UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

THE EFFECT OF TYRE PRESSURE ON VEHICLE PERFORMANCE

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BY

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DECEMBER, 2021

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this project work is the result of my own effort and that no pan of it has been presented for another certificate in this university or elsewhere.

Candidate's Signature: ……………………… Date: …………………………………

REINDOLF ADAWOROMAH

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this project work was supervised in accordance with guidelines on supervision of project work laid down by the Akenten Appiah-Menka University of Skill Training and Entrepreneurial Development, Kumasi.

Supervisor's Signature: …………………… Date: …………………………………………

DR. SHERRY K. AMEDORME

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Last but not the least, my heartfelt thanks go to all my colleagues of the Automotive Education class for their support and advice. May the good Lord richly bless you.

DEDICATION

I dedicate this work to my mom.

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ABBREVIATIONS

GCAA – GHANA CIVIL AVIATION AUTHORITY

GACL – GHANA AIRPORT COMPANY LIMITED

JAF – Japan Automobile federation

TREAD – transport recall enhancement, accountability, and documentation

TPMS – tyre pressure monitoring system

GHG – greenhouse gas

FR – front right tyre

FL – front left tyre

RR – rear right tyre

RL – rear left tyre

MTP – measured tyre pressure

MRTP – manufacturer‘s recommended tyre pressure

AMTP — average measured tyre pressure

ARTP — average recommended tyre pressure

AMRTP — average manufacturer‘s recommended tyre pressure

DOT — department of transportation

F — fuel consumption

N/mm^2 – Newton per millimetre square

p — tyre pressure

ABSTRACT

In the world today, due to the high cost of running a vehicle, there had been many research to see ways of minimizing the cost of usage of vehicle. Some of these costs come from the tyre of the vehicle, amount of fuel needed to run the vehicle smoothly, buying spare parts of vehicles and ensuring safety of the vehicle. The study assessed the effects of vehicle tyre pressures and its influence on the fuel consumption. The study employed both qualitative and quantitative statistical procedures to characterized and analysed the data of GCAA. The study was carried out to find out whether these deviations in the tyre pressure of the vehicles have effect on fuel consumed by the sampled vehicles. Three (3) Toyota Coaster Buses and Two (2) Nissan Urvan minibuses sampled as 1', 2', 3', 4', and 5 were studied. Out of the 160 (100%) vehicles surveyed in the Kotoka International Airport, only 2.5% had the recommended tyre pressure, indicating that 97.5% of the vehicles surveyed deviated from the recommended standard tyre pressures. It was clear that there was direct influence of the vehicles tyre pressure on the fuel consumption. It indicated that when tyre pressure deviate from the recommended tyre pressure, there was an additional fuel consumption by the vehicle. Detailed the result of sample one (1) indicated that (10%) tyre pressure deviated above the recommended tyre pressure which gave an additional fuel loss of 2.72 litres during the travelled from Kumasi to Accra and returned millage of 540km/h. Again, 10.87 litres and 24.46 litres of additional fuel would be incurred for twenty percent (20%) and thirty percent (30%) tyre pressure deviation below the recommended standard tyre pressure influence travelled from Kumasi Airport to Accra (KIA) and returned for samples 2 and 3, respectively. The values of the distance travelled, fuel consumed and tyre pressure for all the samples of the vehicles were also characterized and analysed. Finally, it was clear that any deviation of vehicle tyre pressure had influenced on the usage of the vehicle economy (low-cost).

CHAPTER ONE

INTRODUCTION

1.0 Background of Study

This chapter discusses the background of study, the problem statement, the objective of the research, the significance of research and the scope of the research.

As a vehicle travels, the surface of the tyre and the road come into contact and must be continually tear off, in addition each surface (both the tyre and the road) is gnarled slightly so that in effect, the wheel is rolling uphill. These effects combine to produce a rolling resistance. A ratio of 1:5.3 or more than a two percent is found for the effect on fuel economy for every ten percent change in rolling resistance for highway driving and a ratio of 1:9.6, or about a one percent fuel economy change for every ten percent in rolling resistance for urban driving (Calwell et al., 2003). Consistent with these findings, the German Umweltbundesant reports a thirty percent reduction in a tyre's rolling resistance can reduce an automobile's fuel consumption from two percent to six percent, depending on driving conditions and other factors (Friedrich, 2002).

According to the Rubber Manufacturer's Association, when a tyre is under inflated by one pound per square inch (1psi), the tyre's rolling resistance is increased by approximately 1.1% and that a five to eight percent reduction in fuel efficiency (Calwell et al., 2003). This is similar to the review study done by Schuring and Futamura that found for each ten percent reduction in the rolling resistance coefficient the fuel efficiency increased by (1.2-2.5)% for city and (0.9-2.1)% for highway driving (Schuring and Futamura, 1990). This is because inflation pressure determines tyre stiffness, which has a significant influence on the contact area of the tyre and pressure distribution over the contact surface. Thus, a pressure in the vehicle's tyres is reduced, the rolling resistance increases over the road because the surface contact area and virtual hill height is increased. When the rolling resistance is increased, it takes more energy (fuel) to get the vehicle to go the same distance. The relationship between tyre pressure, rolling resistance and fuel economy is complex and dynamic and is dependent on several other factors, including vehicle type and load, road and environmental conditions.

Overall, rolling resistance makes up a relatively small percentage of the losses in a typical vehicle; it accounts for about four percent of a vehicle's energy expenditure at low speeds and about seven percent at highway speeds (Stein, 2006). However, these modest losses are substantial when the context of the entire US, where automobile travel accounts for the largest source of energy use and GHG emission, with petroleum combustion causing 2438Tg (106 tons) CO_2 or forty three percent of the emissions in 2004. Globally the situation is similar, where in 1990 the transportation sector was responsible for twenty-five percent of the world's energy use, and twenty two percent of the global CO_2 emissions. (Stein, 2006)

The vehicle manufacturer with a recommended inflation pressure, which permits safe operation within the specified load rating and vehicle loading, specifies tyres. Most tyres are marked with a maximum pressure rating. For passenger vehicles and light duty truck, the tyres should be inflated to what the vehicle manufacturer recommends, which is usually located on deal just inside the driver's door, or in the sidewall; this is the maximum inflation pressure, and not the recommended pressure.

Irrespective of its size, every tyre's load capacity, durability, traction and handing is dependent on using the recommended inflation pressure for the application. Since both too little and too much inflation, pressure sacrifices some of the tyre's performance, maintaining the right inflation pressure is a prerequisite.

According to Hillier (1991) 'under inflation' or overloading leads to rapid wear on each side of the tread and internal damage to the casing, whereas 'over inflation' wears the centre of the tread.

The major cause of over-inflation are an inaccurate tyre pressure gauge, hot tyres or incorrect reading by the operator. (Read and Reid, 2000)

If tyre pressure is too high, the tyre contact patch is reduced, which decreases rolling resistance. However, ride comfort is reduced, but traction is not always reduced, stopping distance is not always increased. In addition, going above the maximum sidewall pressure rarely results in the centre of the tyre wearing more than the shoulder.

If tyre pressure is too low, the tyre contact patch is increased, increasing rolling resistance, tyre flexing and friction between road and tyre. This 'under inflation' can lead to tyre overheating, premature tread wear, and tread separation in severe cases.

It is important that vehicle tyres are of the correct pressure for maximum economy (tyre wear and fuel consumption) and safety. That is the tyre should have the correct amount of tread in contact with the road for optimum grip and traction and the air in the tyre that supports the vehicle.

It is important for vehicle users to note that when vehicle tyres are inflated to their correct pressures, the safety of the occupant is guaranteed, the fuel economy of the car is also enhanced as well as the comfortability is achieved. (Reimpell and Stoll, 1996)

1.1 Problem Statement

In recent years, the increasing demand for the safety of an automobile has promoted research and development of the technology of active safety. One of the important factors determining vehicle dynamics including safety is tyre air pressure. A reduction in tyre pressure from the proper level will cause deteriorations in the driving stability, fuel consumption, tyre life, and possible bursts of the tyres.

Survey on the tyre pressure conducted in the parking lot of a company shows that cars with low-pressure (under 140 kPa) tyres occupy about four percent, and sixty four percent of these cars have four tyres with substantially equal pressures which is due to the natural leakage (Ohashi et al., 1997). According to the statistics of Japan Automobile Federation (JAF), tyre problems on highways are the greatest number of cases in which the JAF is asked to rescue. This situation is caused by the difficulty for ordinary drivers to sense the reductions in the air pressures or because of the lack of interest in maintaining proper tyre air pressure.

Similar results are found elsewhere in the world. For example, a recent study in Saudi Arabia found the pressure in twenty-one percent of the inspected tyres was twenty-five percent or more below the vehicle manufacturer's recommended inflation settings (Ratrout, 2005). Tyres typically lose about one pounds per square inch (1psi) of air pressure per month during normal driving conditions, and can lose considerably more during the change in ambient temperature(1 psi per 10 ^{o}F drop). Underinflated tyres decrease fuel economy, shorten tread life, have less lateral traction and longer stopping distances and prone to stress damage, which are more vulnerable to flat tyres and thus resulted in rollovers.

The problem is how far vehicles deviate from the recommended tyre pressure and the relationship between the tyre pressure and fuel consumption.

1.2 Research Objective

The main objective of this thesis is to develop a model for the effect of tyres pressure on fuel consumption in vehicles and come out with some suggestions and recommendations on how to reduce these effects.

The specific objectives of this thesis are to:

1. Develop a model for the effect of tyre pressure on fuel consumption for vehicles.
2. Validate model

3. Find the extent of deviation of tyre pressure of vehicles from the vehicles manufacturer's recommendation
4. Determine the effect of tyre pressure on the economy

1.3 Significant of Research

Tyre pressures of vehicles have direct effect on the fuel consumption. From research, when tyre pressures of vehicles fall below the recommended tyre pressures more fuel are consumed. This means that when vehicles have their tyre pressures below the recommended drivers will spend more money on fuel. The government has to import more crude oil and that means more money has to be directed into road transportation sector of the economy. If that happens, other sectors of the country will not be developed.

When vehicles have the pressures in their tyres deviating from the recommended tyre pressure it can also lead to accidents. When the tyre pressure is below the recommended tyre pressure, it can lead to stress concentration on the tyres, which will burst the tyres and cause accidents. When accidents occur, it may lead to loss of lives and in effect, work force of the country will be lost. This can cause low productivity. Even if no human life is lost, it may lead to loss of property and injury to the motorist.

1.4 Scope of Research

The scope of the study will involve a literature review conducted to find out about various types of tyres in Ghana. In addition, measurement of some vehicles tyre pressures will be taken to see how they deviate from the recommended manufacturer's tyre pressure and to have an overview of how drivers monitor their tyre pressures of their vehicles. The research will involve surveying five vehicles from Ghana Civil Aviation Authority (GCAA) shuttles to see their various tyre pressures in corresponding to the fuel consumed. Then a model will be developed to represent all the five vehicles.

1.5 Organization of the Study

Chapter One of the studies consist mainly of the general introduction to study, its objectives, problem statements and research questions, scope and methodology. The subject under discussion set out the procedure to guide the conduct of the research.

Chapter Two will provide the framework for data analysis and deal with a review of relevant literature on the subject matter. Review of the research, which will be based on both theoretical and empirical evidence, which are relevant to the study. It will explores the nature and extent of the literature on the subject and thus will serve as a foundation for the rest of the study. There will be critical assessment of tyre pressures and their impact on fuel consumption. The problems associated with it and its successes.

Chapter Three will present at how the research will be conducted and the sampling technique used to analyse the data. Chapter Four will present the quantitative analysis of the research; this will include data analysis and presentation that will be collected during the primary survey. Chapter Five will include conclusions of findings and recommendations that will help to ensure fuel economy on vehicles as discussed.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

What is discussed in this chapter includes the various classification of tyres, factors affecting vehicle performance, effects of tyre pressure on vehicles performance and fuel efficiency.

2.1 Types of Tyres

Tyres are ringed – shaped parts, either pneumatic or solid (including rubber, metals and plastic composites), that fit around rims to protect them and enhance their function.

Tyre is a covering mounted on the rim of a wheel that serves as a cushion and surface for traction. Tyres are used on road vehicles, tractors, aircraft and spacecraft landing gear, factory and warehouse machinery, and on a variety of other vehicles, including shopping carts and baby carriages. Tyres are made of chemically treated rubber and fabric. Those for indoor use are generally solid rubber with a smooth surface, while those used outdoors are pneumatic, or hollow and filled with pressurized air, and have a traction pattern cut into the surface.

Pneumatic tyres are used on different types of vehicles, such as bicycles, motorcycles, cars, trucks, earthmovers, and aircrafts. Tyres enable better performance by providing traction, braking, steering, and load support. Tyres form a flexible cushion between the vehicle and the road, with smooths out shock and makes for a comfortable ride.

Figure 1: Pneumatic Automobile Tyres

2.2 Parts and Classification of Tyres

The main parts of the pneumatic tyre are the tread, the body, and the beads. The tread is a thick pad of rubber into which grooves are cut to form cheats or ridges. The tread provides traction to move and stop a vehicle and to prevent skidding and sliding while a vehicle is in motion.

The body gives the tyre its strength and form. It consists of layers of fabric permeated with rubber. The fabric in most passenger – vehicle tyre bodies is polyester. Each fabric layer is called a ply, and the number of piles in its body sometimes describes the strength of a tyre. Most automobile tyres have two plies. The beads of a tyre are the two bands that hold the tyre to its wheel. They are located along the tyre's inner edges and are made up of strands of wire surrounded by rubber and covered with fabric.

Tyres are classified into several standard types, based on the type of vehicle they serve and how they were constructed. Since the manufacturing process, raw materials, and equipment vary according to the tyre type, it is common for tyre factories to specialize in one or more tyre types. In most markets, factories that manufacture passenger and light truck radial tyres are separate and distinct from those that make aircraft or off – the – road (OTR) tyres. The types of tyres include high performance tyres are designed for use at higher speeds, and more often, a more “formula one” driving style. They feature a softer rubber compound for improved traction, especially on high-speed cornering. The tradeoff of this softer rubber is shorter tread life.

Mud and Snow tyre is a classification for specific winter tyres designed to provide improved performance under low temperature conditions, compared to all – season tyres.

The tread compound is usually softer than used in tyres for summer conditions, thus providing better grip on ice and snow, but wears more quickly at higher temperatures. Studded tyres are used in the upper tier classes of ice racing (Markus and Frank 2008) and rallying.

Mud tyres are specially tyres with large, chunky tread patterns design to bite into muddy surfaces. The large, open design also allows mud to clear quickly from between the lugs.

All season truck tyres usually have no business going off – road, as their composition and tread designs are not built to handle beatings from off – road conditions. They do, however, provide long – lasting tread that excels on wet or dry paved roads and offers tremendous longevity. (Han, 2007)

All – terrain tyres are typically used on SUVs and light trucks. These tyres often have stiffer sidewalls for greater resistance against puncture when traveling off – road. The tread pattern offers wider spacing than all – season tyres to remove mud from the tread. (Han, 2007)

Heavy-duty tyres are also called as Truck/Bus tyres. Sizes used these tyres on vehicles such as commercial freight trucks, dump trucks, and passenger buses.

The off – the – road (OTR) tyre classification includes tyres for construction vehicles such as wheel loaders, backhoes, graders, and trenchers, and the like; as well as large mining trucks.

The agricultural tyre includes tyres used on farm vehicles, typically tractors and specialty vehicles like harvesters. High flotation tyres are used in swampy environments and feature large footprints at low inflation pressures.

Racing tyres are highly specialized according to vehicle and racetrack conditions. This classification includes tyres for top – fuel dragsters, drift racers, extreme off – road racing, oval-track racers, jet – powered trucks, and monster trucks – as well as the large market race tyres for Formula One, NASCAR, rallying, MotoGP and so on.

The Industrial tyre is a bit of a catch – all category and includes pneumatic and non – pneumatic tyres for specialty in industrial and construction equipment such as skid loader and forklift trucks.

Aircraft tyres are designed to withstand extremely heavy loads for short durations. The number of tyres required for aircraft increases with the weight of the plane. Aircraft tyre tread patters are designed to facilitate stability in high crosswind conditions, to channel water away to prevent hydroplaning, and for braking effect. Aircraft tyres generally operate at high pressures, up to 200 PSI (13.8 bar, approximately) for airliners, and even higher for business jets. Test of airline aircraft tyres have shown that they are able to sustain pressures of maximum 800 PSI (55.2 bar, approximately) before failing.

There are many different types of motorcycle tyres, which include Sport Touring, Sport Street and track or slick.

Bias tyre (or cross ply) construction utilizes body ply cords that extend diagonally from bead to bead, usually at angles in the range of 30 to 40 degrees, with successive plies laid at opposing angles forming a crisscross pattern to which the tread is applied. The design allows the entire tyre body to flex easily, providing the main advantage of this construction, a smooth ride on rough surfaces. This cushioning characteristic also causes the major disadvantages of a bias tyre: increased rolling resistance and less control and traction at higher speeds.

A belted bias tyre starts with two or more bias – plies to which stabilizer belts are bonded directly beneath the tread. This construction provides smoother ride that is similar to the bias tyre, while lessening rolling resistance because the belts increase tread stiffness.

Radial tyre construction utilizes body ply cords extending from the beads and across the tread so that the cords are laid at approximately right angles to the centerline of the tread, and parallel to each other, as well as stiff stabilizer belts directly beneath the tread. The advantages of this construction include longer tread life, better steering control, and lower rolling resistance. Disadvantages of the radial tyre include a harder ride at low speeds on rough roads and in the context of off – roading, decreased "self – cleaning" ability and lower grip ability at low speeds. Many tyres used in industrial and commercial applications are non – pneumatic, and are manufactured from solid rubber and plastic compounds via molding operations. Solid tyres include those used for lawn mowers, skateboards, golf carts, scooters, and many types of light industrial vehicles, carts, and trailers. One of the most common applications for solid tyres is for material handling equipment (forklifts).

2.3 Importance of Tyres

Tyres are part of the bedrock of a car, truck, piece of construction equipment or bicycle. Tyres add traction, braking, steering and load support to vehicles while also absorbing shock and creating a smooth and comfortable ride. They are o – shaped parts that can be pneumatic or solid and fit around the wheels of the vehicle to protect the wheels and add to their effect. A solid tyre consists of rubber, metal and plastic parts (Williams, 2008).

Vehicle tyres can affect not only the way cars are handled, but also affect the overall performance and fuel economy of a vehicle. One of the most important things to do is a regular schedule to check air pressure in tyres. Incorrect air pressure in tyre causes the tyre failure.

Tyre failure while driving can lead to crush and possibly injure the driver and the passengers. (Gibson, 2006).

2.4 Factors affecting the Performance of a Vehicle

Aerodynamics is one of the leading factors in vehicle performance. Car racing has focused on this aspect early in the 1960's, when the first invented wings were installed on formula one cars. In time, the development of aerodynamic devices grew stronger, often borrowing ideas and solutions from the flight industry. By improving aerodynamics, engineers saw faster lap times and more driver control over the car, both at high and low speeds. The final element that contributes to improved handling and grip is the downforce using the underbody of the vehicle of the vehicle to facilitate airflow and "stick" the car to the tarmac. (Johnson, 2005)

When the hood of the vehicle is pop open, some parts are greasy, others are filled with fluids and some parts are just too hot to touch after a long run. These are the intricacies of the engine adapted by the vehicle, which makes it run with good performance. However, the basis of their performance is not solely accredited to the number of cylinders the vehicle has or the type of arrangement engine parts have adopted.

There is more to the ones running under the hood. This gives the power that the car needs in every change to the gear. The kind of engine that is inside the car helps the vehicle to use gasoline efficiently and effectively. There are other things that one needs to consider. It is simply because the road is not straight and even. (Michaels, 2008)

One of the factors that should be looked at is suspension. Suspension allows the car to ride smoothly even when the road is bumpy. Without it, it will lose the ability to achieve stability in steering or even lose control with car. The purpose of putting them on the vehicle is resolved on two purposes:

1) To distribute weight equally as the car accelerates (on different surface levels of the road)
2) To absorb the energy from the road without causing undue distribute to the body of the car. (Michaels, 2008).

