5.5: Typical daily light/heavy variations in 2007



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	37101	37959	37451	39221	40988	25861	22276
Expansion Factor	1.078	1.103	1.088	1.140	1.191	0.752	0.647

Figure A.5.6: Traffic Volume for a typical week in 2009



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	39505	39860	40299	40529	42908	27164	24937
Expansion Factor	1.084	1.093	1.105	1.112	1.177	0.745	0.684

Figure A5.7: Traffic Volume for a typical week in 2011

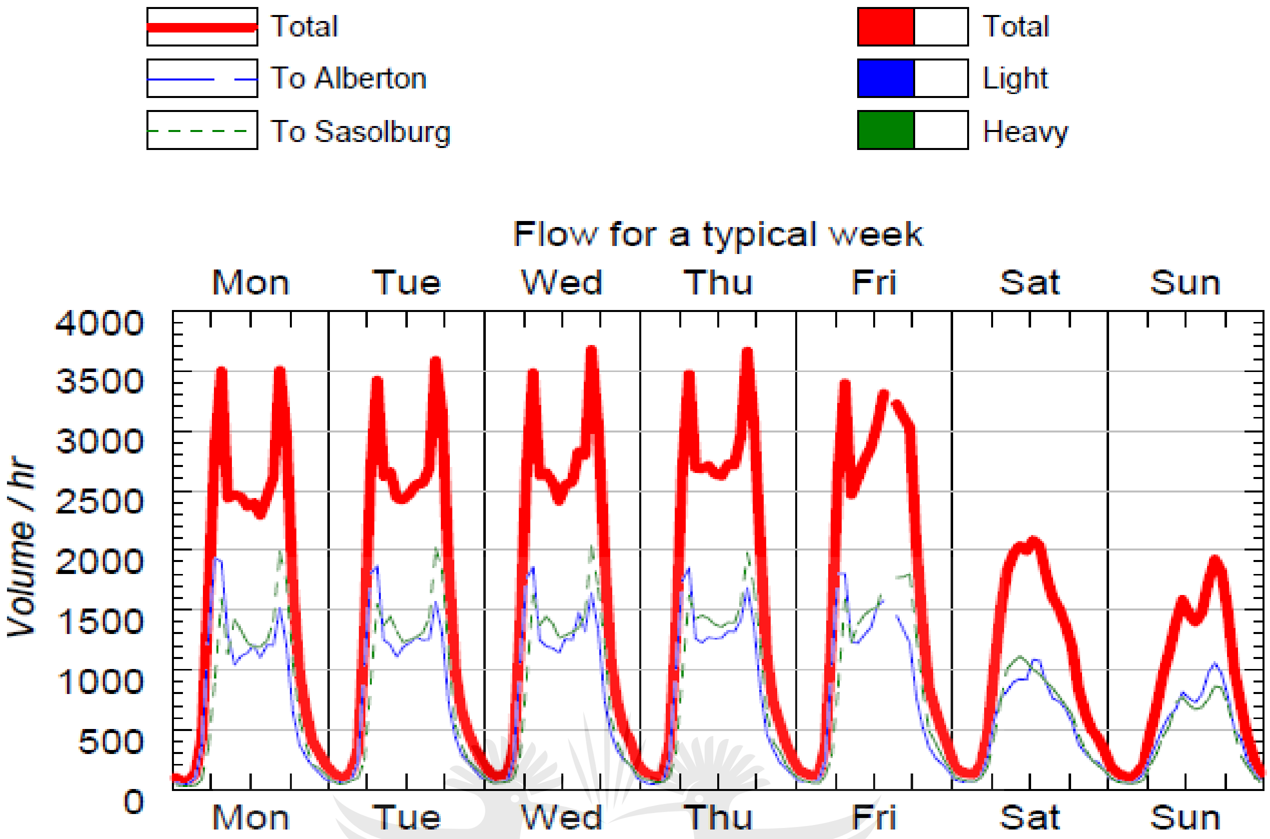


Figure A5.8: Traffic Volume for a typical week in 2013

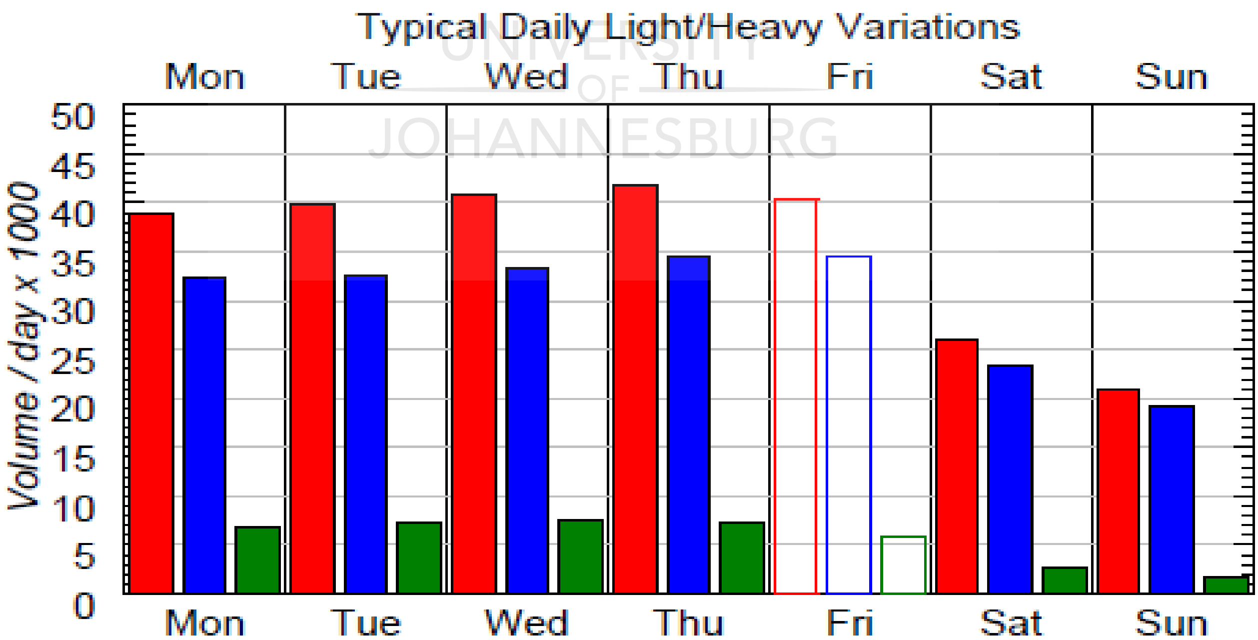


Figure A5.9: Typical daily light/heavy variations in 2013

Appendix A6: Secondary Counting Station 0148 – Klipview

Table A6.1: Surveying of station 0148

Years	Requested period	Hours	Actual period	Hours
2004	01/01 – 31/12	8784	25/10 – 02/11	188
2007	01/01 – 31/12	8760	16/06 – 26/06	237
2009	01/01 – 31/12	8760	30/10 -09/11	239
2010	01/01 – 31/12	8760	28/09 – 07/10	215
2011	01/01 – 31/12	8760	04/10 -13/10	216
2013	01/01 – 31/12	8760	23/08 -30/08	168

Table A6.2: Traffic counts for counting Station 0148

Year	ADT	ADDT	AWDT	%Truck split Short:Medium:Long	E80/HV	No, Axles	Mass (Tonnes)	Night traffic (AV)	Night traffic (HV)
2004	31657	4092 (12.9%)		26:40:34	2	4	24	2912 (9.2%)	
2007	39019	6618 (17%)		28:31:41	1.8	5	29.2	4331 (11.1%)	
2009	38325	4979 (13%)	42749	31:14:55	1.7	5	29.7	7358 (19.2%)	1324 (26.6%)
2010	38936	5352 (13.7%)	43678	32:13:56	1.7	5.2	29.6	7748 (19.9%)	1552 (29%)
2011	41363	6826 (16.5%)	45546	39:9:52		Not given	Not given	8190 (19.8%)	1702 (25.2%)
2013	40648	5666 (13.9%)		31:25:44	1.7	5	28.9	4308 (10.6%)	

Note: No data was recorded for the years 2002, 2003, 2005, 2006, 2008 and 2012. No overloading data was recorded.

