Mechanical Failures as a Contributing Cause to Motor Vehicle Accidents

by

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SUMMARY

Title	:	Mechanical failures as a contributing cause to motor vehicle accidents
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The casualty rate of road vehicle accidents in South Africa is one of the highest in the world. This trend has persisted with little variation over the years, despite the efforts of local road safety organisations and research institutions to decrease them. Some of these road vehicle accidents are due to a mechanical failure of the vehicle. The main goal of this study is to establish how high the incidence of mechanical failure is in these accidents. And further to assess if these percentages of mechanical failures do coincide with trends already indicated nationally as well as internationally.

Detailed information on the condition of vehicles was collected in and around the Pretoria area. Surveys were conducted to obtain local road and traffic information about vehicle conditions. The one survey was defined as Potential Mechanical Defect Tests (PMDT) where vehicles were stopped and given a brief mechanical inspection, and the other was a Minibus Survey where information was obtained about the age of the vehicle and the overall condition and pressure of tyres.

Additional information was obtained from the Accident Response Unit (ARU) and the Forensic Sciences Laboratories, both of the South African Police Services in Pretoria.

The findings of the study are that according to the data collected by the ARU over a period of 2,5 years, on average 3,3% of the accidents reported per year in the region were caused by mechanical failures. These identified percentages correspond with values obtained for international countries. The PMDT data indicate that 40% of the vehicles surveyed in suburban areas and 29% of the vehicles surveyed on the highway had mechanical defects that contravened current road and traffic regulations. The difference between the percentages indicates that the condition of vehicles inspected in the suburban area differs significantly from the condition of those using the highway. In the Minibus Survey, large irregularities in tyre pressure were identified as cause for concern. In general, all of the above findings indicated that maintenance on older vehicles seemed to receive less attention.

It is proposed that annual vehicle inspections should be introduced, especially for vehicles carrying fare-paying passengers, to improve road safety standards on South African roads.

KEYWORDS: vehicle accidents, mechanical failures, contributing factor, potential mechanical defects, tyre pressure irregularities, periodic motor vehicle inspections, overloading, brake defects, road safety.

OPSOMMING

Titel	:	Meganiese falings as 'n bydraende faktor tot motor voertuigongelukke.
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Voertuigongelukke in Suid-Afrika is van die hoogste in die wêreld en dit neem jaarliks toe. Ten spyte die pogings van nasionale padveiligheidorganisasies en navorsings-eenhede om dit te bekamp, het dit steeds 'n hoë sterftesyfer tot gevolg. 'n Aantal van hierdie ongelukke vind plaas as gevolg van 'n meganiese faling wat in die voertuig voorkom. Die doel van hierdie projek is om te bepaal presies hoeveel van hierdie verkeersongelukke toegeskryf kan word aan die meganiese faling van die voertuig self of komponente in die voertuig. Daar word ook gepoog om die bepaalde statistiek te vergelyk met reeds bestaande nasionale, sowel as internasionale persentasies en hieruit aan te toon of daar wel 'n beduidende probleem bestaan ten opsigte van meganiese defekte in Suid-Afrikaanse voertuigongelukke.

'n Verskeidenheid opnames is uitgevoer waarin die algemene toestand van voertuie bepaal is. Hierdie opnames word gekarakteriseer as, Potensiële Meganiese Defek Toetse (PMDT) waar voertuie op die pad geïdentifiseer en afgetrek is vir 'n meganiese ondersoek. Daar is ook 'n Minibus (taxi) opname uitgevoer waar inligting aangaande die ouderdom sowel as die voertuig se bande en banddrukke verkry is.

Verdere inligting is verkry vanaf die Ongeluk Reaksie Eenheid (ORE) en die Forensiese Wetenskaplaboratoriums, beide van die Suid Afrikaanse Polisie Diens, te Pretoria.

Die resultate toon dat, gemiddeld 3,3% per jaar van die aangemelde en ondersoekte ongelukke direk veroorsaak is deur meganiese falings van die voertuig. Hierdie statistiek stem ooreen met internasional geïdentifiseerde syfers. Die PMDT toon dat 40% van die voertuie ondersoek in die stedelike area en 29% van die voertuie ondersoek op die snelweg, meganiese defekte het wat nie voldoen aan die bestaande pad- en verkeersregulasies nie. In die Minibus opname is onreëlmatighede aangaande banddrukke geïdentifiseer as 'n area van kommer. Hier is ook aangetoon dat die onderhoud van ouer voertuie verwaarloos word.

Daar word voorgestel dat jaarlikse padwaardigheids-ondersoeke (periodiese motor voertuig inspeksies) ingestel word. Dit is veral nodig dat die padwaardigheid van voertuie wat passasiers vervoer, gereeld ondersoek moet word. Dit sal verhoed dat onpadwaardige voertuie op die pad voorkom, en dus ook algemene verkeers-veiligheid verbeter.

SLEUTELWOORDE: voertuig ongelukke, meganiese falings, bydraende faktor, potensiële meganiese defekte, banddruk onreëlmatighede, periodiese motor voertuig inspeksies, oorbelading, band defekte, padveiligheid.

LIST OF SYMBOLS

ABBREVIATIONS

SAPS	-	South African Police Service
ARU	-	Accident Response Unit
PMDT	-	Potential Mechanical Defect Tests
PMD	-	Potential Mechanical Defect
MD	-	Mechanical Defect
CSIR	-	National Institute for Transport and Road Research South Africa (now Transportek)
CSS	-	Central Statistical Services (now Statistics South Africa-SSA)
NASS	-	National Accident Sampling System
OAR	-	Officer's Accident Report Form
LDV	-	Light delivery vehicles
SABS	-	South African Bureau of Standards
PMVI	-	Periodic Motor Vehicle Inspection
DOT	-	Department of Transport
OEM	-	Original Equipment Manufacturers

SYMBOLS

$\bar{x}$	-	Average tread depth of the four tyres on the vehicle
p	-	Exceedance probability
BSF	-	Brake Severity Factor
V	-	Substitutional brake application speed when the brake release speed is zero [m/s]
N	-	Frequency of brake application per unit length (1km)
L	-	Length of the journey [km]
Va	-	Brake application speed [m/s]

Vr	-	Brake release speed [m/s]
i	-	Number of brake applications (i = 1,2,…,m)
Wp	-	Pad wear per 10^4km. mm
Wθ	-	Specific wear rate of friction material at disc rotor temperature θ °C [mm^3/kg.m (mm^3/J)]
Ap	-	Pad area [mm^2]
α	-	Mean deceleration value in public roads [m/s^2]
Wt	-	Weight of vehicle [kg]
y	-	Proportion of the total braking effort transmitted through the front and rear axle.
Td	-	Residual torque [N.m]
R	-	Dynamic rolling radius of the tyre [m]

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CHAPTER ONE

INTRODUCTION

1.1 Motivation

1. Introduction

1.1 Motivation (scope of this project)

"My son shall learn to sail a boat before he drives a car. In a sailboat he gets power only through discipline, and this gives him the ability to meet his master nature. But in the motor car he gets power without discipline and without control."

Josian Royce [Welch, A., 1978]

Standing at the threshold of the twenty-first century and looking back on what human beings have achieved in such a short period of time, one anticipates that exciting times lie ahead. In the past decade, motor vehicle technology has progressed rapidly but further technological developments will be called for to meet the needs and requirements of an ever-increasing human population.

This increasing demand and the rivalry between various motor vehicle manufacturers has resulted in the development of the motor vehicles from the early Ford model-T to today's economical family vehicle. The mass production of more vehicles to satisfy demand has significantly increased the number of vehicles on our roads. Inevitably the greater congestion leads to vehicle accidents, often resulting in serious and fatal injuries. The term "accident" as used in traffic studies does not always conform to dictionary definitions which usually define an accident as something unavoidable or unexpected, as if absolute values may be assigned to them. The implication is that an event is either expected or unexpected, avoidable or unavoidable. For instance, one person may regard a situation as "unexpected" but someone else may regard it as "expected" if the second person has a greater knowledge of the situation. Therefore, for the purposes of this study, "vehicle accident" is defined as "a sequence or several sequences of acts or events with a low degree of expectedness or avoidability, which involves at least one traffic unit in motion on a road, and which leads to unintended death, injury, or property damage". Fortunately, road vehicle accidents do not generally occur under normal operating circumstances.

Many factors contribute to most road vehicle accidents. These factors may include a combination of human error, poor road design, adverse weather conditions and vehicle defects. The term "factor" is interpreted as denoting any circumstance connected with an accident without which the accident would have been less likely to occur, or without which the accident would have had less serious consequences. Addressing some of these factors could significantly reduce the number of motor vehicle accidents on South Africa's roads.

The number of road accidents in South Africa during the period from 1994 to 1998 (see Figure 1.1), indicates that road accidents are on the increase [CSS, 1998]. Although this could be the result of the increasing number and greater activity of vehicles using our roads each year, the growing incidence of accidents is still cause for concern. During 1998, 511 605 accidents were reported, of which 7 260 were fatal accidents, resulting in the loss of 9 068 lives [CSS, 1998].

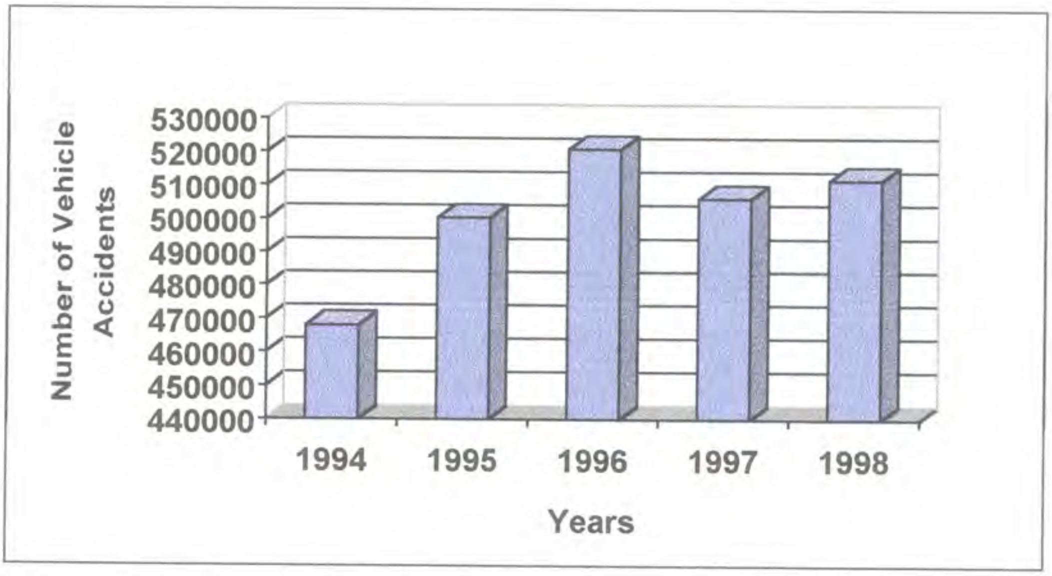


Figure 1.1. Change in number of accidents over a period of eight years

During 1996, 517 600 accidents were recorded, involving over 800 000 motor vehicles: 9 790 people died and approximately 60 000 were seriously injured in these accidents. This means that in 1996 an average of almost 1 418 accidents occurred daily in South Africa [Askew, 1998]. In 1996 motor vehicle accidents cost South Africa approximately R32 million a day or R11,9 billion a year. This cost involves damage to property, loss of quality of life, medical expenses and administrative, legal and miscellaneous costs, etc. and the incalculable cost of pain and suffering.

Globally, it is estimated that approximately 500 000 people die in motor vehicle accidents every year. In a recent analysis of the Global Burden and Disease which assesses changes in the ranking order of the leading causes of the disease burden in the world, motor accidents, which had ranked ninth in 1990, will be the third leading cause in the year 2020 [Askew, 1998].

In view of the above figures, this study is aimed at identifying certain problem areas in road and traffic accidents, and attempting to generate appropriate solutions to reduce these steadily rising statistics.

Although human factors contribute greatly to all vehicle accidents, it may be inappropriate to concentrate on only one contributing factor and neglect the possible interaction of two or more other factors. Unfortunately, research on all the factors contributing to vehicle accidents would require a great deal of human resources, time and logistical support to obtain an accurate and thorough assessment.

Considering the facts presented in this chapter, current trends seem to indicate that an increasing number of vehicle accidents are due to mechanical failures. Although vehicle engineering is making rapid technological progress, the mechanical failures leading to vehicle accidents apparently tend to be overlooked. The objective of this research project is to investigate vehicle accidents caused by mechanical failure. Although mechanical failures are not generally regarded as the major cause of vehicle accidents, proper identification of such cases and appropriate action taken by road transport authorities could help reduce the number and severity of accidents on our roads.

Technological advances lead to higher prices of vehicles and this in effect contributes to a larger market for second-hand vehicles. This in turn leads to a larger number of older vehicles on our roads. As older vehicles are not fitted with modern safety features, it is imperative that these vehicles should be maintained and serviced regularly. Although the vehicle industry tends to ensure that vehicle services are affordable, the current state of the economy enables only a certain portion of the population to afford such facilities.

Consequently many owners of vehicles tend to make use of more economical service alternatives, or they maintain their vehicles themselves or do not maintain them at all. These vehicles are often fitted with cheaper and inferior quality mechanical parts, which in most cases are not endorsed by the vehicle manufacturer.

Over the past two decades the informal passenger transport industry has expanded significantly. Inadequate finance and the high cost of new and existing vehicles have resulted in the use of older and used vehicles for transporting passengers. The high demand for passenger transport has led to the overutilisation of passenger transport units. Unfortunately, overutilisation leads to more frequent mechanical failures because these vehicles are not maintained regularly.

To ensure thorough research on the subject of mechanical failures considered in the present study, it is necessary to do a literature survey of similar projects and determine the scope of their research. Furthermore it is necessary to explain the purpose of the project and what impact it may have on the environment and community. ***Chapter 2*** contains a literature survey of the subject and an introduction to the rest of the research project.

Chapter 3 discusses the technical data obtained from the Accident Response Units (ARU) visited, and the Potential Mechanical Defect Tests (PMDT) conducted. It also discusses the findings derived from the minibus (taxi) survey and similar tyre defect data obtained.

Chapter 4 evaluates and compares the differences in the data obtained from the Accident Response Units and the Potential Mechanical Defect Tests. These differences are thoroughly documented and interpreted. A statistical representation of the data derived from the PMDT is calculated and stated. How representative the obtained data was, will also be indicated.

Chapter 5 contains an explanation of the different Potential Mechanical Defects (PMD) that could occur in a vehicle and a discussion of the results of these failures. A short introduction to road and traffic safety is also provided.

Chapter 6 contains an interpretation of the research results, followed by the conclusion and recommendations for future studies.

CHAPTER TWO

LITERATURE SURVEY

2.1. Background

2.2. Purpose of the research project

2.3. Issues to be addressed

2.4. Beneficiaries

2. Literature survey

2.1 Background

The casualty rate in road traffic accidents in South Africa is one of the highest in the world. This trend has persisted with little variation over the years, despite the efforts of local road safety organisations and research institutions. In 1970, for example, South Africa had an estimated mid-year population of over 20 million and a motor vehicle population of some 2 250 000, with 205 267 reported road traffic accidents involving a casualty rate of 2,05 and a fatality rate of 0,23 per million vehicle kilometres respectively [Odendaal, 1973]. These rates are high by any standards.

As stated in the previous chapter, approximately 511 605 vehicle accidents were reported in South Africa in 1998. This represents a growth of 149% higher than the recorded road accident statistics during 1970. Details of accidents recorded during this period indicate that the South African Police Service (SAPS) did not normally conduct intensive investigations into vehicle accidents, and were only concerned with possible violations of the law. Only over the past few years' projects like the Rapid Response Form of the Department of Transport and the Arrive Alive Campaign helped to determine the factors contributing to the occurrence of vehicle accidents in South Africa. When examining the above-mentioned accidents, there was no definite indication of how these accidents occurred or what the contributing factors were.

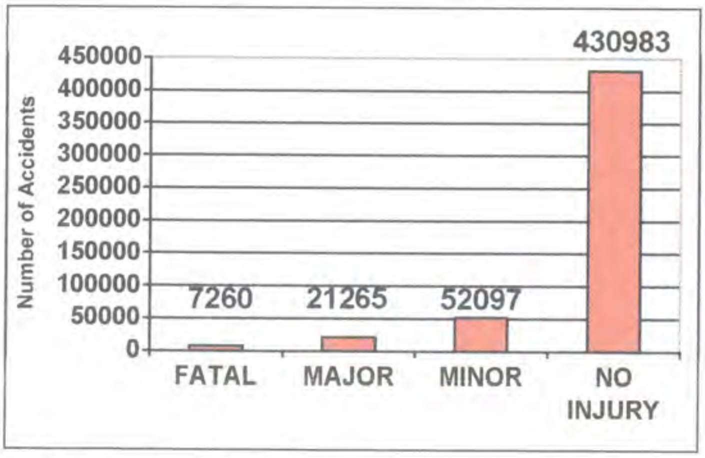


Figure 2.1 Number of accidents according to severity of injury (1998)

Figure 2.1 indicates the severity of injuries sustained in vehicle accidents during 1998 [CSS, 1998]. Also previously mentioned is that most accidents are due to the following factors or combination of factors: human error, poor road surface, adverse weather conditions and mechanical failure of vehicles. Attempts have been made to estimate the percentages of road accidents which can be attributed to defects in or defective performance of the road environment, the vehicle or the road user, and to study their interaction.

A great deal of work on this subject was conducted by the Transport and Road Research Laboratory [Sabey and Staughton, 1975], in which a four year "on the spot" investigation was conducted in South-East Berkshire (England) between 1970 and 1974. After four years of research, the researchers came to the following conclusion: human factors were judged to have been present in about 95% of the accidents and to have been the sole contributor to about 65%. The road environment was a factor in about 28% and the vehicle in about 9%. The researchers attended 2 130 accidents over this four-year period. Their findings are shown in Table 2.1.

Table 2.1 The contribution of factors to vehicle accidents (Sabey and Staughton)

Contributing Factor	Sole Contribution to Accident	Combining Contribution to Accident
Road User	65%	95%
Road/Environment	2,5%	28%
Vehicle	2,5%	9%

A similar project was launched by the National Institute for Transport and Road Research at the CSIR in South Africa. This group had undertaken the National Accident Sampling System (NASS) research project over the period from 1 July 1981 to 31 December 1985. The group investigated 1 667 accidents during this period. This project yielded the following findings: there were 4 153 contributing factors in 1 584 of the accidents that were investigated. This gave an average of 2,62 factors per accident [Pienaar, 1986]. See Table 2.2 for the results of the three main contributing factors.

Table 2.2 The contribution of factors to vehicle accidents (CSIR)

Contributing Factor	Sole Contribution to Accident	Combining Contribution to Accident
Road User	90,6%	See values below
Road/Environment	7,0%	15,2%
Vehicle	2,4%	6,2%

- Distribution of combining contributing factors for the road user in 1 584 investigated accidents: No concentration – 80%, Reckless driving – 47,2%, Speeding – 43,2%, Other – 57,2%

From Table 2.2 it is clear that vehicle factors were the sole contributor to 2,4% of the accidents and were a contributory factor to 6,2% of all the accidents. Unfortunately the above project was suspended due to a lack of human resources and financial backing. The end result of discontinuing this project was that a great deal of information about accidents in South Africa was lost.

Research on vehicle factors relating to accidents can be placed in one of two categories. The first category includes the general studies on isolating the effects of human, environmental and vehicle factors on road accidents (evident in the above-mentioned projects). These studies dealt with causal links 1, 2 and 3 shown in Figure 2.2. The second category concentrates on the effect of periodic motor vehicle inspections on vehicle condition, shown as link 4 in Figure 2.2.

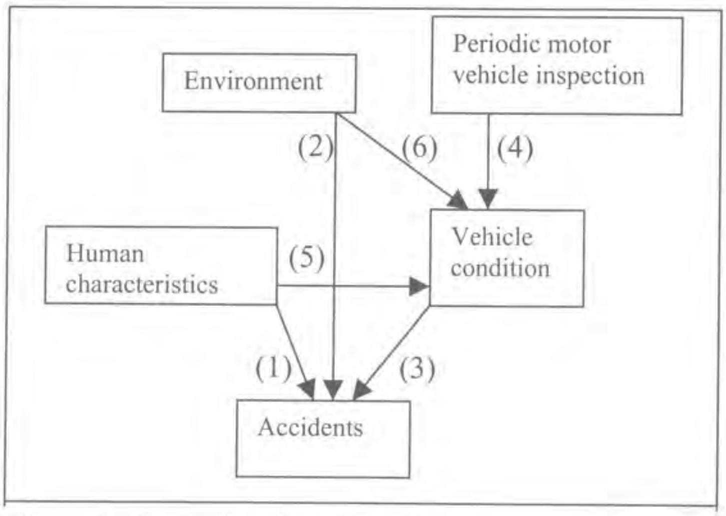


Figure 2.2 Relation of various factors to accidents

Although there is a lack of consensus in past research regarding the usefulness of periodic motor vehicle inspections, there is strong evidence that refined inspection and weighing methods lead to a significant reduction in the number and seriousness of accidents [Ergun, 1985]. Similar findings will be discussed further in this study.

A problem with the roadworthiness of vehicles on South African roads was recently investigated by ***Carte Blanche*** (a documentary television programme on MNET) and telecast on 19 April 1999. This episode thoroughly discussed the point that roadworthiness certificates had been issued for some vehicles without a valid inspection of the vehicles. Further statistics reviewed in this documentary showed that 80% of the vehicles that had caused accidents over the Easter holiday period of 1999 did not have a valid roadworthiness certificate. This in effect implies that some of these vehicles were not roadworthy or had illegally obtained roadworthiness certificates.