Another factor that affects vehicle performance is tyre pressure. Simply put, failure to maintain right tyre pressure on a consistent basis may be results in faster tyre wear, tyre failures and loss of control, thus resulting in possible serious injuries or even property damages. More importantly, having the correct tyre pressures mean that the vehicle will be in better control, lesser chances of experiencing tyre blowouts or punctures and therefore preserving precious life. (Yeo, 2006)

2.5 Effects of Tyre Pressure on Vehicle Performance

The vehicle manufacturer with a recommended inflation pressure, which permits safe operation within the specified load rating and vehicle loading, marks tyres. Most tyres are stamped with a maximum pressure rating (for USA only). For passenger vehicles and light trucks, the tyres should be inflated to what the vehicle manufacturer recommends, which is usually located on a decal juts inside the driver's door, or in the vehicle owners handbook. Tyres should not be inflated to the pressure on the sidewall; this is the maximum pressure, rather than the recommended pressure.

If tyre pressure is too high, the tyre contact patch is reduced, which decreases rolling resistance. However, ride comfort is reduced, but traction is not always reduced, stopping distance is not always increased. (FEA, 2009) also, going above max sidewall pressure rarely results in the center of the tyre wearing more than the shoulder. If tyre pressure is too low, the tyre contact patch is increased, increasing rolling resistance, tyre flexing and friction between the road and tyre. This “under inflation” can lead to tyre overheating, premature tread wear, tread separation in severe cases. Braking distance does not statistically change as tyre pressure increased, suggesting that a larger contact patch from under inflation may not be significant contributor for the conditions explored in these specific tests.

From the above information, it is seen that in the inflation pressure or tyre pressure of a vehicle affects rolling resistance, tyre heating, tread wear, and tread separation and fuel consumption.

2.5.1 Rolling Resistance

Rolling resistance is the resistance to rolling caused by deformation of the tyre in contact with the road surface. As the tyre rolls, tread enters the contact area and is deformed to conform to the roadway. The energy required to make the deformation depends on the inflation pressure, rotating speed, and numerous physical properties of the tyre structure, such as spring force and stiffness. Tyre makers seek lower rolling resistance tyre constructions in order to improve fuel economy in cars and especially trucks, where rolling resistance accounts for a high amount of fuel consumption. The pneumatic tyre also has the more important effect of vastly reducing rolling resistance compared to a solid tyre. Because the internal air pressure acts in all directions, a pneumatic tyre is able to "absorb" bumps in the road as it rolls over them without experiencing a reaction force opposite to the direction of travel, as is the case with a solid (or foam-filled) tyre. Overall, rolling resistance makes up a relatively small percentage of the losses in a typical vehicle; it accounts for about 4% of a vehicle's energy expenditure at low speeds and about 7% at highway speeds (Stein, 2006).

2.5.2 Tread Wear

Friction between the tyre and the road surface causes the tread rubber to wear away over time. Government legal standards prescribe the minimum allowable tread depth for safe operation.

There are several types of abnormal tread wear. Poor wheel alignment can cause excessive wear of the innermost or outermost rims. Gravel roads, rocky terrain, and other rough terrain will cause accelerated wear. Over inflation above the sidewall, max can cause excessive wear to the center of the tread. However, inflating up to the sidewall limit will not cause excessive wear in the center of the tread. Modern tyres have steel belts built in to prevent this. Under inflation, causes excessive wear to the outer ribs. Quite often, the placard pressure is too low and most tyres are underinflated as a result. Unbalanced wheels can cause uneven tyre wear, as the rotation may not be perfectly circular. Tyre manufacturers and car companies have mutually established standards for tread wear testing that include measurement parameters for tread loss profile, lug count, and heel-toe wear. Also can be known as tyre wear. Tyre wear rates reported in the literature range between 0.006 and 0.09 g km−1 per tyre (Rogge et al., 1993). An estimate from Great Britain showed the 18 total tyre wear to be 140 g per meter per year (Environment Agency News, 1999). The actual wear rate is, however, dependent on a range of factors such as driving style, weather, and tyre and road characteristics (EEA, 2003). The wear rate has been shown to be several times higher during urban driving than during motorway driving, due to increased acceleration, braking, and cornering in cities (Stalnaker et al., 1996). Thus, a significant part of the worn tread rubber may be emitted in cities, even though city driving only accounts for a small part of the tyre mileage. The following annual figures on the emissions of tyre wear particles to the environment have been reported for different countries; Great Britain 57 × 106 kg (Environment Agency News, 1999), Germany 60 × 106 kg (Baumann and Ismeier, 1998), Italy 50 × 106 kg (Milani et al., 2004), Sweden 10 × 106 kg (KemI, 2003), Denmark 7.3 × 106 kg (Fauser et al., 2002), and USA 500 × 106 kg (Councell et al., 2004). Most of the abraded rubber is released in the form of relatively large particles that will deposit on the road or close to the road, (Fauser, 1999). Tyre wear particles have complex shapes and morphologies and are rich in porosity (Milani et al., 2004). Rubber from skid marks from twelve different tyres was analysed by pyrolysis gas chromatography mass spectrometry, and tyres were found not to be homogenous. Several peaks that were found in tyre samples were not found in skid mark samples, indicating that these compounds were either lost during the skid process or not left behind (Sarkissian, 2007).

2.5.3 Tread Separation

Tyre blowouts and tread separation are a very hot safety issue in the Kingdom of Saudi Arabia. The local media intensively cover accidents resulting from tyre failure on rural roads. Recent statistics compiled by the Special Forces for road security in the kingdom revealed that 624 traffic accidents resulted from tyre failure in the year 2001. This represents 13% of the total traffic accidents attended to by these forces. Taking into consideration the length of roads under the jurisdiction of the special forces for road security (mainly rural roads), the total number of tyre-related accidents can be transformed into a rate of 1 accident per 11 km of rural road in that year.(Ratrout, 2005) The only study on tyre failure and tread separation in the Kingdom of Saudi Arabia was done by the Saudi ARAMCO Company. It ran from 1981 to 1985 and covered mainly the company's vehicles. The study found that 60% of the surveyed vehicles had their tyre pressure 20% below the recommended pressure and that about 2% of the tyres used by the company had failed because of tread separation. The report concluded that tyre under-inflation was one of the major contributors to tyre failure. (Ratrout, 2005) The National Center for Statistics and Analysis of the USA (NCSA) in USA studied the data collected by the National Accident Sampling System-Crashworthiness Data System (NASS-CDS) between 1995 and 1998 and estimated that ―23,464 tow-away crashes, or 0.5% of all crashes, are caused by blowouts or flat tyres each year (Ratrout, 2005) Many studies and reputable tyre manufacturers indicate that under-inflation in tyres is a major contributor to tyre failure. When tyres are under-inflated, their sidewalls flex more, and 20 consequently the temperature inside them increases up to a point that the tyre cannot withstand and failure occurs (Ratrout, 2005)

2.5.4 Tyre Pressure and Fuel Efficiency

According to the Rubber Manufacturer's Association, when a tyre is under inflated by 1 Ib, the tyre's rolling resistance is increased by approximately 1% and that a 5–8% deterioration in rolling resistance performance, which equates to a roughly 1% reduction in fuel efficiency (Calwell et al., 2003). This is similar to the review study done by Schuring and Futamura (1990) that found for each 10% reduction in the rolling resistance coefficient the fuel efficiency increased by 1.2–2.5% for city and 0.9–2.1% for highway driving. This is because inflation pressure determines tyre stiffness, which has a significant influence on the contact area of the tyre and pressure distribution over the contact surface. Thus, as pressure in the vehicle‘s tyres is reduced, the rolling resistance increases over the road because the surface contact area and virtual hill height is increased. When the rolling resistance is increased, it takes more energy (fuel) to get the automobile to go the same distance. (Schuring and Futamura, 1990) According to this research, there is a direct effect of tyre pressure on fuel consumption. Any decrease in tyre pressure means extra fuel consumed by the vehicles.

2.6 Tyre Pressure Monitoring System

Tyre pressure monitoring systems (TPMS) are electronic systems that monitor the tyre pressures on individual wheels on a vehicle, and alert the driver when the pressure goes below a warning limit. There are several types of designs to monitor tyre pressure. Some actually measure the air pressure, and some make indirect measurements, such as gauging when the relative size of the tyre changes due to lower air pressure. These systems are becoming mandatory in countries such as the United States. For example, to address challenges and safety concerns created by America's increased use of sports utility vehicles (SUVs), the National Highway Traffic Safety Administration created, and the US 106th Congress passed, the Transportation Recall Enhancement, Accountability and Documentation (TREAD) Act (2000). The TREAD Act requires automobile companies to report defects in motor vehicles, tyres, or equipment and requires faulty equipment to be replaced or repaired at no cost to the consumer. The TREAD Act will also reduce energy use because it demands that manufactures install a tyre pressure monitoring system (TPMS) in future automobiles. The deployment of TPMS, which consists of a tire pressure sensor in each tyre, a logic circuit, and a warning system for the driver, will reduce fuel use by assuring America's fleet is driving on properly inflated tyres. It has already been established that the average driver does not understand, monitor or correct vehicle tyre pressure (McKenzie-Mohr et al., 1999; Jones, 2001)

2.7 Conclusion from the literature review

From the review carried out, significant research works draw some correlation between the tyre pressure and the fuel consumption such that when tyre pressure increases, the fuel consumption also decreases until it reaches the recommended tyre pressure and then when tyre pressure increases, fuel consumption decreases. Both under inflation and over inflation of the vehicle tyres affects the fuel consumption. However, none of the researches was able to provide define model that relates tyre pressure to fuel consumption. This thesis seeks to verify if those research works carried out elsewhere in the world also holds in Ghana and develop a model to relate the effect of tyre pressure on fuel consumption.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter looks at how the research was conducted and the sampling technique used to analyze the data.

3.1 Research Design

A survey of vehicles was conducted in La Dade Kotopon Municipal Assembly. The survey was based on field data on vehicles from GCAA headquarters, and GACL headquarters.

A case study approach was chosen for this kind of research. Research constraints as well as the depth of the study were taken into consideration in choosing the case study approach. The study was based on field data on vehicles from the GCAA bus terminal. This is because it is not possible to cover all the vehicles at the airport. This is partly due to logistic and resource constraint.

3.2 Measurement of Tyre Pressure

A survey was conducted to descry how far vehicles plying their trade on roads in La Dade Kotopon have tyre pressure deviated from the manufacturers recommended tyre pressure. Two public institutions namely GCAA and GACL were taken into consideration.

Initially, the survey was conducted in the transport department of GCAA. All the tyre pressures for each vehicle were measured using tyre pressure gauge and compared to the manufacturers recommended tyre pressure. The result is shown in Table 3.1.

Table 3.1: Measured tyre pressure of vehicles at Transport department of GCAA

Vehicle	MEASURED TYRE PRESSURE (N/mm^2)(MTP)				MANUFACTURERS RECOMMENDED TYRE PRESSURE (N/mm^2)(MRTP)			
	FR	FL	RR	RL	FR	FL	RR	RL
1	0.1792	0.1655	0.1655	0.2068	0.2068	0.2068	0.2206	0.2206
2	0.2620	0.2620	0.1655	0.1517	0.2551	0.2551	0.2965	0.2965
3	0.2758	0.2758	0.3378	0.3378	0.3516	0.3516	0.4482	0.4482
4	0.1310	0.1310	0.1517	0.2068	0.2137	0.2137	0.2620	0.2620
5	0.2344	0.2344	0.2068	0.2344	0.2068	0.2068	0.2620	0.2620
6	0.2689	0.2758	0.2068	0.2689	0.2068	0.2068	0.2689	0.2689
7	0.2068	0.1931	0.3447	0.1655	0.3103	0.3103	0.4137	0.4137
8	0.2000	0.1931	0.1517	0.1793	0.2137	0.2137	0.2206	0.2206
9	0.1034	0.3172	0.2206	0.2068	0.2068	0.2068	0.2206	0.2206
10	0.2551	0.0827	0.2137	0.2758	0.3103	0.3103	0.4137	0.4137

From Table 3.1, the average tyre pressures in each vehicle for both measured and recommended were computed. The difference between the average measured tyre pressure and average recommended tyre pressure were then computed to establish the 25-percentage deviation of the tyre pressure. The results are tabulated and presented in Table 3.2.

Table 3.2 Percentage deviation of vehicles at Transport department of GCAA

Vehicle	AVERAGE MEASURED TYRE PRESSURE (N/mm2)(AMTP)	AVERAGE RECOMMENDED TYRE PRESSURE (N/mm2) (ARTP/AMRTP)	DEVIATION =AMTP - AMRTP	PERCENTAGE DEVIATION (%) ((AMTPAMRTP) /AMRTP)*100
1	0.1793	0.2137	-0.0344	-16
2	0.2103	0.2758	-0.0655	-24
3	0.3068	0.3999	-0.0931	-23
4	0.1551	0.2293	-0.0742	-32
5	0.2275	0.2258	0.00173	0.8
6	0.2551	0.2430	0.0121	5
7	0.2275	0.3620	-0.1345	-37
8	0.1810	0.2172	-0.0362	-17
9	0.2120	0.2137	-0.00173	-0.8
10	0.2068	0.3620	-0.1552	-43

Table 3.3: Deviation of tyre pressures at GCAA

DEVIATION	NUMBER OF VEHICLES
ABOVE +30%	2
+(20.01 – 30)%	1
+(10.01 – 20)%	4
+(0.01 – 10)%	11
Recommended	2
-(0.01 – 10)%	9
-(10.01 – 20)%	30
-(20.01 – 30)%	29
BELOW -30%	12
TOTAL	**100**

From Table 3.3, it could be inferred that 98% of the vehicles deviated from the recommended tyre pressure. Only 2% conform to the recommended tyre pressure.

Hence, the survey was extended to GACL transport terminal at the airport to verify whether they have the same trend as obtained GCAA transport department. 60 vehicles were surveyed at GACL.

Table 3.4: Deviation of tyre pressures of the various vehicles at GACL bus terminal.

DEVIATION	GACL Bus Terminal
ABOVE +30%	0
+(20.01 – 30)%	0
+(10.01 – 20)%	3
+(0.01 – 10)%	0
Recommended	2
-(0.01 – 10)%	5
-(10.01 – 20)%	23
-(20.01 – 30)%	21
BELOW -30%	6
TOTAL	**60**

Inquest to the Table 3.3 and Table 3.4, only 2.5% (4) out of the 160 vehicles measured had the recommended tyre pressure, indicating that 97.5% of the vehicles deviated from the recommended tyre pressure. This means that majority of the vehicles surveyed deviated from the recommended tyre pressure. Hence, a case study was carried out on GCAA bus terminal on some of the vehicles to ascertain the effect of tyre pressure of vehicles on the fuel consumption.

3.3 Measurement of tyre pressure and fuel consumption of GCAA buses

The effects of tyre pressure on vehicle performance cannot be overlooked since research has shown that it has effect on tyre wear, fuel consumption, and rolling resistance. It is assumed that when the tyre pressure is below or above the recommended tyre pressure, more fuel may be consumed. This means that more fuel will be needed for the same amount of distance to be covered. Tyre wear can cause tyre blowout, causes discomfort in driving and makes it unsafe to drive the vehicle. Tyre wear also affects the fuel used since it may lead to more fuel consumption. Tyre blowout can also cause accidents. When the rolling resistance is 29 decreased or increased, it can cause tyre wear and also make it unsafe to handle the vehicle. Rolling resistance can also leads to more fuel consumption. Hence a case study was conducted on GCAA headquarters to establish a relation between the tyre pressure and the fuel consumption. The experiment seeks to find out the effect of tyre pressure on the fuel consumed by vehicles. The experiment was carried out for three (3) months period using five of the shuttle buses. In each day tyre pressures, odometer reading, and the fuel reading were recorded for each vehicle. Records were taken at intervals of three (3) hours. The results for vehicle with vehicle 1 readings for the first two days were tabulated and presented in Table 3.5.

Table 3.5: Reading for the first two days for vehicle1

Day	Time	Odometer Reading (km)	Fuel Reading (litres)	Tyre pressure N/mm^2 Right Front	Left Front	Right Rear	Left Rear
1	08:00	39947	39.75	0.2758	0.2758	0.3447	0.3241
	11:00	39991	32.18	0.2758	0.2758	0.3447	0.3241
	14:00	40025	28.39	0.2758	0.2758	0.3447	0.3241
	17:00	400	24.61	0.2758	0.2758	0.3447	0.3241
2	08:00	40080	75.71	0.2758	0.2758	0.3378	0.3172
	11:00	40111	71.92	0.2758	0.2758	0.3378	0.3172
	14:00	40141	68.14	0.2758	0.2758	0.3378	0.3172
	17:00	40206	60.57	0.2758	0.2758	0.3378	0.3172

From Table 3.5 above, average pressure was found and the fuel flow, that is, the fuel was divided by the distance covered were found and presented in Table 3.6.

Average Pressure (N/mm	Fuel Consumption (litres/km^2)
0.3051	0.1721
0.3051	0.1114
0.3051	0.1261
0.3017	0.3030
0.3017	0.1221
0.3017	0.1261
0.3017	0.1164

Readings were taken for three months and the results were tabulated and presented in appendix B. From Table 3.6 and appendix B, the pressures were arranged from 0.3017 N/mm^2 upwards with intervals of 5.5. With the same pressure, different fuel consumptions were attained. For instance, at the pressure of 0.3051 N/mm^2 , the recorded fuel consumptions were, 0.1721, 0.1114, and 0.1261litres/km. Average fuel consumption was used to represent the corresponding tyre pressure; thus for 0.3051 N/mm^2 , an average of 0.1365±0.0258 litres/km was obtained. This was done for the other four vehicles namely Vehicle 2, Vehicle 3, Vehicle 4 and Vehicle 5 and the results are presented Appendix B.

3.4 Model suitability for the data

In the most general sense, a model is anything used in any way to represent something else. Some models are physical objects, for instance, a toy model which may be assembled, and may even be made to work like the object it represents. Models are typically used when it is either impossible or impractical to create experimental conditions in which scientists can directly measure outcomes. Direct measurement of outcomes under controlled conditions will always be more accurate than modelled estimates of outcomes. When predicting outcomes, models use assumptions, while measurements do not. However, it is important to note that in analyzing the data collected from measurements, assumptions are made albeit different to those made through the use of a model. As the number of assumptions in a model increase, the accuracy and relevance of the model will likely diminish.

Modelling is an essential and inseparable part of all scientific activity, and many scientific disciplines have their own ideas about specific types of modelling. There is little general theory about scientific modelling, offered by the philosophy of science, systems theory, and new fields like knowledge visualization.

All models are in simulacra, that is, simplified reflections of reality, but despite their inherent falsity, they are nevertheless extremely useful. Building and disputing models is fundamental to the scientific enterprise. Complete and true representation may be impossible (see non-representational theory), but scientific debate often concerns which is the better model for a given task, such as the most accurate climate model for seasonal forecasting.