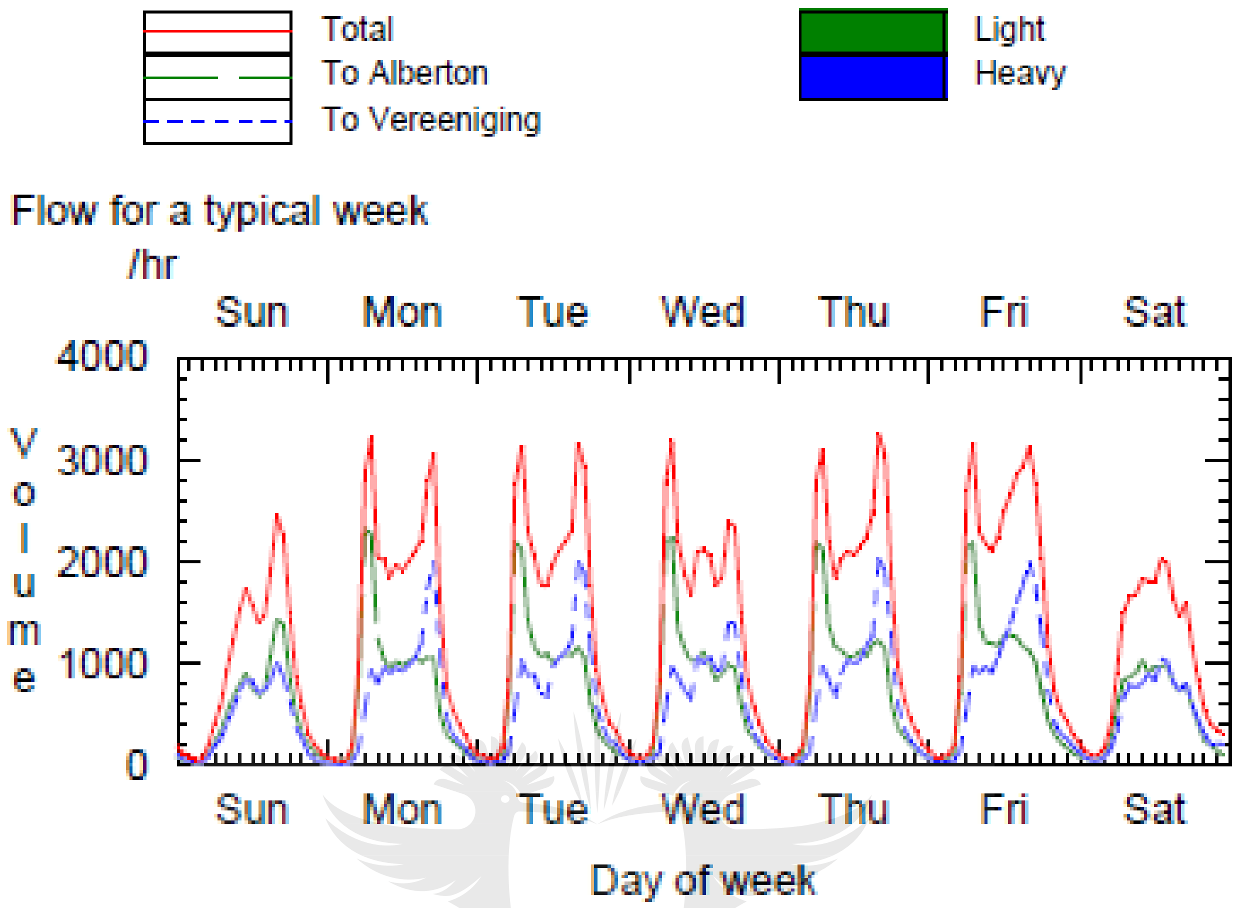


Figure A6.1: Traffic Volume for a typical week in 2004

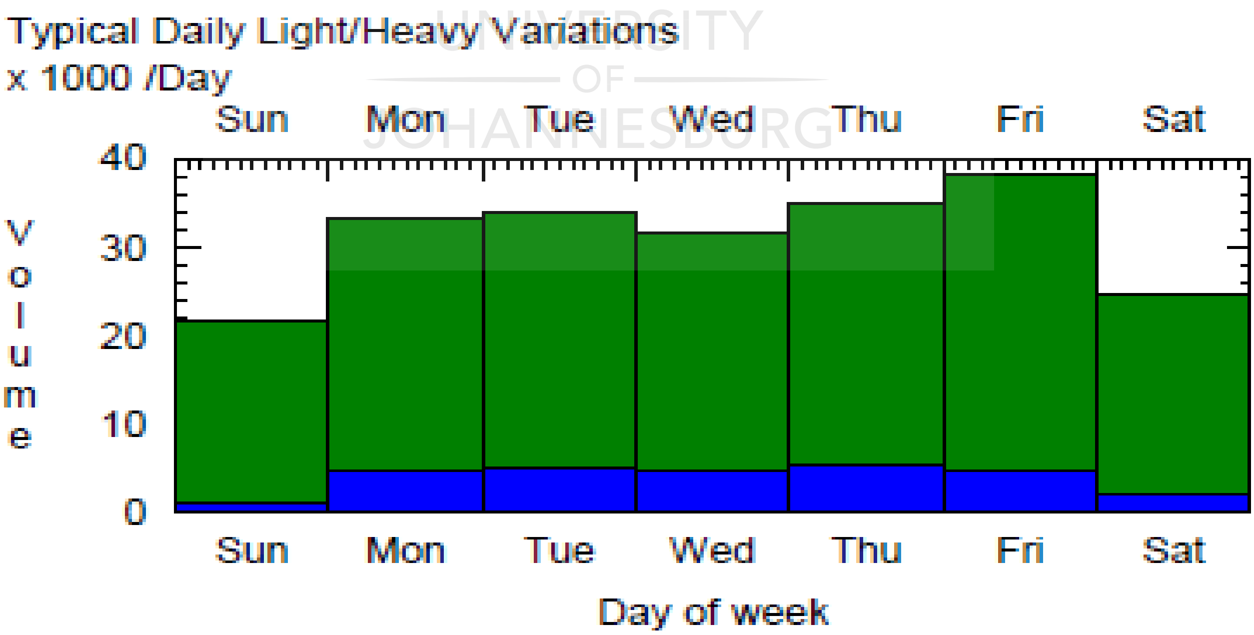


Figure A6.2: Typical daily light/heavy variations in 2004

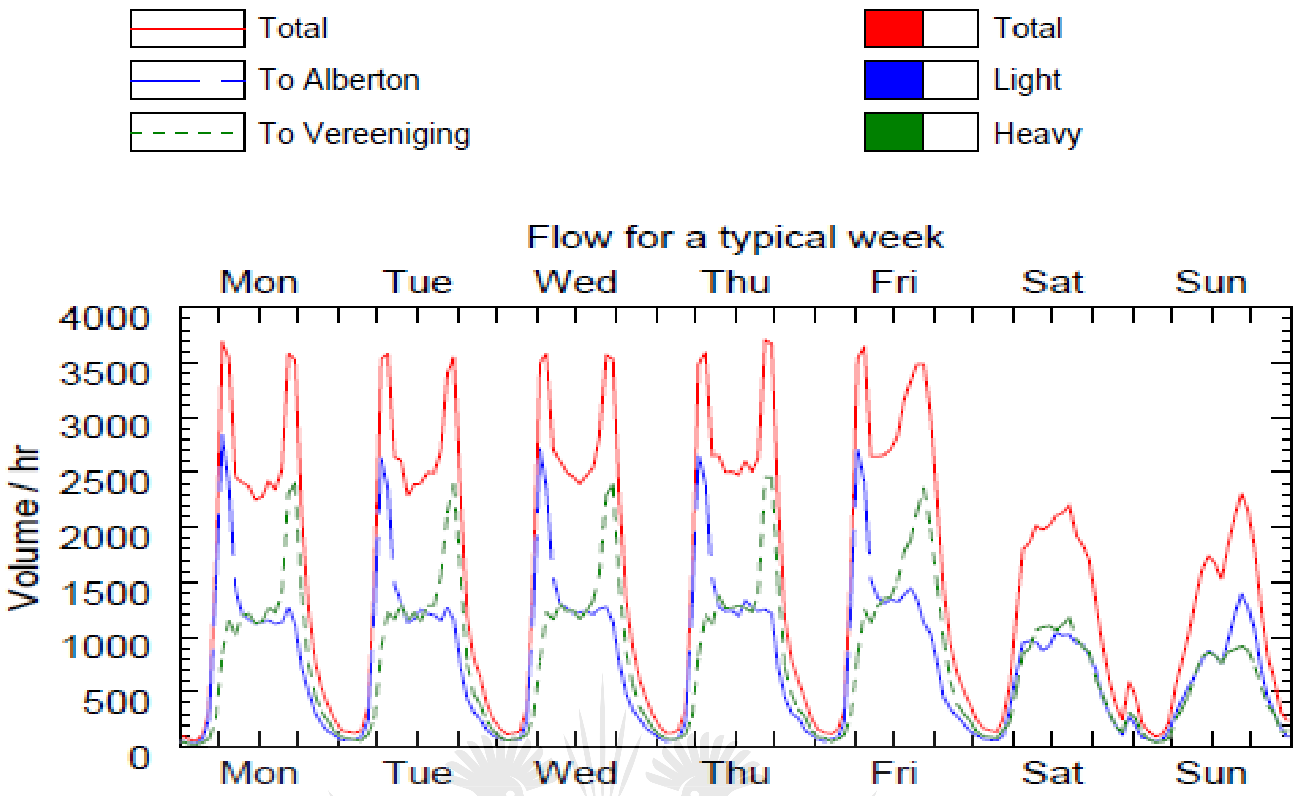


Figure A6.3: Traffic Volume for a typical week in 2007

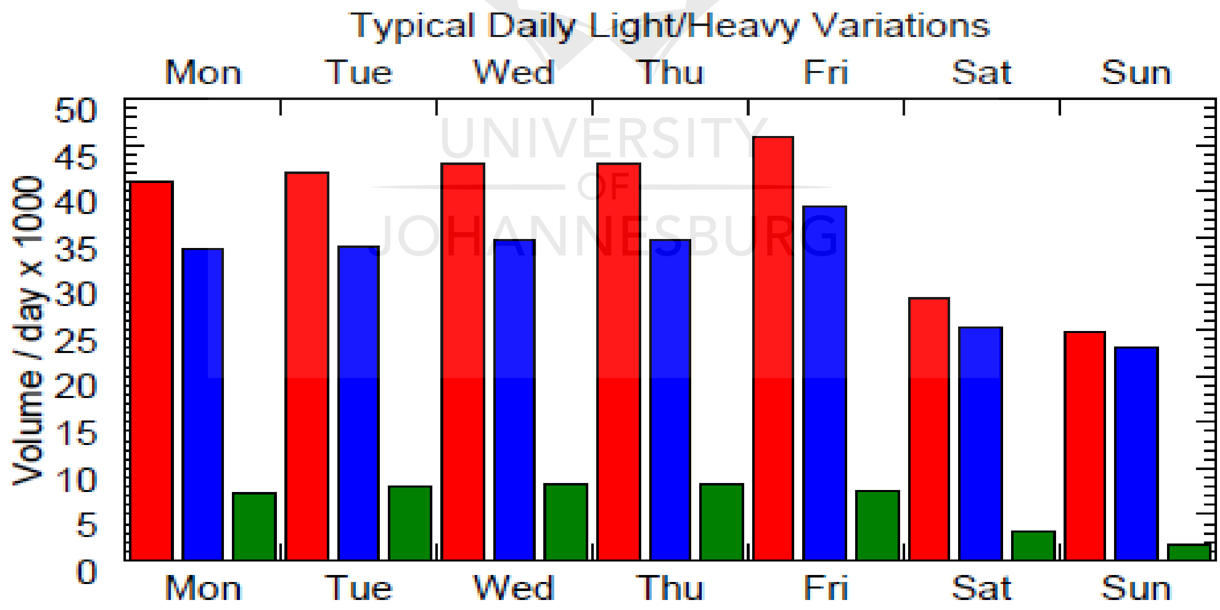
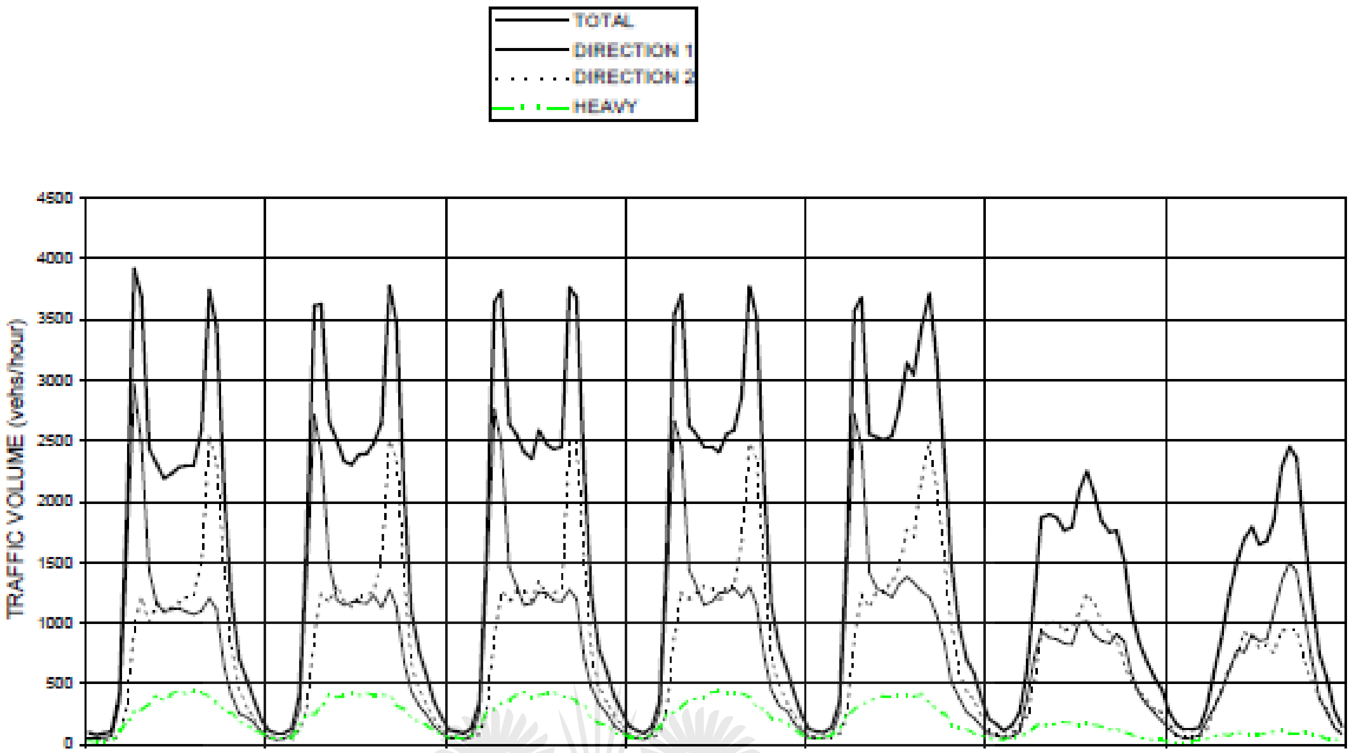
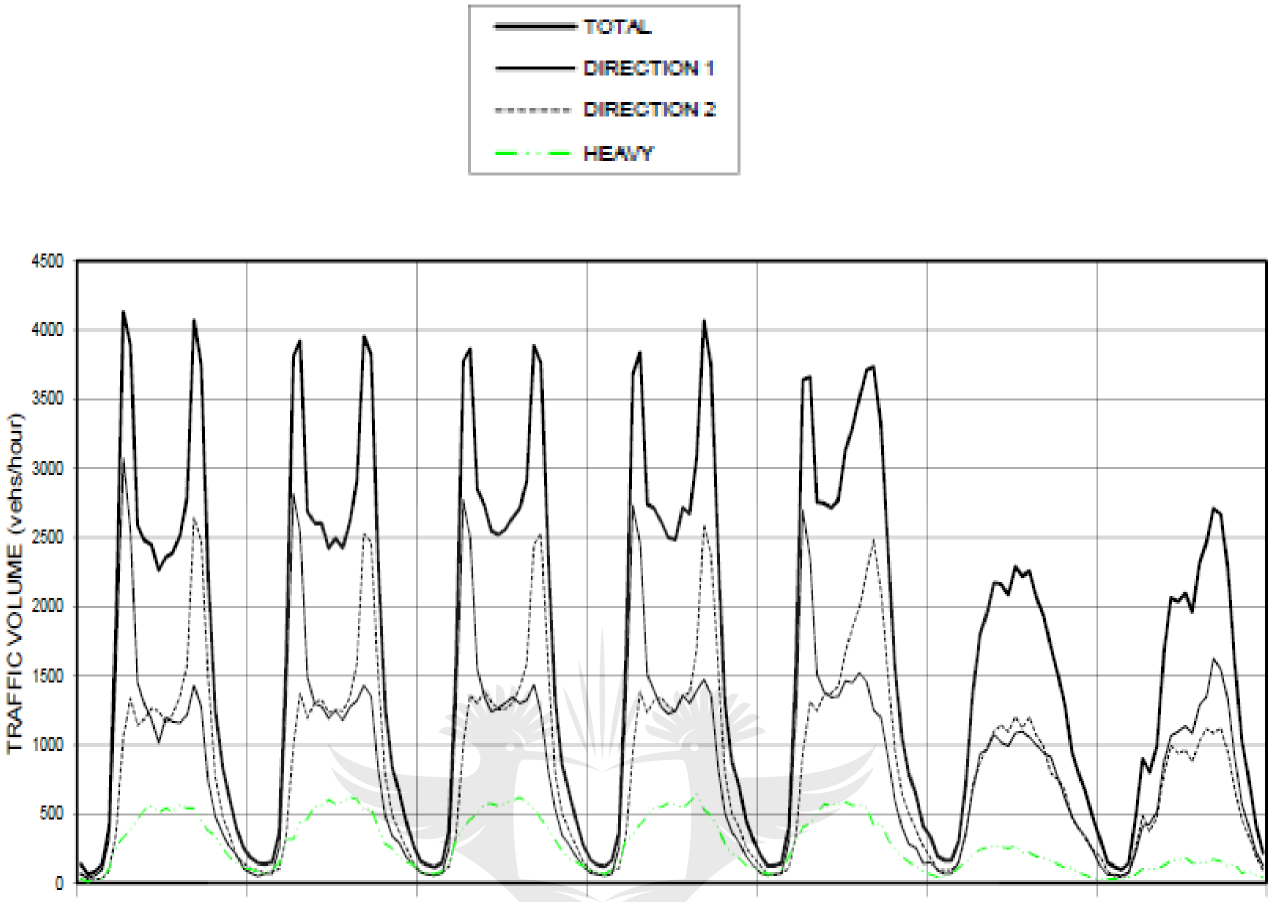


Figure A6.4: Typical daily light/heavy variations in 2007



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	41120	41701	42606	42786	46635	28782	26768
Expansion Factor	1.073	1.088	1.112	1.118	1.188	0.760	0.872

Figure A6.5: Traffic Volume for a typical week in 2009



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	44012	44614	45213	45473	48417	31529	30286
Expansion Factor	1.064	1.079	1.093	1.099	1.171	0.762	0.732

