DESIGN OF OVERLOAD AND UNBALANCE ALERT SYSTEM FOR ISUZU-NPR VEHICLE

By:

Olma Yadessa

DEPARTMENT OF MECHANICAL SYSTEMS AND VEHICLE ENGINEERING

SCHOOL OF MECHANICAL, CHEMICAL AND MATERIALS ENGINEERING

Presented in partial fulfillment of the requirements for the award of the master's degree of science in Automotive Engineering

Adama Science and Technology University

June, 2019

Adama, Ethiopia

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Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the final open defense by Olma Yadessa have read and evaluated his/her thesis entitled "Design of overload and unbalance alert system for ISUZU-NPR vehicle" and examined the candidate. This is, therefore, to certify that the thesis has been accepted in partial fulfillment of the requirements of the Degree of master's.

______________________________	__________	__________
Advisor	Signature	Date
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Chairperson	Signature	Date
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Internal Examiner	Signature	Date
______________________________	__________	__________
External examiner	Signature	Date

Declaration

I hereby declare that this MSc. Thesis is my original work and has not been presented for a degree in any other university, and all sources of material used for this thesis have been duly acknowledged.

Name: ______________________________

Signature: ____________

This MSc. Thesis has been submitted for examination with my approval as thesis advisor.

Name: _____________________________

Signature: _____________

Date of submission: _____________

Advisor’s approval sheet

To: Mechanical Systems and Vehicle Engineering

Subject: Thesis Submission

This is to certify that the thesis entitled “Design of overload and unbalance alert system for ISUZU-NPR vehicle” submitted in partial fulfillment of the requirements for the degree of Master’s in Automotive Engineering, the Graduate program of the department of Automotive Engineering, and has been carried out by Olma yadessa, Id. No: A/PR15369/10 under my supervision. Therefore, I/we recommend that the student has fulfilled the requirements and hence hereby he/she can submit the thesis/dissertation to the department.

____________________	_____________	_____________
Name of major Advisor	Signature	Date

ACKNOWLEDGEMENT

Thanks to God, I managed to complete the study after gone through so many challenges. All praise and many- many thanks to God who gave the strength and confident to me for completing this thesis work.

I would like to express my genuine thanks to my advisor Ato Mekonnen Liben (Asst. professor) for his valuable advices, constant motivation and guidance's during my study.

I would like to express my appreciation to AL-STAZ P.L.C (ISUZU-NPR importer**),** Bishoftu Automotive and Engineering Industry, Anbesa city Bus and Oromia Transport Authority for allowing me to collect specification and gather information through questionnaire necessary for my thesis work.

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Generally, I would like to extend my thanks for all the above people and those who are not mentioned here but contribute their part a lot to towards the success of this thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

ADC	Analog to Digital Convertor
AVL	Automatic Vehicle Location
DAC	Digital-to-Analog Convertor
DOLAS	Design of Vehicle Overload Alert System
DOULDS	Design of Unbalance LED Display System
ECU	Electronic Control Unit
GCW	Gross Combination Weight
GHG	Greenhouse Gas
GIS	Geographical Information System
GPS	Geographical Positioning System
GVW	Gross Vehicle Weight
ITL	Intelligent Traffic Light System
KW	Kerb Weight
LED	Light Emitted Diode
LRR	Low Rolling Resistance
MEMS	Micro Electro Mechanical System
PIC	Programmable Integrated Circuit
PL	Pay Load
RSU	Road Side Units
TS	Tracking Server
VANETS	Vehicular Adhoc Networks

ABSTRACT

The main objective of this thesis is to design overload and an unbalance alert system for an ISUZU - NPR vehicle that can assist a driver to minimize accident. This work is to quantify the effect of overloaded and unbalance of vehicles. The methods used for this work is design of c++ language and MATLAB. For the problem of overloading and unbalancing ISUZU-NPR vehicles, on-board alert systems for same are designed. The system included four strain gauges found at each suspension or mounted under the front and rear leaf springs in such way that it can interface with microcontroller circuit. From the programming result, it is found that the newly designed system in this thesis responded quickly. The design system displayed the status of front and rear axle loads with regards to overload and unbalance using the alert and LED system respectively. If the vehicle is parked on level road, the strain gauge measured the status of leaf springs and tires. Thus, it can be concluded that the alert system can contribute remarkably towards the proper use of vehicles and safe driving.

Keywords: accident**,** engine performance, fuel consumption**,** leaf spring**,** suspension.

CHAPTER ONE

INTRODUCTION

1.1. Background

Overload is to push something or someone too far; a supervisor can overload an employee by assigning too much load. Unbalanced is when something is unbalanced, it's uneven or unstable. If your weight on a surfboard is unbalanced, you risk falling off.