Figure 2.2 indicates clearly that various factors may directly or indirectly affect the condition of the vehicle. For instance, low-income drivers may buy older vehicles with higher mileage, which will indirectly influence the vehicle condition. Furthermore, the driver may not do sufficient maintenance or repairs to correct problems with the condition of the vehicle. Therefore income will directly affect vehicle condition. As mentioned in Chapter 1, the informal passenger transport industry has shown exceptional growth. Unfortunately, due to the immense demand for transport services, this industry tends to use its vehicles under severe operational conditions, such as the following:

- Long periods between maintenance
- Long operational time intervals
- Exposure to hazardous operational conditions, e.g.
  - overloading,
  - high speeds,
  - use of spares not endorsed by manufacturer,
  - use of defective tyres, and
  - incorrect tyre pressure.

All these factors tend to lead to some kind of failure, due to human error or the failure of mechanical components when their fatigue limit has been reached. An example of one of the above points is a survey done by ***CAR*** magazine in September 1997, indicating that 55% of the vehicles using our roads have underinflated tyres. This is just one of the many variables influencing a vehicle's characteristics.

Roadside surveys are being conducted on an annual basis by the Department of Transport, to monitor the obvious defects of minibus taxis. Some of the results for 1992 and 1993 (Department of Transport - DOT surveys) are given in Table 2.3.

Table 2.3 Defects of minibus taxis (DOT surveys): 1992-1993

Defects	**1992 (%)**	**1993 (%)**
Brakes	5,9	4,9
Tyres	14,0	11,7
Steering mechanism	9,9	5,9
Indicators	5,4	7,5
Stop lights	10,4	8,1
Head lights	8,1	9,5

A study by **Matchett and Smith** [1994] tested for roadworthiness defects among minibus taxis, according to ten preselected roadworthy standards as shown in Table 2.4. Of the 641 minibuses included in the survey, only 5 (0,78%) complied with all ten preselected roadworthy standards. The age of the vehicles did not correlate with the defects. One of the main conclusions were that although vehicle defects alone were not a major contributor to accidents, the problem is considered important when combined with the problem of poor driver behavior. The study also concluded that it is suspected that the types of vehicles used as minibus taxis tend to be overloaded and to exceed the manufacturer specifications for passengers and luggage. This damages the vehicle and makes it difficult to control. Some of the results obtained do correlate with data shown in the above DOT surveys.

Table 2.4 Roadworthiness defects of minibus taxis

Defects	Defect Rate (%) (N = 641)
Windscreens	45,6
Tyres	40,2
Steering gear	39,4
Hand brakes	22,3
Windscreen wipers	19,1
Stop lamps	8,5
Indicators	5,2
Brakes	5,0
Rear lamps	3,8
Oil leaks	3,1

A study by **Opperman** [1990] concluded that 24% of the 91 minibus taxi accidents investigated at the scene of the accident had defective tyres. In 19% of these accidents a burst tyre was the major reason for the accident. The study showed that speed, overloading and defective tyres represented the most significant elements in the accidents researched, both as individual contributory factors and in combination.

Considering the use of spares not endorsed by the manufacturer the study by **Meintjes** [1992] gives conclusive evidence. The study evaluated the braking performance of loaded minibus taxis. This was done with special reference to replacement parts. A total of 24 different pads and shoes were evaluated in terms of parameters such as distance, deceleration and pedal force. Ten of these replacement parts failed prematurely during the testing procedure. The study recommended that the SABS and authorities take a definite stance on the use of spares other that the Original Equipment Manufacturers (OEM) components, especially where safety equipment is involved, i.e. brakes, lights, steering mechanism, and so on. All the above studies did therefore indicate certain problems with the informal passenger transport industry. Further results on similar aspects will be discussed later in this project.

Table 2.5, shows the percentage of accidents related to vehicle defects, reported by various sources in various countries. The studies done by Sabey and Staughton [1975], Treat [1980] and the National Institute for Transport and Road Research South Africa (CSIR), used special multidisciplinary accident investigation teams and are more reliable than the other studies which are based mainly on police reports [Pienaar, 1986; et al].

Table 2.5 Role of vehicle defects in accidents

Source	Location	Defect-related accident (%)
National Accident Sampling System [1986]	South Africa	
	Alone	2,4
	Combining	6,2
Texas Transportation Institute [1974][1]	California	6,4
	Indiana	20,6
	Michigan	4,7
	Missouri	3,0
	Ohio	9,5
	Pennsylvania	2,5
	Rhode Island	1,5
	Virginia	9,0
Jacobs & Sayer [1983]	Ghana	16,0
	Botswana	12,0
	Jamaica	1,0
Sabey & Staughton [1975]	UK	
	Alone	2,5
	Combining	9,0
Treat [1980]	USA	
	Alone	2,0
	Combining	12,0

From Table 2.5 a striking observation can be made about the differences in defect-related accidents worldwide. Although South Africa's contribution is generally smaller than some of the other countries, it should be noted that the investigation by the CSIR was done on only 1 667 accidents spanning a period of four and a half years.

[1] The following percentages represent the combining contributory factors leading to motor vehicle accidents.

When comparing the findings in South Africa with those of the UK and the USA, a strongly similar trend can be seen in vehicle accidents related to mechanical defects where these were the sole causal factor. The variations in the rest may be due to the following factors:

- Differences in accident investigation methods,
- Differences inherent in the environment and the condition of the vehicles in various countries.

In October 1997 the "Arrive Alive" campaign was launched in South Africa. The main purpose of launching this campaign was to reduce the number of motor vehicle accidents on South Africa's national roads. An additional purpose was to educate the public and distribute information to the public about the prevention of accidents. A good example was the 1997 Christmas holiday period of the Arrive Alive road safety campaign. It is estimated that during this time there were 300 fewer road deaths, 1 800 fewer serious injuries, and 15 000 fewer accidents [Askew, 1998]. Another example of the effect of the Arrive Alive campaign appears in the *Final Easter Traffic Report [1999]*.

In this report the Minister of Transport announced that there had been a 6,8% reduction in the road deaths reported over the Easter long weekend (1-5 April 1999). During this period 221 people died in 134 vehicle accidents, compared with 237 deaths in 169 fatal accidents reported for Easter 1998. This summary gives the following factors contributing to these accidents: human factors contributed to 56,9% of the fatal accidents; road and environment factors played a role in 24,8% of the fatal accidents and vehicle factors contributed to 18,3%. When considering only the vehicle factors, the report indicates that burst tyres prior to the accident contributed to 15,1% of these fatal accidents. Also showing similar trends identified by the studies of Opperman [1990], discussed in previous paragraphs. Overloading of cargo and/or passenger vehicles contributed to 2,8% of the accidents. The types of vehicles involved in these accidents were as follows: 42% of the 170 vehicles involved in the 134 fatal accidents were passenger vehicles, 19,4% were light commercial vehicles and 10,6% minibus taxis.

Unfortunately, the Arrive Alive project investigates a wide variety of contributing factors to vehicle accidents, where speed as a causative factor of vehicle accidents is considered predominantly. Furthermore, according to the information gathered from various police stations, the accuracy of the actual statistics is doubtful because most policemen are not trained engineers/technicians and usually look for prosecutable offences rather than mechanical problems.

Now that the new Officer's Accident Report Form (OAR) has been issued, this problem might be addressed slightly better in South Africa. Because of the lack of definite and accurate information, a research project could be launched concerning only one of the factors contributing to vehicle accidents. For the purpose of the current research project, link 3 in Figure 2.2 was thoroughly investigated.

2.2 Purpose of this project

The main purpose of this project is to establish the current contribution of mechanical failures to the vehicle accident rate in South Africa. Furthermore the purpose is to assess if these percentages of mechanical failures do coincide with trends already indicated nationally as well as internationally.

2.3 Issues to be addressed

Mechanical failures in vehicles can cause extremely serious and sometimes fatal accidents. In 1995 the serious vehicle accidents due to mechanical failure, and specifically to defective brakes and defective tyres, were as follows [Pienaar, 1998]:

Defective brakes: 2,2%

Defective tyres: 6,3%

These statistics apply only to fatal accidents. Considering that these percentages apply only to fatal accidents, it is clear that the total percentage of accidents due to mechanical failures could be much higher. Although these percentages may seem low, they do indicate that mechanical failures are indeed a problem. The proper identification and resolving of this problem would decrease these figures.

Information obtained from the Arrive Alive offices in Pretoria contained the following data regarding contributory factors to fatal accidents. The data represents information over the period from 1 January 1998 to 30 April 1999. In this period there were 3 527 fatal accidents nationally [Arrive Alive, 1999]. It should be noted that this is only the information that various police stations sent to the Arrive Alive offices. The actual number of fatal accidents nationally may be higher. Table 2.6 shows the factors as a percentage of the number of accidents.

Table 2.6 Factors contributing to fatal accidents in vehicles (1998-1999)

CONTRIBUTING FACTORS	PERCENTAGE PRESENT
Overloading - cargo/passengers	2,3%
Faulty brakes	2,6%
Tyre burst prior to accident	8,0%
Smooth tyres	0,9%
Other	10,5%
Total	24,3%

Once again, tyres and brakes played a large role in the above-mentioned fatal accidents. Another problem, namely overloading, is evident here. Figure 2.3 shows the fatal accidents as a frequency distribution of accidents in the various provinces.

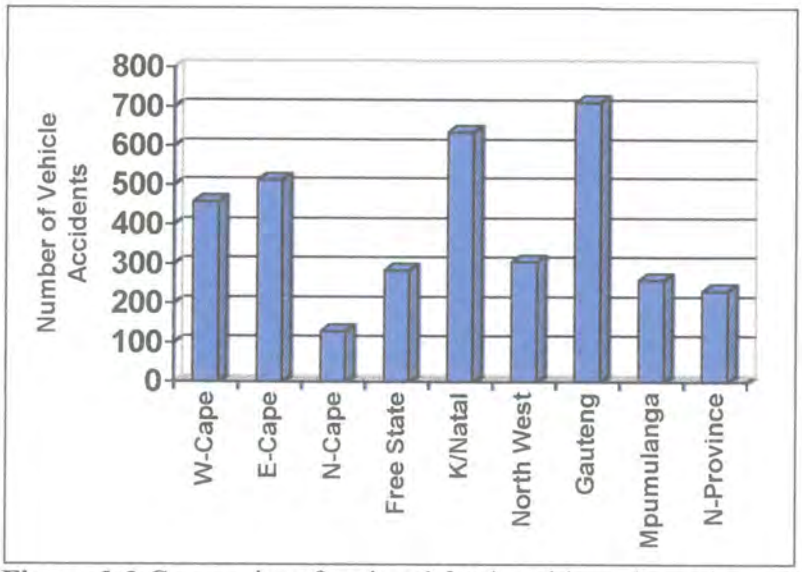


Figure 2.3 Composite of national fatal accidents in each province

The figure indicates that Gauteng Province had the largest number of fatal accidents. This might be because Gauteng has a large percentage (37,1%) of all the motor vehicles on the road in South Africa [Natis News, 1998]. On closer investigation of the statistics obtained from the Pretoria Traffic Department in Gauteng, there were 4 229 accidents in the fourteen "hot spots" in and around the Greater Pretoria Metropolitan Area during the period from 1 January 1999 to 30 July 1999. Table 2.7 displays the distribution and seriousness of these accidents.

Table 2.7 Accidents per road in Pretoria: Jan – July 1999

Roads	**Accidents**				
Description	Fatal	Serious	Slight	Damage	Total
Pretorius St	5	23	82	498	608
Church St	0	17	83	396	496
Schoeman St	0	15	47	350	412
Lynnwood Rd	2	4	61	268	335
N1 North	3	17	46	249	315
Tsamaya Avenue	5	33	44	233	315
DF Malan North	5	20	52	228	305
Duncan St	1	2	31	191	225
Atterbury Rd	0	6	28	189	223
Van der Walt St	1	10	36	166	213
Potgieter St North	0	8	38	161	207
Vermeulen St	0	8	31	163	202
Voortrekkers Rd	2	5	32	160	199
Zambesi Dve North	0	7	37	130	174
Total of all roads	24	175	648	3382	4229

The fatal and serious accidents amount to 4,7% of all the accidents. Further details of these accidents are discussed in Chapter 3 [Pretoria Traffic, 1999].

The following points are addressed in this research project:

1. Various accident response units (ARUs) were visited to obtain information about the specific accidents that had been investigated.

A short questionnaire was formulated and all the relevant information obtained from the accident response units was stored in a database to enable easy storage and retrieval of information.

2. A statistical value for problem vehicles and mechanical defects could now be retrieved via the database. Factors such as vehicle load and distance travelled (km reading), could be investigated.
3. A roadside survey could be generated for investigating Potential Mechanical Defects (PMD) by means of visual mechanical inspection.
4. After analysing the above points, a minibus (taxi) survey could be formulated to investigate specific aspects of the vehicle.
5. A short conclusion could be drafted to discuss the findings.

2.4 Beneficiaries

The beneficiaries are the various Road and Traffic Safety Departments in South Africa.

2.4.1 Specifications

An accurate conclusion regarding accidents that occur due to mechanical failures in vehicles should be handed to the various Road and Traffic Departments. The findings have to be credible and correct.

2.4.2 Research usage

It is hoped that the findings derived from this study will lead to the following:

- Identification of the problems regarding mechanical failures in vehicles, that lead to vehicle accidents. The prevention of vehicle accidents due to the identification of potential mechanical defects in vehicles.
- A possible decrease in the vehicle accident rate.

2.4.3 Impact

The findings derived from this research may help the Road and Traffic Departments to ensure that a large number of the vehicles using the national roads are roadworthy, perhaps by generating a periodic motor vehicle inspection procedure and in this way ensuring safer road usage.

CHAPTER THREE

RESEARCH METHODOLOGY

3. Research methodology

3.1 Scope

This chapter focuses on the following points regarding the data collected and discussions on the contributory role of mechanical defects to vehicle accidents:

- A short background on the information obtained at the Accident Response Units (ARU)
- A review of the findings derived from the data obtained and information about defect-related accidents in the Pretoria region
- A background on expectations regarding the roadworthiness of vehicles
- Discussion of the methods used in the Potential Mechanical Defect Tests (PMDT)
- Discussion of the difference between the two areas tested in the PMDT
- Discussion of data obtained regarding tyre characteristics and defects
- Discussion of data obtained in the minibus (taxi) survey.

3.2 Background

For the purpose of this research project it was decided that the accidents occurring in and around the Pretoria region (Gauteng Province) would be studied. The reason for this decision was that information available about accident statistics in other provinces was inadequate. Although KwaZulu-Natal has the highest incidence of road accidents, the ARU in this region does not have the human resources to investigate all the accidents that are reported. Consequently a great deal of information is lost and it would not be worthwhile to investigate accidents in other regions.

3.3 Accident Response Unit - Koedoespoort (Pretoria)

Before discussing the obtained statistics, it is necessary to highlight a few points on this subject.

Firstly, it is necessary to indicate that the ARU (Pretoria) responds only to accident cases involving culpable homicide and / or police vehicles. Consequently the ARU does not investigate an ordinary accident which does not involve a police vehicle and has not resulted in any fatalities. Therefore the actual number of accidents caused by mechanical failures may be much higher than the number reported. It should be understood that the information and statistics used in the current research study are based on the reports generated by the vehicle inspectors of the particular ARU.

The second point to be taken into account is the difference between an accident due to an actual mechanical failure and an accident ascribed to an alleged mechanical failure. A large percentage of drivers tend to indicate that the accident had been due to, for example, tyre defects. This would be regarded as an alleged failure. Although the vehicle inspectors investigate both cases, they usually indicate whether the alleged mechanical failure did in fact cause the accident.

Thirdly it should be recognized that in many of these accidents, the mechanical failure was only a contributing factor to the actual accident. This leads to the problem that the mechanical defect may indeed have played a large role in causing the accident. It is important to bear this point in mind.

When considering the above-mentioned points, it is clear why such a small number of mechanical failures are actually reported. However, it should also be mentioned that mechanical failures in vehicles do not necessarily lead to accidents and the vehicle may sometimes merely leave the road without causing an accident. These vehicles are in most cases not roadworthy but their drivers usually get away with this offence.

A report on 'Arrive Alive" data, obtained from the CSIR, shows that in October 1997 mechanical failures contributed to 9,2% of vehicle accidents in Gauteng Province [Pienaar, 1998]. Nationally 5,9% of the accidents reported in the same month had a mechanical failure as a contributing factor. It should be noted that these figures are based upon all the fatal accidents that had been reported to the Arrive Alive offices in this particular month, and not just the culpable homicide cases.

In the Pretoria region over the same period, approximately 2% of the culpable homicide accident cases investigated by the ARU in this region, were due to a mechanical failure. From these figures it is possible to deduce that this accident-contributing factor is a problem.

The accident reports investigated at the Pretoria ARU cover a period of two and a half years[1]. From these reports Figure 3.1 provides the percentage of mechanical failures inspected in accidents for the Pretoria region in each year. The ARU investigated and reported on 1 228 accidents in 1996, 1 216 in 1997 and 619 accidents in 1998 up to June. Although Figure 3.1 indicates that the percentages are small, the figures do assess the problem of mechanical defects contributing to accidents. As mentioned before, these were only the accident cases involving culpable homicide and / or police vehicles in the Pretoria region. It is difficult to indicate whether this figure would be higher if all the reported accidents were taken into consideration.

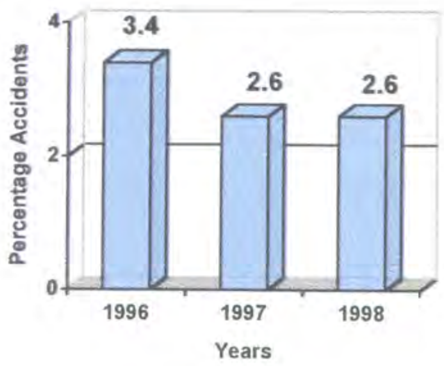


Figure 3.1 Indicating percentage of mechanical failures in accidents for each year.

As a great deal of technical information was gathered at the ARU in Pretoria, it was necessary to establish a formulated database to store information about the specifics of the accident reports at the ARU. The reports generated from the database make it possible to identify whether a mechanical failure in the vehicle system did indeed cause an accident. A good example of the information stored in the database is shown in Figure 3.1, where the number of accidents caused by mechanical failures is presented for the years 1996-1998.

[1] The reports for 1998 included data only up to the end of June.

See Appendix A for the questionnaire used at the ARU and the computer disk containing the specific database. Also read Appendix F for information on how to use the database. By means of the database, queries can be made about the information stored. For example, the response to investigating a specific vehicle make causing accidents due to a tyre defects is shown in Figure 3.2. Therefore these queries enabled rapid identification of certain problem areas. A further example is Figure 3.3 indicating the distribution of mechanical defects in the accidents reported on and stored in the database. As mentioned previously, the figures given above are for the accidents reported on by the ARU (Koedoespoort). The actual number of accidents, which were caused by a mechanical failure in the vehicle (Pretoria region), may therefore be higher or lower.

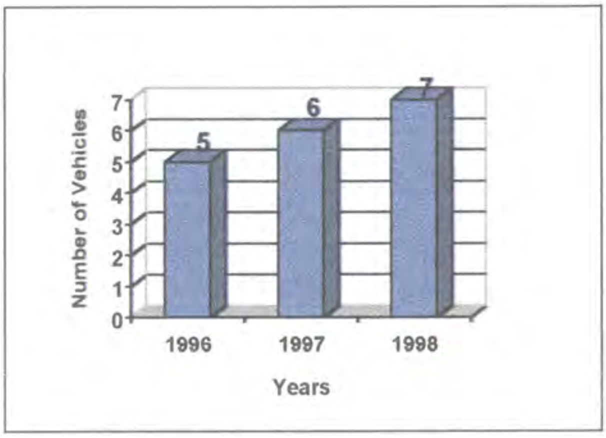


Figure 3.2 Number of Toyota vehicles in accidents due to tyre defects.

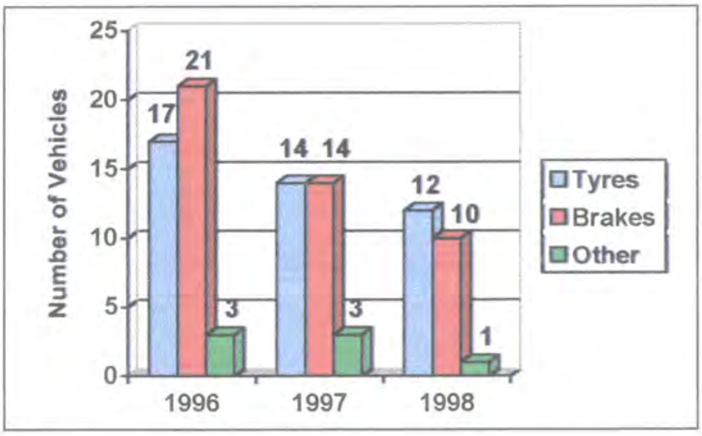


Figure 3.3 Distribution of accidents involving mechanical defects

Figure 3.3 clearly indicates that tyres and brakes are the main problems featuring in the accidents reported on by the ARU.

Chapter 2 indicates that there were 4 229 accidents in the fourteen 'hot spots' in and around the Pretoria metropolitan area (1 January to 30 July 1999) [Pretoria Traffic, 1999]. After identifying these 'hot spots' the Pretoria Traffic Department conducts random surveys where vehicles are pulled off the road to inspect certain components of the vehicle. It should be noted that the following information was obtained from the Pretoria Traffic Department involving random surveys done over the mentioned period. In these surveys a designated number of vehicles (10) per location were stopped and investigated. The traffic official inspected the vehicle according to a list of possible offences. Figure 3.4 and Table 3.1 indicates the tyre and brake offences and the amount of data obtained over the mentioned period.