A model is evaluated primarily by its consistency to empirical data; any model inconsistent with reproducible observations must be modified or rejected. However, a fit to empirical data alone is not sufficient for a model to be accepted as valid. Other factors important in evaluating a model include: Ability to explain past observations, ability to predict future observations, cost of use, especially in combination with other models, refutability, enabling estimation of the degree of confidence in the model, simplicity, or even aesthetic appeal. People may attempt to quantify the evaluation of a model using a utility function. All models can be classified under these three

1) static-dynamic
2) Deterministic probabilistic
3) iconic-analog-symbolic

This research will concentrate on mathematical models using statistical method of modelling. A statistical method of model is a formalization of relationships between variables in the form of mathematical equations. A statistical model describes how one or more random variables are related to one or more random variables. The model is statistical as the variables are not deterministically but stochastically related. In mathematical terms, a statistical model is frequently thought of as a pair (Y, P) where Y is the set of possible observations and P the set of possible probability distributions on Y. It is assumed that there is a distinct element of P which generates the observed data. Statistical inference enables us to make statements about which element(s) of this set are likely to be the true one. According to the number of the endogenous variables and the number of equations, statistical models can be classified as complete models (the number of equations equals to the number of endogenous variables) and incomplete models. Some other statistical models are the general linear model (restricted to continuous dependent variables), the generalized linear model (for example, logistic regression), the multilevel model, and the structural equation model. For this research least squares method of estimation for regression will be used to estimate the model. Least squares method is the simplest and thus very common estimator. It is conceptually simple and computationally straightforward. Least squares estimates are commonly used to analyze both experimental and observational data. Other methods are there but cannot give good result for the collected data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

Having reviewed the necessary literature on tyre pressure and its effects, there is the need to ascertain and validate some of the information presented in the literature across the world.

This chapter looks at the quantitative analysis of the study. This includes data analysis and presentation of the data that were collected during the primary survey.

4.1 Deviation from recommended tyre pressure

A field survey was conducted at the GCAA bus terminal to find out whether the various vehicles sampled, that is, one hundred (100), for the study had the recommended tyre pressure for smooth running of the vehicles. Tyre pressure gauge was used to measure, the tyre pressures of the vehicles. For each vehicle all the tyres were measured. Figure 4.1 shows how measured tyre pressure of vehicles on GCAA bus terminal deviate from the manufacturers recommended tyre pressure. It could be inferred that almost all one hundred (100) vehicles studied deviated from the recommended tyre pressure. Only two (2) out of the 100 vehicles studied, representing two (2) percent, conformed to the manufacturer's recommended tyre pressure. The remaining ninety-eight (98) vehicles, representing ninety-eight (98) percent, deviated from the recommended tyre pressure.

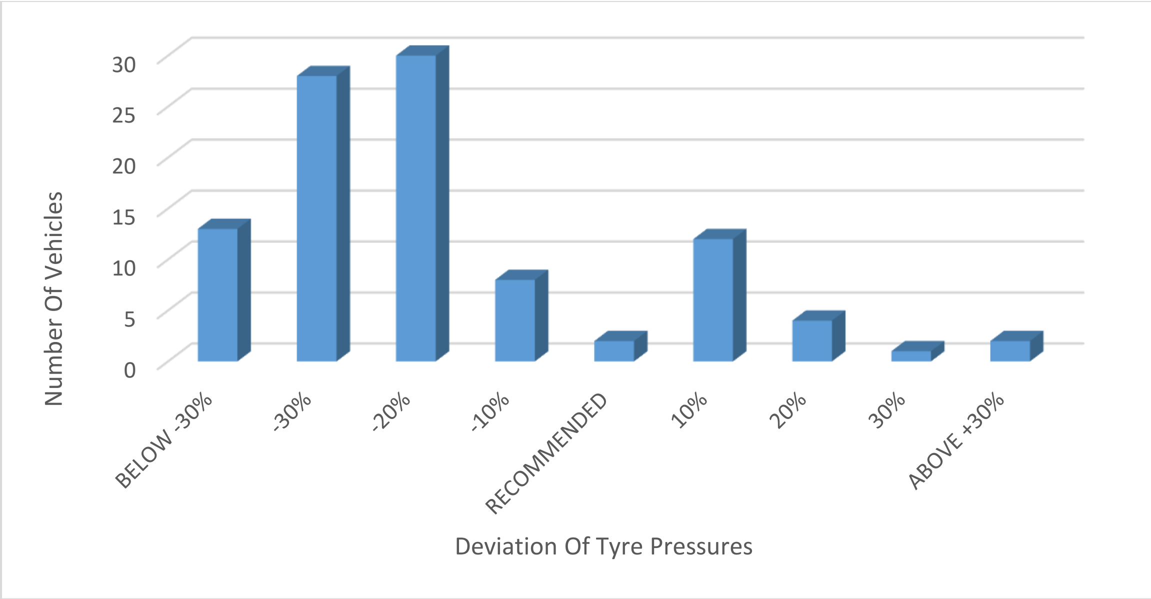

Figure 4.1: A graph showing how measured tyre pressures of vehicles on GCAA bus terminal deviate from the manufacturers recommended tyre pressure.

With respect to the above phenomenon, eighty (80) percent of the deviating vehicles, being the vast majority, fell short of the recommended tyre pressure. Proportionally, eight (8) vehicles representing eight (8) percent were noted to have their tyre pressure being (0 – 9.99) % less than the recommended standard. Thirty (30) vehicles representing thirty (30) percent had their tyre pressures being (10 – 19.99) % less than the recommended tyre pressure, whilst the tyre pressure of twenty-nine (29) vehicles also deviated by (20 – 29.99) % less than the ideal pressure. The remaining twelve (12) vehicles had their measured tyre pressure more than thirty (30) percent below the recommended tyre pressure.

On the flip side however, the remaining eighteen (18) percent of the vehicles rather exceeded the manufacturer ‘s recommended tyre pressure. In other words, eleven (11) vehicles had their tyre pressure being (0 – 9.99) % more than the recommended pressure. Four (4) vehicles also had their tyre pressure being (10 – 19.99) % more than the recommended standard, whilst one (1) vehicle deviated by thirty (20 – 29.99) % more than the ideal tyre pressure. The remaining two (2) vehicles had their measured tyre pressure more than thirty (30) percent above the recommended tyre pressure.

With this result, in view one other bus terminal at the Kotoka International Airport, which was the GACL bus terminal, was studied to see how far vehicles there have deviated from the manufacturers recommended tyre pressure. Hence, the results obtained for the GACL terminal are presented in Figure 4.2. From Figure 4.2, it could be seen that at GACL all the vehicles deviated from the recommended tyre pressure. 92% of the vehicles had their measured tyre pressures below the recommended tyre pressure whilst 8% had their measured tyre pressure above the recommended tyre pressure.

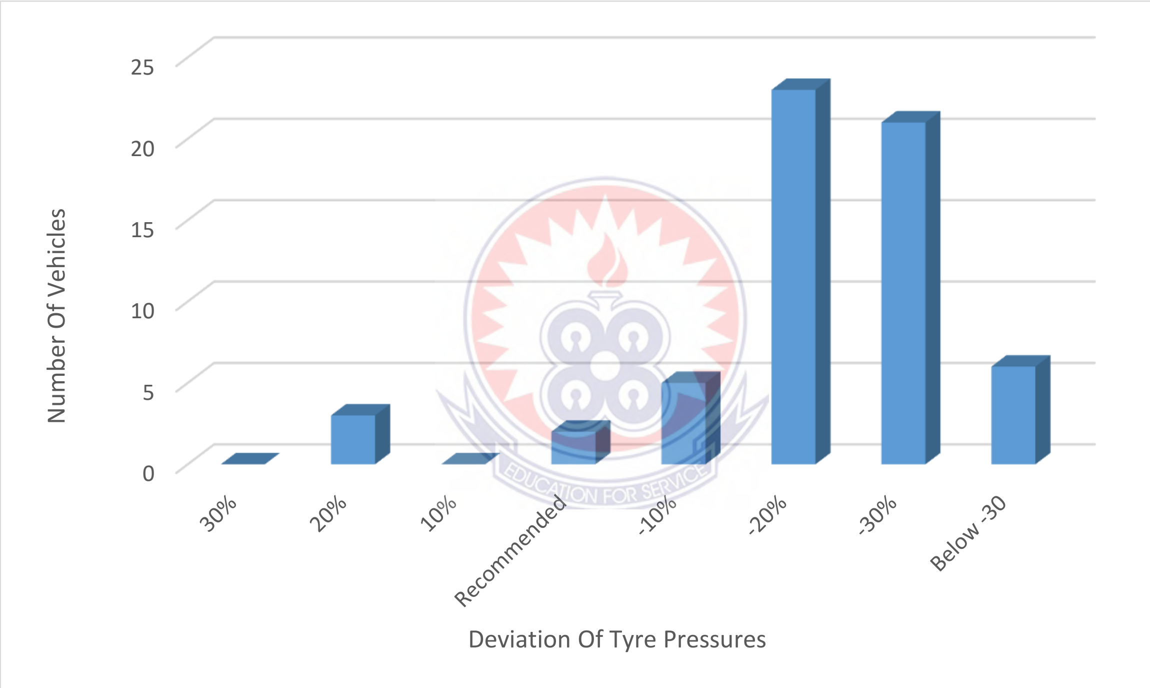

Figure 4.2: A graph showing how tyre pressures of vehicles in GACL bus terminal, deviate from the manufacturers recommended tyre pressure

Combining all the two study areas, as shown in Figure 4.1 and 4.2, out of the total of one hundred and sixty (160) vehicles survey at the Kotoka International Airport, only four (4) out of the 160 vehicles representing two point five (2.5) percent, conformed to the manufacturer 's recommended tyre pressure. The remaining one hundred and fifty six (156) vehicles, representing ninety-seven point five (97.5) percent, deviated from the recommended tyre pressure. With respect to the phenomenon below, eighty three (83) percent of the deviating vehicles, being the vast majority, fell short of the recommended tyre pressure. Proportionally, fourteen (14) vehicles representing eight point even five (8.75) percent were noted to have their tyre pressure being ten (10) percent less than the ideal or recommended standard. Fifty three (53) vehicles representing thirty three point one two five (33.125) percent had their tyre pressures being twenty (20) percent less than the recommended tyre pressure, whilst the tyre pressure of fifty (50) vehicles also deviated by thirty (30) percent less than the ideal pressure. The remaining eighteen (18) vehicles had their measured tyre pressure more than thirty (30) percent below the recommended tyre pressure.

Having carried out an extensive study on the tyre pressure of about one hundred and sixty (160) vehicles in the La Dade Kotopon Municipal Assembly it is very alarming to note that only two point five (2.5) percent of the vehicles conformed to the manufactures required tyre pressure. This leaves much to be desired necessitating a study on its effect on vehicle performance. Emanates from the fact that more energy is now required to move the vehicle and maintain the designated speed it requires. This means more fuel will be required and will therefore increase the cost of fuel since consumption of fuel is very high. Drivers will have to spend much more on fuel expenditure in order to keep their vehicles running smoothly. Therefore, this will reduces the revenue that commercial drivers would have earned from their operations. Some of these costs are also transferred to the general public who patronize these commercial vehicles leading to hikes in the prices of fares, goods and services. The significant increase in the fuel consumption will be discussed in the next section of this chapter when the performances of five vehicles on GCAA bus terminal are studied. With the increase in fuel consumption, there is a need to get more crude oil in the country. This therefore means government will have to commit more resources to the importation of crude oil in the country. The little hard earned foreign exchange will have to be used in the importation of this commodity. Resources that could be channeled to other vital sectors of the economy come to a standstill hindering the smooth running of the economy. This will therefore affects the developmental agenda of government as well. From the environmental point of view, as more fuel is burnt it emits more carbon monoxides into the atmosphere causing environmental problems. It is therefore clear that under-inflated tyres do indeed contribute to pollution and its related diseases. With the environmental hazards more resources will therefore have to be invested into health care in order to minimize its effect. Drivers normally experience a lot of discomfort and inconveniences when the vehicle is underinflated. When a tyre is underinflated, most of the vehicle's weight is concentrated on the tread which is located just under the sidewalls of the tyre, rather than being spread out evenly across the full width of the tyre. This means that as the tyre rolls, the sidewall gets continually flexed (squished, if you will) and heats up. This affects both performance and safety. Rolling resistance, which is caused by deformation of the tyre in contact with the road surface, is another problem that may be brought about because of the deviations in the tyre pressures of the vehicles studied. The type of roads that these vehicles ply may also contribute to the increases in the rolling resistance of the tyre to the road inferring that more energy must be applied in order to move the vehicles. This has contributed to the decline and rise of the fuel flow despite increases in the tyre pressure. Low tyre pressure, excess vehicle weight and high temperatures can cause additional flexing and stress on the sidewalls and can lead to tyre failure. In addition, tyres with low pressure wear more quickly, degrade the vehicle's handling, lower the vehicle's load carrying ability and increase fuel consumption. In a worst-case scenario, under inflated tyres can lead to a catastrophic blowout or tread separation. It can be concluded that tyre wear and rolling resistance affect fuel consumption. With the increase in fuel consumption and its effect on socio-economic development there is therefore the need to look at the issue at stake more critically. The facts suggest that a largely unseen and potentially dangerous problem exists for drivers.

4.2 Model Development

4.2.1 Modeling using least squares method

The scatter diagrams for the various collected data were plotted as shown in Figures 4.3, 4.4, 4.5, 4.6 and 4.7. From the scatter diagrams, it could be inferred that the corellation between the fuel consumption and the tyre pressures are in the form of a polynomial function of a second degree. Hence a model can be developed using the least squares method of modeling.

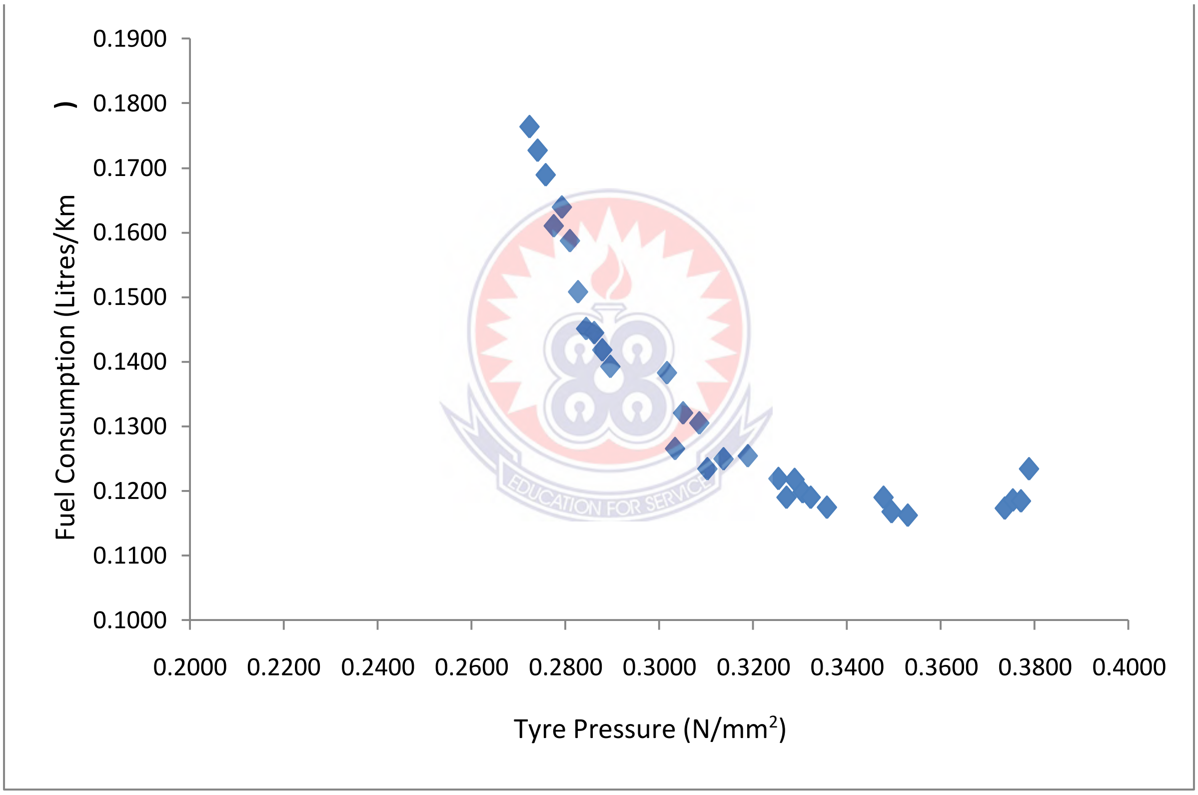

Figure 4.3: A scatter diagram for Vehicle 1 showing fuel consumption verses tyre pressure

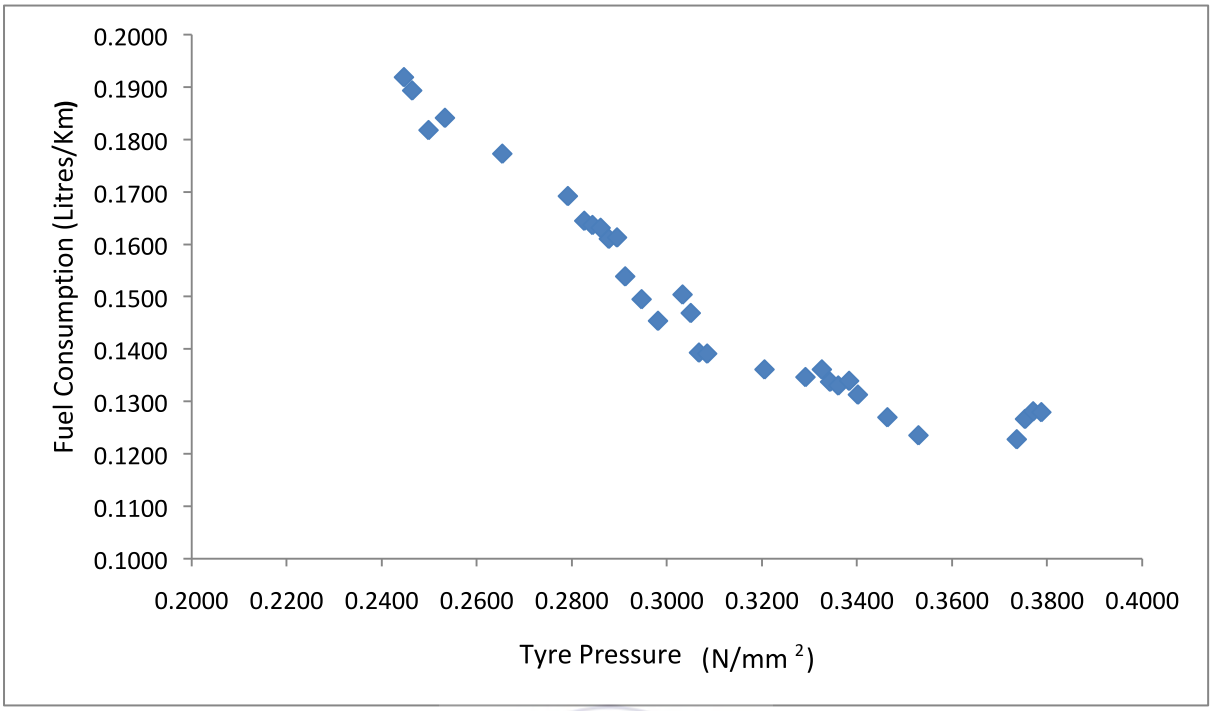

Figure 4.4: A scatter diagram for vehicle 2 showing fuel consumption against tyre pressure