A vehicle overloaded and unbalanced is less stable and thus incurs additional risk for the other road users. In this study it is tried to resolve this problem of overloading and unbalance of a vehicle by allocating overload and unbalance alert system which will work based on load of vehicle. Exceeding a vehicle’s maximum permissible weight is not only a danger to the driver and road users rather it is an illegal offence which carries a range of risks and penalties with fixed fines to prison sentence. For any business, maximizing efficiency is key to reduce operating cost and improving profit margins. When transporting goods, the temptation to overload of a vehicle in a bid to maximize payload and reduce overall fuel costs can be a costly mistake. Overloaded and unbalanced vehicles significantly increase fuel consumption. Tires are more prone to wear, steering becomes more difficult to control and vehicles take longer to react to braking. This can dramatically affect vehicle handling, increase daily wear and tear and increase the likelihood of a costly and potentially fatal accident. This work to quantify the effect of overloaded and unbalance of vehicles and protect all modes of mobility from accident. For the problem of overloading and unbalancing vehicles, for an alert system for ISUZU- NPR vehicle is designed. The system includes strain gauges, power source, sensor, control circuit and interface circuit with microcontroller. Overloading and unbalancing on vehicles would increase the load on the engine and increase fuel consumption (Raj Reddy, 2015). Overloaded vehicles produce higher kinetic energy and higher centrifugal force, resulting in greater impact forces and damages to other vehicles or to the infrastructure, especially when met with an accident and are more likely to be fatal. Many researchers have shown that the important reason for road damage is the vehicle load (Matthijs Klomp, 2010).

1.2. Statement of the problem

Overload and unbalance can cause the tires to overheat and wear rapidly which increases the chance of premature, dangerous and expensive failure or blow-outs, therefore it will be less stable, difficult to steer and take longer to stop. For developing this system is selected ISUZU because, in our country accident happened once more on ISUZU-NPR as composed data from Awash Insurance, Bishoftu Automotive Engineering Industry, Anbesa City Bus and Company and Oromia Traffic Agency (appendix). By overloading and unbalancing the vehicle it will incur higher maintenance costs to the vehicle tires, brakes, shock absorbers and higher fuel consumption. The driver's control and operating space in the overloaded vehicle is diminished, escalating the chances for an accident. The overloaded and unbalanced cannot accelerate as normal and it make uncomfortable for loaded material. The whole suspension system comes under stress and, over time, the weakest point can give way. This thesis is focused to solve the problem mentioned above by use of alert system.

1.3. Objectives

1.3.1. General objective

The main objective of this thesis is to design overload and an unbalance alert system for ISUZU- NPR that can assist the driver to minimize accident.

1.3.2. Specific Objectives

The specific objectives are:

- To collect the specifications of the ISUZU-NPR.
- To prepare the part and assembly drawing of the system using AUTOCAD.
- To calculate the static and dynamic load of the ISUZU-NPR.
- To find static and dynamic load of ISUZU- NPR result using MATLAB.
- To develop alert system code using C++ language.

1.4. Significance of the thesis

The significance of the proposed thesis work is to know the weight and weight limit of ISUZU-NPR, the maximum permitted axle weight and gross vehicle weight (GVW) can be found bonnet, or on the chassis of trailers and ensure the GVW is checked before setting out using an in-house or public weighbridge and minimize accident happened in case of inclination, centrifugal force and banking road. While public weighbridges can be used to obtain accurate GVWs, in some cases the approach and exit paths are not sufficiently flat or level to give accurate results for axle weight, which should if possible be checked using an in-house weighbridge. The GVW is the maximum permitted weight of the vehicle (plus any load it carrying), while the GVW is the maximum permitted weight of the vehicle plus any trailer being towed (plus any load being carried in the vehicle and trailer). Ensure the load is distributed appropriately to avoid overloading axles. After any drop-offs, re-check the distribution of the remaining load.

1.5. Beneficiaries

Automotive industries, transport authority, traffic police, driver, vehicle owners, researchers, society and country as a whole get benefitted with this work.

1.6. Delimitation (Scope)

It is clear that as the load of the ISUZU-NPR vehicle is over and unbalanced the possibility of maneuvering with the force of the driver becomes more difficult. Hence this work will be limited to design of overload and unbalance alert systems for these vehicles.

1.7 organization of thesis

The scope of this thesis is to design overload and an unbalance alert system for ISUZU- NPR that can assist the driver to minimize accident

Chapter one: Overload is to push something or someone too far; a supervisor can overload an employee by assigning too much load. Unbalanced is when something is unbalanced, it's uneven or unstable. In this study it is tried to resolve this problem of overloading and unbalance of a vehicle by allocating overload and unbalance alert system which will work based on load of vehicle.

Chapter two: In this in this topics detection, protection or control the overloaded they use a load sensor on the chassis frame, the vehicle load information accurately and safely used from the single chip microcontroller and the load signal is coming from one home. In this mechanism overload detection, protection or control systems are detecting, control or protect the gross vehicle weight.

Chapter three: The system includes strain gauges, power source, sensor, control circuit and interface circuit with microcontroller.

Chapter four: Depend on vehicle situation the weight, wheel loads, and axles load of vehicles are different be subject to vehicle position. In this state, when the angle of bank, acceleration, angle of inclination and height of center of gravity fluctuated the weight of a vehicle is varied and not more than gross weight. Wheels load and axles load value is varied because the load is transferred from one wheel to another wheel or from one axle to another axle.