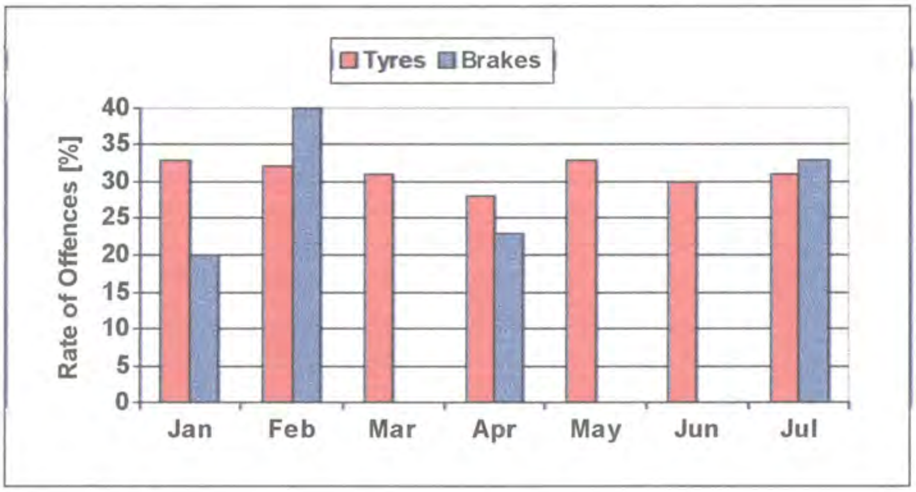


Figure 3.4 Tyre and brake offences per month (Jan-Jul 1999)

Table 3.1 Size and count of offences per month (Jan-Jul 1999)

			Offences per month –Tyres				
Month	Jan	Feb	Mar	Apr	May	Jun	Jul
Size	63	74	77	130	49	70	136
Count	21	24	24	36	16	21	42
Rate	33%	32%	31%	28%	33%	30%	31%
			Offences per month - Brakes				
Size	5	5	0	30	0	0	3
Count	1	2	0	7	0	0	1
Rate	20%	40%	-	23%	-	-	33%

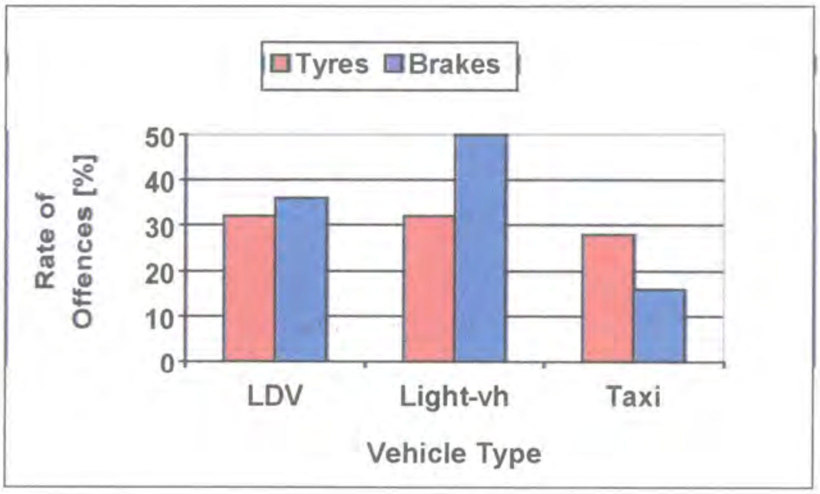


Figure 3.5 Tyre and brake offences per transport mode (Jan-Jul 1999)

Figure 3.5 gives the offences per transport mode. For the purposes of this project, only the data on light motor vehicles, light delivery vehicles (LDVs) and minibus taxis are important. Figure 3.5 indicates that 469 vehicles were inspected for offences involving tyres and the drivers of 146 of these vehicles were prosecuted. A total of 35 vehicles were inspected for brake defects and 9 drivers were prosecuted. Although the data discussed so far gives a good idea of the current problem concerning defect-related accidents and vehicle conditions, it was still necessary to do a roadside survey to inspect the condition of vehicles using our roads.

3.4 Potential Mechanical Defect Tests (PMDT)

3.4.1 Background

Unfortunately the statistics obtained at the Accident Response Unit and discussed in the previous paragraphs, do not provide enough information to show whether or not the mechanical roadworthiness of some of the vehicles on our roads really is a problem.

Although a vehicle is issued with a roadworthiness certificate when it is purchased, these vehicles do deteriorate with use over time. Therefore the owner of the vehicle is responsible for adhering to the road and traffic regulations and ensuring that the vehicle is roadworthy.

However, the owners of vehicles do not always comply with these regulations. A large number of the vehicles using our national roads are not roadworthy and may consequently cause or initiate an accident.

3.4.2 Test procedure

In view of such non-compliance, it was deemed necessary to devise a test for potential mechanical defects so as to inspect in a survey a sample of the vehicles using public roads in Gauteng Province. This roadside survey took about 5-8 minutes, after stopping the vehicle and pulling it off the road. It is necessary to indicate that only passenger vehicles, light commercial vehicles and minibuses were stopped and investigated in these surveys. After finishing the testing of the selected vehicle the next identified vehicle was stopped from the general population. Three different checklists were compiled so that three people could do the actual testing and concentrate on specific parts of the vehicle. The reasons for testing, for thoroughly inspecting the following components and the procedure for testing are explained below:

A. Tyres

- Measure the total vehicle weight and determine axle-loads

  Procedure: Using a reasonably flat part of the road, four individual tyre scales are placed out in a rectangular pattern. After stopping the vehicle it is jacked up to insert the scales under the individual tyres. The vehicle tyre scales are used for obtaining the loads on each tyre. The respective axle-loads can be determined by summating the two rear and the two front loads. Alternatively a weighbridge can be used to determine these values.

  Reason: If the determined value is higher than the total axle-load that the vehicle should carry (obtained from the vehicle manual), the vehicle is overloaded and can cause a deterioration in the vehicle's roadworthiness.

- Determine tyre loads (if possible)

  Procedure: See previous point.

Reason: This will help determine if the vehicle's tyres can carry the vehicle load that they are subjected to. These loads must comply with the standards given in SABS 1550:1992 [Taxi Tyres, 1993].

- Determine tyre size (applicable to vehicle model)

  Procedure: The tyre specifications are usually displayed on the tyre sidewall and can be easily identified. These specifications give an indication of load capacity and speed capability.

  Reason: As in the case of the above, this information is required to make sure that the vehicle complies with Road Traffic Regulations 363 and 369(1)(viii) which give the alternative tyre fittings for a specified maximum rear axle load (see Appendix B) [Taxi Tyres, 1993]. A vehicle fitted with the wrong tyre size may cause an accident because the tyre does not comply with the vehicle's characteristics.

- Measure tyre wear

  Procedure: A tyre wear gauge can be used for accurately measuring the depth of individual tyre grooves. When determining the average tread depth of an individual tyre, the tread depths are measured at three different positions across the width of the tyre (on the two shoulders and in the centre). These values are summated and divided by three.

  Reason: Road Traffic Regulation 347 prohibits using a tyre with a tread depth of less than 1 mm and therefore it is necessary to inspect the tyre to obtain this value [Taxi Tyres, 1993]. Vehicles with little tread depth may cause accidents due to burst tyres, impact deflation and inadequate tread for braking quickly in hazardous conditions, e.g. slippery roads.

- Check if the wheels have all their wheel nuts

  Procedure: Visual inspection of wheels.

  Reason: Although this is not as critical as some of the above points, some cases have indicated that loose or missing wheel nuts could lead to the wheel being shaken loose from the axle.

- Check play of wheel bearings

  Procedure: The vehicle is jacked up to ensure that the tyre is lifted off the ground. Wheel deflection can be felt by placing the hands on the top and bottom of the tyre and applying pressure.

  If the wheel can be deflected, it indicates a definite play on the vehicle's wheel bearings [Remling, 1978].

  Reason: Play on wheel bearings can cause various problems, and is discussed in detail in Chapter 5.

B. Brakes

- Inspect brake pad thickness (if possible)

  Procedure: If possible, the brake pad thickness can be inspected visually.

  Reason: In terms of SABS 47, brakes may not have any metal-to-metal contact. When a vehicle's brakes have worn down to metal-to-metal contact, the braking ability of the vehicle becomes critically impaired. This is even more dangerous in wet weather.

- Inspect brake fluid pipes (as well as brake fluid container)

  Procedure: Visual inspection of the brake lines beneath the vehicle. Critical points such as the entrance to the master cylinder and the individual wheel cylinders should also be inspected. Also inspect behind the wheel hub.

  Reason: A leakage of brake fluid leads to impaired braking and could obviously cause an accident.

- Inspect brake pedal clearance

  Procedure: A definite indication of the clearance of the brake pedal above the floorboard can be measured by depressing the brake pedal.

  Reason: This could also indicate the vehicle's degree of braking ability.

C. Steering mechanism

- Inspect clearance of or play on steering wheel

Procedure: The degree of play on the steering wheel can be determined visually by means of a protractor. The protractor is placed on the steering wheel, and while turning the steering wheel, the protractor is held stationary. This will indicate the degrees of play on the steering wheel before the tyres move.

Reason: This will indicate the vehicle's capacity to respond quickly and accurately when the driver turns the steering wheel. A steering wheel with a large play could therefore be a potential hazard.

- Inspect suspension joints and bushes

  Procedure: Visual inspection beneath the vehicle.

  Reason: Because these joints and bushes work constantly, they tend to age rapidly. Although they are not a serious a problem, lack of maintenance on these parts could lead to discomfort or early failure under extreme working conditions.

From the information obtained in the above tests, it is possible to indicate how many of the investigated vehicles are actually roadworthy and also to identify the potential mechanical defects of the investigated vehicles. It should be stated that this test is done merely for statistical reasons and is not intended to incriminate certain road users.

An effort was made to select a sample of vehicles using a ***Simple Random Sampling*** method where every vehicle in the general population was given an equal chance of being selected. It was further attempted to select vehicles which had traveled 100 000 km and more, and the process of identifying these vehicles has already been discussed in previous paragraphs. For these surveys no specific ***Sample size*** was pre-determined and the samples were drawn from the general population during the time 09:00 to 16:00. The determined dates for these surveys can be seen in the following paragraphs. The selection of the proportion of vehicles for this survey was done considering a 95% level of confidence. The checklists formulated for the purpose of these tests appear in Appendix C.

Once again, due to the amount of information gathered through the PMDT, a database had to be generated. As was the case with the previous database, this one can also be used for investigating certain problem areas (also see CD).

3.4.3 Test findings

For the purpose of the project it was decided that two different traffic regions would be investigated:

- **Suburban area** - With the help of the Centurion Traffic Department, a test station was established on the Old Johannesburg Road. Over a period of three days (15-17 May 1999), 75 randomly selected vehicles were stopped and inspected. In the suburban survey 73% of these vehicles had an odometer reading of 100 000 km and more. The distribution of the type of vehicles inspected can be seen in Figure 3.6. As indicated in the figure the largest percentage of vehicles inspected were passenger vehicles.

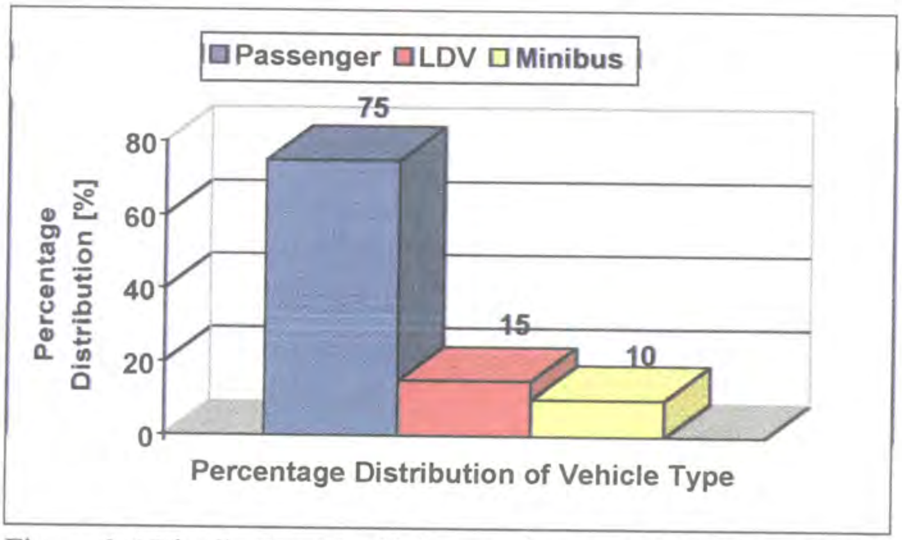


Figure 3.6 Distribution of vehicle types inspected (Suburban area)

For the suburban area the following results were obtained: Figure 3.7 indicates the number of vehicles (75) inspected in the suburban region. It is clear that more than 40% of the tested vehicles had potential mechanical defects.

A potential mechanical defect in a vehicle is defined as a mechanical part, which has reached a certain point in its operational lifetime where it may fail (due to age, fatigue or high working cycles) and cause a mechanical breakdown in the vehicle. Figure 3.8 shows the distribution of defects in the vehicles tested. This figure indicates that vehicle tyres are a problem area.

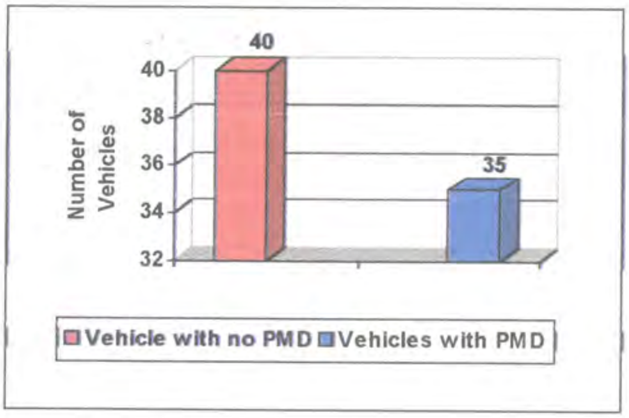


Figure 3.7 Vehicles tested in Centurion for PMD.

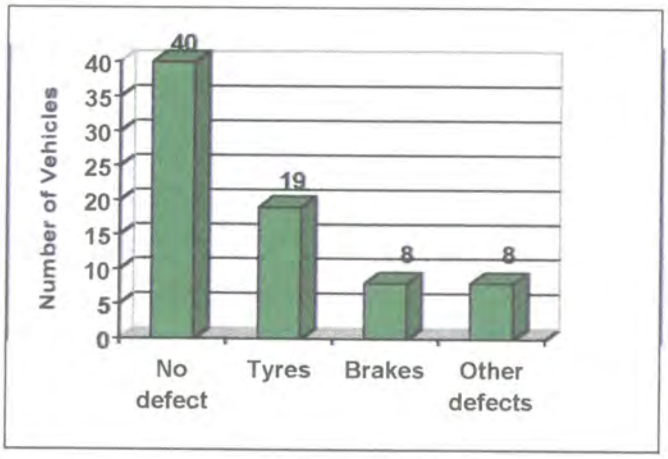


Figure 3.8 Distribution of PMD in tested vehicles

- **Highway area** - The Pietersburg highway (N1) was selected for the purpose of these tests. With the help of the staff of the Mantsolo Traffic Test Station, 82 vehicles were stopped and tested over a period of two days (22-23 April 1999). The findings of this survey were that 92% of these vehicles had odometer readings of 100 000 km and more. The percentage distribution of the type of vehicles inspected on the highway can be seen in Figure 3.9. From this figure it is clear that there was a more even distribution of vehicle types inspected in this region.

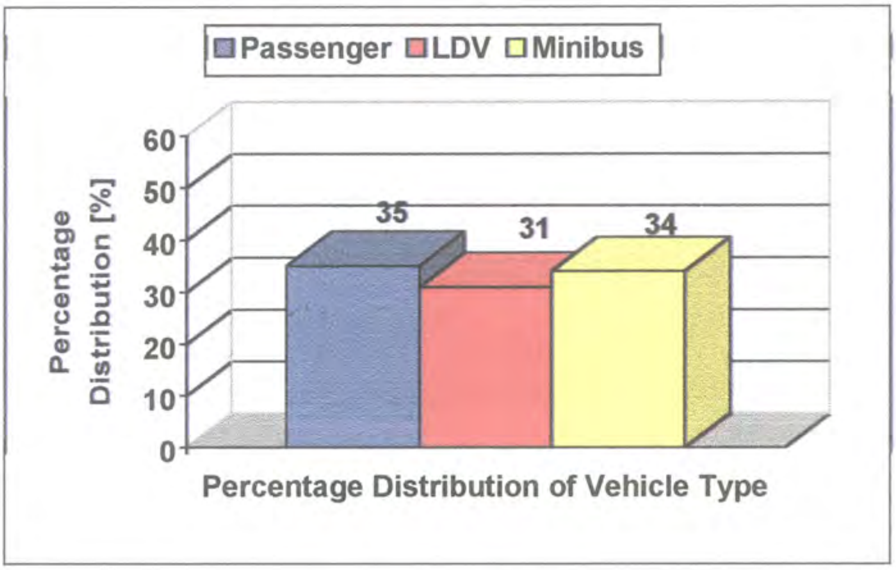


Figure 3.9 Distribution of vehicle types inspected (Highway area)

After doing PMDT on the highway traffic region, the following statistics were obtained: It should again be mentioned that older vehicles were targeted for the above tests, namely vehicles which had an odometer reading of **100 000 km** and more. Figure 3.10 and Figure 3.11 are the same as Figure 3.7 and 3.8 above, but depict the data obtained from testing vehicles on the Pietersburg highway. The trend differs from the trend of the data obtained in the suburban survey.

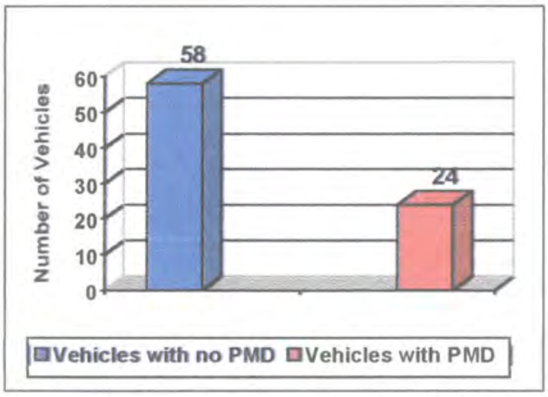


Figure 3.10 Vehicles tested for PMD on the Pietersburg highway

Testing for PMDT in two different traffic environments was done to determine the differences in the characteristics of the vehicles using these routes.

There were distinct differences, since the vehicles tested in the suburban area comprised a larger number of light commercial, company and suburban vehicles. Most of these vehicles travelled short distances.

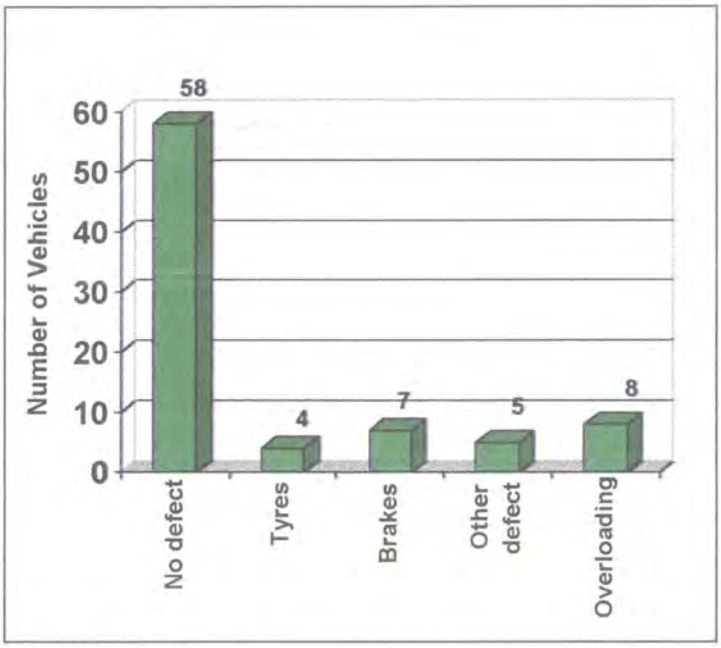


Figure 3.11 Distribution of PMD in tested vehicles

By contrast, the Pietersburg highway had a higher concentration of passenger vehicles and minibuses. These vehicles also travelled longer distances. The findings shown in Figure 3.10 and Figure 3.11 make it possible to draw the following conclusions:

- Of the 82 vehicles inspected, 24 had potential mechanical defects. This indicates that 29,2 % of the vehicles tested were in effect a potential danger on the road.

- When comparing the potential tyre defects of the tested vehicles in the two traffic regions, it is clear that the vehicles using the Pietersburg highway had fewer problems with tyres. The possible reasons are as follows:

- The distances between the origins and destinations of the vehicles tested, are far greater, implying that the vehicle owners tend to maintain their vehicles for fear of breaking down on the highway.

- The traffic test station on the highway may motivate the vehicle owners to ensure that their vehicles are roadworthy for fear of being pulled over and fined.

- Another problem with the inspected vehicles was identified in these tests, namely the overloading of vehicles, especially those in the passenger transport sector. Although most vehicles are designed to allow for occasional overloading, many of the vehicles tested are constantly overloaded for long periods of time. This could lead to the early failure of components because the parts fail prematurely due to fatigue.

3.4.4 Discussion

When investigating the above figures, it is important to realise that although a vehicle undergoes a roadworthiness test before a vehicle licence is issued and the vehicle is registered, many of these vehicles will at some time become unroadworthy. This point has been thoroughly discussed but still seems to be regarded as irrelevant. Although a large number of the inspected vehicles were generally in good condition, the age of the vehicle and the high cost of vehicle maintenance are problems for the owner, so that the vehicle may become a potential mechanical hazard. Data obtained from the above vehicle tests appear in the CD made available for researching these values.

3.5 Minibus (taxi) survey

In view of the data discussed in the preceding paragraph, a decision was taken to investigate the condition of the tyres of vehicles operating in the passenger transport sector. Tyre inflation plays a major role in determining tyre characteristics. Although tyre manufacturers basically stipulate the tyre pressures for various vehicles, there is a tendency to ignore the importance of this factor to vehicle safety. Of the **7 260** fatal accidents on South African roads during 1998, **214** were the direct result of tyre defects.

However, these findings which were obtained from the SAP 352 form, were found to be inaccurate, largely because of the lack of detailed information [Grobbelaar, 1999].

The following data were obtained from ***Expert Services*** (Forensic Engineers), based in Pretoria. These engineers receive a number of vehicle tyres, which must be forensically inspected to determine the cause of failure. The data obtained from inspecting 25% of the tyres in the forensic laboratories are reflected in Figure 3.12, which indicates the details of the tyre defects.