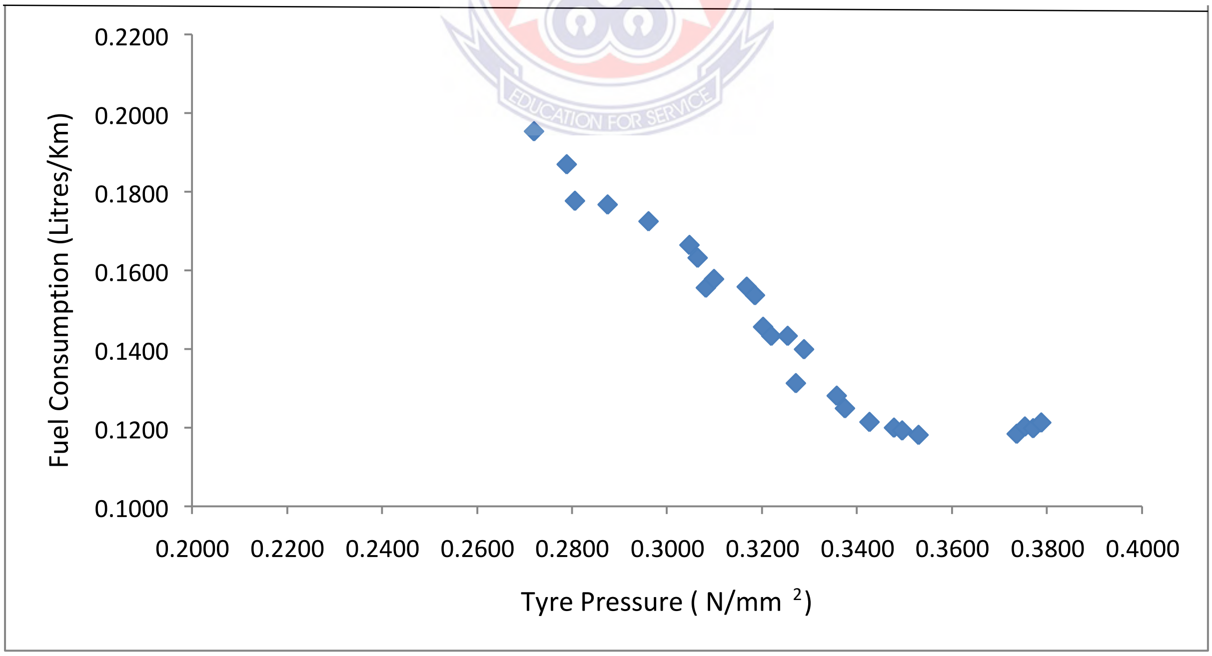

Figure 4.5: A scatter diagram for vehicle 3 showing fuel consumption against tyre pressure

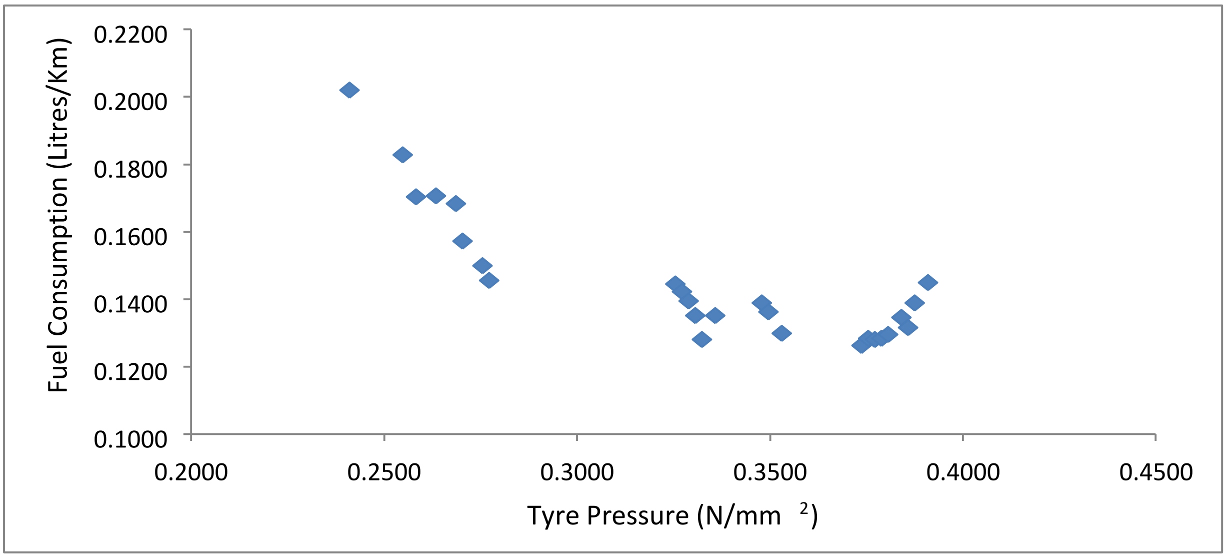

Figure 4.6: A scatter diagram for vehicle 4 showing fuel consumption against tyre pressure

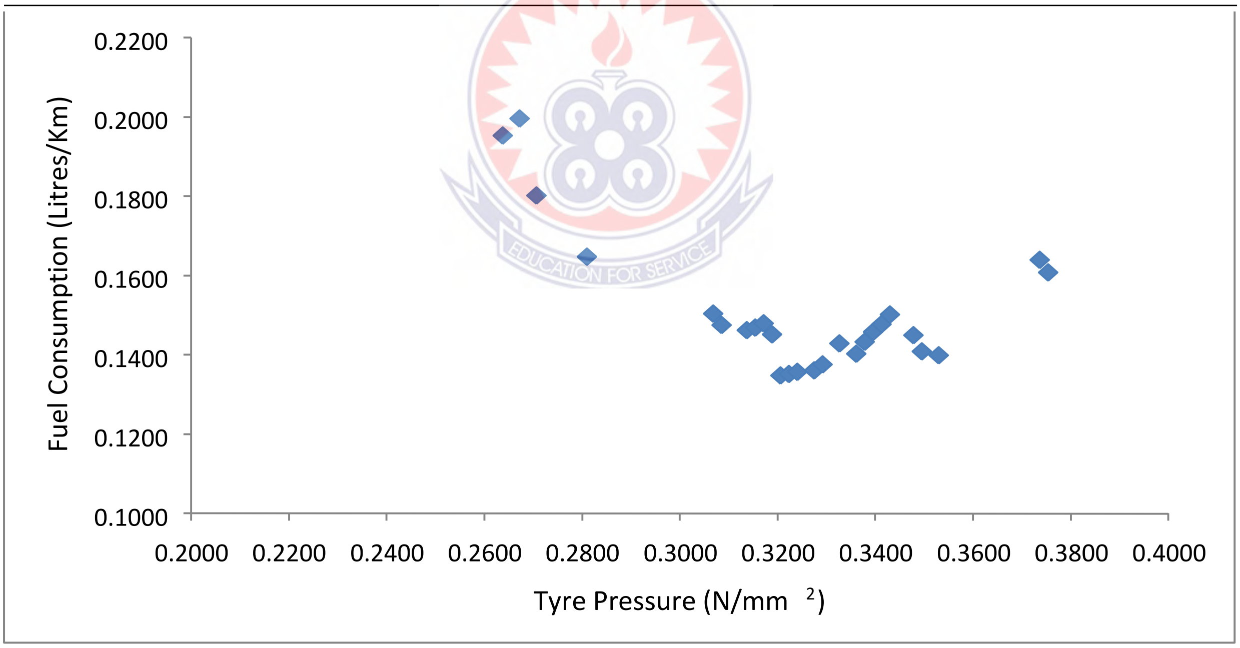

Figure 4.7: A scatter diagram for vehicle 5 showing fuel consumption against tyre pressure

The least squares method of regression and correlation was used to develop the models for the five vehicles. In the least squares method, the equation for the model is given by

$F = B_0 + B_1p + B_2p^2 + e,$

where F represent the fuel consumption, p represents tyre pressure, B_0, B_1, and B_2 are constants for the polynomial which must be derived from the data obtained, and e represent the error in the data. This equation can be written into three equations as

$$\sum_{i=1}^{n} F_i = B_0 n + B_1 \sum_{i=1}^{n} p_i + B_2 \sum_{i=1}^{n} p_i^2 \text{ .... } (1)$$

$$\sum_{i=1}^{n} p_i F_i = B_0 \sum_{i=1}^{n} p_i + B_1 \sum_{i=1}^{n} p_i^2 + B_2 \sum_{i=1}^{n} p_i^3 \text{ ..... } (2)$$

$$\sum_{i=1}^{n} p_i^2 F_i = B_0 \sum_{i=1}^{n} p_i^2 + B_1 \sum_{i=1}^{n} p_i^3 + B_2 \sum_{i=1}^{n} p_i^4 \text{ ..... } (3)$$

Putting the various values for the different vehicles into these equations and solving for various constants, B_0, B_1, and B_2 give the equation for each vehicle. For instance, for vehicle 1, the tyre pressure values were tabulated and the summations found as shown in Table 4.1.

Table 4.1: Substituted values and their summation for Vehicle 1 for solving the equation

Tyre Pressure (N/mm^2) (P)	Fuel Consumption (Litres/km) (F)	p^2	p^3	p^4	pf	p^2f
0.2723	0.1764	0.0742	0.0202	0.0055	0.0480	0.0131
0.2741	0.1727	0.0751	0.0206	0.0056	0.0473	0.0130
0.2758	0.1689	0.0761	0.0210	0.0058	0.0466	0.0128
0.2775	0.1610	0.0770	0.0214	0.0059	0.0447	0.0124
0.2792	0.1639	0.0780	0.0218	0.0061	0.0458	0.0128
0.2810	0.1587	0.0789	0.0222	0.0062	0.0446	0.0125
0.2827	0.1508	0.0799	0.0226	0.0064	0.0426	0.0121
0.2844	0.1451	0.0809	0.0230	0.0065	0.0413	0.0117
0.2861	0.1445	0.0819	0.0234	0.0067	0.0413	0.0118
0.2879	0.1418	0.0829	0.0239	0.0069	0.0408	0.0118

0.2896	0.1393	0.0839	0.0243	0.0070	0.0403	0.0117
0.3017	0.1383	0.0910	0.0274	0.0083	0.0417	0.0126
0.3034	0.1266	0.0920	0.0279	0.0085	0.0384	0.0116
0.3051	0.1321	0.0931	0.0284	0.0087	0.0403	0.0123
0.3085	0.1305	0.0952	0.0294	0.0091	0.0403	0.0124
0.3103	0.1235	0.0963	0.0299	0.0093	0.0383	0.0119
0.3137	0.1250	0.0984	0.0309	0.0097	0.0392	0.0123
0.3189	0.1255	0.1017	0.0324	0.0103	0.0400	0.0128
0.3254	0.1220	0.1059	0.0345	0.0112	0.0397	0.0129
0.3271	0.1190	0.1070	0.0350	0.0115	0.0389	0.0127
0.3289	0.1218	0.1081	0.0356	0.0117	0.0401	0.0132
0.3306	0.1199	0.1093	0.0361	0.0119	0.0396	0.0131
0.3323	0.1190	0.1104	0.0367	0.0122	0.0396	0.0131
0.3358	0.1175	0.1127	0.0378	0.0127	0.0395	0.0132
0.3478	0.1190	0.1210	0.0421	0.0146	0.0414	0.0144
0.3495	0.1168	0.1222	0.0427	0.0149	0.0408	0.0143
0.3530	0.1163	0.1246	0.0440	0.0155	0.0410	0.0145
0.3737	0.1174	0.1396	0.0522	0.0195	0.0439	0.0164
0.3754	0.1186	0.1409	0.0529	0.0199	0.0445	0.0167
0.3771	0.1185	0.1422	0.0536	0.0202	0.0447	0.0169
0.3788	0.1235	0.1435	0.0544	0.0206	0.0468	0.0177
Summation = 9.7875	4.1741	3.1239	1.0081	0.3289	1.3021	0.4107

Substituting these values in to the equations gives

$4.1741 = 31B_0 + 9.7875B_1 + 3.1239B_2$ …………………………………… (1)

$1.3021 = 9.7875B_0 + 3.1239B_1 + 1.0081B_2$ ……………………………….. (2)

$0.4107 = 3.1239B_0 + 1.0081B_1 + 0.3289B_2$ ……………………………….. (3)

Solving these equations simultaneously gives

$B_0 = 3.6285$, $B_1 = -21.4049$ and $B_2 = 32.3927$.

Substituting into the main equation gives $F = 3.6285 - 21.4049p + 32.3927p^2$ as the equation for Vehicle 1. This procedure was repeated four the other four vehicles and the results are shown in Appendix C and the equations obtained are tabulated and presented in Table 4.2.

Table 4.2: Various vehicles' equations for the five vehicles

VEHICLE	VEHICLES' EQUATIONS
1	$F = 3.6285 - 21.4049p + 32.3927p^2$
2	$F = 0.6272 - 2.5941p + 3.3428p^2$
3	$F = 0.5568 -1.7946p + 1.618p^2$
4	$F = 1.4454 - 7.9701p + 11.7484p^2$
5	$F = 0.6402 - 2.7463p + 3.7853p^2$

With these equations obtained, the various model graphs were drawn as shown in Figures 4.8, 4.9, 4.10, 4.11 and 4.12.