Figure A6.6: Traffic Volume for a typical week in 2011

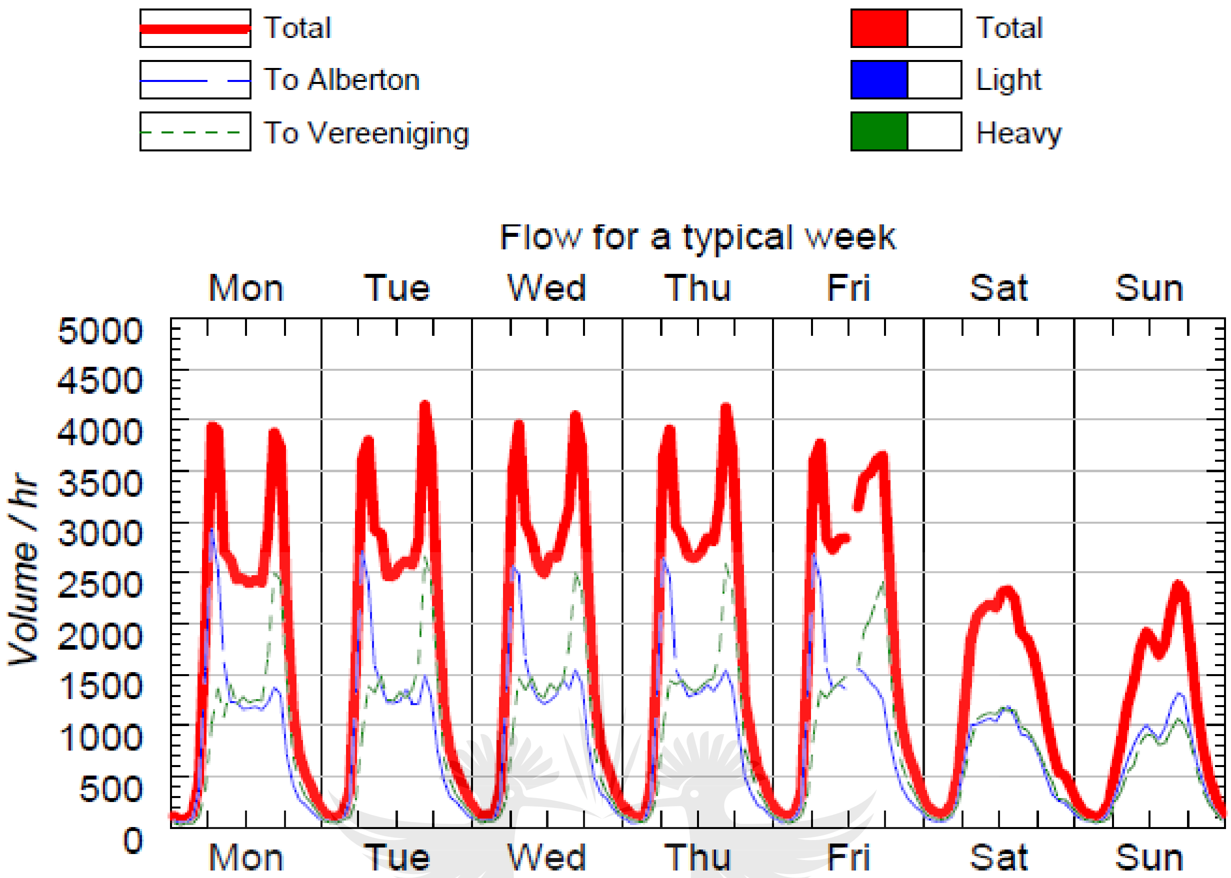


Figure A6.7: Traffic Volume for a typical week in 2013

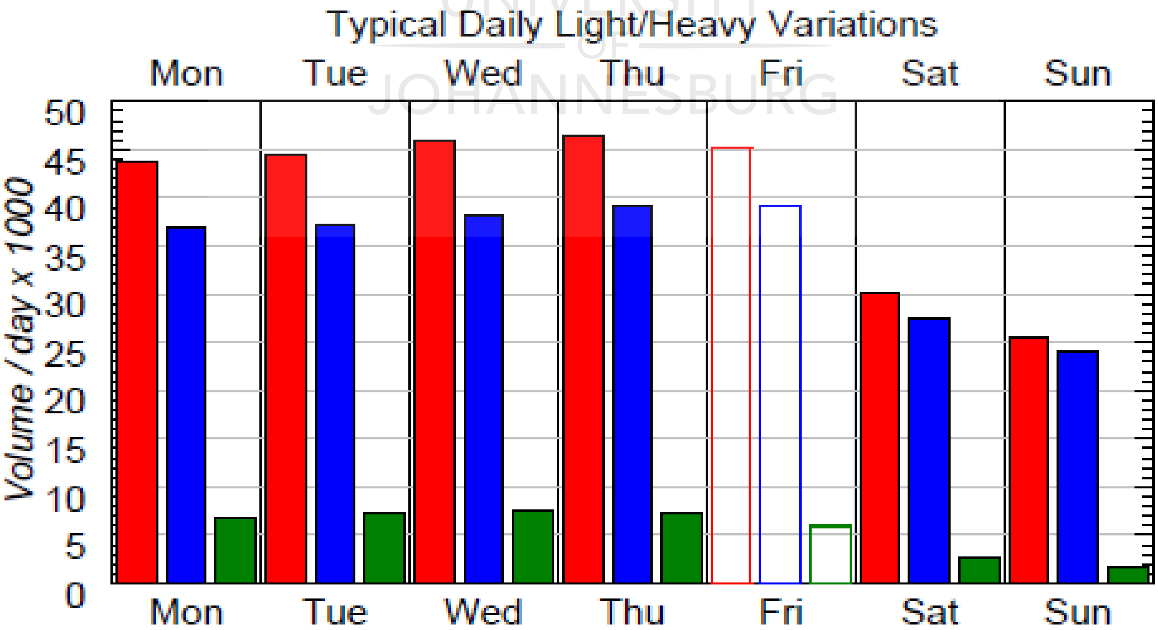


Figure 6.8: Typical daily light/heavy variations in 2013

Appendix 7 Secondary Counting Station 0232 – R59 Meyerton

Table A7.1: Surveying of station 0232

Years	Requested period	Hours	Actual period	Hours
2007	01/01 – 31/12	8760	12/10 – 02/11	188
2009	01/01 – 31/12	8760	08/09 -16/09	192
2010	01/01 – 31/12	8760	20/10 – 20/10	188
2011	01/01 – 31/12	8760	06/10 -14/10	192

Table A7.2: Traffic counts for counting Station 0232

Year	ADT	ADDT	AWDT	Truck split %Short %Medium %Long	E80/HV	No, Axles	Tonnes	Night traffic (AV)	Night traffic (HV)
2007	33240	6419 (19.3%)		26:33:41	1.8	5	29.4	4222 (12.7%)	
2009	32532	5030 (15.5%)	36401	33:15:52	1.7	5	28.9	6376 (19.6%)	1298 (25.8%)
2010	34775	5323 (15.3%)	38798	35:13:52	1.6	5	28.5	7268 (29.9%)	1528 (28.7%)
2011	35203	6747 (19.2%)	38764	39:13:48		Not given	Not given	7146 (20.3%)	1700 (25.2%)

Note: No data was recorded for the years 2002, 2003, 2004, 2005, 2006, 2008, 2012 and 2012