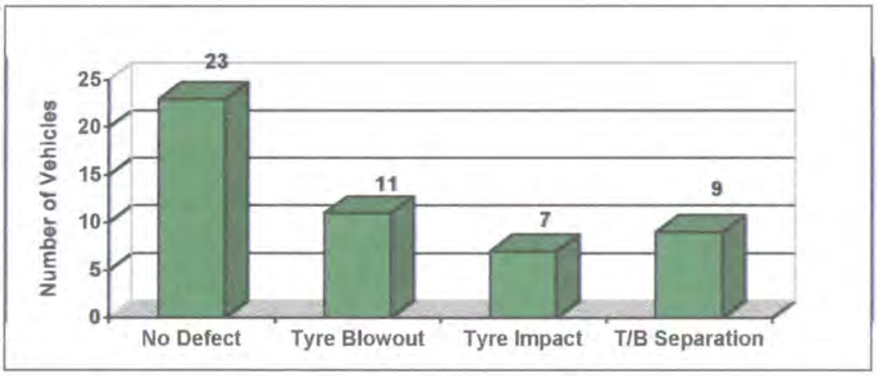


Figure 3.12 Details of defects of inspected tyres.

Of the tyres inspected, 46% showed no defects, but the remaining 54% had caused a vehicle accident. Mechanical defects in 59% of this 54% of tyres had caused vehicle accidents. In Figure 3.12 a tyre blowout indicates either a burst inner tube or a burst tyre. Tyre impact indicates impacts on the tyre sidewall, tread area and shoulder, which make the tyre deflate rapidly. Tyre and Belt (T/B) separation indicates the separation of the tread area from the tyre and should be seen as a tyre defect.

Further data concerning tyre inflation irregularities were obtained by conducting a survey of minibus taxis. The survey was done on minibuses using the Pretoria metropolitan routes. In this survey tyre wear and tyre inflation were measured and yielded the results shown in Table 3.2. Fortunately the data was obtained while the vehicle was still cold and therefore cold tyre inflation pressures could be measured. These would therefore accurately indicate the tyre pressure that the driver had pumped the vehicle's tyres. In Table 3.2 excessive tyre wear indicates a tyre which has an average tread depth of less than 1 mm. Driver-indicated pressure shows the pressure that the driver had used when pumping the vehicle's tyres.

The inflation irregularities indicated in Table 3.2 were determined after considering the driver-indicated pressure.

Table 3.2 List of items checked in minibus (taxi) survey

	Items checked	**% of Cases**
	Number of cases (60 vehicles)	
1.	Current odometer reading	
	0 - 50 000 km	0
	50 000 - 100 000 km	0
	100 000 - 200 000 km	1,67%
	200 000 - 300 000 km	30%
	300 000 - 400 000 km	41,67%
	> 400 000 km	26,67%
2.	Excessive wear on left front tyre	0%
	Excessive wear on right front tyre	1,67%
	Excessive wear on left rear tyre	3,3%
	Excessive wear on right rear tyre	3,3%
3.	Correct inflation: driver-indicated	
	Left front tyre	28,33%
	Right front tyre	25%
	Left rear tyre	26,67%
	Right rear tyre	40%
4.	Over-inflation: driver-indicated	
	Left front tyre	18,33%
	Right front tyre	16,67%
	Left rear tyre	15%
	Right rear tyre	13,33%
5.	Under-inflation: driver-indicated	
	Left front tyre	53,33%
	Right front tyre	58,33%
	Left rear tyre	56,67
	Right rear tyre	46,67

In other words, if drivers indicated they inflated their vehicles' tyres to a pressure of 300 kPa and values measured were lower than the indicated values; the tyres were regarded as being under-inflated. The observation regarding irregularities in tyre inflation is noteworthy.

Under-inflation is probably the greatest concern nowadays and the vehicles tested showed an average of approximately 50% of the required pressure in all the vehicle tyres inspected (pressure gauge had an absolute confidence interval of less than 10 kPa). Another problem with the age of the vehicles is also worth mentioning. More than 50% of the vehicles inspected had an odometer reading of more than 300 000 km. Although only 60 vehicles were inspected, it was striking that approximately 18 000 of these minibuses operate from the Pretoria region, i.e. 31,6% of all the heavy passenger vehicles (carrying 12 or more passengers) registered in Gauteng [Natis News, 1998].

Figures 3.13 to 3.16 include tyre wear and tyre inflation details of both the front and rear tyres. Figures 3.13 and 3.14 indicate the average tyre wear measured for the front and rear tyres respectively. Only one right front tyre had the minimum permissible 1 mm tread depth measured on the tread depth indicator, but it is interesting to note that 3,3% of the left front tyres and 8,33% of the right front tyres of the inspected vehicles had a tread depth of 2 mm or less.

The rear tyres presented a similar picture. Small percentages of the left and right rear tyres had a tread of just on or less than the minimum permissible depth. Furthermore 15% of the left rear tyres and 16,6% of the right rear tyres had a 2 mm or less tread depth. These tyres were very close to the minimum permissible tread depth.

Figures 3.15 and 3.16 indicate the tyre pressures measured during the minibus (taxi) survey. For minibuses the correct pressure for the front tyre is approximately 300 kPa and for the rear tyres, between 375 kPa and 520 kPa [Taxi Tyres, 1993]. Not indicated in Figure 3.15 is that the left and right front tyres showed an average tyre pressure of 275 kPa and 270 kPa respectively.

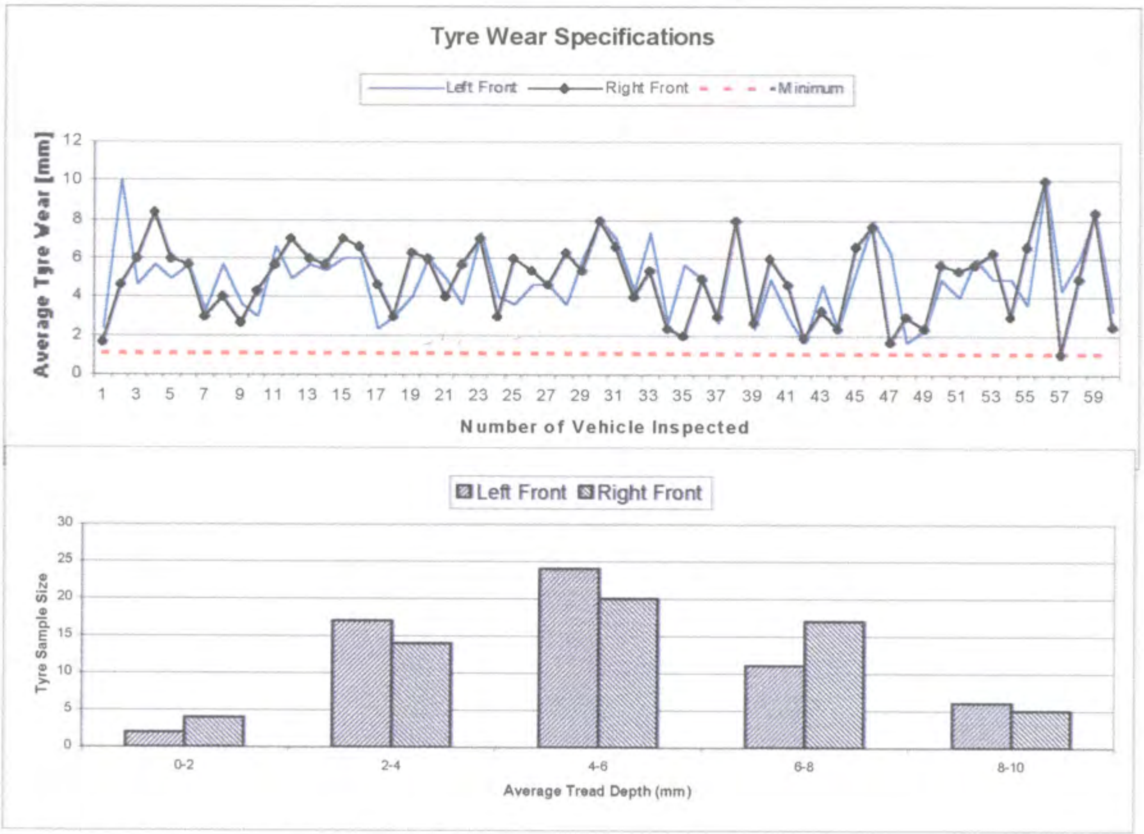


Figure 3.13 Tyre tread depth detail for front tyres

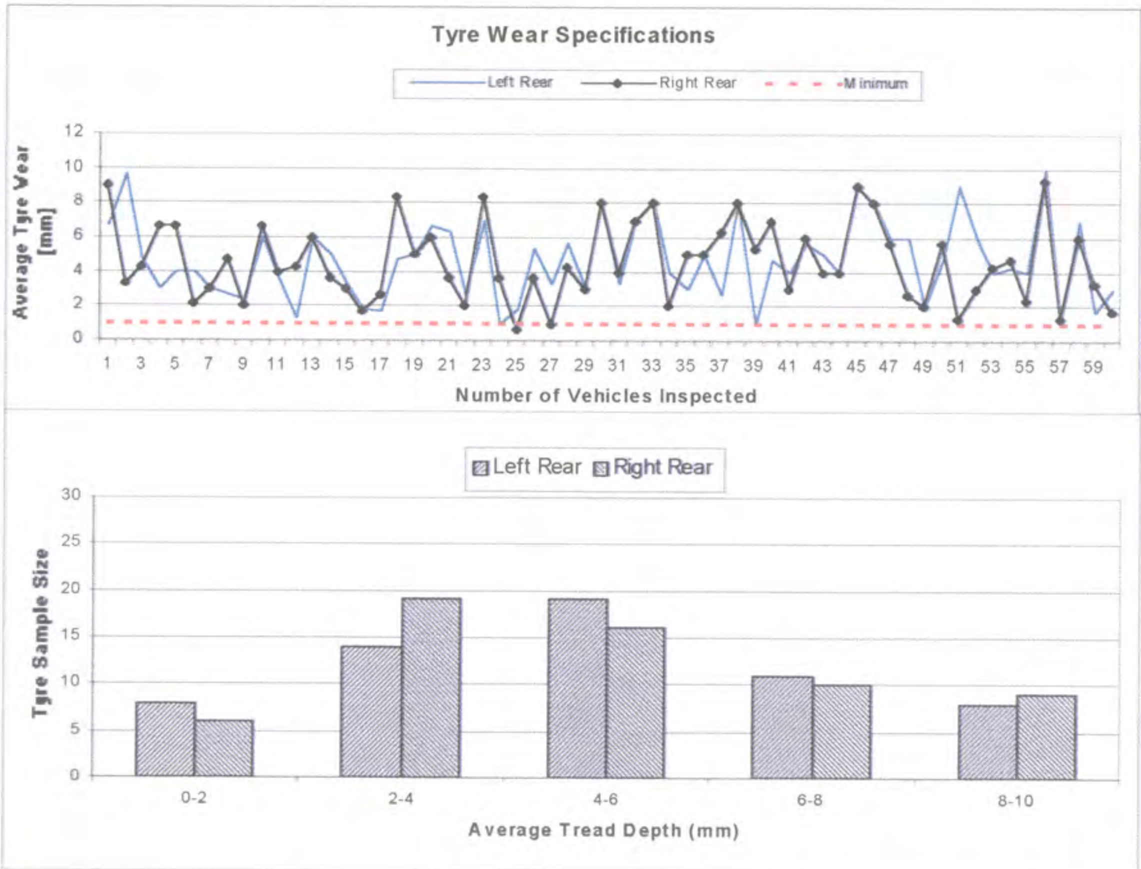


Figure 3.14 Tyre tread depth detail for rear tyres

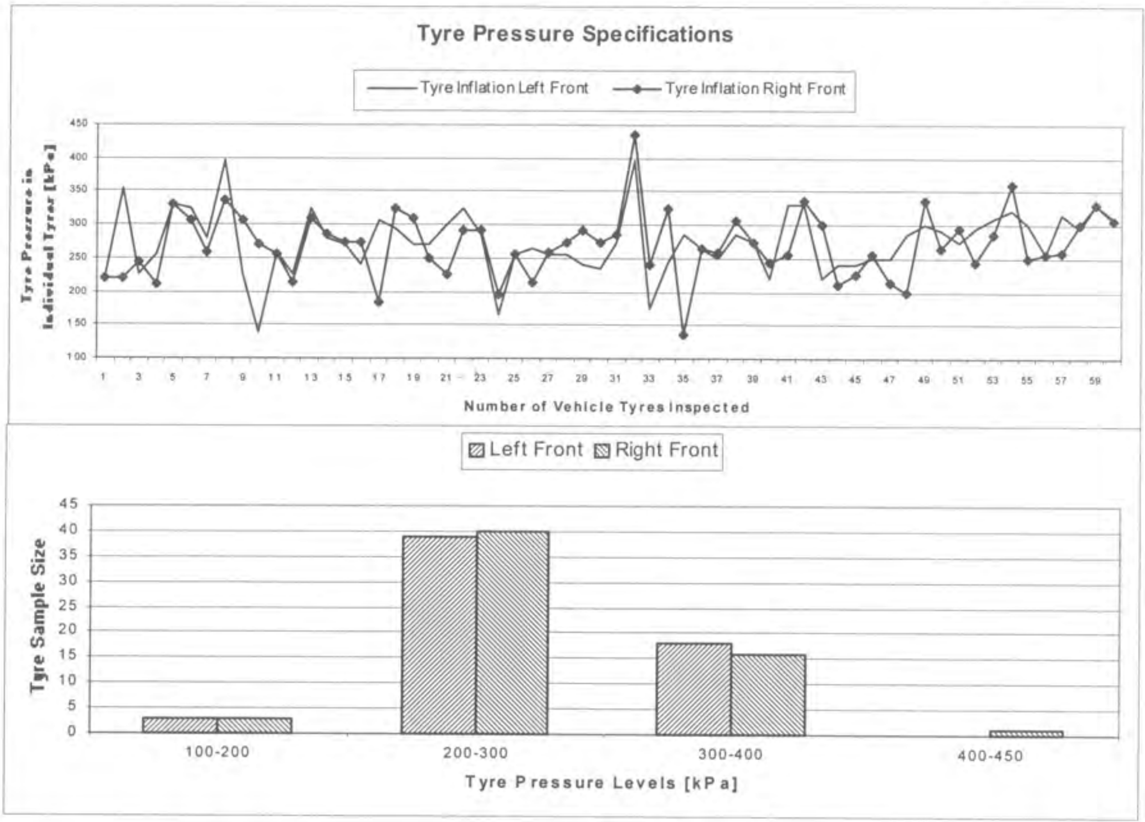


Figure 3.15 Tyre pressure details for front tyres.

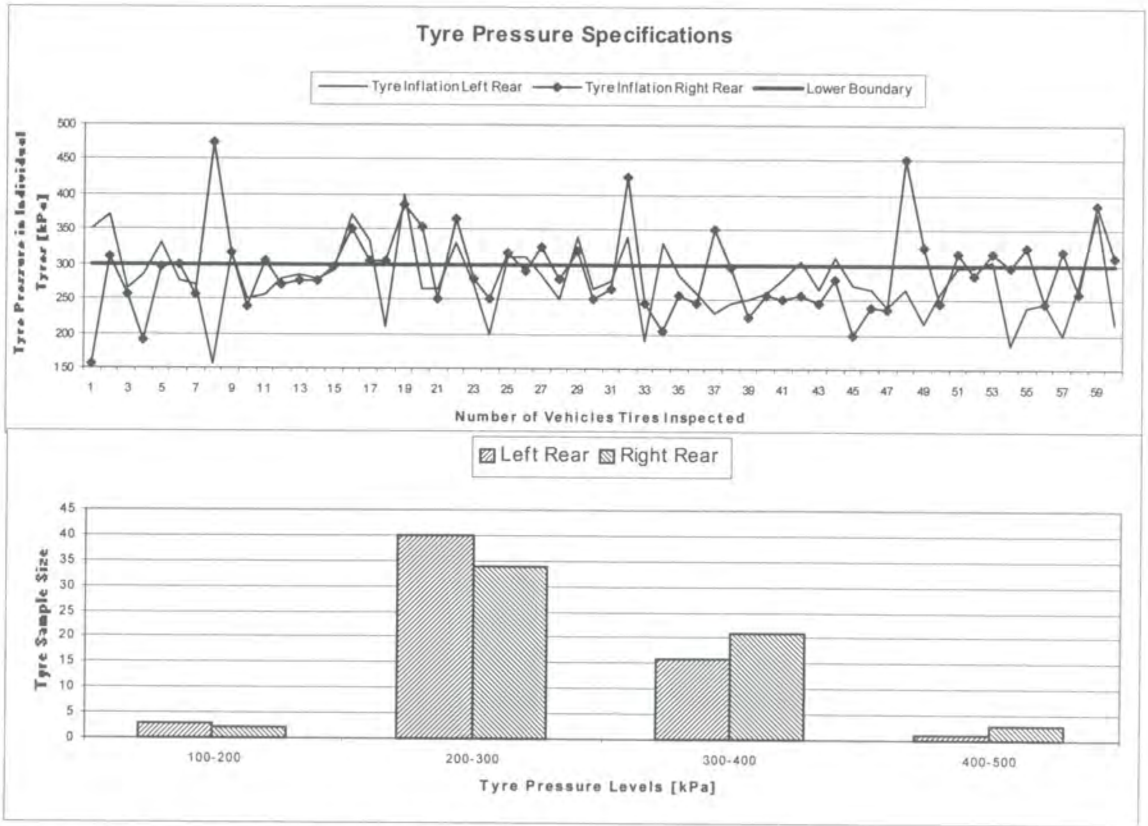


Figure 3.16 Tyre pressure details for rear tyres.

When taking a 20% variation[2] on the recommended 300 kPa front tyre pressure, it is clear that the calculated average pressure values fall within this range. It is interesting to note that 2,5% of the inspected front tyres had a pressure higher than the upper limit of this range and 19% of the front tyres had a pressure below the lower limit of this range. It should be noted that it is more acceptable to have a vehicle's tyres pumped to a pressure higher than the upper limit than for the tyres to be under-inflated.

Figure 3.16 indicates the 20% lower limit of 300 kPa on the recommended rear tyre pressure of 375 kPa. The upper limit is not shown because it is necessary to indicate the following: the average rear tyre pressures calculated were 277 kPa and 289 kPa for left and right tyres respectively. As there is an absolute confidence interval of less than 10 kPa on the pressure gauge, it is clear that both these averages are less than the minimum limit of the recommended pressure in the rear tyres. Both these values indicate that under-inflation of tyres is a far more serious problem in these vehicles. 68% of the left rear tyres and 53% of the right rear tyres of the vehicles inspected were below this limit.

Further details showed that 50% of the inspected vehicles had two or more different makes of tyres fitted on their vehicle and that 18,3% of the vehicles had differing tyre sizes on the left and right side of the vehicle. For example, one vehicle in the survey had a Dunlop SP LT3 195 R14C on the right front wheel of the vehicle, and a Continental 185 R14C on the left front wheel of the vehicle. These disparities will eventually result in extreme tyre wear patterns as well as problems with the vehicle's handling (the vehicle tends to swerve to one side of the road). In view of the findings, the following points should be discussed:

- A large number of the minibuses inspected had odometer readings of more than 300 000 km.
- Irregular inflation was found to be a major problem and the consequences of these irregularities will be discussed in Chapter 5.
- Tyre wear specifications were not as bad as had been anticipated.

[2] Indicated by tyre manufacturers as effective pressure limits for safe usage.

However, it should be remembered that it takes only one defective tyre to cause an accident.

- The questionnaire formulated for the minibus (taxi) survey appears in Appendix D, also see the CD formulated, containing information regarding the data obtained.

CHAPTER FOUR

POTENTIAL MECHANICAL DEFECTS

4. Potential Mechanical Defects (PMD)

4.1 Scope

This chapter focuses on the following points concerning PMD:

- Combining accident statistics obtained at the ARU and statistics from the PMDT.
- A short discussion on the differences in the statistics derived from the two road regions on which vehicles were tested.
- Analysing the above information and identifying possible problem areas.

4.2 Statistical analysis

The statistics obtained from the ARU indicate that defective brakes and tyres were the most common mechanical factors contributing to accidents in the Pretoria region (see Figure 3.3). It should be mentioned again that these accidents only involved the culpable homicide cases inspected by this unit. The data obtained showed that an average of 1,44% of the accidents per year related to brakes, while an average of 1,37% per year were related to tyre failures. Although these values are fairly low, they do indicate that there seems to be a problem with mechanical defects causing vehicle accidents. By analysing the data obtained in the PMDT, the following values were obtained: (see Figure 4.1 below)

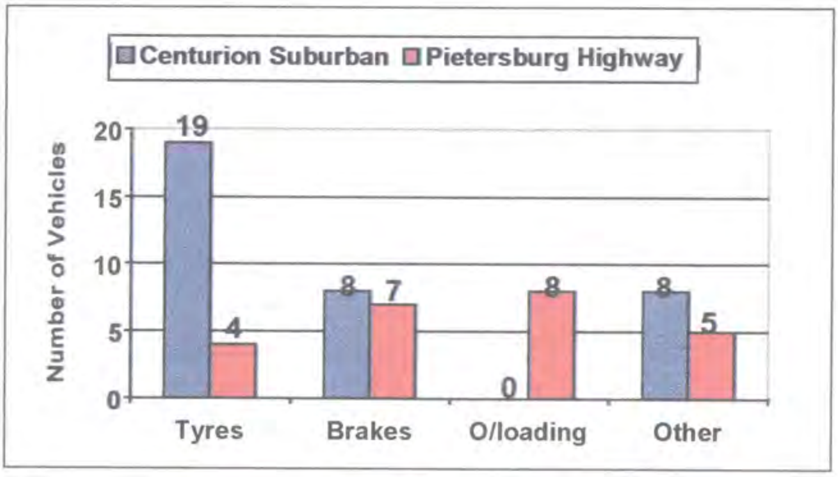


Figure 4.1 Indication of PMD – vehicles inspected in two different regions.