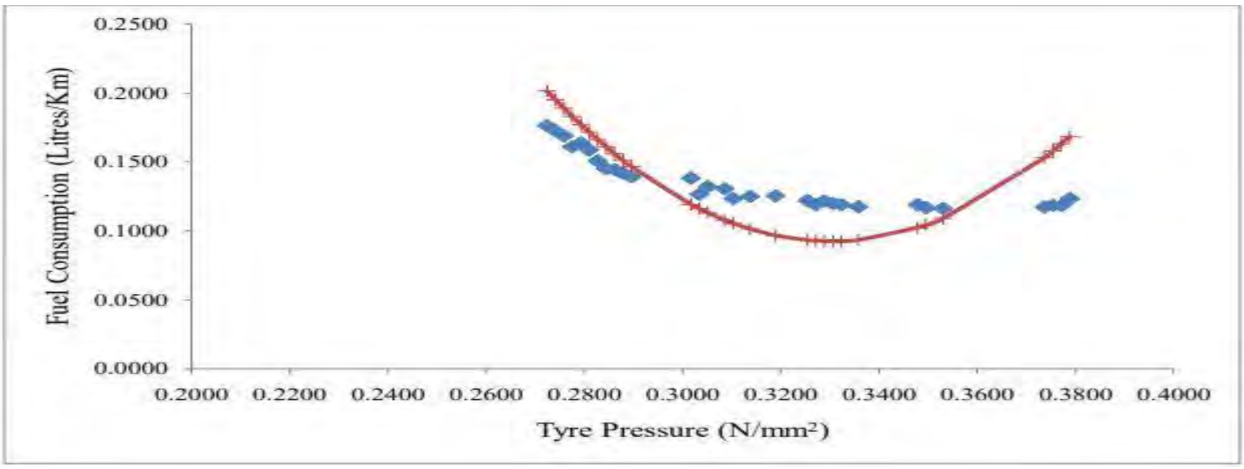

Figure 4.8: Model values of Vehicle 1 compared to the measured values

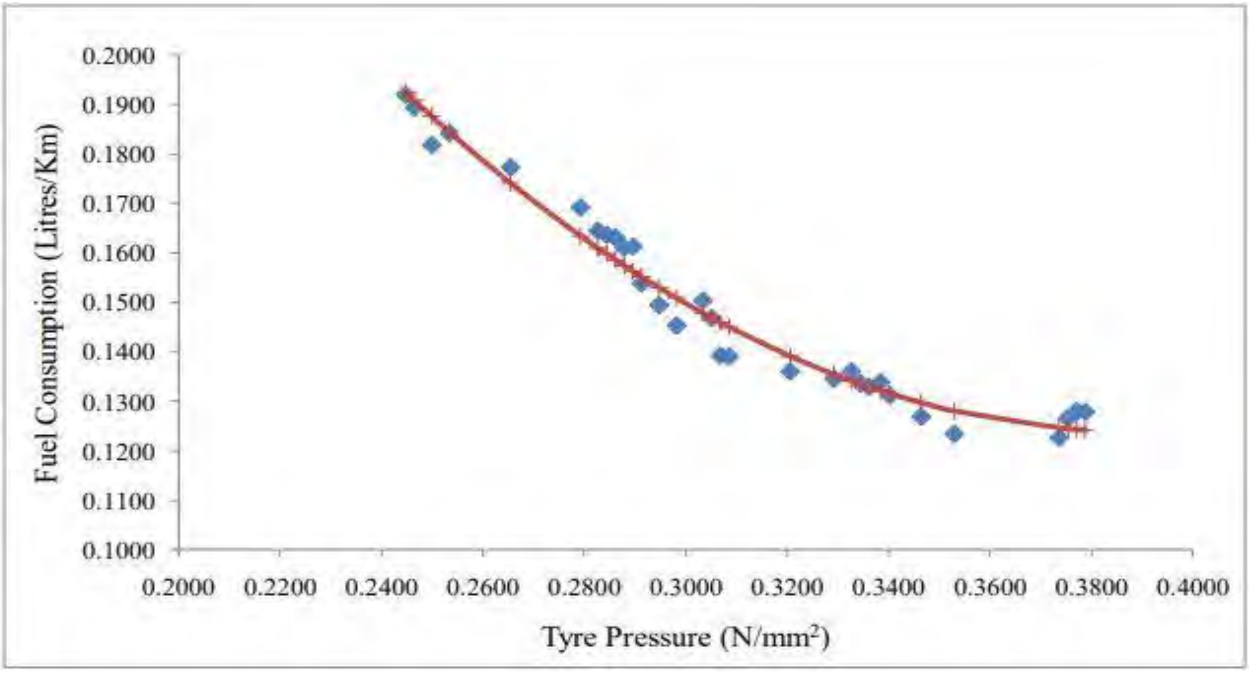

Figure 4.9: Model values of Vehicle 2 compared to the measured values

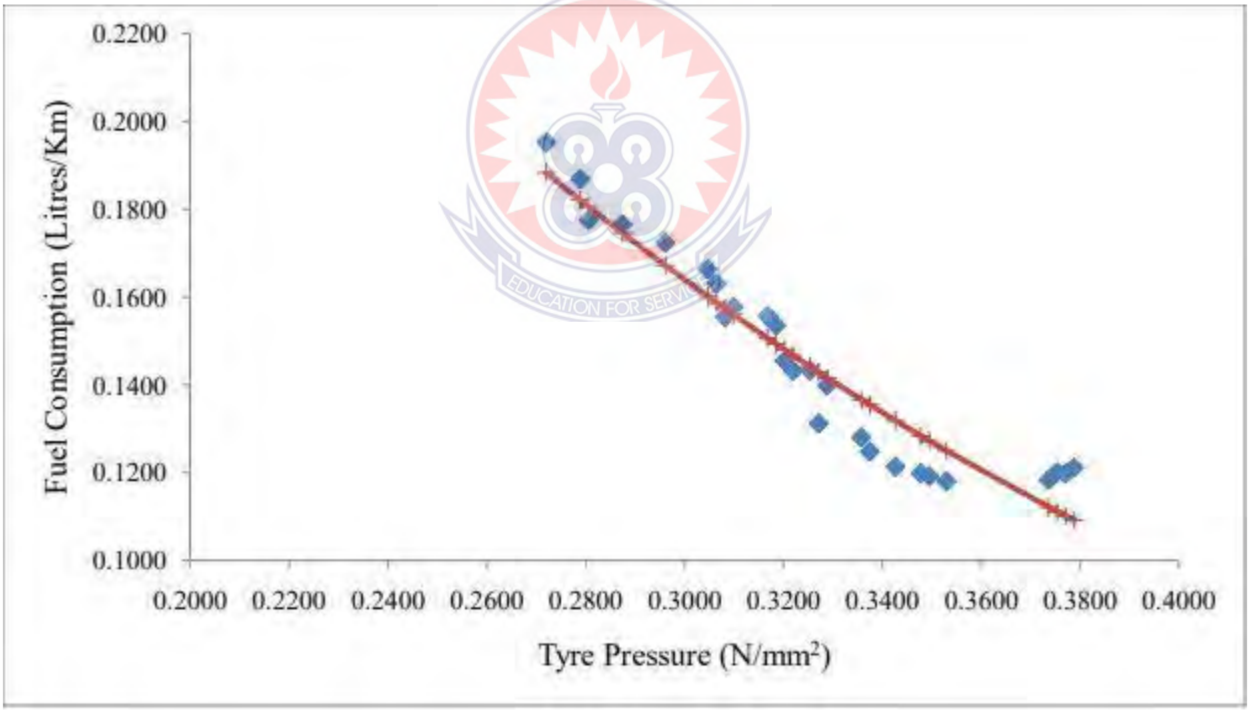

Figure 4.10: Model values of Vehicle 3 compared to the measured values

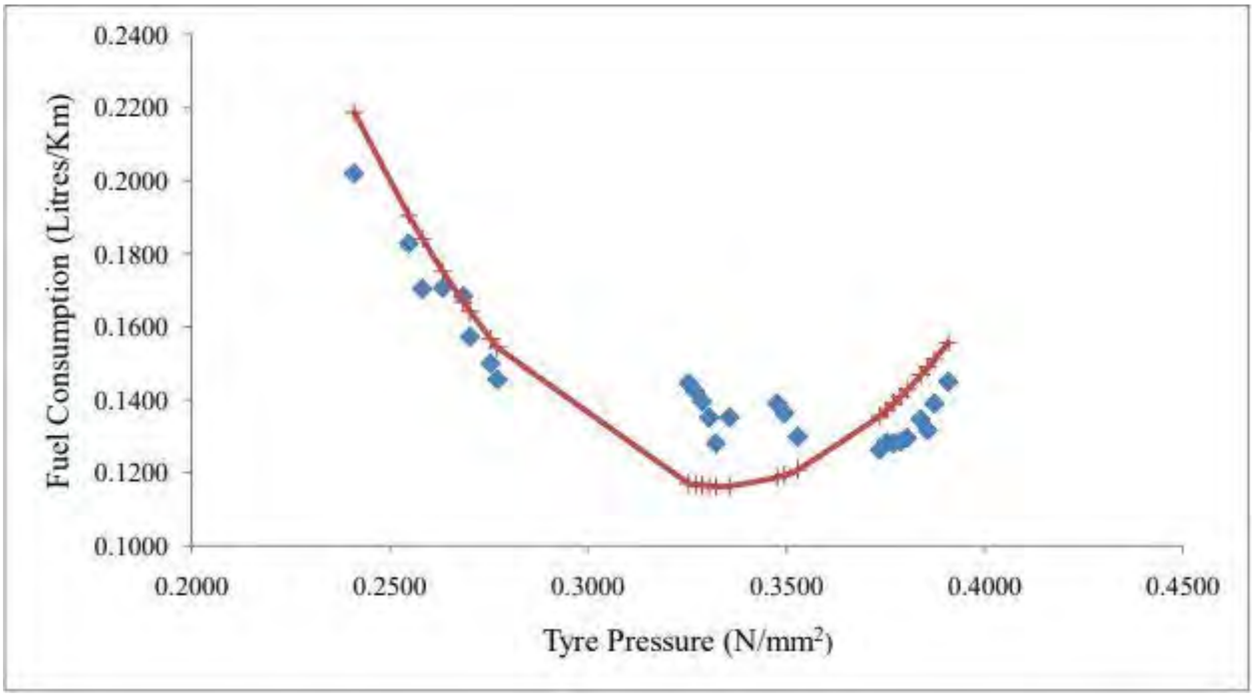

Figure 4.11: Model values of Vehicle 4 compared to the measured values

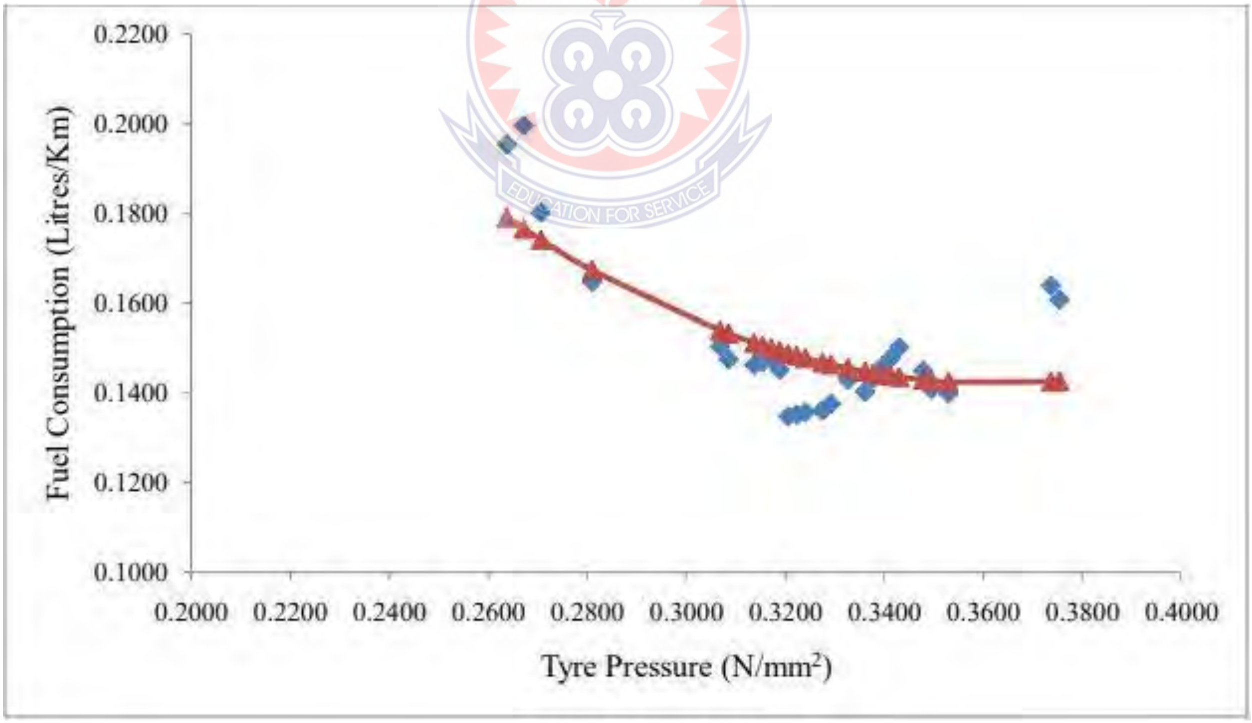

Figure 4.12: Model values of Vehicle 5 compared to the measured values

4.2.2 Verification of the model

To verify the model, two steps were adopted. First, the R^2 values were found for all the five vehicles using the least squares method for correlation. R^2 values represent the correlation, that is, how closely the variables are associated, were found using this equation

$$R^2 = \frac{(B_1\sum_i (p_i - \dot{p})(F_i - \dot{F}) + B_2\sum_i(p_i^2 - \dot{p}^2)(F_i - \dot{F})}{\sum_i(F_i - \dot{F})^2}$$

So considering Vehicle 1, the various values were substituted and their summations found as shown in Table 4.3.

Table 4.3: Substituted values and their summation for Vehicle 1 for solving R2

Tyre Pressure (N/mm^2)(F)	Fuel Consumption (litres/km)(p)	p^2	$p - \dot{p}$	$p^2 - \dot{p}^2$	$F - \dot{F}$	$(p - \dot{p})(F-\dot{F})$	$(p^2 - \dot{p}^2)(F - \dot{F})$	$(F - \dot{F})^2$
0.2723	0.1764	0.0742	-0.0434	-0.0266	0.0417	-0.00181	-0.00111	0.0017
02741	0.1727	0.0751	-0.0417	-0.0257	0.0381	-0.00159	-0.00098	0.0014
0.2758	0.1689	0.0761	-0.0399	-0.0247	0.0343	-0.00137	-0.00085	0.0012
0.2775	0.1610	0.0770	-0.0382	-0.0238	0.0264	-0.00101	-0.00063	0.0007
0.2792	0.1639	0.0780	-0.0365	-0.0228	0.0293	-0.00107	-0.00067	-0.00067
0.2810	0.1587	0.0789	-0.0348	-0.0218	0.0241	-0.00084	-0.00053	0.0006
0.2827	0.1508	0.0799	-0.0330	-0.0209	0.0162	-0.00053	-0.00034	-0.00034
0.2844	0.1451	0.1451	-0.0313	-0.0199	0.0105	-0.00033	-0.00021	0.0001
0.2861	0.1445	0.0819	-0.0296	-0.0189	0.0099	-0.00029	-0.00019	0.0001
0.2879	0.2879	0.2879	-0.0279	-0.0179	0.0072	-0.0002	-0.00013	0.0001
0.2896	0.1393	0.0839	-0.0261	-0.0169	0.0046	-0.00012	-0.00012	0.0000
0.3017	0.1383	0.0910	-0.0141	-0.0098	0.0037	-5.2E-05	-3.6E-05	0.0000

0.3034	0.1266	0.0920	-0.0124	-0.0087	-0.008	9.97E-05	7.05E-05	0.0000
0.3051	0.1321	0.0931	-0.0106	-0.0077	-0.0025	2.71E-05	1.96E-05	0.0000
0.3085	0.1305	0.0952	-0.0072	-0.0056	-0.0041	2.95E-05	2.29E-05	0.0000
0.3103	0.1235	0.0963	-0.0055	-0.0045	-0.0112	6.12E-05	5.05E-05	0.0001
0.3137	0.1250	0.0984	-0.0020	-0.0024	-0.0096	1.94E-05	2.27E-05	0.0001
0.3189	0.1255	0.1017	0.0032	0.0009	-0.0092	-2.9E-05	-8.4E-06	0.0001
0.3254	0.1220	0.1059	0.0097	0.0051	-0.0127	-0.00012	-6.5E-05	0.0002
0.3271	0.1190	0.1070	0.0114	0.0062	-0.0156	-0.00018	-9.7E-05	0.0002
0.3289	0.1218	0.1081	0.0131	0.0074	-0.0128	-0.00017	-9.5E-05	0.0002
0.3306	0.1199	0.1093	0.0149	0.0085	-0.0147	-0.00022	-0.00013	0.0002
0.3323	0.1190	0.1104	0.0166	0.0097	-0.0156	-0.00026	-0.00015	0.0002
0.3358	0.1175	0.1127	0.0200	0.0120	-0.0171	-0.00034	-0.0002	0.0003
0.3478	0.1190	0.1210	0.0321	0.0202	-0.0156	-0.0005	-0.00032	0.0002
0.3495	0.1168	0.1222	0.0338	0.0214	-0.0178	-0.0006	-0.00038	0.0003
0.3530	0.1163	0.1246	0.0373	0.0238	-0.0184	-0.00068	-0.00044	0.0003
0.3737	0.1174	0.1396	0.0579	0.0389	-0.0173	-0.001	-0.00067	0.0003
0.3754	0.1186	0.1409	0.0597	0.0402	-0.0160	-0.00096	-0.00064	0.0003
0.3771	0.1185	0.1422	0.0614	0.0414	-0.0162	-0.00099	-0.00067	0.0003
0.3788	0.1235	0.1435	0.0631	0.0427	-0.0112	-0.00071	-0.00048	0.0001
SUMMATION = 9.7875	4.1741	3.1239	0.0000	0.0000	0.0000	-0.01573	-0.00989	0.0106
AVERAGE = 0.3157	0.1346	0.1008						

The values found were substituted into the equation and the R^2 value was found to be 1.54. This was repeated the other four vehicles and the results obtained are tabulated and presented in Appendix C and Table 4.4.

Table 4.4: The various correlations or R^2 values for the five vehicles

Vehicle	Vehicles' Equations	R^2	$\lvert 1-R^2 \rvert$
1	$F = 3.6285 - 21.4049p + 32.3927p^2$	1.54	0.54
2	$F = 0.6272 - 2.5941p + 3.3428p^2$	0.93	0.07
3	$F = 0.5568 -1.7946p + 1.618p^2$	0.90	0.10
4	$F = 1.4454 - 7.9701p + 11.7484p^2$	1.39	0.39
5	$F = 0.6402 - 2.7463p + 3.7853p^2$	0.53	0.47

Secondly, the model fuel consumption values were compared with measured fuel consumption to find out the deviation as shown in Figures 4.8, 4.9, 4.10, 4.11 and 4.12.

Comparing the R^2 values and the model values of the five vehicles, it could be seen that, the equation for vehicle 2 is the best and can be used as the model. This vehicle has R^2 value of 0.93 and the fuel consumption model values deviate by ±4 which is within experimental error. So, the equation

$F = 0.6272 - 2.5941p + 3.3428p^2$ with $R^2 = 0.93$ can be accepted as the model for now. This model was tested using the data for the other four vehicles and the results obtained for the R^2 values are presented in Table 4.5.

Table 4.5: Comparing the R^2 values when using the vehicles own equation and when using the model

Vehicle	Using vehicles own equation R^2	Using vehicles own equation $\lvert 1-R^2 \rvert$	Using the model R^2	Using the model $\lvert 1-R^2 \rvert$
1	1.54	0.54	0.73	0.27
2	0.93	0.07	0.93	0.07
3	0.90	0.10	0.46	0.54
4	1.39	0.39	1.12	0.12
5	0.53	0.47	0.64	0.36

From Table 4.5, it could be said that using the model gives better R^2 than using the vehicles own equation. Which means that the model gives better fuel consumption values compared with using the vehicles own equation. Only Vehicle 3 has better R^2 value when using its own equation than using the model but the rest shows the opposite. This means that, the model can be used for all the five vehicles and by extension all vehicles if possible. Nevertheless, from the general equation using least squares method, an error value 'e' has to be computed when error values exceed ±5. Using the general model equation for the other four vehicles it was seen that the error values exceed that value and so the error value 'e' of the equation has to be found for the four vehicles and the least value taken. Using 95% confidence, the equation gives $F = 0.6272 - 2.5941p + 3.3428p^2 \pm 1.96\sigma_e$, where σ_e represent standard deviation of the error values.

$\sigma_e = \sqrt{\frac{\sum(e-\tilde{e})^2}{N}}$, where N is the number of values taken.

Considering vehicle 1, the various values are substituted and their summations found as shown in Table 4.6.

Table 4.6: Substituted values and their summation for Vehicle 1 for solving the error

Tyre Pressure (N/Mm2)	Measured Fuel Consumption(F)	Using Vehicle's Own Equation (F)	Using Model (F)	Error (E)	e^2
0.2723	0.1764	0.2016	0.1687	0.0077	0.0000595
0.2741	0.1727	0.1952	0.1673	0.0054	0.0000290
0.2758	0.1689	0.1890	0.1660	0.0029	0.0000084
0.2775	0.1610	0.1830	0.1830	-0.0037	0.0000138
0.2792	0.1639	0.1772	0.1635	0.0005	0.0000002
0.2810	0.1587	0.1716	0.1622	-0.0035	0.0000123
0.2827	0.1508	0.1662	0.1610	-0.0102	0.0001036
0.2844	0.1451	0.1609	0.1598	-0.0147	0.0002152
0.2861	0.1445	0.1559	0.1586	-0.0141	0.0001993
0.2879	0.1418	0.1511	0.1575	-0.0156	0.0002438
0.2896	0.1393	0.1464	0.1563	-0.0170	0.0002904
0.3017	0.1383	0.1192	0.1489	-0.0105	0.0001113
0.3034	0.1266	0.1161	0.1479	-0.0213	0.0004535

0.3051	0.1321	0.1132	0.1469	-0.0148	0.0002194
0.3085	0.1305	0.1079	0.1450	-0.0145	0.0002100
0.3103	0.1235	0.1056	0.1441	-0.0207	0.0004277
0.3137	0.1250	0.1015	0.1424	-0.0174	0.0003022
0.3189	0.1255	0.0967	0.1399	-0.0144	0.0002083
0.3254	0.1220	0.0932	0.1370	-0.0151	0.0002273
0.3271	0.1190	0.0928	0.1363	-0.0173	0.0002983
0.3289	0.1218	0.0925	0.1356	-0.0138	0.0001910
0.3306	0.1199	0.0924	0.1350	-0.0151	0.0002265
0.3323	0.1190	0.0926	0.1343	-0.0153	0.0002327
0.3358	0.1175	0.0934	0.1331	-0.0155	0.0002418
0.3478	0.1190	0.1023	0.1293	-0.0103	0.0001057
0.3495	0.1168	0.1043	0.1289	-0.0121	0.0001453
0.3530	0.1163	0.1090	0.1280	-0.0117	0.0001380
0.3737	0.1174	0.1531	0.1246	-0.0072	0.0000525
0.3754	0.1186	0.1580	0.1245	-0.0058	0.0000341
0.3771	0.1185	0.1632	0.1243	-0.0058	0.0000341
0.3788	0.1235	0.1685	0.1242	-0.0008	0.0000006
SUMMATION = 9.7875	4.1741				0.0050357

These summations were substituted into the equation and error found was ±0.025. This was repeated for the other four vehicles and the results are tabulated and presented in Appendix C and Table 4.7.

Table 4.7: Error values for the other four vehicles when using the model

Vehicle	Error Values
1	±0.025
3	±0.025
4	±0.018
5	±0.0295

Taken the least gives the final general equation of $F = 3.3428p^2 - 2.5941p + 0.6272 \pm 0.018$. Since ±0.018 is the least it can be used, because using the largest error value will mean that the error for the other vehicles will be increased. The model is also verified using the data for vehicle 2 and the results are presented in Table 4.8. It could be inferred from the table that the model can be used since the percentage error is within experimental error of ± 5%.

Table 4.8: Verification of the model using the data for vehicle 2

Pressure (N/mm^2)	Measured Fuel consumption(litre/km) (mfc)	Predicted fuel consumption (litre/km) (pfc)	Error (mfc-pfc)	% error
0.2448	0.1919	0.1925	-0.00059	-0.31
0.2465	0.1894	0.1909	-0.00149	-0.78
0.2499	0.1818	0.1877	-0.00585	-3.12
0.2534	0.1842	0.1845	-0.00036	-0.19
0.2655	0.1773	0.1741	0.00316	1.82
0.2792	0.1692	0.1635	0.00573	3.50
0.2827	0.1645	0.1610	0.00346	2.15
0.2844	0.1637	0.1598	0.00386	2.41
0.2861	0.1631	0.1586	0.00451	2.84
0.2879	0.1610	0.1575	0.00357	2.27
0.2896	0.1613	0.1563	0.00497	3.18
0.2913	0.1539	0.1552	-0.00135	-0.87
0.2948	0.1495	0.1530	-0.00353	-2.30
0.2982	0.1454	0.1509	-0.00554	-3.67
0.3034	0.1504	0.1479	0.00250	1.69
0.3051	0.1468	0.1469	-0.00007	-0.05
0.3068	0.1393	0.1460	-0.00669	-4.58
0.3085	0.1391	0.1450	-0.00596 -	-4.11
0.3206	0.1361	0.1391	-0.00306	-2.20
0.3292	0.1346	0.1355	-0.00089	-0.66
0.3327	0.1361	0.1342	0.00189	1.41
0.3344	0.1337	0.1335	0.00015	0.12
0.3361	0.1330	0.1329	0.00005	0.04
0.3384	0.1339	0.1322	0.00171	1.30
0.3403	0.1312	-0.00032	-0.00032	-0.24
0.3465	0.1269	0.1297	-0.00280	-2.16
0.3530	0.1235	0.1280	-0.00457	-3.57
0.3737	0.1227	0.1246	-0.00192	-1.54
0.3754	0.1266	0.1245	0.00212	1.71
0.3771	0.1280	0.1243	0.00372	2.99
0.3788	0.127	0.1242	0.00367	2.95

4.2.3 Using the model to predict fuel consumptions

From the experiment, it could be seen that the relationship between the fuel consumption, and the tyre pressures of various vehicles is in the form of $F = B_2p^2 - B_1p + B_0 \pm e$.

Where B_0, B_1, B_2 and e depends on other factors of the vehicle such as the age of the vehicle, the conditions under which the measurements were taken and so on. This equation although cannot be used to represent all other vehicles but can be used to predict fuel consumptions for vehicles when their tyre pressures are known.

Taking vehicle 1 as an example, the predicted fuel consumptions using the model for various tyre pressures were calculated and compared with the measured fuel consumption and the results are tabulated as shown in Table 4.9.

From Table 4.9, it could be concluded that some of the measured fuel consumptions fall within the predicted fuel consumption and the rest, which does not fall within the predicted fuel consumption, deviate by ±7percentage that is within experimental error.