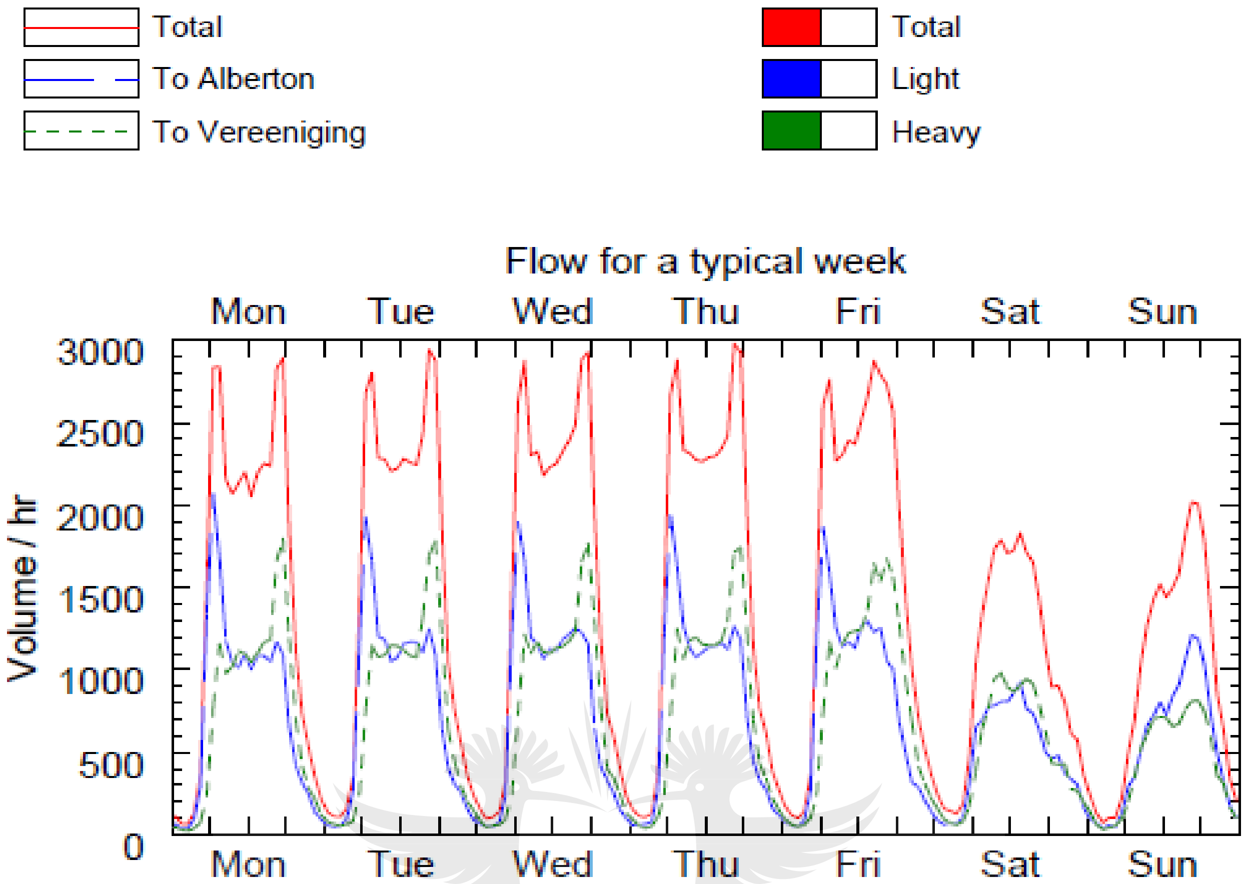


Figure A7.1: Traffic Volume for a typical week in 2007