Considering the above figure it is again necessary to indicate that 75 vehicles were inspected in the suburban area and 82 vehicles were inspected on the highway. From the figure it is clear that there was a high incidence of tyre and brake defects. A further point worth noting is the different variables affecting the above statistics. Let us, for example discuss the tyre data in Figure 4.1. In the suburban region, 25,3% of the motor vehicles tested had insufficient tread in terms of Road Traffic Regulation 347 [Taxi Tyres, 1993]. By contrast, only 4,9% of the vehicles using the highway did not comply with this regulation. It should be noted that the above percentages are representative of the vehicles targeted in the PMDT that had an odometer indicating 100 000 km or more.

Brakes comprised 10,67% of the defects found in vehicles inspected in the suburban region and 8,54% in those inspected on the highway. These defects are categorised as follows:

- Insufficient brake-pedal pressure
- Serious leakage of brake fluid (empty brake-fluid reservoir).
- No brakes and hand-brake (visually determined defects, due to the brakes not being tested while driving the vehicle).

The other defects consisted of play on wheel bearings, defective suspension and steering mechanism as shown in the following findings:

<u>Suburban region</u>

- Wheel-bearing play - 8%
- Defective suspension - 1,33%
- Defective steering mechanism - 1,33%

<u>Highway region</u>

- Wheel-bearing play - 4,87%
- Defective suspension - 0,0%
- Defective steering mechanism - 1,2%

Another point that should be mentioned is the difference in the statistics for the overloading of the vehicles inspected. It is clear that vehicles using the highway had a greater tendency to overload than those using the suburban routes did.

Unfortunately the public transport services are at risk here. It should be mentioned that according to SABS 1550:1992; an average weight of 63-75 kg could be applied per passenger conveyed in the vehicle. Road Traffic Regulation 369(1)(viii) requires that the minibus shall have a plate affixed to it, containing the permissible front and rear axle massload (denoted as 'A-rating') [Taxi Tyres, 1993]. Of the 82 vehicles inspected on the highway, 9,75% were overloaded and did not comply with the specified maximum axle massloads specified in the above regulation. On many of these vehicles the permissible loads were not even displayed. The result of overloading will be discussed later in this project.

4.3 Review of findings

The above statistics clearly indicate the difference in the data obtained in the suburban region and the data obtained on the highway. Possible reasons for this difference, as regards the highway data, may be –

- because traffic officers constantly pull vehicles over and inspect them at the weighbridge (Mantsolo) on the Pietersburg highway, vehicle owners who use this route are compelled to maintain their vehicles in accordance with the applicable road and traffic regulations;
- furthermore, since these vehicles travel fairly long distances on each trip, it is necessary for the vehicle owners to maintain their vehicle in correct condition to avoid breakdowns on the highway.

As regards the suburban region, the data obtained indicate that vehicle owners tend to neglect the maintenance of their vehicles. Possible reasons for this may be –

- they travel shorter distances;
- as a large number of commercial (company) vehicles use these routes and work according to a tight schedule, drivers tend to neglect maintaining the vehicles in accordance with the specific regulations;
- as there is less law enforcement on suburban routes, vehicles on these routes are not subjected to regular random inspections by traffic officers, and this may be a reason that owners tend to neglect proper maintenance of these vehicles.

Most of the inspected vehicles were in a good condition, but the implications of the indicated potential defects are not taken seriously. The following statistical approximations concerning the data obtained from the PMDT can now be made.

4.4 Statistical representation

4.4.1 Chi-squared test

When considering the data obtained on the vehicles investigated in the suburban and highway regions, the influences PMD have on the vehicle components will be discussed in the following paragraphs. For the purpose of this discussion the following PMD will be discussed and their effects weighed up against one another:

- Tyre tread depth against wheel-bearing play
- Tyre tread depth against suspension condition.

For example, tyre tread depth may display a severe loss of tread depth on one side of the tyre surface, which may be due to a combination of factors such as poor wheel-balancing, tyre inflation problems and wheel-bearing play. Consequently it was deemed necessary to investigate these characteristics and if possible identify possible trends.

With the help of the Statistics Department at the University of Pretoria, the above points were evaluated as follows:

- Tyre treads were divided into three categories:
  - $x \leq 3$ where x is the average tread depth of the four tyres on the vehicle
  - $3 < x \leq 5$
  - $x \geq 5$ which obviously indicates new tyres.

- The wheel-bearing play and suspension condition are divided into three categories according to the following:
  - **Good / Very good,** indicating no defect in the investigated component.
  - **Average**
  - **Bad / Very bad,** indicating a large play in the wheel bearings and a suspension with no rubbers and in an overall defective condition.

Figures 4.2 and 4.3 are based upon the above information obtained in the Centurion suburban region and Figures 4.4 and 4.5 give the information gathered on the Pietersburg highway. By means of the chi-squared method incorporated into the SAS database used by the Statistics Department (University of Pretoria), Figures 4.2 to 4.5 were evaluated and the statistical independence of each cell in relation to the others was established [SAS Institute, 1989].

Because the purpose of sampling is to gain information about the nature or distribution of elements in a particular population, it is necessary to determine the independence of each of these elements. Unfortunately the independence of each cell, indicated in the above-mentioned figures, could not be effectively determined as only a limited number of vehicles had been inspected (the sample in the survey was too small). The program used, indicated that some of the cells had expected counts of less than five items and this would invalidate the chi-squared method. The output from the program and statistical definitions appear in Appendix E.

Nonetheless the above figures do indicate certain problems and these will be discussed in the following paragraphs. Figure 4.2 (Tyre tread against wheel-bearing play) indicates, in the Bad / Very Bad category, that the tread depth of vehicle tyres is diminishing in a trend that is rising toward a worst-case scenario, namely a vehicle with four tyres with an average tread depth of less than 3 mm and a wheel-bearing play exceeding the permissible limit.

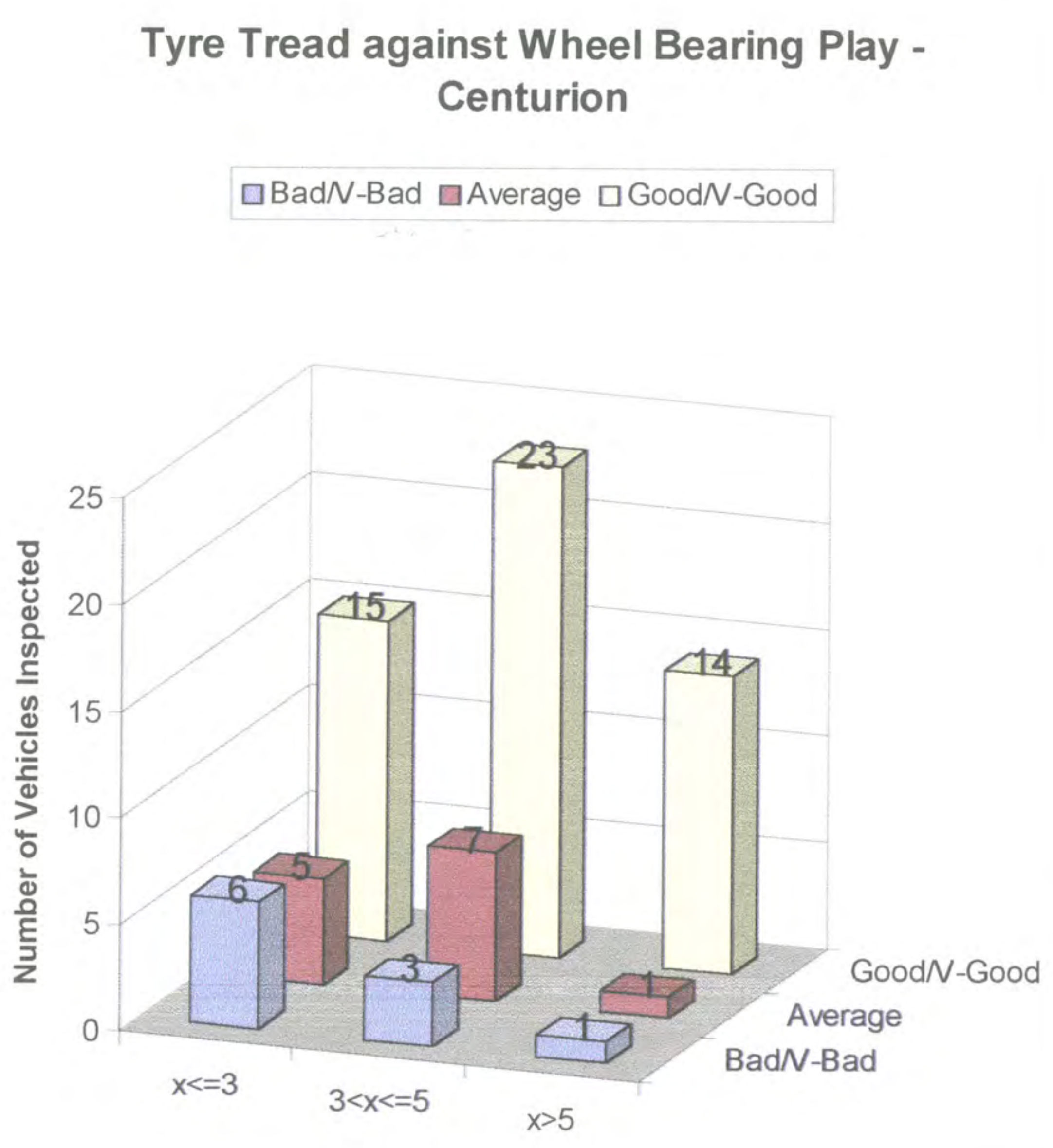
The Average and Good / Very Good category indicates an approximately normal distribution over the tread depth categories, with a growing trend in the number of vehicles moving from the Bad / Very Bad to Good / Very Good category.

In the tread depth categories, the majority of the vehicles inspected (33) fall into the $3 < x \leq 5$ category. A cause for concern is the large proportion of vehicles (26) in the tread depth category $x \leq 3$. Another problem is that 23,1% of these vehicles fall into the category for Bad / Very Bad wheel-bearing play. Furthermore these vehicles represent 8% of the vehicles investigated in this specific category. Therefore this does imply that many vehicles with a certain number of potential mechanical defects may be using the roads.

Figure 4.3 indicates a more even distribution for the categories for suspension condition, although there is still an upward trend to the worst-case scenario in the Bad / Very Bad category of tyre tread depth. Fortunately the condition of a vehicle's suspension is not as critical as wheel-bearing play, but should still be investigated to ensure the correct maintenance of the vehicle as a whole.

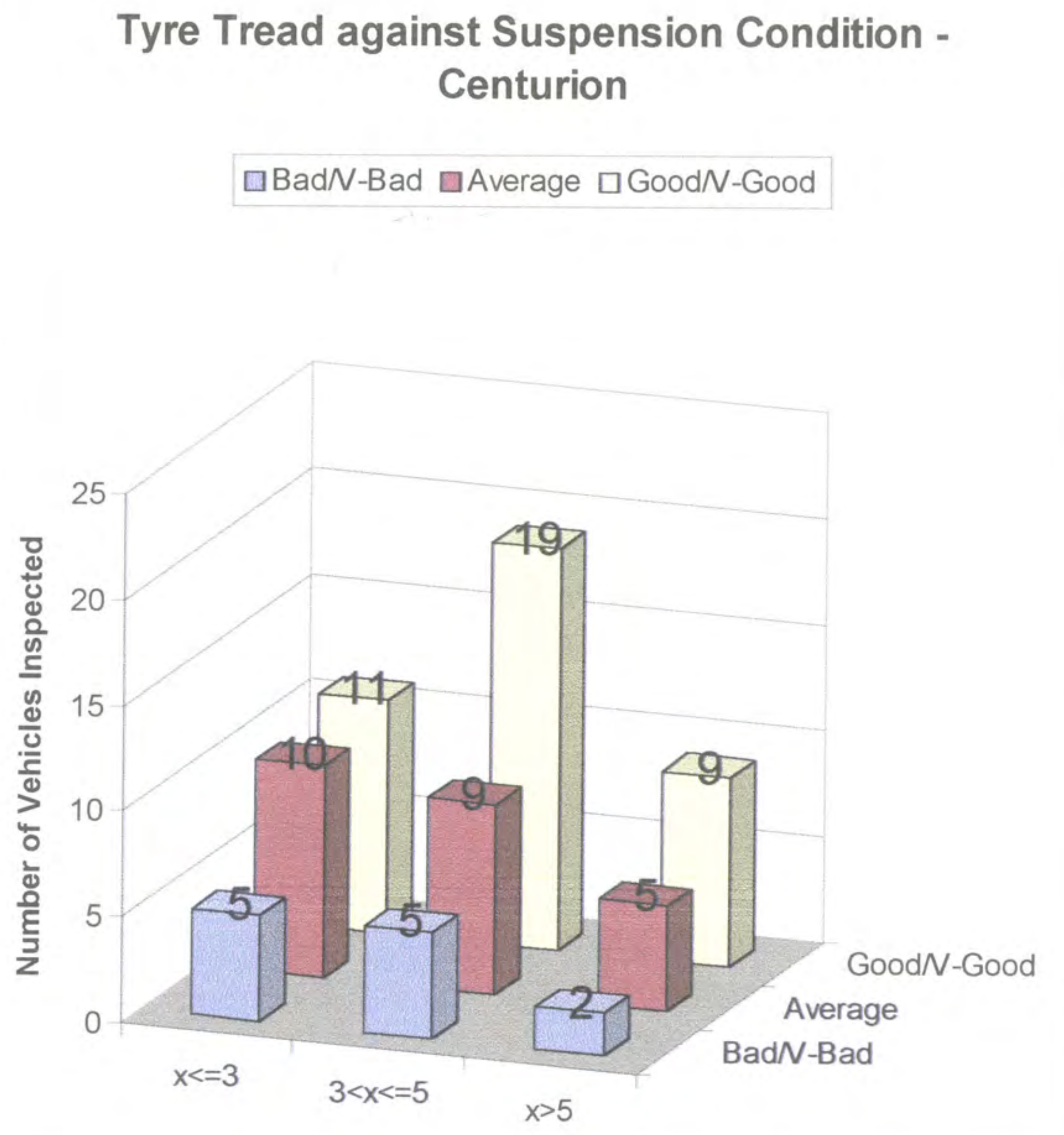
Figure 4.4 (Tyre tread against wheel-bearing play), indicating the tests done on the Pietersburg highway, shows a different trend from that of the tests done on the Old Johannesburg Road in the Centurion suburban region. A larger number of the vehicles inspected were distributed in the categories for $3 < x \leq 5$ to $x > 5$ and Average to Good / Very Good. However, 17% of the tested vehicles had a tread depth of less than 3 mm.

Figure 4.5 indicates a result similar to that shown in Figure 4.4. These figures clearly indicate that the vehicles tested on the highway were in a better overall mechanical condition than the vehicles in the suburban region.



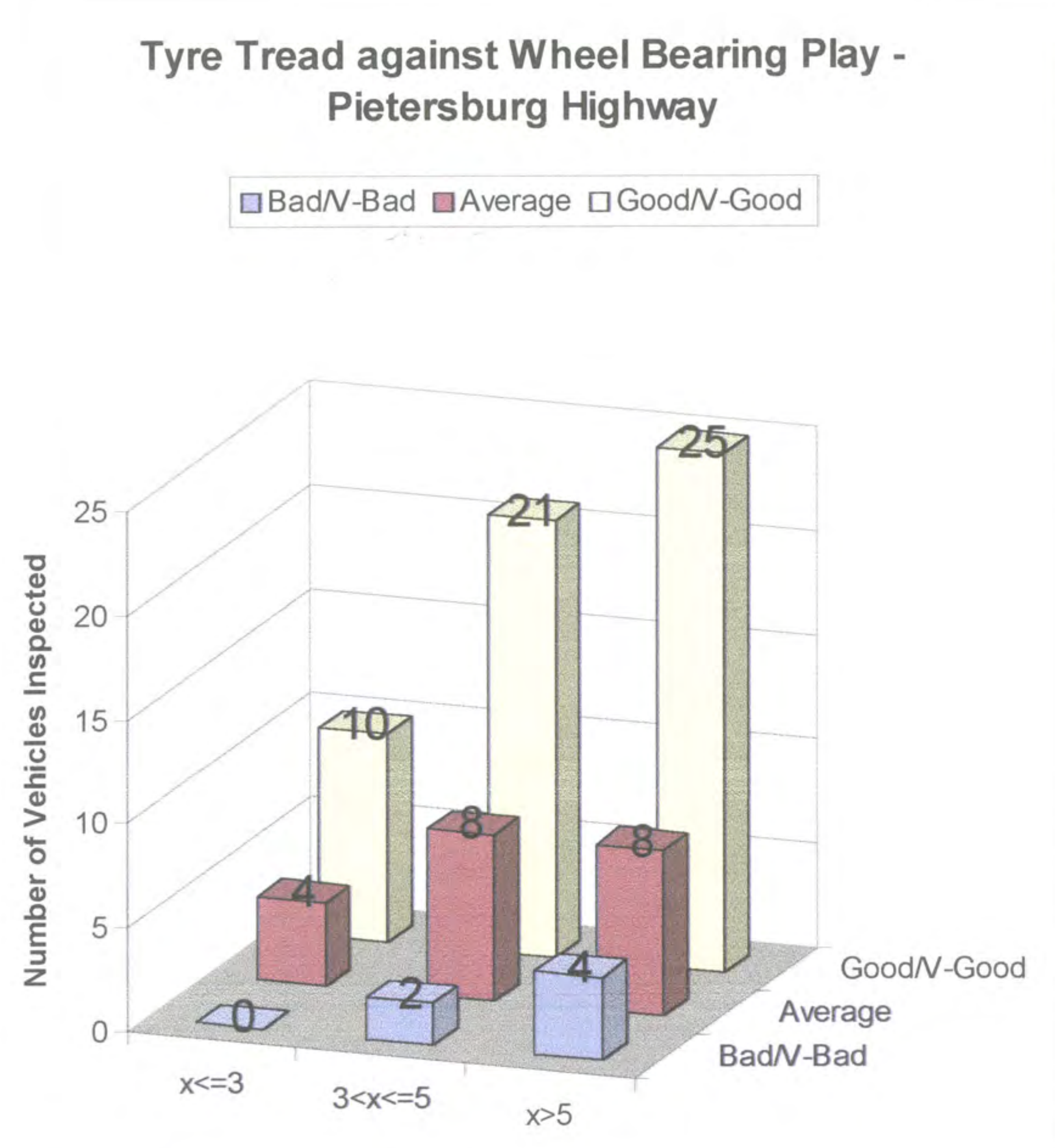
	x<=3	3<x<=5	x>5
Bad/V-Bad	6	3	1
Average	5	7	1
Good/V-Good	15	23	14

Figure 4.2 Data obtained in Centurion on the Old Johannesburg Road (Tyre tread/ wheel bearing play)



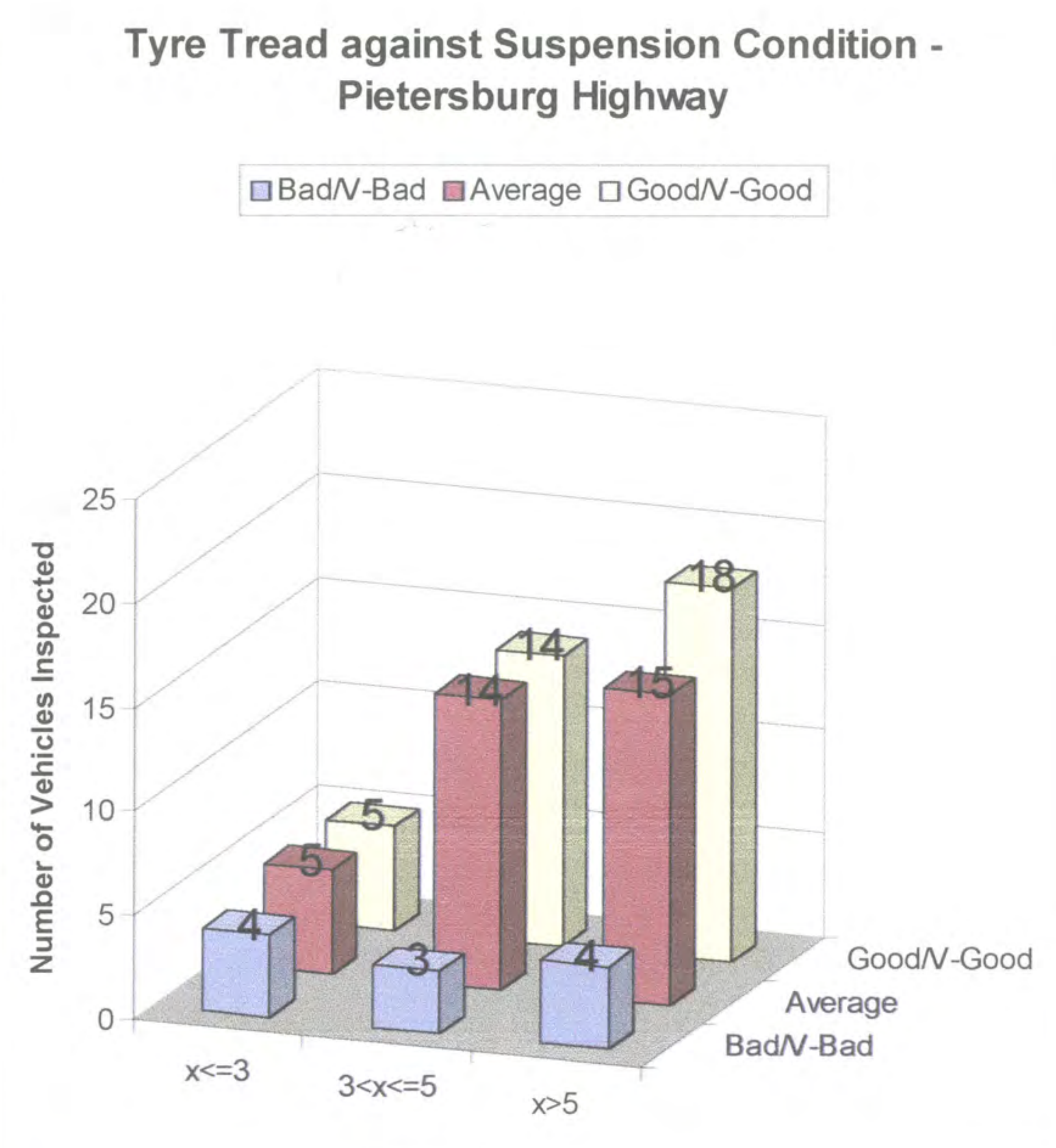
	x<=3	3<x<=5	x>5
Bad/V-Bad	5	5	2
Average	10	9	5
Good/V-Good	11	19	9

Figure 4.3 Data obtained in Centurion on the Old Johannesburg Road (Tyre tread/suspension)



	x<=3	3<x<=5	x>5
Bad/V-Bad	0	2	4
Average	4	8	8
Good/V-Good	10	21	25

Figure 4.4 Data obtained on the Pietersburg highway (Tyre tread/wheel bearing play)



	x<=3	3<x<=5	x>5
Bad/V-Bad	4	3	4
Average	5	14	15
Good/V-Good	5	14	18

Figure 4.5 Data obtained on the Pietersburg highway (Tyre tread/suspension)

4.4.2 Binomial distribution

Using the Binomial Probability Distribution the exceedance probability (p) for comparing certain category frequencies in the above figures can be determined [Cumulative Binomial Probability, 1955]. For the purpose of this investigation the exceedance probability indicates the significance of more vehicles in the PMDT that are correct and therefore lie in the combined average to good / very good categories than those vehicles not complying with the permissible regulations.