Table 4.9: Predicted fuel flow compared with the measured fuel consumption for vehicle 1

Pressure (N/mm^2)	Measured Fuel consumption(litre/km) (mfc)	Predicted Fuel consumption (pfc)	Error (mfc- pfc)	% error
0.2723	0.1764	0.1687	0.00771	4.57
0.2741	0.1727	0.1673	0.00538	3.22
0.2758	0.1689	0.1660	0.00289	1.74
0.2775	0.1610	0.1648	-0.00372	-2.26
0.2792	0.1639	0.1635	0.00046	0.28
0.2810	0.1587	0.1622	-0.00351	-2.16
0.2827	0.1508	0.1430	0.00782	5.47
0.2844	0.1451	0.1418	0.00333	2.35
0.2861	0.1445	0.1406	0.00388	2.76
0.2879	0.1418	0.1395	0.00239	1.71
0.2896	0.1393	0.1383	0.00096	0.69
0.3017	0.1383	0.1309	0.00745	5.69
0.3034	0.1266	0.1299	-0.00329	-2.54

0.3051	0.1321	0.1289	0.00319	2.47
0.3085	0.1306	0.1270	0.00351	2.76
0.3103	0.1235	0.1261	-0.00268	-2.12
0.3137	0.1250	0.1244	0.00062	0.50
0.3189	0.1255	0.1219	0.00357	2.93
0.3254	0.1220	0.1190	0.00292	2.46
0.3271	0.1191	0.1183	0.00073	0.62
0.3289	0.1218	0.1176	0.00418	3.55
0.3306	0.1199	0.1170	0.00295	2.52
0.3323	0.1191	0.1163	0.00274	2.36
0.3358	0.1175	0.1151	0.00245	2.13
0.3478	0.1191	0.1113	0.00772	6.93
0.3495	0.1168	0.1109	0.00595	5.36
0.3530	0.1163	0.1100	0.00625	5.68
0.3737	0.1174	0.1246	-0.00724	-5.81
0.3754	0.1186	0.1245	-0.00584	-4.69
0.3771	0.1185	0.1243	-0.00584	-4.70
0.3788	0.1235	0.1242	-0.00075	-0.61

4.3 Effect on the Ghanaian economy

From the model established, that is, $F = 0.6272 - 2.5941p + 3.3428p^2 \pm 0.018$, it could be seen that, as the tyre pressures of the vehicles increase, less fuel are consumed to cover the same distance until the pressure reaches the recommended tyre pressure, which is the maximum tyre pressure and then more fuel are consumed with any increase in the tyre pressure. This means that when the vehicles do not use the recommended tyre pressure there will be some extra fuel consumed by the vehicles, which will amount to extra cost for the drivers.

With this model established, then the additional fuel consumed for various deviations can then be found. This additional fuels used were found for Kumasi (Airport)/Accra (KIA) return trip (540 km). The results were tabulated and presented in Table 4.10.

Table 4.10: Additional fuel consumed for Kumasi (Airport)/Accra (KIA) return trip using the model

Percentage Deviation (%)	Pressure Deviation (N/mm^2)	Additional Fuel (Litres)
+20	0.4656	10.87
+10	0.4268	2.72
recommended	0.388	0.00
-10	0.3492	2.72
-20	0.3104	10.87
-30	0.2716	24.46

From the survey of the 160 vehicles, as shown in Table 3.1, 98% of these vehicles had their measured tyre pressure deviate from the recommended tyre pressure. Therefore, assuming that, 100,000 vehicles plying their trade on Kumasi (Airport/Accra (KIA) road, there will be 21,212 vehicles for ten percent deviation below the recommended tyre pressure.

Similarly, there will be 31,818 vehicles for twenty percent deviation below the recommended tyre pressure. There will be 30,455 vehicles for thirty percent deviation below the recommended tyre pressure. In addition, there will be 9,848 vehicles for ten percent deviation above the recommended tyre pressure.

For 100,000 vehicles plying their trade on the Kumasi (Airport)/Accra (KIA) road, using the model for Kumasi (Airport)/Accra (KIA) return trip, then for various deviations, their corresponding additional fuel incurred is shown in Table 4.10.

Table 4.11: Additional fuel incurred for 100,000 vehicles for Kumasi (Airport) /Accra (KIA) return trip for a day.

Percentage Deviation (%)	Pressure Deviation (N/mm^2)	Additional fuel (litres/day)
+10	0.4268	26743.83
Recommended	0.388	0
-10	0.3492	57682.11
-20	0.3104	345976.4
-30	0.2716	745016.7

From Table 4.9, for +10%, -10%, -20% and -30% deviations additional fuel of 1,175,419.04 litres will be incurred, this will amount to GHC 1,386,994.47.

This correspond to 93,333 vehicles out of 100,000 vehicles, that is, 93.333% deviation of the vehicles.

The rest of the deviations are for above +30%, +30%, +20% and below -30% which makes up for 4.67% deviation.

From this, it could be seen that more fuel are consumed when vehicles do not use the recommended tyre pressure. This will be that more fuel has to be imported into the country by the government. According to one research on Ghana‘s daily oil importation as shown in Table 4.12, it could be seen that 45,380bbl/day of fuel is imported.

Table 4.12: Ghana‘s daily oil importation

Year	Oil - imports	Rank	Percent Change
2018	45,520	84	
2019	45,520	86	0.00 %
2020	45,380	91	-0.31 %

45,380 barrels per day is equal to 5,247,198.64 litres of fuel, which means that using the information in Table 4.11 will give 22.4% of the national fuel imported. This means that, additional 22.4% increase in fuel has to be imported for 100,000 vehicles when their tyre pressures are deviating as shown in Table 3.1.

It is therefore clear from the ensuring discussion that using the recommended tyre pressures are always desirable and safe. Besides saving fuel, money, and minimizing emissions, properly inflated tyres are safer and less likely to fail at high speeds. Under- inflated tyres may give longer stopping distances and will skid longer on wet surfaces. Properly inflated tyres will last longer and wear easily.

Tyres play a crucial role in the safety of a vehicle. As the only part of the car that physically touches the ground, tyres are one of the key factors affecting a vehicle's handling and overall safety. Proper tyre inflation and maintenance can extend tyre life, increase fuel efficiency and improve vehicle safety.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.0 Introduction

Chapter five, as the last chapter, seeks to conclude the entire research. It is therefore based on a summary of the major findings, after which appropriate recommendations would be made to ensure an efficient utilization of vehicular fuel.

5.1 Conclusion

It could be concluded that 84.49% of the vehicles studied had their measured tyre pressure below the manufacturers recommended tyre pressure.

However, only 13.01% of the vehicles have their measure tyre pressure above the recommended tyre pressure. In all, 97.50% of the surveyed vehicles deviated from the recommended tyre pressure.

The model obtained is $F = 0.6272 - 2.5941p + 3.3428p^2 \pm 0.018$ which can also be used to predict the amount of fuel consumed.

The model was validated with its own data which showed a deviation of ± 5percentage which is within experimental error.

Using the recommended tyre pressures reduces the fuel consumption by 17.60% thus reducing cost. It also minimized emissions thereby making movement safe and desirable.

5.2 Recommendations

The above conclusion translates into the recommendations below;

Every car owner or driver must keenly ensure that their vehicles tyre pressure always conform to the manufacturer‘s recommended tyre pressure.

There should be a massive public education or awareness about this need. This need, according to the research, is against the backdrop that when tyre pressure falls below the recommended tyre pressure, the decrease in the pressure invariably leads to an increase in fuel consumption. Also underscoring this need is the fact that most drivers or car owners fail to regularly check the level of their tyre pressure. When tyres are underinflated or overinflated more fuel is consumed than using the recommended tyre pressure for vehicle.

The correct tyre pressures for the vehicle should be maintained, and take steps to ensure the consistency and integrity of tyres pressures.

Lastly, tyre pressures should be checked regularly to make sure that they are at the correct pressure levels to improve fuel efficiency, better and safer handling and increase the longevity of tyres lives which translate into money saved. Hence, if drivers constantly check their tyre pressure and ensure conformity to the manufacturer‘s recommended tyre pressure, fuel consumption would invariably decrease as the tyre pressure increases or approaches the recommended tyre pressure.

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APPENDIX A

Table A1a: Measured tyre pressure of vehicles at GCAA bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE(MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (AVERAGE MTP- AVERAGE MRTP) (N/mm^2)	% DEVIATION
	FRONT RIGHT	FRONT LEFT	REAR RIGHT	REAR LEFT		FRONT RIGHT	FRONT LEFT	REAR RIGHT	REAR LEFT			
1	0.1793	0.1655	0.1655	0.2069	0.1793	0.2069	0.2069	0.2206	0.2206	0.2137	-0.0345	-16.00
2	0.2620	0.2620	0.1655	0.1517	0.2103	0.2551	0.2551	0.2965	0.2965	0.2758	-0.0655	-24.00
3	0.2758	0.2758	0.3379	0.3379	0.3068	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0931	-23.00
4	0.1448	0.1517	0.1517	0.2069	0.1638	0.2137	0.2137	0.2620	0.2620	0.2379	-0.0741	-32.00
5	0.2206	0.2206	0.2069	0.2275	0.2189	0.2069	0.2069	0.2275	0.2275	0.2172	0.0017	0.80
6	0.2689	0.2758	0.2069	0.2689	0.2551	0.2069	0.2069	0.2689	0.2896	0.2430	0.0121	5.00
7	0.2069	0.1931	0.3448	0.1655	0.2275	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1345	-37.00
8	0.2000	0.1931	0.1517	0.1793	0.1810	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0362	-17.00

9	0.1034	0.3172	0.2206	0.2069	0.2120	0.2069	0.2069	0.2206	0.2206	0.2137	-0.0017	-0.80
10	0.2551	0.0827	0.2137	0.2758	0.2069	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1551	-43.00
11	0.0965	0.1862	0.2689	0.2069	0.1896	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1724	-48.00
12	0.2206	0.2069	0.2069	0.2137	0.2120	0.2275	0.2275	0.2689	0.2689	0.2482	-0.0362	-15.00
13	0.2758	0.2620	0.1793	0.2344	0.2379	0.2206	0.2206	0.2206	0.2206	0.2206	0.0172	8.00
14	0.2069	0.2896	0.2758	0.2758	0.2620	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1000	-28.00
15	0.2965	0.2965	0.0965	0.2965	0.2465	0.1793	0.1793	0.2000	0.2000	0.1896	0.0569	0.30
16	0.2069	0.1862	0.1655	0.1655	0.1810	0.2069	0.2069	0.2689	0.2689	0.2379	-0.0569	-23.00
17	0.2344	0.2413	0.1586	0.2069	0.2103	0.2206	0.2206	0.2206	0.2206	0.2206	-0.0103	-5.00
18	0.1724	0.1655	0.2000	0.2206	0.1896	0.2137	0.2137	0.2344	0.2344	0.2241	-0.0345	-16.00
19	0.2206	0.1517	0.1310	0.1310	0.1586	0.2137	0.2137	0.2344	0.2344	0.2241	-0.0655	-29.00

Table A1b: Measured tyre pressure of vehicles at GCAA bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE(MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (AVERAGE MTP- AVERAGE MRTP) (N/mm^2)	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
20	0.2827	0.2758	0.2758	0.2758	0.2775	0.2413	0.2413	0.2827	0.2827	0.2620	0.0155	6.00
21	0.1379	0.2896	0.2137	0.2137	0.2137	0.1931	0.1931	0.2344	0.2344	0.2137	0.0000	0.00
22	0.2000	0.2137	0.2689	0.2689	0.2379	0.2069	0.2069	0.2689	0.2689	0.2379	0.0000	0.00
23	0.2896	0.2620	0.3034	0.3034	0.2896	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0724	-20.00
24	0.1655	0.2000	0.2620	0.2069	0.2086	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0086	-4.00
25	0.1655	0.1655	0.1241	0.1586	0.1534	0.2069	0.2069	0.2482	0.2482	0.2275	-0.0741	-34.00
26	0.2482	0.2689	0.2413	0.2758	0.2586	0.2069	0.2069	0.2482	0.2482	0.2275	0.0310	14.00
27	0.3241	0.2965	0.2413	0.4206	0.3206	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0414	-11.00

28	0.2689	0.1379	0.1793	0.3310	0.2293	0.1931	0.1931	0.2344	0.2344	0.2137	0.0155	7.00
29	0.1931	0.2069	0.2000	0.2000	0.2000	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0414	-18.00
30	0.1379	0.1379	0.1793	0.1241	0.1448	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0586	-29.00
31	0.3585	0.3723	0.3310	0.2896	0.3379	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0621	-16.00
32	0.2069	0.2069	0.2069	0.1931	0.2034	0.2069	0.2069	0.2482	0.2482	0.2275	-0.0241	-11.00
33	0.2206	0.2344	0.2069	0.2275	0.2224	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0190	-8.00
34	0.2413	0.2413	0.2896	0.2620	0.2586	0.2758	0.2758	0.3792	0.3792	0.3275	-0.0690	-27.00
35	0.2827	0.2758	0.3172	0.2551	0.2827	0.2206	0.2206	0.2620	0.2620	0.2413	0.0414	18.00
36	0.1724	0.1862	0.0896	0.1931	0.1603	0.2137	0.2137	0.2344	0.2344	0.2241	-0.0638	-28.00
37	0.2069	0.1448	0.1448	0.1379	0.1586	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0827	-36.00
38	0.2344	0.2069	0.1793	0.1931	0.2034	0.2413	0.2413	0.2551	0.2551	0.2482	-0.0448	-18.00
39	0.2206	0.2344	0.2965	0.2689	0.2551	0.2758	0.2758	0.4482	0.4482	0.3620	-0.1069	-30.00
40	0.1517	0.2758	0.3379	0.1448	0.2275	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1345	-37.00
41	0.1586	0.2069	0.1517	0.1517	0.1672	0.1931	0.1931	0.2275	0.2275	0.2103	-0.0431	-21.00
42	0.0690	0.1931	0.2206	0.2069	0.1724	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0310	-15.00
43	0.2344	0.2275	0.1517	0.0965	0.1775	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0259	-13.00

Table A1c: Measured tyre pressure of vehicles at GCAA bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE(MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (AVERAGE MTP- AVERAGE MRTP) (N/mm^2)	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
44	0.1862	0.1931	0.1517	0.1517	0.1707	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0465	-21.00
45	0.2758	0.2758	0.0758	0.3172	0.2362	0.1931	0.1931	0.2137	0.2137	0.2034	0.0328	16.00
46	0.3034	0.3034	0.3723	0.2896	0.3172	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0448	-12.00
47	0.2689	0.2137	0.1586	0.1655	0.2017	0.2551	0.2551	0.3103	0.3103	0.2827	-0.0810	-29.00
48	0.2551	0.2344	0.2000	0.2206	0.2275	0.2620	0.2620	0.2827	0.2827	0.2724	-0.0448	-16.00
49	0.2000	0.2344	0.2413	0.2344	0.2275	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0138	-6.00
50	0.1448	0.1724	0.2206	0.2482	0.1965	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0448	-19.00
51	0.3379	0.3310	0.2689	0.1310	0.2672	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0948	-26.00

52	0.2000	0.2137	0.2137	0.2206	0.2120	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0293	-13.00
53	0.2758	0.2758	0.2758	0.2758	0.2758	0.2413	0.2413	0.2758	0.2758	0.2586	0.0172	4.00
54	0.2620	0.3034	0.1931	0.1034	0.2155	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0259	-11.00
55	0.2069	0.2206	0.2069	0.1931	0.2069	0.2206	0.2206	0.2275	0.2620	0.2327	-0.0259	-11.00
56	0.3654	0.3654	0.3585	0.2896	0.3448	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0552	-14.00
57	0.1931	0.1793	0.1655	0.1724	0.1775	0.2069	0.2069	0.2689	0.2689	0.2379	-0.0603	-25.00
58	0.1379	0.3448	0.2689	0.2551	0.2517	0.3516	0.3516	0.4482	0.4482	0.3999	-0.1482	-37.00
59	0.3103	0.3448	0.3034	0.2965	0.3137	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0862	-22.00
60	0.3448	0.3930	0.2896	0.2000	0.3068	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0931	-23.00
61	0.1034	0.3172	0.2206	0.2069	0.2120	0.2069	0.2069	0.2206	0.2206	0.2137	-0.0017	-0.01
62	0.2551	0.0827	0.2137	0.2758	0.2069	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1551	-0.43
63	0.0965	0.1862	0.2689	0.2069	0.1896	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1724	-0.48
64	0.2206	0.2206	0.2206	0.2275	0.2275	0.2413	0.2413	0.2689	0.2689	0.2603	-0.0396	-0.15
65	0.2758	0.2620	0.1793	0.2344	0.2379	0.2206	0.2206	0.2206	0.2206	0.2206	0.0172	0.08
66	0.2069	0.2896	0.2758	0.2758	0.2620	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1000	-0.28
67	0.3034	0.2965	0.0965	0.2965	0.2430	0.1793	0.1793	0.2000	0.2000	0.1844	0.0586	0.32

Table A1d: Measured tyre pressure of vehicles at GCAA bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE(MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (AVERAGE MTP- AVERAGE MRTP) (N/mm^2)	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
68	0.2206	0.2344	0.1862	0.1586	0.1896	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0431	-0.19
69	0.1931	0.1241	0.1586	0.1862	0.1638	0.2069	0.2069	0.2413	0.2413	0.2189	-0.0552	-0.25
70	0.1586	0.1379	0.2344	0.1793	0.1741	0.2482	0.2482	0.2758	0.2758	0.2655	-0.0914	-0.34
71	0.2896	0.2344	0.1862	0.2069	0.2206	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0121	-0.05
72	0.1310	0.1241	0.1241	0.1379	0.1293	0.1793	0.1793	0.2000	0.2000	0.1844	-0.0552	-0.30
73	0.2827	0.3516	0.2827	0.2827	0.2999	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0621	-0.17
74	0.3103	0.3103	0.3654	0.3103	0.3241	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0379	-0.10
75	0.2000	0.2344	0.2413	0.2344	0.2189	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0138	-0.06

76	0.1448	0.1724	0.2206	0.2482	0.1879	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0448	-0.19
77	0.3379	0.3310	0.2689	0.1310	0.2672	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0948	-0.26
78	0.2000	0.2137	0.2000	0.2069	0.2034	0.2069	0.2069	0.2620	0.2620	0.2327	-0.0293	-0.13
79	0.2758	0.2758	0.2758	0.2758	0.2758	0.2551	0.2551	0.2758	0.2758	0.2655	0.0103	0.04
80	0.2620	0.3034	0.1931	0.1034	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-0.11
81	0.2069	0.2206	0.2069	0.2275	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-0.11
82	0.3654	0.3654	0.3585	0.2896	0.3448	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0552	-0.14
83	0.2137	0.1793	0.1724	0.1724	0.1827	0.2206	0.2206	0.2689	0.2689	0.2430	-0.0603	-0.25
84	0.2758	0.3448	0.2689	0.3516	0.3103	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0896	-0.22
85	0.3103	0.3448	0.3034	0.2965	0.3137	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0862	-0.22
86	0.3448	0.3930	0.2896	0.2000	0.3068	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0931	-0.23
87	0.2344	0.2344	0.2413	0.2344	0.2275	0.2069	0.2069	0.2620	0.2620	0.2258	0.0017	0.01
88	0.2689	0.2551	0.2069	0.2689	0.2551	0.2069	0.2069	0.2689	0.2689	0.2430	0.0121	0.05
89	0.2069	0.1931	0.3448	0.1655	0.2275	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1345	-0.37
90	0.2000	0.1931	0.1517	0.1793	0.1810	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0362	-0.17