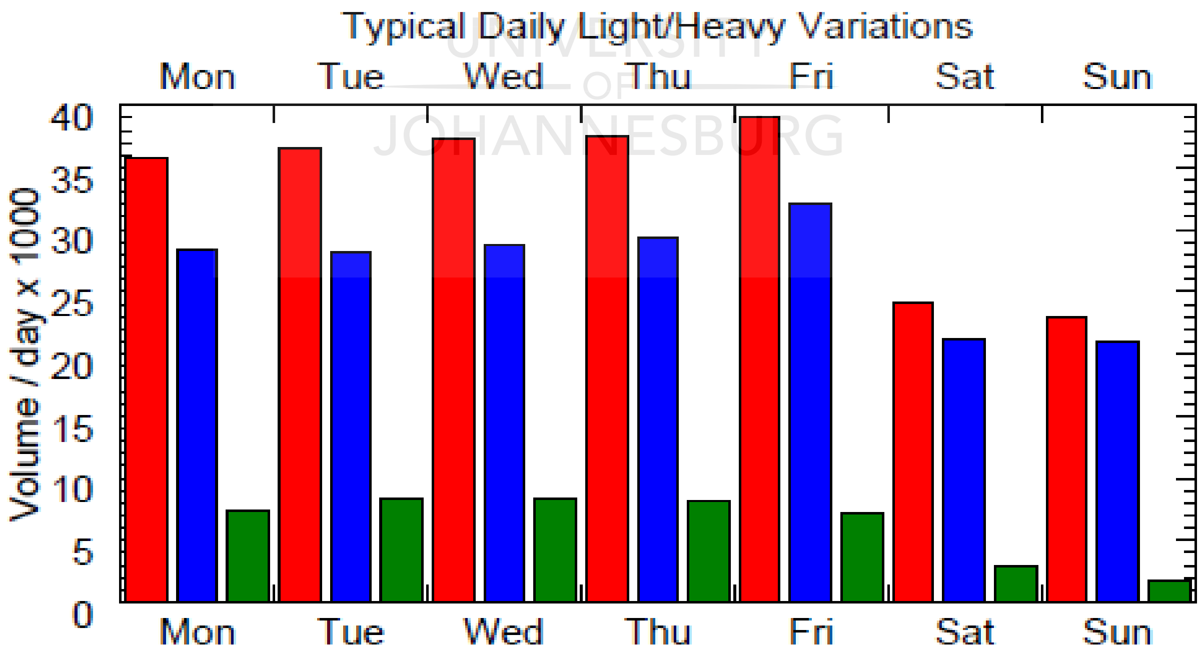
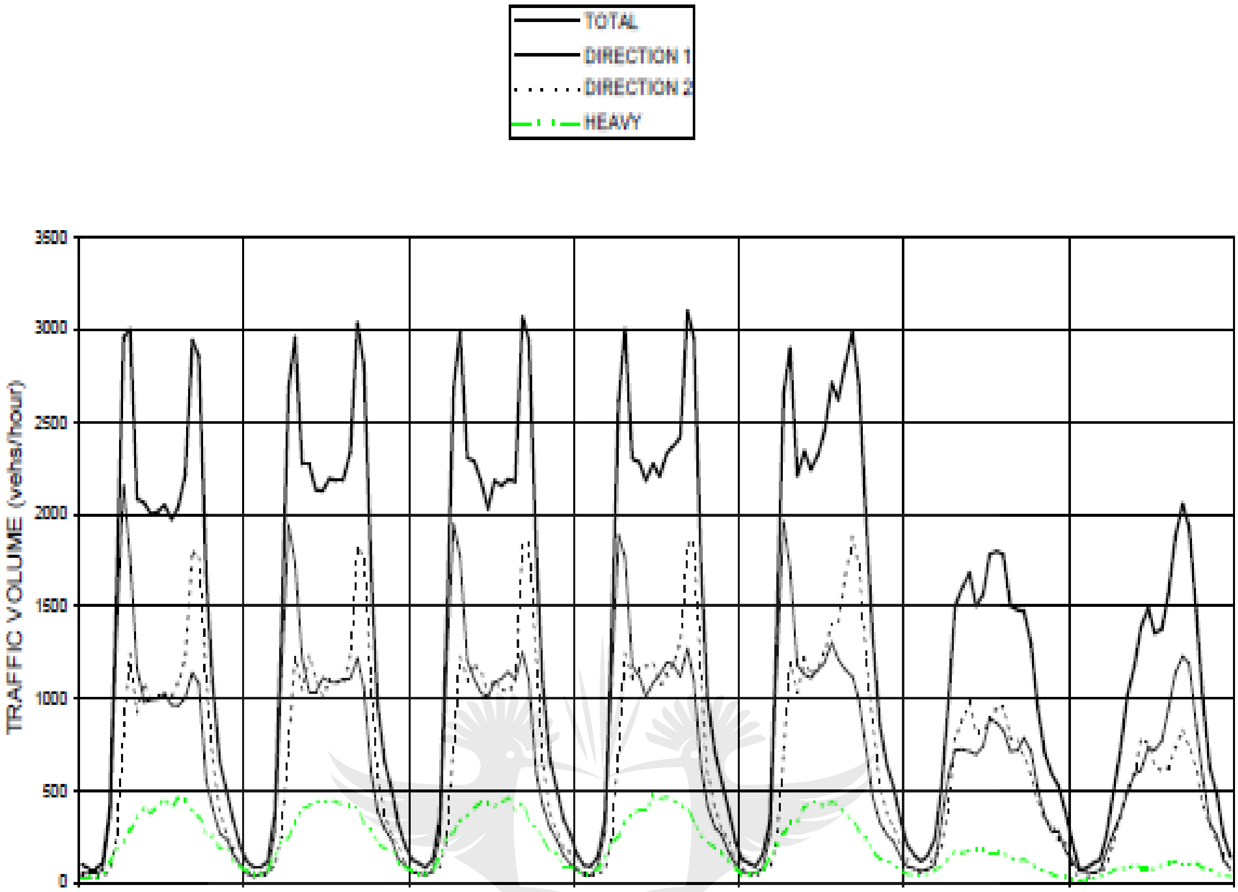
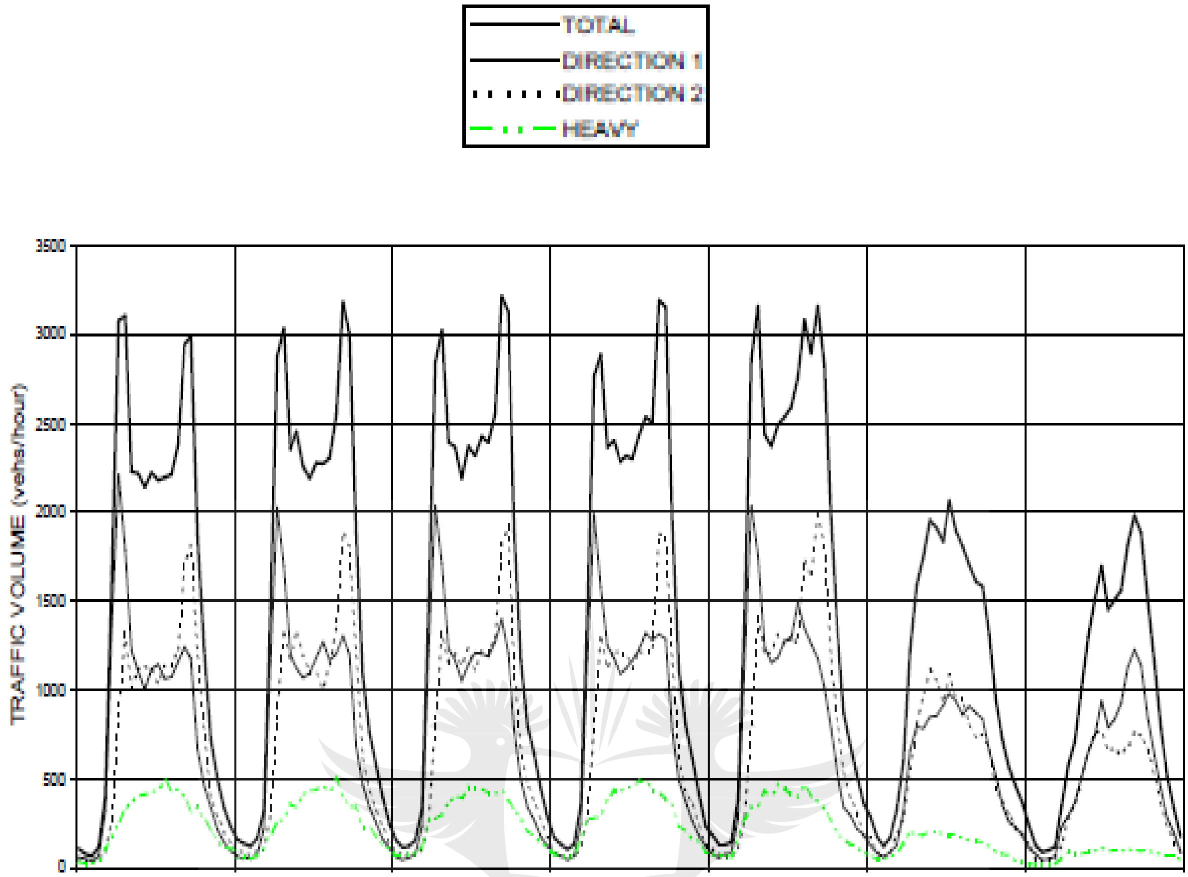