Contingency Tables 4.1 to 4.4 give the distribution of vehicles to categories such as suspension condition/wheel bearing play to different tyre tread depths. See Appendix E for statistical definition of binomial distribution. The statistical calculations are as follows:

Findings for the suburban region (Centurion) the results are:

Table 4.1 Tyre tread against suspension condition - Centurion (x = mean)

Tread Depth (mm) →	**$x \leq 3$**	**$3 < x \leq 5$**	**$x > 5$**
↓ *Suspension Condition*			
Bad / Very Bad	5	5	2
Average	10	9	5
Good / Very Good	11	19	9

Because most vehicles are expected to fall in the average to good / very good category these frequencies are compared against the bad / very bad category. This modeling will be undertaken for each column of the tyre tread depth.

For: $x \leq 3$	$3 < x \leq 5$	$x > 5$
21/26 vs. 5/26	28/33 vs. 5/33	14/16 vs. 2/16

In other words the proportion is 5/26, this indicates that 5 vehicles out of 26 inspected units do not comply with the suspension conditions identified in this study, for $x \leq 3$ tread depth category.

The following values are determined:

$p = 0{,}001 \leq 0{,}05$ $p = 0{,}000 \leq 0{,}05$ $p = 0{,}002 \leq 0{,}05$

where $\leq 0{,}05$ meaning : 1 - 0,05 = 95% confidence in statistical result.

The exceedance probabilities (p), are determined by means of statistical tables testing for example, the hypothesis that 50% of the inspected suspensions are in the average to good / very good category. For the above three categories a p-value of less than 5% was obtained which indicates that all the proportions are significantly different, indicating that there are more vehicles complying with road and traffic regulations regarding suspension condition for all the tread depth categories.

Table 4.2 Tyre tread against wheel bearing play - Centurion (x = mean)

Tread Depth (mm) →	$x \leq 3$	$3 < x \leq 5$	$x > 5$
↓ *Wheel Bearing Play*			
Bad / Very Bad	5	5	2
Average	10	9	5
Good / Very Good	11	19	9

For: $x \leq 3$ $3 < x \leq 5$ $x > 5$

20/26 vs. 6/26 30/33 vs. 3/33 15/16 vs. 1/16

$p = 0{,}004 \leq 0{,}05$ $p = 0{,}000 \leq 0{,}05$ $p = 0.000 \leq 0{,}05$

As it was the case with Table 4.1, the p-values are all below the 5% level and therefore significantly more of the wheel bearing play cases are in the average to good / very good category as opposed to the bad / very bad category. This is the case for all the tread depth categories.

Findings for the Pietersburg highway region the results are:

Table 4.3 Tyre tread against suspension condition - Pietersburg highway (x = mean)

Tread Depth (mm) →	**x ≤ 3**	**3 < x ≤ 5**	**x > 5**
↓ *Suspension Condition*			
Bad / Very Bad	4	3	4
Average	5	14	15
Good / Very Good	5	14	18

For: x ≤ 3	3 < x ≤ 5	x > 5
10/14 vs. 4/14	28/31 vs. 3/31	33/37 vs. 4/37
p = 0,0898 > 0,05	p = 0,000≤ 0,05	p = 0,000≤ 0,05

As we can see from the above results, p = 0,0898 is the only one not significant less than the 5% level. This in effect means that there were more vehicles in the average tyre tread depth column x ≤ 3, falling between the bad / very bad category than was expected. In other words, considering the column referred to, it is clear that from the 14 vehicles found here, there are a higher number of vehicles having PMD than expected when compared to the other tread depth categories.

Table 4.4 Tyre tread against wheel bearing play - Pietersburg highway (x = mean)

Tread Depth (mm) →	**x ≤ 3**	**3 < x ≤ 5**	**x > 5**
↓ *Wheel Bearing Play*			
Bad / Very Bad	0	2	4
Average	4	8	8
Good / Very Good	10	21	25

For: $x \leq 3$	$3 < x \leq 5$	$x > 5$
14/14 vs. 0/14	29/31 vs. 2/31	33/37 vs. 4/37
$p = 0{,}000 \leq 0{,}05$	$p = 0{,}000 \leq 0{,}05$	$p = 0{,}000 \leq 0{,}05$

All the above p-values are significant.

Considering the above it is clear that a large number of vehicles actually comply with the applied road and traffic regulations. However there are a small percentage of these vehicles not adhering to the regulations and are unfortunately seen as potential hazardous vehicles.

4.5 Discussion

Unfortunately it was not possible to indicate how representative the data were that had been obtained in the PMDT of vehicles in the suburban region. In other words, the number of vehicles inspected did not represent all the vehicles using that particular route.

This makes it difficult to generalise the findings to indicate if there are problem areas concerning these vehicles. Fortunately, the data concerning the number of vehicles using the Pietersburg highway could be obtained from **Mikros Systems**. This company uses traffic-counting equipment to monitor the number of vehicles using national roads in South Africa. Figure 4.6 shows the number of vehicles passing the test station in relation to the PMDT done on 22 and 23 April 1999 [Vehicle Counting Data, 1999]. Testing on 22 April took place from 10:00 to 16:00 and in total 50 vehicles were inspected in the PMDT. Testing on 23 April took place from 10:00 to 13:00 and 32 vehicles were inspected.

Figure 4.6 indicates that the PMDT accounts for 3,75% of the number of vehicles using the highway per hour on 22 April, between the indicated hour intervals when testing took place, and 2,54% of the vehicles using the highway on 23 April 1999.

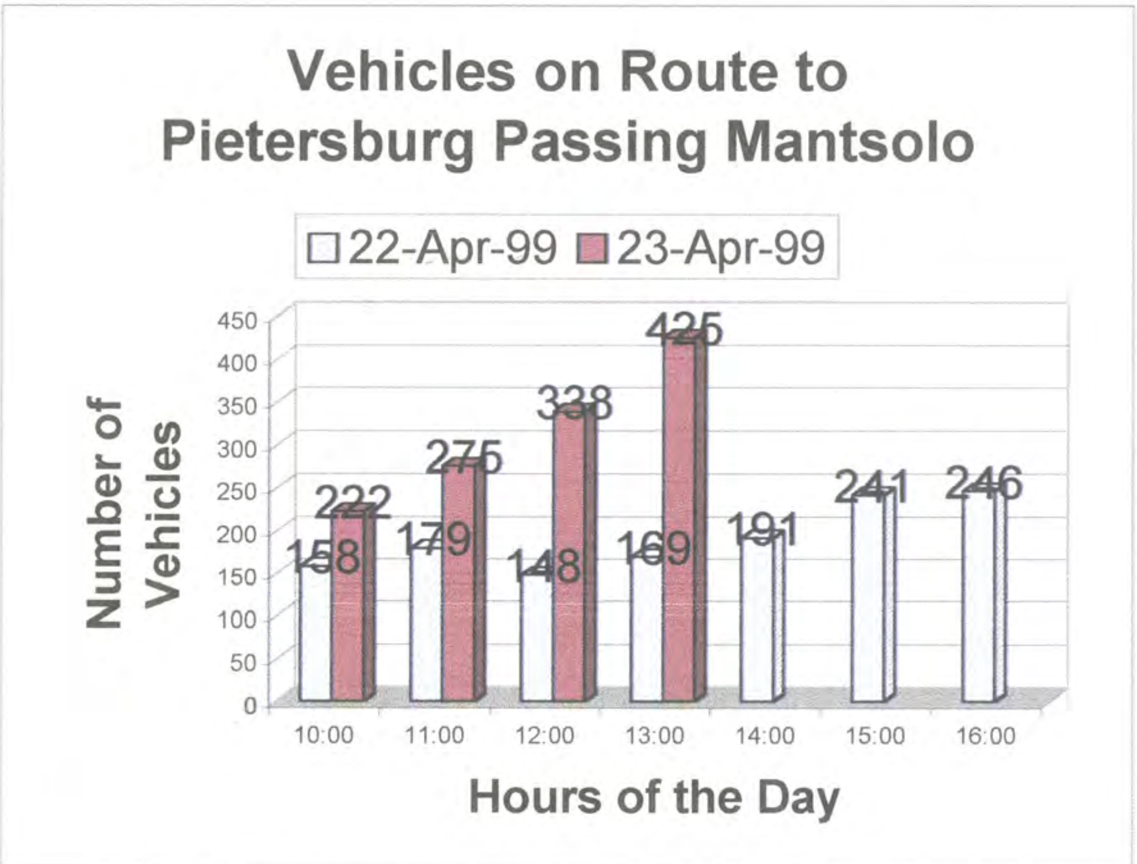


Figure 4.6 Number of vehicles using the Pietersburg highway (22-23 April 1999)

Chapter 3 indicates that 24 vehicles out of the 82 vehicles inspected had a PMD. This in effect shows that 0,93% of the vehicles using the highway on the designated two days had a PMD. Possible reasons for this value being low:

- The small number of vehicles tested during the two days
- The data on the number of vehicles per hour represent all the vehicles traveling past the test station, not solely the light motor and passenger vehicles selected for testing
- The overall condition of the vehicles was satisfactory.

Although these values are low, certain important factors concerning PMD were identified and should be noted. It should be mentioned that there is a difference in the statistics discussed in this chapter.

Firstly the information obtained from the ARU is based upon actual accidents and is therefore accurate and definite information. The information obtained from the PMDT consists of a technical identification of potential defects that may be present in the specific inspected vehicle. It cannot be predicted whether any of these identified vehicles could indeed cause an accident and they should simply be regarded as a potential hazard on the road.

Chapter 5 discusses the various potential mechanical defects in detail. The implications of the defect and to what extent it should be ignored is also indicated.

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CHAPTER FIVE

VEHICLE SAFETY

5.1 Scope

5.2 Vehicle safety in traffic

5.3 The impact of Potential Mechanical Defects

5.3.1 Tyres

5.3.2 Brakes

5.3.3 Wheel bearings

5. Vehicle safety

5.1 Scope

This chapter focuses on the following:

- A short discussion of vehicle safety
- A discussion of potential mechanical defects and the possible implications of these defects for the roadworthiness of vehicles.

5.2 Vehicle safety

The automobile, or horseless carriage as it was originally known, appeared at the end of the nineteenth century, approximately a hundred years ago, as a direct consequence of the invention and availability of suitable internal combustion engines [Dixon, 1996]. Unfortunately, as was the case with any other powered system, the safety of the vehicle was a great problem even in those days. Vehicle safety can currently be divided into the following two categories:

- Active safety
- Passive safety.

Active safety

- **Driving safety** is the result of the harmonious suspension design of the vehicle in terms of wheel suspension, springing, steering and braking, and is reflected in optimum dynamic vehicle behaviour.
- **Conditional safety** results from minimising to as low a level as possible the physiological stress of vibration, noise and climatic conditions on the occupants of the vehicle.
- **Perceptual safety** concentrates on
  - lighting equipment;
  - acoustic warning devices; and
  - a clear direct and indirect view of the road.

- **Operating safety**, which ensures low stress for the driver and therefore a high degree of driving safety, requires the best possible ergonomic design to ensure comfort in the driver's cabin and the best design of the vehicle's controls to ensure ease of operation.

Passive safety

- **Exterior safety** covers all the vehicle-related measures that are designed to minimise the severity of injury to pedestrians following impact by the vehicle in an accident.
- **Interior safety** covers vehicle measures whose purpose is to minimise the acceleration and gravity forces acting on the vehicle occupants in the event of an accident, to provide sufficient survival space and to ensure the operability of the vehicle components that are critical for removing passengers from the vehicle after an accident has occurred [Bosch, 1996].

Figure 5.1 below gives an overview of all the above safety details.

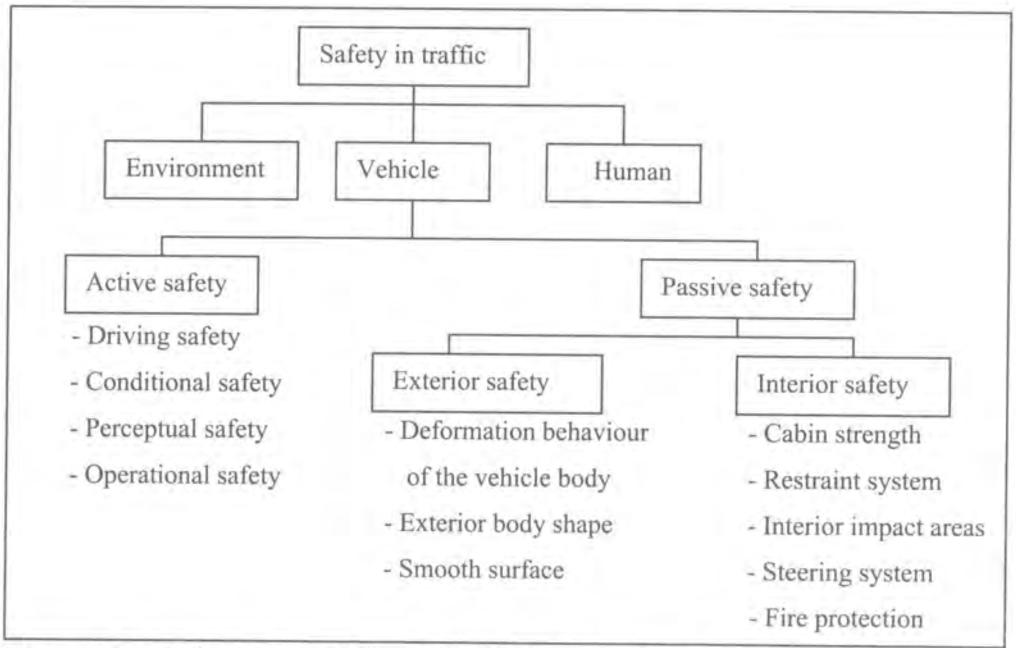

Figure 5.1. Safety characteristics involving the vehicle.

Taking all of the above into account, the following paragraphs concentrate on the effect that a mechanical failure of the vehicle systems may have on the characteristics and safety of the vehicle.

5.3 The impact of Potential Mechanical Defects

Due to the development of the technological structure of the vehicle over the past decade, it is necessary to discuss what the influences are on the vehicle characteristics when certain subsystems do not comply with the manufacturer's standards. Even though the subsystems may not be completely defective, they are capable of contributing to an accident. It is therefore necessary to put these potential defects into perspective.

5.3.1 Tyres

Modern vehicle wheels generally comprise a rim and nave or wheel disc. The rim is that part of the wheel on which the tyre is mounted. The nave joins the rim to the wheel hub. In most cases, wheel size is primarily determined by the load-bearing capacity of the tyre.

Four small areas of the tyre tread are the only contact between a light motor vehicle and the road. That frictional contact is crucial because it allows the power developed by the engine to put a vehicle in motion and keep it moving. It also allows the driver to use the steering system to control the vehicle's direction and to use the brakes to stop the vehicle. For the purpose of the present project, the discussion involves the effect of different tyre characteristics on the performance of the vehicle. Tyres are classified according to the respective requirements for operating conditions and for various vehicle types and sizes. The requirements for tyres fitted on passenger and light commercial vehicles can be subdivided into the following categories:

- Driving safety
- Service life
- Economy
- Comfort and handling
- Load capacity.

Service life is the most important item in this discussion. Due to age and sometimes extreme usage conditions the tyre tread tends to wear down. These extreme conditions are classified as follows:

- Over-inflation - Illustration A
- Under-inflation - Illustration B
- Misalignment of wheels - Illustration C
- Other causes of irregular tyre wear:
  Faulty steering, poor suspension, defective brakes and overloading.

See Figure 5.2 for tyre wear as a result of the above-mentioned points.

Figure 5.2 Indication of irregular tyre wear.

Before discussing some of these points it is useful to portray a correct tyre profile. See Figure 5.3 on the next page.

Over-inflated tyres do not allow full contact between the tread and the road surface (see Figure 5.2). This tyre characteristic leads to the following problems [Remling, 1978]:

- Decreased contact between the tread and the road surface

- The transmission of excessive road shock to the steering and suspension systems
- Abnormal wear in the centre of the tyre contact area.

Figure 5.3 Correct tyre profile.

Under-inflation is caused by normal air loss combined with neglect by the driver. These tyres not only bulge out at the sidewalls, but also provide poor contact between the tyre tread and the road surface [Remling, 1978]. Under-inflation causes the following problems:

- Increased steering effort and poor steering response
- Tendency to skid and poor control when turning because the tyre tread deflects and distorts with side-thrust loads
- Early tyre failure brought on by the heat generated in the excessive flexing of the tyre sidewalls
- Abnormal wear on the outer edges of the tyre tread area.

As mentioned in previous paragraphs, tyre inflation irregularities play a major role in tyre wear. The point concerning inflation methods is discussed more thoroughly below. Although tyre manufacturers set the standards for tyre pressures, the importance of this factor to vehicle safety tends to be neglected. An investigation into tyre inflation gauges at filling stations, done by the **Microptics Pressure Calibration Service** and led by M.J. Grobbelaar, yielded the following results [Grobbelaar, 1998]:

- The investigation into the accuracy of tyre pressure gauges in Pretoria revealed that 32% gave inaccurate readings at different predetermined pressure values.

The report identifies the following points as factors leading to incorrect tyre pressure:

1. Inaccuracy of tyre pressure gauges at filling stations
2. Lack of knowledge of the correct tyre pressure
3. Uncertainty about the interrelation between the tyre inflation pressure, travelling speed and vehicle loading capacity
4. Legislation empowers road traffic departments to inspect the visible condition of the tyre but not the invisible, i.e. the air pressure in the tyre
5. Public awareness that tyre pressure gauges tend to be inaccurate
6. Tyres which are inflated at the wrong atmospheric temperature.

Tyres may be under-inflated or over-inflated. **Under-inflation** is the biggest factor contributing to accelerated tyre wear and burst tyres. It makes the tyre flex excessively in places where it was not designed to flex and causes wear on the inner and outer edges. This leads to poor handling of the vehicle and to the overheating, stress and early failure, excessive wear rates, and flex breaks in the tyre. As speeds increase the excessive contact-patch deformation leads to waves being formed in the tread, which generates excessive heat. The result is structural damage to the tyre and eventual tyre failure, possibly causing an accident.

As mentioned above, **over-inflation** causes fast irregular wear on the centre treads. This may lead to early failure, tread cracking and greater susceptibility to impact failures. It reduces road safety factors further because of the loss of traction and the slippage of the drive wheels. It also increases the ground bearing pressure, and heightens the likelihood of a puncture. The different inflation pressures in tyres may have the following effects since the air pressure in a tyre, not the tyre itself, bears the load of the vehicle. The volume of air is compressed and evenly distributed in the tyre, and this provides the load-bearing capacity.

As mentioned previously, there is a relation between loading capacity, tyre pressure and vehicle speed. As a function of the degree of deflection in the sidewalls of the tyre, the speed and load of the vehicle may vary between certain boundaries. The minimum deflection occurs at ideal pressure, which results in less friction and cooler running conditions.

Taking all the above into account, the following points should be noted. Tyre maintenance is the subject of tyre management manuals, which specify the following: 1. Checking the cold inflation pressures, 2. Applying high tyre pressures when carrying full loads and 3. Getting to know the correct pressure for the correct tyres fitted to the vehicle.

Despite all the information on these points, tyre pressure still seems to fluctuate. Motorists should therefore be educated in the importance of knowing the influences of different variables on tyre characteristics, to ensure the safer use of vehicles.

Low tread depth entails a reduction in the size of the protective layer covering belts and casing. This reduction in tread depth results in a disproportionate increase in braking distances under certain road circumstances. For instance, in the case of a light front-wheel-drive passenger vehicle; Table 5.1 gives the values of different tread levels and their effect on braking the vehicle from a speed of 100 km/h (highly dependent upon the road surface, tyre profile and the tyres' rubber mixture) [Bosch, 1996]. Although low tyre tread has some advantages on dry roads at high temperatures, these advantages will not be discussed here. Though not stated in the reference it is assumed that these tests given in Table 5.1 were done on wet roads.

Table 5.1 Stopping distance as a factor of tread depth

Light FWD passenger vehicle					
Tread depth (mm)	8	4	3	2	1
Stopping distance (m)	76	99	110	129	166
(%)	100	130	145	170	218

When considering wet roads, the following conclusions can be drawn. The higher the water levels the greater the risk of aquaplaning. Three principal factors influence aquaplaning: the road, the vehicle's tyres and speed. Research has shown that tyres in general and tyre tread in particular have the greatest influence. There can be up to a 25 km/h difference in speed between a full tread and the legal minimum tyre tread [Reimpell & Stoll, 1996]. In other words, a vehicle with lower levels of tyre tread depth will tend to aquaplane at lower speeds than vehicles with full tread. Another problem is the fitting of regrooved tyres. According to SABS 047-1, no regrooved tyres are permissible on passenger vehicles or taxi vehicles [Taxi Tyres, 1993]. Regrooving is only permissible on tyres indicating this possibility.