Table A1e: Measured tyre pressure of vehicles at GCAA bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE(MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (AVERAGE MTP- AVERAGE MRTP) (N/mm^2)	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
91	0.1034	0.3172	0.2206	0.2069	0.2120	0.2069	0.2069	0.2206	0.2206	0.2137	-0.0017	-0.01
92	0.2551	0.2758	0.2620	0.2896	0.2706	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0914	-0.25
93	0.2758	0.2620	0.2689	0.2551	0.2655	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0965	-0.27
94	0.2206	0.2206	0.2206	0.2275	0.2206	0.2413	0.2413	0.2758	0.2758	0.2603	-0.0396	-0.15
95	0.2758	0.2620	0.1793	0.2344	0.2379	0.2206	0.2206	0.2206	0.2206	0.2206	0.0172	0.08
96	0.2069	0.2896	0.2758	0.2758	0.2620	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1000	-0.28
97	0.3034	0.2965	0.0965	0.2965	0.2430	0.1793	0.1793	0.2000	0.2000	0.1844	0.0586	0.32
98	0.2069	0.2069	0.1655	0.1724	0.1862	0.2206	0.2206	0.2689	0.2689	0.2430	-0.0569	-0.23
99	0.2827	0.2758	0.3172	0.2551	0.2741	0.2206	0.2206	0.2620	0.2620	0.2327	0.0414	0.18
100	0.1724	0.1862	0.0896	0.1931	0.1603	0.2137	0.2137	0.2344	0.2344	0.2241	-0.0638	-0.28

Table A2a: Measured tyre pressure of vehicles at GACL bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE (MTP)(N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP)(N/mm^2)				AVERAGE (N/mm^2)	DEVIATION (MTP-MRTP) a(N/mm^2)	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
1	0.2206	0.2344	0.1862	0.1517	0.1982	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0431	-17.86
2	0.1931	0.1241	0.1586	0.1862	0.1655	0.2069	0.2069	0.2413	0.2482	0.2258	-0.0603	-26.72
3	0.1586	0.1517	0.2344	0.1655	0.1775	0.2482	0.2482	0.2758	0.2758	0.2620	-0.0845	-32.24
4	0.2896	0.2344	0.1862	0.2069	0.2293	0.2206	0.2206	0.2620	0.2620	0.2413	-0.0121	-5.00
5	0.1103	0.1103	0.1103	0.1172	0.1120	0.1793	0.1793	0.2000	0.2000	0.1896	-0.0776	-40.91
6	0.2827	0.3516	0.2827	0.2827	0.2999	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0621	-17.14
7	0.3103	0.3103	0.3654	0.3103	0.3241	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0379	-10.48
8	0.2206	0.2344	0.2275	0.2275	0.2275	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0190	-8.15
9	0.2413	0.2344	0.2896	0.2482	0.2534	0.2413	0.2206	0.4482	0.4482	0.3396	-0.0931	-27.41
10	0.2827	0.2758	0.3172	0.2551	0.2827	0.2206	0.2206	0.2620	0.2620	0.2327	0.0414	17.78
11	0.1724	0.1862	0.0896	0.1931	0.1603	0.2137	0.2137	0.2344	0.2344	0.2241	-0.0638	-28.46

12	0.2069	0.1379	0.1448	0.1448	0.1500	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0827	-35.56
13	0.2344	0.2069	0.1793	0.1931	0.2000	0.2413	0.2413	0.2551	0.2551	0.2448	-0.0448	-18.31
14	0.2206	0.2344	0.2965	0.2689	0.2551	0.2758	0.2758	0.4482	0.4482	0.3620	-0.1069	-29.52
15	0.1517	0.2758	0.3379	0.1448	0.2275	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1345	-37.14
16	0.1586	0.1793	0.1517	0.1379	0.1638	0.1931	0.1931	0.2069	0.2069	0.2069	-0.0431	-20.83
17	0.0690	0.1931	0.2206	0.2069	0.1724	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0310	-15.25
18	0.2344	0.2275	0.1517	0.0965	0.1775	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0259	-12.71
19	0.1862	0.1931	0.1517	0.1517	0.1707	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0465	-21.43
20	0.2758	0.2758	0.0758	0.3172	0.2362	0.1931	0.1931	0.2137	0.2137	0.2034	0.0328	16.10
21	0.3034	0.3034	0.3723	0.2896	0.3172	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0448	-12.38
22	0.2689	0.2137	0.2069	0.1931	0.2206	0.2069	0.2551	0.3310	0.3310	0.2810	-0.0603	-21.47

Table A2b: Measured tyre pressure of vehicles at GACL bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE (MTP)(N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP)(N/mm^2)				AVERAGE (N/mm^2)	DEVIATION	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
23	0.2551	0.2344	0.2000	0.2206	0.2275	0.2620	0.2620	0.2827	0.2827	0.2724	-0.0448	-16.46
24	0.2000	0.2344	0.2413	0.2344	0.2189	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0138	-5.93
25	0.1655	0.1517	0.2206	0.2482	0.1879	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0448	-19.26
26	0.3379	0.3310	0.2689	0.1310	0.2672	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0948	-26.19
27	0.2000	0.2137	0.2137	0.2206	0.2034	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0293	-12.59
28	0.2758	0.2758	0.2758	0.2758	0.2758	0.2551	0.2551	0.2758	0.2758	0.2655	0.0103	3.90
29	0.2620	0.2689	0.1931	0.1379	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-11.11
30	0.2069	0.2206	0.2069	0.2275	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-11.11
31	0.3654	0.3654	0.3585	0.2896	0.3448	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0552	-13.79
32	0.1931	0.1793	0.1655	0.1724	0.1827	0.2069	0.2069	0.2689	0.2689	0.2430	-0.0603	-24.82
33	0.1724	0.1586	0.1448	0.1586	0.1500	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0827	-35.56

34	0.2344	0.2069	0.1793	0.1931	0.2000	0.2413	0.2413	0.2551	0.2551	0.2448	-0.0448	-18.31
35	0.2206	0.2344	0.2965	0.2689	0.2551	0.2758	0.2758	0.4482	0.4482	0.3620	-0.1069	-29.52
36	0.1517	0.2758	0.3379	0.1448	0.2275	0.3103	0.3103	0.4137	0.4137	0.3620	-0.1345	-37.14
37	0.1586	0.2069	0.1517	0.1379	0.1638	0.1931	0.1931	0.2206	0.2206	0.2069	-0.0431	-20.83
38	0.1034	0.1586	0.2206	0.2069	0.1724	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0310	-15.25
39	0.1724	0.2275	0.1517	0.1448	0.1775	0.1931	0.1931	0.2137	0.2137	0.2034	-0.0259	-12.71
40	0.1862	0.1931	0.1517	0.1517	0.1707	0.2137	0.2137	0.2206	0.2206	0.2172	-0.0465	-21.43
41	0.2758	0.2689	0.1379	0.2620	0.2362	0.1931	0.1931	0.2137	0.2137	0.2034	0.0328	16.10
42	0.3034	0.3034	0.3723	0.2896	0.3172	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0448	-12.38
43	0.2689	0.2137	0.1586	0.1586	0.2000	0.2069	0.2551	0.3310	0.3310	0.2810	-0.0810	-28.83
44	0.2551	0.2344	0.2000	0.2206	0.2275	0.2620	0.2620	0.2827	0.2827	0.2724	-0.0448	-16.46
45	0.2000	0.2344	0.2413	0.2344	0.2189	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0138	-5.93
46	0.1517	0.1655	0.2206	0.2482	0.1879	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0448	-19.26

Table A2c: Measured tyre pressure of vehicles at GACL bus terminal compared to the recommended tyre pressure

VEHICLE	MEASURED TYRE PRESSURE (MTP) (N/mm^2)				AVERAGE (N/mm^2)	MANUFACTURERS RECOMMENDED TYRE PRESSURE (MRTP) (N/mm^2)				AVERAGE (N/mm^2)	DEVIATION	% DEVIATION
	FR	FL	RR	RL		FR	FL	RR	RL			
47	0.3379	0.3310	0.2689	0.1310	0.2672	0.3103	0.3103	0.4137	0.4137	0.3620	-0.0948	-26.19
48	0.2000	0.2137	0.2137	0.2206	0.2034	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0293	-12.59
49	0.2758	0.2758	0.2758	0.2758	0.2758	0.2551	0.2551	0.2758	0.2758	0.2655	0.0103	3.90
50	0.2620	0.2344	0.1931	0.1724	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-11.11
51	0.2069	0.2206	0.2069	0.2275	0.2069	0.2206	0.2206	0.2620	0.2620	0.2327	-0.0259	-11.11
52	0.3654	0.3654	0.3585	0.2896	0.3448	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0552	-13.79
53	0.1931	0.1793	0.1655	0.1724	0.1827	0.2069	0.2069	0.2689	0.2689	0.2430	-0.0603	-24.82
54	0.1379	0.3448	0.2689	0.2551	0.2517	0.3516	0.3516	0.4482	0.4482	0.3999	-0.1482	-37.07
55	0.3103	0.3448	0.3034	0.2965	0.3137	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0862	-21.55
56	0.3448	0.3930	0.2896	0.2000	0.3068	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0931	-23.28
57	0.1793	0.1655	0.1655	0.2069	0.1793	0.2069	0.2069	0.2206	0.2206	0.2137	-0.0345	-16.13
58	0.2620	0.2620	0.1655	0.1517	0.2103	0.2551	0.2551	0.2965	0.2965	0.2758	-0.0655	-23.75
59	0.2758	0.2758	0.3379	0.3379	0.3068	0.3516	0.3516	0.4482	0.4482	0.3999	-0.0931	-23.28
60	0.1310	0.1310	0.1862	0.2069	0.1551	0.2137	0.2137	0.2620	0.2620	0.2293	-0.0741	-32.33

APPENDIX B

Table B1a: Measured values for Vehicle 1

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
1	09:00	39947	0	39.75	0.00	0.2758	0.2758	0.3448	0.3241	0.3051	
	12:00	39991	44	32.18	7.57	0.2758	0.2758	0.3448	0.3241	0.3051	0.1721
	15:00	40025	34	28.39	3.79	0.2758	0.2758	0.3448	0.3241	0.3051	0.1113
	18:00	40055	30	24.61	3.79	0.2758	0.2758	0.3448	0.3241	0.3051	0.1262
2	09:00	40080	25	75.71	7.57	0.2758	0.2758	0.3379	0.3172	0.3017	0.3028
	12:00	40111	31	71.92	3.79	0.2758	0.2758	0.3379	0.3172	0.3017	0.1221
	15:00	40141	30	68.14	3.79	0.2758	0.2758	0.3379	0.3172	0.3017	0.1262
	18:00	40206	65	60.57	7.57	0.2758	0.2758	0.3379	0.3172	0.3017	0.1165
3	09:00	40225	19	58.67	1.89	0.2896	0.2896	0.3585	0.3379	0.3189	0.0996
	12:00	40267	42	53.00	5.68	0.2896	0.2896	0.3585	0.3379	0.3189	0.1352
	15:00	40308	41	47.32	5.68	0.2896	0.2896	0.3585	0.3379	0.3189	0.1385
	18:00	40349	41	41.64	5.68	0.2896	0.2896	0.3585	0.3379	0.3189	0.1385
4	09:00	40422	73	30.28	11.36	0.2896	0.2758	0.3379	0.3379	0.3103	0.1556
	12:00	40454	32	24.61	5.68	0.2896	0.2896	0.3448	0.3310	0.3137	0.1774
	15:00	40486	32	18.93	5.68	0.2896	0.2896	0.3448	0.3310	0.3137	0.1774
	18:00	40497	11	17.03	1.89	0.2896	0.2896	0.3448	0.3310	0.3137	0.1721

Table B1b: Measured values for Vehicle 1

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
5	09:00										
	12:00										
	15:00										
	18:00										
6	09:00										
	12:00										
	15:00										
	18:00										
7	09:00										
	12:00										
	15:00										
	18:00										
8	09:00	40959	0	79.49	0.00	0.2758	0.2758	0.3448	0.3172	0.3034	
	12:00	40999	40	73.82	5.68	0.2758	0.2758	0.3448	0.3172	0.3034	0.1420
	15:00	41016	17	70.03	3.79	0.2758	0.2758	0.3448	0.3172	0.3034	0.2227
	18:00	41045	29	66.24	3.79	0.2827	0.2827	0.3448	0.3241	0.3086	0.1305
9	09:00										
	12:00										
	15:00										
	18:00										

Table B1c: Measured values for Vehicle 1

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
10	09:00										
	12:00										
	15:00										
	18:00										
11	09:00	44145	0	79.49	0.00	0.2551	0.2551	0.3172	0.3034	0.2827	
	12:00	44171	26	71.92	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.2912
	15:00	44203	32	64.35	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.2366
	18:00	44256	53	56.78	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.1428
12	09:00	44289	33	53.00	3.79	0.2551	0.2551	0.3172	0.3034	0.2827	0.1147
	12:00	44324	35	45.42	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.2163
	15:00	44359	35	37.85	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.2163
	18:00	44432	73	30.28	7.57	0.2551	0.2551	0.3172	0.3034	0.2827	0.1037
13	09:00	44471	39	26.50	3.79	0.2551	0.2689	0.3172	0.3034	0.2861	0.0971
	12:00	44498	27	22.71	3.79	0.2551	0.2689	0.3172	0.3034	0.2861	0.1402
	15:00	44519	21	15.14	7.57	0.2551	0.2689	0.3172	0.3034	0.2861	0.3605
	18:00	44548	29	11.36	3.79	0.2620	0.2689	0.3241	0.3034	0.2896	0.1305
14	09:00	44571	23	79.49	3.79	0.2620	0.2620	0.3241	0.3034	0.2879	0.1646
	12:00	44593	22	75.71	3.79	0.2620	0.2620	0.3241	0.3034	0.2879	0.1721
	15:00	44609	16	71.92	3.79	0.2620	0.2620	0.3241	0.3034	0.2879	0.2366
	18:00	44638	29	68.14	3.79	0.2620	0.2620	0.3241	0.3034	0.2879	0.1305

Table B2a: Measured values for Vehicle 2

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)					
						Right Front	Left Front	Right Rear	Left Rear	Average (N/mm^2)	fuel Consumption (litres/km)
1	09:00	47060	0	26.50	0.00	0.2896	0.2758	0.1931	0.3034	0.2655	
	12:00	47101	41	17.03	9.46	0.2896	0.2758	0.1931	0.3034	0.2655	0.2308
	15:00	47126	25	11.36	5.68	0.2896	0.2758	0.1931	0.3034	0.2655	0.2271
	18:00	47165	39	3.79	7.57	0.2896	0.2758	0.1931	0.3034	0.2655	0.1941
2	09:00	47225	60	75.71	11.36	0.2896	0.2758	0.1931	0.3034	0.2655	0.1893
	12:00	47255	30	70.03	5.68	0.2896	0.2758	0.1931	0.3034	0.2655	0.1893
	15:00	47284	29	64.35	5.68	0.2896	0.2758	0.1931	0.3034	0.2655	0.1958
	18:00	47324	40	56.78	7.57	0.2896	0.2758	0.1931	0.3034	0.2655	0.1893
3	09:00										
	12:00										
	15:00										
	18:00										
4	09:00	47380	56	47.32	9.46	0.2896	0.2758	0.193	0.3034	0.2655	0.1690
	12:00	47417	37	41.64	5.68	0.3034	0.2965	0.2000	0.3172	0.2792	0.1535
	15:00	47433	16	37.85	3.79	0.3034	0.2965	0.2000	0.3172	0.2792	0.2366
	18:00	47471	38	32.18	5.68	0.3034	0.2965	0.2000	0.3172	0.2792	0.1494

Table B2b: Measured values for Vehicle 2

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
	09:00										
	12:00										
	15:00										
5	18:00										
	09:00										
	12:00										
	15:00										
6	18:00										
	09:00										
7	12:00										

	15:00										
	18:00										
	09:00	48535	0	18.93	0.00	0.2827	0.2758	0.3310	0.3034	0.2982	
	12:00	48573	38	81.39	5.68	0.3034	0.2758	0.3310	0.3034	0.3034	0.1494
	15:00	48598	25	75.71	3.79	0.3034	0.2758	0.3310	0.3034	0.3034	0.1514
8	18:00	48644	46	68.14	7.57	0.2827	0.2758	0.3310	0.3034	0.2982	0.1646
	09:00										
	12:00										
	15:00										
9	18:00										

Table B2c: Measured values for Vehicle 2

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2) Right Front	Left Front	Right Rear	Left Rear	Average (N/mm^2)	fuel Consumption (litres/km)
	09:00										
	12:00	52800	0	1.89	0.00	0.2758	0.3448	0.3172	0.2896	0.3068	
	15:00										
10	18:00										
	09:00										
	12:00										
	15:00										
11	18:00										
12	09:00	52889	0	83.28	0.00	0.2758	0.3448	0.3172	0.2896	0.3068	

	12:00	52909	20	79.49	3.79	0.2758	0.3448	0.3172	0.2896	0.3068	0.1893
	15:00	52960	51	71.92	7.57	0.2758	0.3448	0.3241	0.2896	0.3086	0.1484
	18:00	52998	38	68.14	3.79	0.2758	0.3448	0.3241	0.2896	0.3086	0.0996
	09:00	53064	66	56.78	11.36	0.2758	0.3448	0.3103	0.2896	0.3051	0.1721
	12:00	53123	59	49.21	7.57	0.2758	0.3172	0.2896	0.2827	0.2913	0.1283
	15:00	53158	35	45.42	3.79	0.2758	0.3172	0.2896	0.2827	0.2913	0.1082
13	18:00	53197	39	37.85	7.57	0.2758	0.3172	0.2896	0.2827	0.2913	0.1941
	09:00	53225	28	34.07	3.79	0.2827	0.3310	0.2896	0.2758	0.2948	0.1352
	12:00	53259	34	28.39	5.68	0.2827	0.3310	0.2896	0.2758	0.2948	0.1670
	15:00	53289	30	22.71	5.68	0.2827	0.3241	0.2827	0.2758	0.2913	0.1893
14	18:00	53308	19	83.28	3.79	0.2827	0.3241	0.2827	0.2758	0.2913	0.1992

Table B3a: Measured values for Vehicle 3

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
	09:00	42322	0	34.07	0.00	0.3310	0.3310	0.3241	0.3310	0.3120	
	12:00	42361	39	26.50	7.57	0.3310	0.3310	0.3241	0.3310	0.3120	0.1941
	15:00	42399	38	20.82	5.68	0.3310	0.3310	0.3241	0.3310	0.3120	0.1494
1	18:00	42419	20	15.14	5.68	0.3310	0.3310	0.3241	0.3310	0.3120	0.2839
	09:00	42469	50	7.57	7.57	0.3310	0.3310	0.3241	0.3310	0.3120	0.1514
	12:00	42509	40	1.89	5.68	0.3310	0.3310	0.3241	0.3310	0.3120	0.1420
	15:00	42548	39	75.71	7.57	0.3310	0.3310	0.3241	0.3310	0.3120	0.1941
2	18:00	42576	28	68.14	7.57	0.3310	0.3310	0.3241	0.3310	0.3120	0.2704
3	09:00	42611	35	62.46	5.68	0.3310	0.3310	0.3241	0.3310	0.3120	0.1622

	12:00										
	15:00										
	18:00										
	09:00	42637	26	58.67	3.79	0.3310	0.3379	0.3379	0.3379	0.3206	0.1456
	12:00	42676	39	54.89	3.79	0.3448	0.3448	0.3448	0.3448	0.3275	0.0971
	15:00	42698	22	49.21	5.68	0.3448	0.3448	0.3448	0.3448	0.3275	0.2581
4	18:00	42731	33	43.53	5.68	0.3448	0.3448	0.3448	0.3448	0.3275	0.1721

Table B3b: Measured values for Vehicle 3

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2) Right Front	Left Front	Right Rear	Left Rear	Average (N/mm^2)	fuel Consumption (litres/km)
	09:00										
	12:00										
	15:00										
5	18:00										
	09:00										
	12:00										
	15:00										
6	18:00										
	09:00										
	12:00										
	15:00										
7	18:00										
	09:00	43302	0	83.28	0.00	0.3379	0.3379	0.3310	0.3379	0.3189	
	12:00	43354	52	73.82	9.46	0.3379	0.3379	0.3310	0.3379	0.3189	0.1820
	15:00	43374	20	70.03	3.79	0.3379	0.3379	0.3310	0.3379	0.3189	0.1893
8	18:00	43394	20	66.24	3.79	0.3379	0.3379	0.3310	0.3379	0.3189	0.1893
	09:00										
	12:00										
	15:00										
9	18:00										