Figure A7.2: Typical daily light/heavy variations in 2007



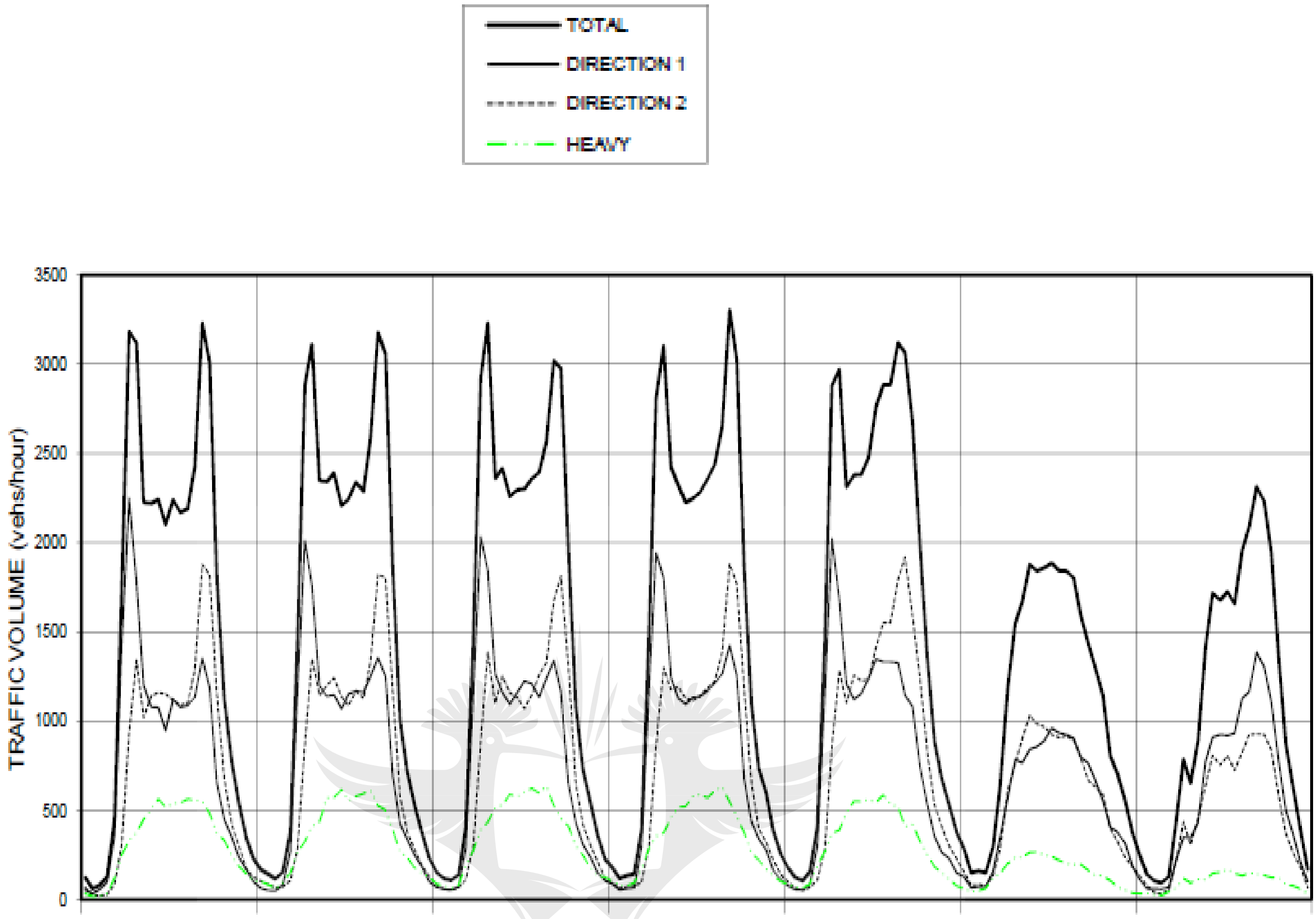
	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	34838	35828	38009	38705	38731	24460	21255
Expansion Factor	1.074	1.086	1.107	1.128	1.191	0.752	0.853