Discussion

The above information indicates the importance of inspecting tyres daily. Any tyre with a tread depth of less than 1 mm should be replaced. Tread wear should be evenly distributed across the entire tread. Any uneven wear should be regarded as abnormal and its cause determined and corrected. Tyre pressure should be monitored frequently. A short PMDT that can be done by the general public is to use a match to determine the amount of tread depth left on their tyres. If the head of the match is covered in measuring the depth of tread, the tyre is still save.

5.3.2 Brakes

If all the systems were listed in their order of importance, the brake system would probably be top of the list. A failure in the brake system can cause property damage, serious injury and even death. The braking equipment in a vehicle can be defined as all the braking systems fitted to a vehicle, whose function is either to reduce the vehicle's speed, bring the vehicle to halt, or keep it stationary if already halted [Bosch, 1996]. The braking systems consist of the following:

- **Service braking system** which comprises all the elements allowing the driver to reduce the speed of a vehicle gradually during normal driving
- **Secondary braking system** which is used in the event of the failure of the service braking system
- **Parking braking system,** which allows the vehicle to be mechanically held stationary, even on an inclined surface.

The rest of this chapter investigates only the components that directly influence the general braking ability of the vehicle. An important element in the braking system of a vehicle is the thickness of the brake pads (disc brakes) or brake shoes (drum brakes), and the frictional material wear on these elements. Obviously these elements should have a standardised durability. When pressure is applied to the brakes, the kinetic energy of a vehicle is converted into heat. Naturally the kinetic energy will vary according to vehicle load, traffic conditions and the road itself, so the brake pad temperature will also vary according to the amount of energy absorbed.

The effective use of brakes on public roads depends on traffic conditions and the road itself, i.e. whether it is a highway, suburban road, country road, gradient, etc. The following factors affect the absorption of kinetic energy and consequently brake temperature:

- Frequency of brake application
- Vehicle speed at brake application
- Vehicle speed when brakes are released
- Rate of deceleration.

The above points are defined as "Brake Severity Factors (BSF)". **Minegishi**

$$BSF = V^2 \times N = (1/L) \times \sum_{i=1}^{m} (Vai^2 - Vri^2) \qquad (5.1)$$

uses equation (5.1) to express the BSF [1984].

where V = Substituted brake application speed when the brake release speed is zero [m/s]

N = Frequency of brake application per unit length (1 km)

L = Length of the journey [km]

Va = Brake application speed [m/s]

Vr = Brake release speed [m/s]

i = Number of brake applications (i = 1,2,…,m)

In order to predict the brake pad life in common operational conditions, **Minegishi** plotted brake pad wear (per 10^4 km mm) against the BSF ($(m/s)^2/km$) where pad wear is defined as shown in equation (5.2).

$$Wp = \frac{(10^4 \times W\theta)}{2 \times Ap} \times \left\{ \frac{Wt}{4g} \times (V^2 \times N) \times y + \frac{Td}{R} \times (1000 - \frac{(V^2 \times N)}{2 \times \alpha}) \right\} \quad (5.2)$$

where Wp = Pad wear per 10^4km. mm

Wθ = Specific wear rate of friction material at disc rotor temperature θ °C [mm^3/kg.m(mm^3/J)]

Ap = Pad area [mm^2]

α = Mean deceleration value in public roads [m/s^2]

Wt = Weight of vehicle [kg]

y = Proportion of the total braking effort transmitted through the front and rear axle

Td = Residual torque [N.m]

R = Dynamic rolling radius of the tyre [m].

Figure 5.4 shows Minegishi's mathematical model for plotting brake pad wear against BSF [1984].

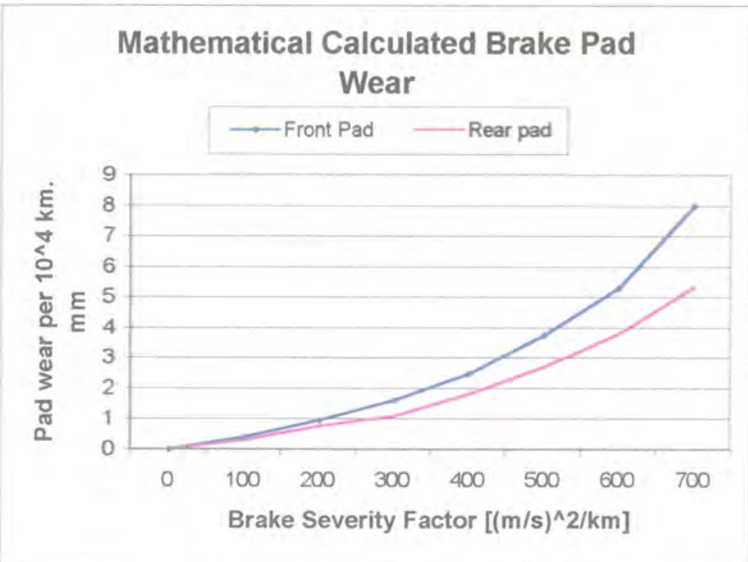

Figure 5.4 Indication of brake-pad wear

Figure 5.4 indicates that as the BSF increases, the pad wear increases too. The front brake pads in particular tend to wear down much faster. The pads comprising an axle set will rarely wear equally and they will have to be replaced when the worst-worn pad is down to a prescribed minimum thickness.

Braking systems

Many of the passenger and light commercial vehicles utilise the following braking systems:

- Disc brakes on front and rear wheels
- A combination of disc brakes on the front and drum brakes on the rear wheels.

Brake-pad thickness is very important in disc brakes. Insufficient frictional material will cause metal-to-metal contact and would not provide enough braking efficiency. Such contact also causes excessive wear in both the brake pads and the brake discs. The metal-to-metal contact gives a poor coefficient of friction, so that the vehicle needs a greater stopping distance. In many cases, this is the reason for accidents.

With regard to drum brakes, the phenomenon of "brake fade" is one of the problems with braking. This problem arises when drum brakes become overheated because of the kinetic energy dissipated when the brakes are in operation. As the drum brakes overheat, two changes may take place. Firstly, in some types of brake lining, the coefficient of friction between the lining and the drum decreases as the temperature rises. This results in less and less efficient braking, and the driver must apply more force to the brake pedal in order to stop the vehicle. Secondly, the diameter of the brake drum may expand due to overheating and this moves the drum directly away from the brake shoes. This again forces the driver to depress the brake pedal further. Both of the above problems effectively decrease the vehicle's ability to stop.

Another factor worth mentioning is the brake fluid or hydraulic system used in the braking system. A hydraulic system carries the force that operates the mechanical braking action to each wheel. Figure 5.5 depicts a typical hydraulic system.

Figure 5.5 Typical hydraulic system used in braking vehicles

Failure in this system means that the vehicle brakes are useless. The following are common problems here:

- Brake fluid is hygroscopic, in other words it absorbs moisture from the atmosphere. So strong is its affinity for moisture that the brake fluid absorbs it not only at the exposed surface in the reservoir, but also through the micro-porosity of flexible hoses and past the lips of pressure seals [Baker, 1986]. Even small amounts of water in a brake system will lower the boiling point of the fluid. Under severe use, such as during repeated braking, the temperature of the fluid rises to well above the boiling point of water. This forms steam which, unlike a fluid, can be compressed. This causes the pressure in the system to be wasted on compressing the steam instead of stopping the vehicle.

This results in a lack of pressure, and the brake pads may not be pushed against the disks and drums with enough force [Remling, 1978].

- Water in a braking system can cause other problems besides a loss of pressure. As water is heavier than brake fluid it settles in the lowest parts of the system. This leads to rust and corrosion inside the callipers and wheel cylinders and to the eventual failure of those parts (see Figure 5.5). Leakage and constant refilling of the reservoir are the first indications of brake failure.
- Air in the system also leads to excessive pedal pressure and, depending on the size of the bubble, may make it impossible to generate sufficient pressure in the system to stop the vehicle with any degree of safety. The bubble can be removed by bleeding the brake system.

Discussion

The safety of a vehicle travelling at high speeds depends directly on the correct operation of the different systems in the vehicle. A braking system, which is not operating correctly at high speeds, will have fatal consequences. As with any other system in the vehicle, observation and maintenance are extremely important. Although detail inspection of the brake pad thickness of a vehicle is in most cases difficult, the general inspection of the brake lining and brake fluid reservoir will help implicate possible problems in this area. The following component forms part of the tyre and braking system but is important enough to merit a separate discussion.

5.3.3 Wheel bearings

Although wheels and tyres are discussed above, an intricate part of these components, namely the wheel bearings, have not yet been discussed. Without the wheel/tyre configuration it would not be possible to ensure safe, fast and controllable movement of the vehicle. Wheel and tyre rotation would not be possible without a composite of component parts, such as the wheel bearings that play one of the most important roles.

The wheel bearings ensure not only the smooth rotation of the tyre but also the proper alignment of the tyre so that the brake shoes can come in contact with the rotating drum or rotor, without any wobbling. The front and rear tyres of a vehicle are mounted on hubs. The hub provides the means for mounting a tyre so that it will rotate on its axle. The hub usually contains two bearings which allow the hub to rotate freely, even with the weight of the vehicle pressing down on the tyres. As shown in Figure 5.6 the brake drums or rotors are also mounted on the hub.

Figure 5.6 A typical front wheel hub and drum assembly

The bearings used in hubs are tapered and commonly use rollers to provide rolling friction. These bearings are subjected to two major forces, namely radial loads and thrust loads. A ***radial*** load acts perpendicularly, or at a right angle to the axis of the tyre [Remling, 1978]. The weight of the vehicle pushes down on the road in a straight line from the spindle to the road. When the tyre rotates, this load still pushes straight down, but the force is borne by another part of the tyre.

A ***thrust*** load acts parallel to the axis of the tyre. It tends to push the tyre off or further onto the spindle. The tyres of a vehicle are subjected to considerable thrust loads, especially when cornering. Because of these thrust loads the wheel bearings must do much more than spin freely and support the weight of the vehicle. They must keep the tyres from sliding in or out on their spindle. Figure 5.7 indicates the force of radial and thrust loads on the vehicle's wheel bearings. Because wheel bearings are designed to handle both radial and thrust loads these components must be serviced at regular intervals (32 000 – 64 000 m).

The condition of wheel bearings is very important because worn or loose bearings often make a vehicle pull to one side, cause vibrations and hamper proper braking.

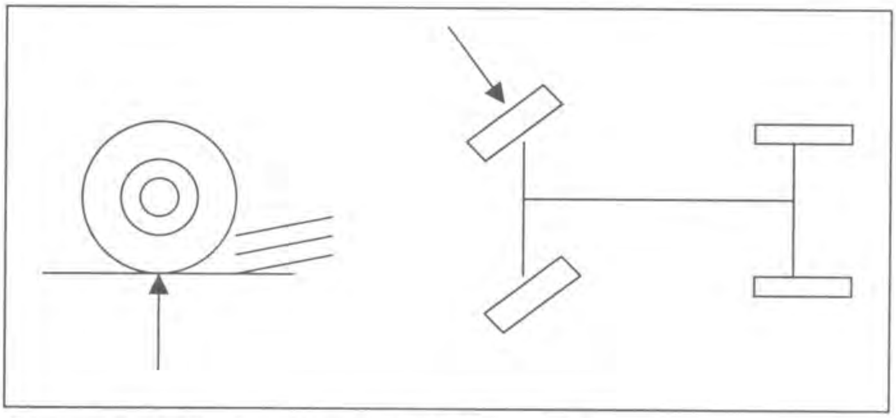

Figure 5.7. Indication of radial and thrust loads.

Discussion

In many cases the condition of wheel bearings is directly related to maintenance by the owner. Wheel bearings that are properly adjusted, properly lubricated and kept free of dirt will usually outlast the vehicle on which they are installed.

Although wheel bearings are not as critical for safety as for example defective brakes, they do affect the vehicle's characteristics significantly. And if a vehicle has a composite of defects, which includes play on the wheel bearings, the vehicle has a greater potential to cause an accident.

A short PMDT can be done to asses the condition of the wheel bearings by quickly lifting up the front part of the vehicle and following steps as outlined in chapter 3.

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CHAPTER SIX

CONCLUSION

6.1 Synopsis

6.2 Recommendations

6. Conclusion

6.1 Synopsis

Mechanical defects in vehicles have been identified as a contributory cause to vehicle accidents. The implications of these defect-related vehicle accidents, although such accidents are a relatively small proportion of the total number of accidents, have generally not been investigated thoroughly enough. The main purpose of the study was to establish the current contribution of mechanical failures on the accident-rate in South Africa. And further to assess if these percentages of mechanical failures do coincide with trends already indicated nationally as well as internationally. The study further endeavored to indicate current problems (mechanical of nature) encountered with the vehicles using our roads.

In this study the following conclusions could be drawn: the casualty rate in road vehicle accidents in South Africa is among the highest in the world and this trend has been maintained with little variation through the years. Between 1994 and 1998, the number of vehicle accidents increased from 467 997 to 511 605, indicating a growth of 9,3%. Now although these are basic statistics obtained from the CSS there is not a definite indication of how accurate these values are. Unfortunately the causative factors in these accidents are not prominently stated.

The present research project found that accidents related to mechanical defects in South Africa compare with the percentages obtained from the United Kingdom and the United States of America. Unfortunately the values for these countries are based on data obtained 10 to15 years ago and are therefore rather outdated. Some of the studies done in South Africa had to be discontinued owing to the lack of proper funding. Current data obtained from the Arrive Alive road safety campaign show that mechanical defects[1] involving tyres (8,9%) and brakes (2,6%) contribute to fatal vehicle accidents.

[1] Based on the reports obtained over the period 01/01/98 to 30/04/99 concerning 3 527 fatal vehicle accidents.

However, it is difficult to estimate how representative these values are for national conditions at present, especially as the reports take only the fatal accidents into account.

Detailed information about vehicle accidents and the condition of vehicles was collected in and around the Pretoria region. The Accident Response Unit in Pretoria indicated that on average, approximately 3% of vehicle accidents per year were due to mechanical defects. The data furthermore showed that tyres and brakes were the main contributors to mechanically related accidents in the Pretoria region. Over a period of two and a half years an average of 1,37% (per year) of the accidents were tyre-related and 1,4% brake-related. Once again these values were based only on the fatal accidents inspected and are rather low.

Further data obtained from the Pretoria Traffic Department show that a large percentage of vehicles investigated in its surveys had defective tyres and brakes that constituted offences. These vehicles were stopped during a routine roadside inspection and the figures indicate that there is indeed a problem concerning the roadworthiness of the vehicles on South African roads.

Interesting results were obtained from the PMDT to determine the percentage of mechanical defects present on vehicles in two different traffic regions around the Pretoria area. The roadside survey indicated that 40% of the inspected vehicles in the suburban area and 29% of the vehicles on the highway had mechanical defects that did not comply with current road and traffic regulations. In the suburban area, vehicles had a larger number of tyre and brake defects whereas overloading, especially of minibuses (taxi vehicles) was the main problem on the highway.

There were clear differences in the data obtained for these two traffic regions. The reason for these differences is discussed in Chapter 3, but it should be noted that the vehicles that were inspected on the highway were in much better condition than those inspected in the suburban region. This might be attributed to the fact that vehicles using the highway are inspected more regularly by law enforcement officers, due to the traffic test station that is situated on this particular highway route.

In identifying problem areas such as tyres, brakes and overloading in the above obtained and generated data, it was necessary to investigate a road-using unit, which is consistently identified with these problems. This resulted in the minibus (taxi) survey which indicated that: a large percentage of the inspected vehicles had odometer readings of more than 300 000 km, indicating that the vehicles were older models. The specifications for tyre tread depth were acceptable, though a small percentage of the vehicles inspected were close to the minimum permissible level of tread depth. Tyre pressure irregularities were identified as the greatest problem in these investigations and are cause for concern.

Considering the statistics discussed in this study it is clear that vehicle defect related accidents have a percentage range of approximately 2-5% in the actual number of motor vehicle accidents investigated. Surveys conducted in this study as well as other indicated surveys reflect larger percentages concerning mechanical defects on the actual vehicle inspected. The reason for the difference in these values could be:

- The ineffective investigation method of motor vehicle accidents.
- Not all vehicles containing mechanical defects cause motor vehicle accidents.

6.2 Recommendations

The findings of the current study indicate clearly that mechanical defects do play a role in causing vehicle accidents. The percentages obtained concerning mechanical failures causing vehicle accidents also coincide with values obtained nationally as well as internationally. Furthermore the problem of the roadworthiness of vehicles is also stated as a major cause for concern. Although the obtained and generated values give a rather general impression of the contribution that mechanical defects make to vehicle accidents, there still seems to be a problem with recognising the prominent role these defects play in vehicle accidents. Moreover the education of road users seems to lack a definite impact.

Therefore the first recommendation could be a proper schooling of new and already existing road users on basic steps of maintaining their vehicle.

It is also necessary to indicate to these people what the possible causes are of using a defective vehicle. An implementation possibility could be using a visual chart (pocket book size), which is approved by the Department of Transport to install on the vehicle. This chart could have simple checkpoints listed on it and should be small enough to be fitted on the vehicle, not obstructing any of the drivers' view. Although the feasibility of such a process is not easily determinable, the visual effect it will have on the driver every time he enters his vehicle could result in more roadworthy vehicles on our roads.

With regard to the number of older vehicles on our roads, an interesting recommendation might be that Periodic Motor Vehicle Inspections (PMVI) should be implemented. PMVI are defined as mandatory inspections where the vehicle is subjected to a general roadworthiness inspection at an interval of every three years. As mentioned in Chapter 2, past research has shown some disagreement on the effect of PMVI and especially how it helps prevent more vehicle accidents. Unfortunately current economic constraints also prohibit such projects in South Africa.

However, previous paragraphs indicate that the vehicles using a certain route showed fewer potential mechanical defects than vehicles using a different route. Therefore it is clear that the data obtained in the PMDT clearly indicate the benefits of regular inspections. It could further be recommended that only vehicles with an odometer reading of 100 000 km and more, should be subjected to these roadworthiness inspections. Although the aim of this project was to investigate passenger vehicles, light commercial vehicles and minibuses, it should be recommended that all vehicles (over 100 000 km) should be subjected to these tests. However, there is no indication whether such tests would be effective and if current test stations will have the capacity to accommodate such additional processes.

Furthermore it should be recommended that all vehicles using national roads (highways), should be subjected to vehicle weighing. This would indeed implicate the road users who are transgressing local road and traffic regulations on overloading.

It would further eliminate possible problems relating to defective tyres and brakes and give the traffic officers at the test station enough time to assess quickly the current condition of the stopped vehicle. Possible offences could be prosecuted and might help to ensure that the vehicles on our roads are safe and up to standard.

Minibus tyre inflation monitoring can also help implicate these units not complying to set traffic and road regulations. Methods considering the monitoring can either be manually or by means of a tire profile measuring system, indicating correct or incorrect tire profiles for the specific vehicle load.

A positive recommendation could be the training of traffic officers of the SAPS on the methods of doing a quick PMDT at roadblocks. The methods of these tests followed could be similar as indicated in this project or a shorter version could be easily generated. The basic training will also help assess these officers in attaining the necessary background on mechanical aspects of the vehicle, needed to accurately complete accident report forms.

A last point of interest could be the generation of a national database concerning the specifics and details of every accident in South Africa. This would help with the easy everyday statistical and logistical modelling, and ensure the overall regulation of any problems. It could also help future researchers in identifying certain problem areas and form the basis for further studies concerning this subject.

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Appendix A

Questionnaire: Accident Response Unit - Koedoespoort (Pretoria)

A.1 Questionnaire: Accident Response Unit - Koedoespoort (Pretoria)

Number: Day/Month/Year/Accident Specification

____

1. Police Station:______________ Report no.(SAP 352):______________
2. Date of Accident:______________
3. IR no.:____________________
4. Scene of Accident:____
5. Testbook number:______________ Unit of Concern:_________________
6. Test Official:__________________

Vehicle Specifications:

1. Registration no.:______________
2. Fabricate:___________________
3. Model:______________________
4. Km Reading:__________________
5. Vehicle Classification:___________(Normal, Medium, Heavy)
6. Any Forensic Tests:_____________(Yes, No)

Failure Criteria:

1. Mechanical Component that Failed________________________________
2. Discussion of Official____
3. Discussion on Forensic Tests (if any)_____________________________

A.2 Explanation of all the above terms

1. The police station in the region where the accident occurred, is specified. The SAP 352 forms completed by the traffic officer at the scene of the accident, are stored at this station.
2. The IR Number or incident report number is used as an identity number for the specific accident and the legal docket that is opened.
3. The Scene of Accident is specified for the province, city/town and street or highway where the accident occurred.
4. The Textbook Number is used as a reference number at the specific accident response unit, indicating that the report was opened when the vehicle was inspected. The number with further specific details are also stored on a database at the specific ARU.
5. The Test Official indicates the specific person responsible for compiling the accident report.
6. The Forensic Tests indicate any sample sent to the forensic engineers for scientific analysis. An example might be a tyre defect, which could not be determined at the scene of the accident.

Failure Criteria:

1. Indicating the specific component that failed and caused the accident.
2. Indicating the comments of the official after the official did a technical inspection of the vehicle.
3. Indicating whether the sample sent was indeed the cause of the accident or whether it had failed as a result of the accident.

Accident Specification:

s1 = Tyres (for example, tyre blowouts)

s2 = Defective brakes

s3 = Defective steering mechanism

s4 = Any axles which had failed.

s5 = Any other mechanical failure.