Table B3c: Measured values for Vehicle 3

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
10	09:00										
	12:00	46202	0	34.07	0.00	0.4413	0.3999	0.3310	0.3999	0.3585	
	15:00	46232	30	30.28	3.79	0.4413	0.3999	0.3310	0.3999	0.3585	0.1262
	18:00	46275	43	22.71	7.57	0.4413	0.3999	0.3310	0.3999	0.3585	0.1761
11	09:00	46291	16	81.39	3.79	0.3792	0.3310	0.3930	0.3310	0.3361	0.2366
	12:00	46340	49	73.82	7.57	0.3861	0.3241	0.3241	0.3241	0.3206	0.1545
	15:00	46367	27	70.03	3.79	0.3861	0.3241	0.3241	0.3241	0.3206	0.1402
	18:00	46395	28	66.24	3.79	0.3861	0.3241	0.3241	0.3241	0.3206	0.1352
12	09:00	46431	36	62.46	3.79	0.3861	0.3241	0.3241	0.3241	0.3206	0.1052
	12:00	46463	32	56.78	5.68	0.3861	0.3241	0.3241	0.3241	0.3206	0.1774
	15:00	46494	31	49.21	7.57	0.3861	0.3241	0.3241	0.3241	0.3206	0.2442
	18:00	46528	34	37.85	11.36	0.3861	0.3241	0.3241	0.3241	0.3206	0.3340
13	09:00	46573	45	32.18	5.68	0.3861	0.3241	0.3241	0.3241	0.3206	0.1262
	12:00	46601	28	28.39	3.79	0.3585	0.4137	0.4137	0.4137	0.3827	0.1352
	15:00	46639	38	20.82	7.57	0.2896	0.4137	0.4137	0.4137	0.3654	0.1992
	18:00	46660	21	17.03	3.79	0.2896	0.4137	0.4137	0.4137	0.3654	0.1803
14	09:00	46678	18	15.14	1.89	0.3448	0.4068	0.4137	0.4068	0.3775	0.1052
	12:00	46692	14	79.49	3.79	0.3379	0.4068	0.4137	0.4068	0.3758	0.2704
	15:00	46713	21	75.71	3.79	0.3379	0.4068	0.4137	0.4068	0.3758	0.1803
	18:00	46744	31	71.92	3.79	0.3379	0.4068	0.4137	0.4068	0.3758	0.1221

Table B4a: Measured values for Vehicle 4

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2) Right Front	Left Front	Right Rear	Left Rear	Average (N/mm^2)	fuel Consumption (litres/km)
1	09:00	47550	0	37.85	0.00	0.3034	0.3310	0.3723	0.3861	0.3482	
	12:00	47599	49	30.28	7.57	0.3034	0.3310	0.3723	0.3861	0.3482	0.1545
	15:00	47627	28	26.50	3.79	0.3034	0.3310	0.3723	0.3861	0.3482	0.1352
	18:00	47678	51	18.93	7.57	0.3034	0.3310	0.3723	0.3861	0.3482	0.1484
2	09:00	47697	19	15.14	3.79	0.2965	0.3310	0.3723	0.3792	0.3448	0.1992
	12:00	47762	65	3.79	11.36	0.2965	0.3310	0.3723	0.3792	0.3448	0.1747
	15:00										
	18:00										
3	09:00										
	12:00										
	15:00										
	18:00										
4	09:00										
	12:00	48384	622	41.64	83.28	0.3103	0.3448	0.3861	0.3999	0.3603	0.1339
	15:00	48417	33	35.96	5.68	0.3103	0.3448	0.3861	0.3999	0.3603	0.1721
	18:00	48450	33	30.28	5.68	0.3103	0.3448	0.3861	0.3999	0.3603	0.1721

Table B4b: Measured values for Vehicle 4

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2) Right Front	Left Front	Right Rear	Left Rear	Average (N/mm^2)	fuel Consumption (litres/km)
	09:00										
	12:00										
	15:00										
5	18:00										
	09:00										
	12:00										
	15:00										
6	18:00										
	09:00										
	12:00										
	15:00										
7	18:00										
	09:00	49045	0	83.28	0.00	0.3034	0.3310	0.3034	0.3861	0.3310	
	12:00	49098	53	71.92	11.36	0.3034	0.3310	0.3034	0.3861	0.3310	0.2143
	15:00	49115	17	68.14	3.79	0.3034	0.3310	0.3034	0.3861	0.3310	0.2227
8	18:00	49132	17	64.35	3.79	0.3034	0.3310	0.3034	0.3861	0.3310	0.2227
	09:00										
	12:00										
	15:00										
9	18:00										

Table B4b: Measured values for Vehicle 4

Day	Time	Speedometer Reading (km)	Difference (km)	Fuel Reading (litres)	Difference (litres)	Tyre Pressure (N/mm^2)				Average (N/mm^2)	fuel Consumption (litres/km)
						Right Front	Left Front	Right Rear	Left Rear		
10	09:00										
	12:00										
	15:00										
	18:00										
11	09:00	52579	0	83.28	0.00	0.3516	0.3310	0.3448	0.3585	0.3465	
	12:00	52634	55	75.71	7.57	0.3723	0.3448	0.3723	0.3792	0.3672	0.1377
	15:00	52669	35	71.92	3.79	0.3723	0.3448	0.3723	0.3792	0.3672	0.1082
	18:00	52705	36	68.14	3.79	0.3723	0.3448	0.3723	0.3792	0.3672	0.1052
12	09:00	52737	32	64.35	3.79	0.3723	0.3448	0.3654	0.3792	0.3654	0.1183

	12:00	52774	37	60.57	3.79	0.3723	0.3448	0.3654	0.3792	0.3654	0.1023
	15:00	52811	37	53.00	7.57	0.3723	0.3448	0.3654	0.3792	0.3654	0.2046
	18:00	52842	31	45.42	7.57	0.3723	0.3448	0.3654	0.3792	0.3654	0.2442
	09:00	52871	29	41.64	3.79	0.3448	0.3448	0.3448	0.3792	0.3534	0.1305
	12:00	52925	54	32.18	9.46	0.3723	0.3448	0.3723	0.3448	0.3585	0.1753
	15:00	52941	16	28.39	3.79	0.3723	0.3448	0.3723	0.3448	0.3585	0.2366
13	18:00	52978	37	20.82	7.57	0.3723	0.3448	0.3723	0.3448	0.3585	0.2046
	09:00	52994	16	83.28	1.89	0.4689	0.5240	0.4620	0.4689	0.4809	0.1183
	112:00	53021	27	77.60	5.68	0.4689	0.5240	0.4620	0.4689	0.4809	0.2103
	15:00	53056	35	71.92	5.68	0.4620	0.5171	0.4620	0.4689	0.4775	0.1622
14	18:00	53089	33	66.24	5.68	0.4620	0.5171	0.4551	0.4689	0.4758	0.1721

APPENDIX C

USING LEAST SQUARES MODELLING METHOD TO FIND THE MODEL

Table C1: Substituted values and their summation for Vehicle 2

TYRE PRESSURE (N/mm^2)	FUEL CONSUMPTION (LITRES/KM)	p^2	p^3	p^4	pf	p^2f
0.2448	0.1919	0.0599	0.0147	0.0036	0.0470	0.0115
0.2465	0.1894	0.0608	0.0150	0.0037	0.0467	0.0115
0.2499	0.1818	0.0625	0.0156	0.0039	0.0454	0.0114
0.2534	0.1842	0.0642	0.0163	0.0041	0.0467	0.0118
0.2655	0.1773	0.0705	0.0187	0.0050	0.0471	0.0125
0.2792	0.1692	0.0780	0.0218	0.0061	0.0472	0.0132
0.2827	0.1645	0.0799	0.0226	0.0064	0.0465	0.0131
0.2844	0.1637	0.0809	0.0230	0.0065	0.0465	0.0132
0.2861	0.1631	0.0819	0.0234	0.0067	0.0467	0.0134
0.2879	0.1610	0.0829	0.0239	0.0069	0.0464	0.0133
0.2896	0.1613	0.0839	0.0243	0.0070	0.0467	0.0135
0.2913	0.1538	0.0849	0.0247	0.0072	0.0448	0.0131
0.2948	0.1495	0.0869	0.0256	0.0075	0.0441	0.0130
0.2982	0.1453	0.0889	0.0265	0.0079	0.0433	0.0129
0.3034	0.1504	0.0920	0.0279	0.0085	0.0456	0.0138
0.3051	0.1468	0.0931	0.0284	0.0087	0.0448	0.0137

0.3068	0.1393	0.0941	0.0289	0.0089	0.0427	0.0131
0.3085	0.1391	0.0952	0.0294	0.0091	0.0429	0.0132
0.3206	0.1361	0.1028	0.0330	0.0106	0.0436	0.0140
0.3292	0.1346	0.1084	0.0357	0.0117	0.0443	0.0146
0.3327	0.1361	0.1107	0.0368	0.0122	0.0453	0.0151
0.3344	0.1337	0.1118	0.0374	0.0125	0.0447	0.0149
0.3361	0.1330	0.1130	0.0380	0.0128	0.0447	0.0150
0.3384	0.1339	0.1145	0.0388	0.0131	0.0453	0.0153
0.3403	0.1312	0.1158	0.0394	0.0134	0.0447	0.0152
0.3465	0.1269	0.1200	0.0416	0.0144	0.0440	0.0152
0.3530	0.1235	0.1246	0.0440	0.0155	0.0436	0.0154
0.3737	0.1227	0.1396	0.0522	0.0195	0.0458	0.0171
0.3754	0.1266	0.1409	0.0529	0.0199	0.0475	0.0178
0.3771	0.1280	0.1422	0.0536	0.0202	0.0483	0.0182
0.3788	0.1279	0.1435	0.0544	0.0206	0.0484	0.0184
Summation = 9.6141	4.6257	3.0281	0.9682	0.3141	1.4113	0.4376

$4.6257 = 31B_0 + 9.6141B_1 + 3.0281B_2$ ………………………………….. (1)

$1.4113 = 9.6141B_0 + 3.0281B_1 + 0.9682B_2$ ………………………….. (2)

$0.4376 = 3.0281B_0 + 0.9682B_1 + 0.3141B_2$ ………………………….. (3)

Solving these equations simultaneously give $B_0 = 0.6272$, $B_1 = -2.5941$ and $B_2 = 3.3428$ and substituting into the equation gives the equation of the vehicle as $F = 0.6272 - 2.5941p + 3.3428p^2$.

Table C2: Substituted values and their summation for Vehicle 3

TYRE PRESSURE (N/mm^2)	FUEL CONSUMPTION (LITRES/KM)	p^2	p^3	p^4	pf	p^2f
0.2720	0.1953	0.0740	0.0201	0.0055	0.0531	0.0144
0.2789	0.1869	0.0778	0.0217	0.0060	0.0521	0.0145
0.2806	0.1776	0.0787	0.0221	0.0062	0.0498	0.0140
0.2875	0.1767	0.0827	0.0238	0.0068	0.0508	0.0146
0.2961	0.1724	0.0877	0.0260	0.0077	0.0511	0.0151
0.3047	0.1664	0.0929	0.0283	0.0086	0.0507	0.0155
0.3065	0.1631	0.0939	0.0288	0.0088	0.0500	0.0153
0.3082	0.1555	0.0950	0.0293	0.0090	0.0479	0.0148
0.3099	0.1577	0.0960	0.0298	0.0092	0.0489	0.0151
0.3168	0.1558	0.1004	0.0318	0.0101	0.0493	0.0156
0.3185	0.1536	0.1015	0.0323	0.0103	0.0489	0.0156
0.3203	0.1456	0.1026	0.0328	0.0105	0.0466	0.0149
0.3220	0.1433	0.1037	0.0334	0.0107	0.0461	0.0149
0.3254	0.1433	0.1059	0.0345	0.0112	0.0466	0.0152
0.3272	0.1312	0.1070	0.0350	0.0115	0.0429	0.0140
0.3289	0.1399	0.1082	0.0356	0.0117	0.0460	0.0151
0.3358	0.1280	0.1127	0.0379	0.0127	0.0430	0.0144
0.3375	0.1248	0.1139	0.0384	0.0130	0.0421	0.0142

0.3427	0.1214	0.1174	0.0402	0.0138	0.0416	0.0142
0.3478	0.1199	0.1210	0.0421	0.0146	0.0417	0.0145
0.3495	0.1192	0.1222	0.0427	0.0149	0.0417	0.0146
0.3530	0.1181	0.1246	0.0440	0.0155	0.0417	0.0147
0.3737	0.1183	0.1396	0.0522	0.0195	0.0442	0.0165
0.3754	0.1202	0.1409	0.0529	0.0199	0.0451	0.0169
0.3771	0.1198	0.1422	0.0536	0.0202	0.0452	0.0170
0.3788	0.1212	0.1435	0.0544	0.0206	0.0459	0.0174
Summation = 8.4747	3.7752	2.7859	0.9235	0.3087	1.2132	0.3933

$3.7752 = 27B_0+8.4747B_1+2.7859B_2$ ………………………………………….. (1)

$1.2132 = 8.4747B_0+2.7859B_1+0.9235B_2$……………………………………….(2)

$0.3933 = 2.7859B_0+0.9235B_1+0.3087B_2$ …………………………………….. (3)

Solving these equations simultaneously give $B_0 = 0.5568$, $B_1 = -1.7946$ and $B_2 = 1.618$ and substituting into the equation gives the equation of the vehicle as

$F = 0.5568 – 1.7946p + 1.618p^2$.

Table C3: Substituted values and their summation for Vehicle 4

TYRE PRESSURE (N/mm^2)	FUEL CONSUMPTION (LITRES/KM)	p^2	p^3	p^4	pf	p^2f
0.2410	0.2020	0.0581	0.0140	0.0034	0.0487	0.0117
0.2547	0.1828	0.0649	0.0165	0.0042	0.0466	0.0119
0.2582	0.1704	0.0667	0.0172	0.0044	0.0440	0.0114
0.2634	0.1706	0.0694	0.0183	0.0048	0.0449	0.0118
0.2685	0.1684	0.0721	0.0194	0.0052	0.0452	0.0121
0.2703	0.1572	0.0730	0.0197	0.0053	0.0425	0.0115
0.2754	0.1499	0.0759	0.0209	0.0058	0.0413	0.0114
0.2772	0.1456	0.0768	0.0213	0.0059	0.0403	0.0112
0.3254	0.1445	0.1059	0.0345	0.0112	0.0470	0.0153
0.3271	0.1422	0.1070	0.0350	0.0115	0.0465	0.0152
0.3289	0.1395	0.1081	0.0356	0.0117	0.0459	0.0151
0.3306	0.1351	0.1093	0.0361	0.0119	0.0447	0.0148
0.3323	0.1280	0.1104	0.0367	0.0122	0.0425	0.0141
0.3358	0.1351	0.1127	0.0378	0.0127	0.0454	0.0152
0.3478	0.1389	0.1210	0.0421	0.0146	0.0483	0.0168
0.3495	0.1362	0.1222	0.0427	0.0149	0.0476	0.0166
0.3530	0.1299	0.1246	0.0440	0.0155	0.0458	0.0162
0.3737	0.1263	0.1396	0.0522	0.0195	0.0472	0.0176

0.3754	0.1284	0.1409	0.0529	0.0199	0.0482	0.0181
0.3771	0.1280	0.1422	0.0536	0.0202	0.0483	0.0182
0.3788	0.1284	0.1435	0.0544	0.0206	0.0486	0.0184
0.3806	0.1295	0.1448	0.0551	0.0210	0.0493	0.0188
0.3840	0.1346	0.1475	0.0566	0.0217	0.0517	0.0198
0.3857	0.1316	0.1488	0.0574	0.0221	0.0508	0.0196
0.3875	0.1389	0.1501	0.0582	0.0225	0.0538	0.0209
0.3909	0.1449	0.1528	0.0597	0.0234	0.0567	0.0221
SUMMATION: 8.5727	3.7670	2.8884	0.9919	0.3462	1.2218	0.4059

$3.7670 = 27B_0+8.5727B_1+2.8884B_2$ …………………………………………………. (1)

$1.2218 = 8.5727B_0+2.8884B_1+0.9919B_2$ ……………………………………….. (2)

$0.4059 = 2.8884B_0+0.9919B_1+0.3462B_2$ ……………………………………….. (3)

Solving these equations simultaneously give B_0 = 0.1.4454, B_1 = -7.9701 and B_2 = 11.748 and substituting into the equation gives the equation of the vehicle as $F = 0.6272 – 2.5941p + 3.3428p^2$.

Table C4: Substituted values and their summation for Vehicle 5

TYRE PRESSURE (N/mm^2)	FUEL CONSUMPTION (LITRES/KM)	p^2	p^3	p^4	pf	p^2f
0.2637	0.1953	0.0695	0.0183	0.0048	0.0515	0.0136
0.2672	0.1996	0.0714	0.0191	0.0051	0.0533	0.0142
0.2706	0.1802	0.0732	0.0198	0.0054	0.0488	0.0132
0.2810	0.1647	0.0789	0.0222	0.0062	0.0463	0.0130
0.3068	0.1504	0.0941	0.0289	0.0089	0.0461	0.0142
0.3085	0.1475	0.0952	0.0294	0.0091	0.0455	0.0140
0.3137	0.1462	0.0984	0.0309	0.0097	0.0459	0.0144
0.3154	0.1468	0.0995	0.0314	0.0099	0.0463	0.0146
0.3172	0.1479	0.1006	0.0319	0.0101	0.0469	0.0149
0.3189	0.1451	0.1017	0.0324	0.0103	0.0463	0.0148
0.3206	0.1348	0.1028	0.0329	0.0106	0.0432	0.0139
0.3223	0.1351	0.1039	0.0335	0.0108	0.0436	0.0140
0.3240	0.1357	0.1050	0.0340	0.0110	0.0440	0.0142
0.3275	0.1361	0.1072	0.0351	0.0115	0.0446	0.0146
0.3292	0.1376	0.1084	0.0357	0.0117	0.0453	0.0149
0.3327	0.1429	0.1107	0.0368	0.0122	0.0475	0.0158
0.3361	0.1403	0.1130	0.0380	0.0128	0.0471	0.0158
0.3378	0.1433	0.1141	0.0386	0.0130	0.0484	0.0164

0.3396	0.1458	0.1153	0.0391	0.0133	0.0495	0.0168
0.3413	0.1477	0.1165	0.0397	0.0136	0.0504	0.0172
0.3430	0.1502	0.1176	0.0404	0.0138	0.0515	0.0177
0.3478	0.1449	0.1210	0.0421	0.0146	0.0504	0.0175
0.3495	0.1408	0.1222	0.0427	0.0149	0.0492	0.0172
0.3530	0.1399	0.1246	0.0440	0.0155	0.0494	0.0174
0.3737	0.1639	0.1396	0.0522	0.0195	0.0613	0.0229
0.3754	0.1608	0.1409	0.0529	0.0199	0.0604	0.0227
SUMMATION = 8.4165	3.9234	2.7454	0.9019	0.2983	1.2626	0.4099

$3.9234 = 27B_0+8.4165B_1+2.7454B_2$ …………………………………………………….. (1)

$1.2626 = 8.4165B_0+2.7454B_1+0.9019B_2$ ……………………………………………… (2)

$0.4099 = 2.7454B_0+0.9019B_1+0.2983B_2$ ……………………………………………… (3)

Solving these equations simultaneously give $B_0 = 0.6402$, $B_1 = -2.7463$ and $B_2 = 3.7853$ and substituting into the equation gives the equation of the vehicle as $F = 0.6402 – 2.7463p + 3.7853p^2$.