Figure A7.3: Traffic Volume for a typical week in 2009



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	37188	38073	38778	38812	41328	28845	22489
Expansion Factor	1.070	1.085	1.115	1.110	1.188	0.775	0.847

Figure A7.4: Traffic Volume for a typical week in 2010



	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
Day of Week ADT	37730	38114	38376	38582	41020	26962	25637
Expansion Factor	1.072	1.083	1.090	1.096	1.165	0.766	0.728

Figure A7.5: Traffic Volume for a typical week in 2011

Appendix 8 Consolidated data

Table A8.1: Average values for consolidated stations; ADT, ADDT, night traffic and Truck Split

Year	Counting Station	Average daily traffic ADT	Average heavy daily traffic ADTT	Night Traffic	Truck split %		
2004					Short	Medium	Long
	0114	25199	1404	2268	51	26	23
	0087						
	0086	33249	4224	3691	29	33	38
	0148	31657	4092	2912	26	40	34
	0232						
	0119	30509	5004	3112	27	34	39
	0118	15316	3028	1807	25	34	41
Average values		**27186.00**	**3550.40**	**2758.00**	**32**	**33**	**35**
2005							
	0114						
	0087	56126	3818	6398	10	35	55
	0086						
	0148						
	0232						
	0119						
	0118						
Average values		**56126**	**3818**	**6398**	**10**	**35**	**55**
2006							
	0114						
	0087	56807	3997	6249	10	37	53
	0086						
	0148						
	0232						
	0119						
	0118						
Average values		**56807**	**3997**	**6249**	**10**	**37**	**53**
2007							
	0114						
	0087	59407	3997	6713	9	44	47
	0086	37736	5343	4038	29	29	42
	0148	39019	6618	4331	28	31	41

	0232	33240	6419	4222	26	33	41
	0119	34467	6286	4033	28	32	40
	0118	16224	2964	1996	23	24	53
Average values		**36682.17**	**5271.17**	**4222**	**24**	**32**	**44**
2009							
	0114						
	0087	55905	4090		15	14	70
	0086						
	0148	38325	4979	7358	31	14	55
	0232	32532	5030	6376	33	15	52
	0119	34408	5176	7054	31	13	56
	0118						
Average values		**40292.50**	**4818.75**	**6929.33**	**28**	**14**	**58**
2010							
	0114	32161	4682	6850	65	18	17
	0087	56872	4547		30	22	47
	0086	39183	4411	8307	27	22	52
	0148	38936	5352	7748	32	13	56
	0232	34775	5323	7268	35	13	52
	0119						
	0118	17489	2822	3533	30	13	57
Average values		**36569.33**	**4522.83**	**6741.20**	**37**	**17**	**47**
2011							
	0114	28586	2662	4774	60	20	20
	0087	56037	4666		30	20	49
	0086	40648	5726	8333	41	8	51
	0148	41363	6826	8190	39	9	52
	0232	35203	6747	7146	39	13	48
	0119	36457	6656	7036	38	9	53
	0118	18848	3755	4033	36	15	49
Average values		**36734.57**	**5291.14**	**6585.33**	**40**	**13**	**46**
2012							
	0114	28469	2000	5700	52	22	26
	0087	55501	4626		32	19	48
	0086						
	0148						
	0232						
	0119						
	0118						

Average values		**41985**	**3313**	**5700**	**42**	**21**	**37**
2013							
	0114	27760	1800	2847	50	24	26
	0087						
	0086						
	0148	40648	5666		31	25	44
	0232						
	0119	36015	5663	3746	28	24	48
	0118						
Average values		**34808**	**4376**	**3297**	**36**	**24**	**39**

Table A8.2: Average values for consolidated stations; E80/day, E80/HV, number of axles per truck and mass per truck

Year	**Counting Station**	**E80/HV**	**Theoretical E80/HV**		**Number of axles per heavy vehicle**	**Mass per truck**	**Legally permissible mass per truck**
			Individual Axle Method	TRH16 (1991) recommendation			
2004							
	0114	2	2.46	2.20	5	24	24
	0087						
	0086	2	2.46	2.20	5	24	24
	0148	2	1.54	1.70	4	24	24
	0232						
	0119	2	2.46	2.20	5	24	24
	0118	2	2.46	2.20	5	25	24
	Average Values	**2**	**2.276**	**2.1**	**4.8**	**24.2**	**24**
2005							
	0114						
	0087	3	2.46	2.20	5	29	24
	0086						
	0148						
	0232						
	0119						
	0118						
	Average Values	**3**	**2.46**	**2.20**	**5**	**29**	**24**
2006							
	0114						
	0087	3	2.46	2.20	5	29	
	0086						
	0148						
	0232						
	0119						
	0118						
	Average Values	**3**	**2.46**	**2.20**	**5**	**29**	**24**
2007							
	0114						
	0087	2.1	2.46 – 3.76	2.20 – 3.50	5.7	33.6	24
	0086	1.8	2.46	2.20	5	29	24
	0148	1.8	2.46	2.20	5	29.2	24

	0232	1.8	2.46	2.20	5	29.4	24
	0119	1.8	1.5 – 2.46	1.8 – 2.2	4.9	24	24
	0118	1.8	2.46 – 3.76	2.20 – 3.50	5.4	31.1	24
	Average Values	**1.85**	**2.6**	**2.4**	**5.2**	**29.4**	**24**
2009							
	0114						
	0087	1.4	2.46 – 3.76	2.20 – 3.50	5.5	23.38	24
	0086						
	0148	1.7	2.46	2.20	5	29.7	24
	0232						
	0119	1.7	2.46 – 3.76	2.20 – 3.5	5.2	29.8	24
	0118						
	Average Values	**1.6**	**2.9**	**2.6**	**5.2**	**27.6**	**24**
2010							
	0114	1.2	1.24 – 1.54	1.70 – 1.80	3.4	19.5	24
	0087	0.99					
	0086	1.8	2.55	2.29	5.2	30.3	24
	0148	1.7	2.46 – 3.76	2.20 – 3.50	5.2	29.7	24
	0232	1.7	2.46	2.20	5	28.9	24
	0119						
	0118	1.7	2.46 – 3.76	2.20 – 3.50	5.2	30.1	24
	Average Values	**1.5**	**2.64**	**2.52**	**4.8**	**27.7**	**24**
2011							
	0114						
	0087	1.4					
	0086	2			5	24	
	0148						
	0232						
	0119						
	0118						
	Average Values	**1.7**					
2012							
	0114						
	0087	1.2					
	0086	2			5	24	
	0148						
	0232						
	0119						
	0118						

	Average Values	**1.6**			**5**	**24**	
2013							
	0114	1.4	1.54	2.20	4	23.2	24
	0087						
	0086	2			5	24	
	0148	1.7	2.46	2.20	5	28.9	24
	0232						
	0119	1.8	2.46 – 2.2	2.20 – 3.50	5.1	29.8	24
	0118						
	Average Values	**1.7**	**2.39**	**2.37**	**4.8**	**26.5**	**24**