Appendix B

Taxi Tyres: SABS Code

Table B-1 Tyres for Minibuses for current production models

Model	A Rating (kg)		Recommended tyre size by manufacturer	Pressure (kPa)	
	Front	Rear		Front	Rear
Toyota 10 seat	1 450	1 700	195 R14 C 6 Ply	300	375
Toyota 14 seat	1 450	1 700	195 R14 C 6 Ply	300	375
Toyota 16 seat	1 450	1 700	195 R14 C 6 Ply	300	375
Nissan 10 seat	1 088	1 247	185 SR 14 Reinforced	240	280
Nissan 16 seat	1 262	1 589	185 R14 C Fr 6/Rr 8 Ply	275	400
VW Kombi 10	1 200	1 300	185 R14 C 6 Ply[1]	300	300
VW Kombi 15	1 300	1 400	185 R14 C 6 Ply	300	350
Isuzu 16 seat	1 250	1 600	195 R14 C 6 Ply	250	350

Note all the 16 seaters work to a rear axle load of 1 600 kg to 1 700 kg for a calculated passenger mass of 63 kg to 75 kg.

Operators who run with maximum loads should therefore fit tyres that can carry 1 700 kg or more.

1) These commercial radial ply tyres are recommended for VW Taxi use.

Appendix C

Potential Mechanical Defect Tests - Checklists

Vehicle________________

Registration____________

Km Reading____________

CHECKLIST:

1. Vehicle Weight____________ kg (Tarra) Total Weight_____________kg

2. Number of Passengers _________

3. Individual tyre loads:

   Left front_________ Right front__________

   Left rear _________ Right rear __________

4. Tyre wear:

   Left Front:

   Outside________ Middle_________ Inside_________

   Right Front:

   Outside________ Middle_________ Inside_________

   Left Rear:

   Outside________ Middle_________ Inside_________

   Right Rear:

   Outside________ Middle_________ Inside_________

5. Are all the wheelnuts present and tight____________

6. Any further comments______________________________________

   ____

Vehicle________________

Registration____________

Km Reading____________

CHECKLIST:

Underneath the vehicle

1. Brake pad thickness (if applicable):

   Left front_________ Right front__________

   Left rear _________ Right rear __________

2. Brake fluid pipes: ______________________________________

   ____

3. Inspect for leaks behind wheel hubs: ____________________________

4. Wheel bearing play (Scale: Excellent, Good, Average, Bad, Very Bad)

   ____

5. Inspect suspension joints and bushes: (Front end)
   (Scale: Excellent, Good, Average, Bad, Very Bad)

   ____

6. Any further comments____________________________________

   ____

Vehicle________________

Registration____________

Km Reading____________

CHECKLIST:

1. Tyre size (specification)

   Left front________________ Right front________________

   Left rear ________________ Right rear ________________

2. Play on steering wheel (DEGREES): _________

3. Inspect brake pedal clearance: ______________________________

4. Inspect brake fluid holder: _________________________________

5. Tie rod ends: Loose________

   Tight_________

6. Any further comments_______________________________________

   ____

Steering mechanism

1. Tie rod ends: Loose______

   Tight_______

2. Inspect suspension joints and bushes:__________________________

   ____

Appendix D

Minibus Survey - Questionnaire

MINIBUS SURVEY

1. Vehicle Details

- What make of minibus is used?

Nissan E20	Toyota Hi-Ace	Isuzu Relay	VW Kombi	Other

- How many seats do the minibus have? 16/15 ☐ 10☐ 8☐
- What is the minibus's current mileage: ……………km
- When was the minibus purchased: ……………..year.
- How many kilometres do the minibus travel per day: ……………….km
- How many days per week: ………….days
- Tyre specifications:

Tyre make

Front Left………………… Front Right………………

Rear Left ………………… Rear Right………………

Where was the tyres purchased:……………………………………………

Tyre wear

Front Left…………… Front Right………..

Rear Left …………… Rear Right………...

Tyre Inflation

Front Left……………kPa Front Right………..kPa

Rear Left ……………kPa Rear Right………...kPa

- Any other failures on the minibus……………………………………

Appendix E

Statistical Analysis and Definitions

Statistical analysis

E-1. Chi-squared test of independence

When studying a phenomenon, it is sometimes necessary to consider two observational characteristics (variables) simultaneously in order to determine the association or relation between these characteristics. The chi-squared method used in this study will help to determine the relation between different vehicle component defects in general and in particular their independence from one another (i.e. degrees of freedom).

Let X be a random variable that can take on values $x_1,\ldots,x_m$ and Y be a random variable which can take on values $y_1,\ldots,y_q$ [Gibra, 1973]. Observe the values of n independent random vectors, each having distribution $P_{X,Y}$. Let p_{ij} be the observed proportion of pairs with values (x_i,y_j). Let $p_{i.}$ be the observed proportion of pairs whose first co-ordinate is x_i, and let $p_{.j}$ be the observed proportion of pairs whose second co-ordinate is y_j. Suppose that

$P\{X = x_i, Y = y_j\} = p_{ij}$ $\qquad$ $P\{X = x_i\} = p_{i.}$ $\qquad$ $P\{Y = y_j\} = p_{.j}$

If X and Y are independent, then $p_{ij} = p_{i.}p_{.j}$. Hence a reasonable test of independence of X and Y is based on the statistic whose value is

$$c^2 = n \sum_{i=1,\ldots m\ j=1,\ldots q} \frac{(p_{ij} - p_{i.}p_{.j})^2}{p_{i.}p_{.j}} \qquad (e.1)$$

Let H_o be the hypothesis that X and Y are independent. When H_o is not true, c^2 should tend to be larger than when H_o is true. Thus, a reasonable test of H_o is to reject H_o when

$$c^2 > \chi_{(m-1)(q-1)}^{\ 2}(1-\alpha) \qquad (e.2)$$

where $\chi^2_{(m-1)(q-1)}(1-\alpha)$ is the upper 1 - α point on the chi-squared distribution with (m - 1)(q - 1) degrees of freedom. It is convenient to list the various observed and computed frequencies in a table, as shown in Table E.1.

Table E.1 Contingency table

	1 . j . q	Row total
1	p_{11} . p_{1j} . p_{iq}	$p_{1.}$
.	. .	.
i	p_{i1} . p_{ij} . p_{ik}	$p_{i.}$
.	. .	.
m	p_{m1} . p_{mj} . p_{mq}	$p_{m.}$
Column total	$p_{.1}$. $p_{.j}$. $p_{.q}$	n

The test for independence can be adapted to random variables with a density as follows: Divide the sample space for X (the real line) into m intervals. An attempt should be made to choose these intervals so that each one has a probability as close to 1/m as possible. Similarly, divide the sample space Y into q intervals with a probability close to 1/q. As a rule of thumb, experimental evidence indicates that it is desirable to have n/q and n/m at least equal to 5.

Note that the values of X and Y are irrelevant. Only the observed frequencies are now needed to compute. See the result of the tests as follows. It should be noted that the categories Average and Bad / Very bad were added to some of the calculations (Table of Tyret by C).

Chi-Square Method

****

Pietersburg Highway & Centurion

OBS	TYRET	CLASS	TT	C	WBP	WBC	SOP	SOC
1	x<=3	Bad/V-Bad	1	1	0	6	4	5
2	x<=3	Average	1	1	4	5	5	10
3	x<=3	Good/V-Good	1	3	10	15	5	11
4	3<x<=5	Bad/V-Bad	2	1	2	3	3	5
5	3<x<=5	Average	2	1	8	7	14	9
6	3<x<=5	Good/V-Good	2	3	21	23	14	19
7	x>5	Bad/V-Bad	3	1	4	1	4	2
8	x>5	Average	3	1	8	1	15	5
9	x>5	Good/V-Good	3	3	25	14	18	9

****

WBP - Wheel Bearing Play (Pietersburg highway)
WBC - Wheel Bearing Play (Centurion region)
SOP - Suspension Condition (Pietersburg highway)
SOC - Suspension Condition (Centurion region)

Pietersburg Highway & Centurion

TABLE OF TYRET BY C (Wheel Bearing Play)

```
TYRET     C

Frequency,
Expected ,
Percent  ,
Row Pct  ,
Col. Pct  ,        1,        3,  Total
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
3<x<=5   ,      10 ,      21 ,     31
         , 9.8293 , 21.171 ,
         ,  12.20 ,  25.61 ,  37.80
         ,  32.26 ,  67.74 ,
         ,  38.46 ,  37.50 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x<=3     ,       4 ,      10 ,     14
         ,  4.439 ,  9.561 ,
         ,   4.88 ,  12.20 ,  17.07
         ,  28.57 ,  71.43 ,
         ,  15.38 ,  17.86 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x>5      ,      12 ,      25 ,     37
         , 11.732 , 25.268 ,
         ,  14.63 ,  30.49 ,  45.12
         ,  32.43 ,  67.57 ,
         ,  46.15 ,  44.64 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
Total          26        56        82
            31.71     68.29    100.00
```

```
STATISTICS FOR TABLE OF TYRET BY C

Statistic                        DF      Value        Prob
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square                        2      0.077       0.962
Likelihood Ratio Chi-Square       2      0.078       0.962
Mantel-Haenszel Chi-Square        1      0.001       0.980
Phi Coefficient                          0.031
Contingency Coefficient                  0.031
Cramer's V                               0.031

Sample Size = 82
```

```
**********************************************************************
```

Pietersburg Highway & Centurion

```
TABLE OF TYRET BY CLASS  (Wheel Bearing Play)

TYRET     CLASS
Frequency,
Expected ,
Percent  ,
Row Pct  ,
Col. Pct  ,Average ,Bad/V-Bad,Good/V-Good,Total
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
3<x<=5    ,      8 ,      2 ,     21 ,     31
          ,  7.561 , 2.2683 , 21.171 ,
          ,   9.76 ,   2.44 ,  25.61 ,  37.80
          ,  25.81 ,   6.45 ,  67.74 ,
          ,  40.00 ,  33.33 ,  37.50 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x<=3      ,      4 ,      0 ,     10 ,     14
          , 3.4146 , 1.0244 ,  9.561 ,
          ,   4.88 ,   0.00 ,  12.20 ,  17.07
          ,  28.57 ,   0.00 ,  71.43 ,
          ,  20.00 ,   0.00 ,  17.86 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x>5       ,      8 ,      4 ,     25 ,     37
          , 9.0244 , 2.7073 , 25.268 ,
          ,   9.76 ,   4.88 ,  30.49 ,  45.12
          ,  21.62 ,  10.81 ,  67.57 ,
          ,  40.00 ,  66.67 ,  44.64 ,
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
Total           20        6       56       82
             24.39     7.32    68.29   100.00
```

STATISTICS FOR TABLE OF TYRET BY CLASS

Statistic	DF	Value	Prob
Chi-Square	4	1.940	0.747
Likelihood Ratio Chi-Square	4	2.884	0.577
Mantel-Haenszel Chi-Square	1	0.037	0.847
Phi Coefficient		0.154	
Contingency Coefficient		0.152	
Cramer's V		0.109	

Sample Size = 82
WARNING: 44% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

****

Pietersburg Highway & **Centurion**

TABLE OF TYRET BY C (Wheel Bearing Play)

TYRET / C: Frequency, Expected, Percent, Row Pct, Col Pct

TYRET		1	3	Total
3<x<=5	Frequency	10	23	33
	Expected	10.12	22.88	
	Percent	13.33	30.67	44.00
	Row Pct	30.30	69.70	
	Col Pct	43.48	44.23	
x<=3	Frequency	11	15	26
	Expected	7.9733	18.027	
	Percent	14.67	20.00	34.67
	Row Pct	42.31	57.69	
	Col Pct	47.83	28.85	
x>5	Frequency	2	14	16
	Expected	4.9067	11.093	
	Percent	2.67	18.67	21.33
	Row Pct	12.50	87.50	
	Col Pct	8.70	26.92	
Total		23	52	75
		30.67	69.33	100.00

STATISTICS FOR TABLE OF TYRET BY C

Statistic	DF	Value	Prob
Chi-Square	2	4.143	0.126
Likelihood Ratio Chi-Square	2	4.494	0.106
Mantel-Haenszel Chi-Square	1	0.798	0.372
Phi Coefficient		0.235	
Contingency Coefficient		0.229	
Cramer's V		0.235	

Sample Size = 75

****

Pietersburg Highway & **Centurion**

TABLE OF TYRET BY CLASS (Wheel Bearing Play)

TYRET / CLASS Frequency Expected Percent Row Pct Col. Pct	Average	Bad/V-Bad	Good/V-Good	Total
3<x<=5	7 5.72 9.33 21.21 53.85	3 4.4 4.00 9.09 30.00	23 22.88 30.67 69.70 44.23	33 44.00
x<=3	5 4.5067 6.67 19.23 38.46	6 3.4667 8.00 23.08 60.00	15 18.027 20.00 57.69 28.85	26 34.67
x>5	1 2.7733 1.33 6.25 7.69	1 2.1333 1.33 6.25 10.00	14 11.093 18.67 87.50 26.92	16 21.33
Total	13 17.33	10 13.33	52 69.33	75 100.00

STATISTICS FOR TABLE OF TYRET BY CLASS

Statistic	DF	Value	Prob
Chi-Square	4	5.644	0.227
Likelihood Ratio Chi-Square	4	5.838	0.212
Mantel-Haenszel Chi-Square	1	1.250	0.264
Phi Coefficient		0.274	
Contingency Coefficient		0.265	
Cramer's V		0.194	

Sample Size = 75
WARNING: 56% of the cells have expected counts less than 5. Chi-Square may not be a valid test.

****

Pietersburg Highway & Centurion

TABLE OF TYRET BY C (Suspension Condition)

TYRET / C — Frequency, Expected, Percent, Row Pct, Col. Pct	1	3	Total
3<x<=5	17	14	31
	17.012	13.988	
	20.73	17.07	37.80
	54.84	45.16	
	37.78	37.84	
x<=3	9	5	14
	7.6829	6.3171	
	10.98	6.10	17.07
	64.29	35.71	
	20.00	13.51	
x>5	19	18	37
	20.305	16.695	
	23.17	21.95	45.12
	51.35	48.65	
	42.22	48.65	
Total	45	37	82
	54.88	45.12	100.00

STATISTICS FOR TABLE OF TYRET BY C

Statistic	DF	Value	Prob
Chi-Square	2	0.686	0.710
Likelihood Ratio Chi-Square	2	0.695	0.706
Mantel-Haenszel Chi-Square	1	0.099	0.753
Phi Coefficient		0.091	
Contingency Coefficient		0.091	
Cramer's V		0.091	

Sample Size = 82

****

<u>Pietersburg Highway</u> & Centurion

TABLE OF TYRET BY CLASS (Suspension Condition)

TYRET CLASS
Frequency,
Expected ,
Percent ,
Row Pct ,
Col. Pct

TYRET		Average	Bad/V-Bad	Good/V-Good	Total
3<x<=5	Frequency	14	3	14	31
	Expected	12.854	4.1585	13.988	
	Percent	17.07	3.66	17.07	37.80
	Row Pct	45.16	9.68	45.16	
	Col. Pct	41.18	27.27	37.84	
x<=3	Frequency	5	4	5	14
	Expected	5.8049	1.878	6.3171	
	Percent	6.10	4.88	6.10	17.07
	Row Pct	35.71	28.57	35.71	
	Col. Pct	14.71	36.36	13.51	
x>5	Frequency	15	4	18	37
	Expected	15.341	4.9634	16.695	
	Percent	18.29	4.88	21.95	45.12
	Row Pct	40.54	10.81	48.65	
	Col. Pct	44.12	36.36	48.65	
Total		34	11	37	82
		41.46	13.41	45.12	100.00

```
STATISTICS FOR TABLE OF TYRET BY CLASS

Statistic                     DF      Value        Prob
ƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒƒ
Chi-Square                     4      3.505        0.477
Likelihood Ratio Chi-Square    4      2.982        0.561
Mantel-Haenszel Chi-Square     1      0.131        0.718
Phi Coefficient                       0.207
Contingency Coefficient               0.202
Cramer's V                            0.146

Sample Size = 82
WARNING: 33% of the cells have expected counts less
         than 5. Chi-Square may not be a valid test.
```

```
*******************************************************************
```

Pietersburg Highway & **Centurion**

```
TABLE OF TYRET BY C  (Suspension Condition)

TYRET     C
Frequency,
Expected ,
Percent  ,
Row Pct  ,
Col. Pct ,        1,        3,  Total
ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
3<x<=5   ,      14 ,      19 ,     33
         ,   15.84 ,   17.16 ,
         ,   18.67 ,   25.33 ,  44.00
         ,   42.42 ,   57.58 ,
         ,   38.89 ,   48.72 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x<=3     ,      15 ,      11 ,     26
         ,   12.48 ,   13.52 ,
         ,   20.00 ,   14.67 ,  34.67
         ,   57.69 ,   42.31 ,
         ,   41.67 ,   28.21 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
x>5      ,       7 ,       9 ,     16
         ,    7.68 ,    8.32 ,
         ,    9.33 ,   12.00 ,  21.33
         ,   43.75 ,   56.25 ,
         ,   19.44 ,   23.08 ,

ƒƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆƒƒƒƒƒƒƒƒˆ
Total          36        39       75
            48.00     52.00   100.00
```

STATISTICS FOR TABLE OF TYRET BY C

Statistic	DF	Value	Prob
Chi-Square	2	1.505	0.471
Likelihood Ratio Chi-Square	2	1.509	0.470
Mantel-Haenszel Chi-Square	1	0.118	0.731
Phi Coefficient		0.142	
Contingency Coefficient		0.140	
Cramer's V		0.142	

Sample Size = 75

****

Pietersburg Highway & **Centurion**

TABLE OF TYRET BY CLASS (Suspension Condition)

TYRET CLASS
Frequency,
Expected ,
Percent ,
Row Pct ,

Col. Pct	Average	Bad/V-Bad	Good/V-Good	Total
3<x<=5	9	5	19	33
	10.56	5.28	17.16	
	12.00	6.67	25.33	44.00
	27.27	15.15	57.58	
	37.50	41.67	48.72	
x<=3	10	5	11	26
	8.32	4.16	13.52	
	13.33	6.67	14.67	34.67
	38.46	19.23	42.31	
	41.67	41.67	28.21	
x>5	5	2	9	16
	5.12	2.56	8.32	
	6.67	2.67	12.00	21.33
	31.25	12.50	56.25	
	20.83	16.67	23.08	
Total	24	12	39	75
	32.00	16.00	52.00	100.00

STATISTICS FOR TABLE OF TYRET BY CLASS

Statistic	DF	Value	Prob
Chi-Square	4	1.602	0.808
Likelihood Ratio Chi-Square	4	1.618	0.806
Mantel-Haenszel Chi-Square	1	0.185	0.667
Phi Coefficient		0.146	
Contingency Coefficient		0.145	
Cramer's V		0.103	

Sample Size = 75
WARNING: 22% of the cells have expected counts less
than 5. Chi-Square may not be a valid test.

E-2. Binomial Distribution

Suppose we are sampling with replacement from a lot that is p% defective [Gibra, 1973]. If an item is drawn at random, then, it can be classified as defective with probability p or non-defective with probability q = 1 - p. The outcomes of a single carrying out of the experiment then are

0 if the item drawn is non-defective

1 if the item drawn is defective

Now if n independent trials are performed the total number of defective items will be equal to k, where k = 0, 1, . . . , n.

Definition C.1: Random variable X is said to be *binomial distributed* with parameters n and p if its probability function is given by

$$P_x(k) = \binom{n}{k} p^k q^{n-k} \quad (k = 0,1,..,n \quad 0 \leq p \leq 1 \quad p + q = 1) \qquad (e.3)$$

where [$P_x(k)$ = Probability that k items defective]

Since $P_x(k)$ is a probability function it follows that

$$\sum_{k=0}^{n} P_x(k) = \sum_{k=0}^{n} \binom{n}{k} p^k q^{n-k} = (p+q)^n = 1$$

To facilitate computations, the binomial distribution has been tabulated in tables of the Cumulative Binomial Probability Distribution [1955]. See attached Tables to help determine the exceedance probabilities. For the purpose of this study p where chosen as 50% defective. In other words there is a possibility that 50% of the inspected vehicles are situated in the bad / very bad category as opposed to the average to very good category.

Appendix F

Database Generation

Database Functions and Instructions

As mentioned in Chapter 2 and 3 a database were generated to assist in saving information gathered in the following three cases:

- Accident Response Unit Reports
- Potential Mechanical Defect Tests
- Minibus Survey

The aim of this database will be to ensure quick access to the obtained information and to be an investigation tool in researching certain aspects of the information. The database was written in **Microsoft Access** using Office 97. A quick introduction to the database will be given in the following paragraphs.

To implement the database, insert the CD-disk in a CD-ROM. Use Windows Explorer to select the current drive the disk was inserted in. Double click on the name found on the disk, and the program will be automatically opened. The main menu consists of the following four buttons connecting you to the individual data collections:

- Accident Response Units
- Potential Mechanical Defect Tests
- Minibus Survey
- Exit the Database

In choosing the ***Accident Response Unit*** button, a menu consisting of all the information gathered at this unit from 1996 to July 1998 is shown. The following buttons are made available for further inspection:

- View or enter data - ARU 1996
- View or enter data - ARU 1997
- View or enter data - ARU 1998
- Menu - ARU Accidents (1996-1997)
- Menu - ARU Accidents (1998)
- Go to main menu

With these buttons individual databases is selected wherein information regarding the mentioned years can be stored and viewed. The contribution of individual mechanical defects in these specified years can also be investigated.

In selecting the ***Potential Mechanical Defect Tests*** button, the menu for both the suburban and highway regions are open. As with the previous example it is also possible to store new information in these files. The reports concerning the main mechanical defects have already been generated and can be viewed in this menu. In these reports the vehicle make, registration, km reading and potential mechanical defect can be viewed. The following buttons are made available for further inspection:

- View or enter data - Centurion suburban
- Go to reports menu - Centurion suburban
- View or enter data - Pietersburg highway
- Go to reports menu - Pietersburg highway
- Go to main menu

In selecting the ***Minibus Survey*** button in the main menu you'll get access to all the information gathered by doing this survey. The following buttons will appear for further investigation:

- View or enter data - Minibus survey
- Go to reports menu - Minibus survey
- Go to main menu

In selecting to go to the reports menu the following reports can be investigated:

- Tyre pressure specifications - Front tyres
- Tyre pressure specifications - Rear tyres
- Tyre wear specifications - Front tyres
- Tyre wear specifications - Front tyres

To exit the database it is necessary to go to the main menu and select the exit database button. Further functions are thoroughly explained in the database.