Chapter five: The system of this thesis is to alert or LED display the function it need hardware like a strain gauge each of the wheel where friction load applied on ISUZU- NPR. Strain gauge is constructed by forming a grid made of fine electric resistance wire or photographically etched metallic resistance foil on an electrically insulating base (backing), and attaching gauge leads. The system included four strain gauges found at each suspension or mounted to under the leaf spring of the front leaf spring and rear leaf spring interface circuit with microcontroller.

CHAPTER TWO

LITERATURE REVIEW

2.1. Review of previous research works

Wang Jiayao, (2013). Discussed the vehicle load detection device is completed by the freight vehicle load automatic detection and display device, which is composed by the circuit connection of the weighting sensors, the signal transmitters, the mileage sensors and the load detection displays. The weighting sensors have employed the metal resistance strain sensors which have been symmetrically installed between the rear plate and the rear axle steel prop under the beams of vehicle rear wheels. The mileage sensors have adopted the photoelectric speed sensors which have been installed in the vehicle transmission. The load detection display has employed the intelligent automated instrumentation and the measured signals have been sent to the RS232 interface of S3C2440A.

H. D. Kattimani, (2017). This focused on Overload Detection and Protection. Different vehicles have different maximum weights for which they are designed. Hence if this maximum weight exceeds than it is difficult to stop the vehicle and thus the vehicle becomes less stable .Effectiveness to stop the vehicle decreases due to overheating of breaks which will result in harder breaking mechanism as the vehicle is heavier. The parts of the vehicle are of great concern and overloading will incur major loss or reduction in their effective usage and will decrease the efficiency of the vehicles. As the overloading is illegal the insurance covered by it becomes invalid. The load sensor that is placed on the chassis collects, the vehicle load information accurately and reliably and transit the real-time information to the computer processor efficiently and safely using the single chip microcontroller the information can be received in the form of variety of amplified signals by load sensors in harsh environment, calculates the total load and then transmit the data to the LED.

Mehran, (2015). Developed a weight sensor that can measure the weight of the vehicle with the extra load, seems to be necessary. Many equipment have been designed for automatic vehicle load monitoring system and navigation monitoring system, but the system which we designed has these qualities: a weight sensing device attached to a base of a vehicle, and where in the weight sensing device is a load cell; a compression spring attached to the weight sensing device and to a suspension spring of the vehicle; a voltage conversion unit attached to the weight sensing device to convert an output resistance of the load cell into a voltage; an automatic vehicle location data and a voltage conversion unit; and a central server connected to the AVL to receive a vehicle location data and a voltage data for computing a vehicle load at an instant. Where in the vehicle location data and the vehicle load at any instant is communicated simultaneously to a driver of the vehicle.

Brian Taylor, (2012). The purpose of this paper is to demonstrate the need for, and cost effectiveness of, enforcement of commercial vehicle weights and dimensions laws. Additionally, this paper will show that effective weight enforcement, in conjunction with a comprehensive data collection program form the foundation for a scientific based road asset management framework, which is vital to make effective road asset management decisions. In Commercial vehicle weights and dimension laws are enforced by highway agencies to ensure that excessive damage (hence reduced life) is not imposed on the highway infrastructure. Illegally overweight trucks rob the [highway] system of its life without reimbursing the public and compete unfairly with other trucking firms. These same overweight trucks pose a safety hazard to the travelling public who share the road and create a substantial economic burden to taxpayers.

Tariku Sinshaw, (2017). The purpose of this work is the Design of Overload Monitoring System in Public Transportation Based on Microcontroller. The problem of overloading is generally under control in many developed countries while it is still a challenge too many developing and under developed nations. Now a day, with the increasing number of people in cities of Ethiopia, the problem of poor transportation services has grown to an alarming extent. Due to no availability of bus information, the buses are overloaded for most of the times, which often results in some kinds of fault occurrence in buses and peoples get late further. The GSM/PIR based monitoring and controlling passenger system is a system that makes use of PIR infrared radiation motion analyzer which counts passengers.

These modules include bus station module, in bus module and bus stop module. Bus station module contains GSM modem interfaced to the microcontroller and receives bus information from in bus module. The bus starts to transmit the number of peoples to the bus station and bus stop terminal while crossing the road.

Munshi Nurul Islam, (2014). This outer worked Vehicle Tracking and Accident Alert System for accident alert system to rescuing people in accidents. The latest like GPS are highly useful now a day, this system enables the owner to observe and track his vehicle and find out vehicle movement and its past activities of vehicle. This new technology, popularly called vehicle Tracking Systems which created many wonders in the security of the vehicle. This hardware is fitted on to the vehicle in such a manner that it is not visible to anyone who is inside or outside of the vehicle. Thus it is used as a covert unit which continuously or by any interrupt to the system, sends the location data to the monitoring unit. When the vehicle is stolen, the location data from tracking system can be used to find the location and can be informed to police for further action. Some Vehicle tracking System can even detect unauthorized movements of the vehicle and then alert the owner. This gives an edge over other pieces of technology for the same purpose. This accident alert system in it detects the accident and the location of the accident occurred and sends GPS coordinates to the specified mobile, computer. It is integrated in the circuit system by connecting all the sensors to or gate whose output is connected to the pin of microcontroller.

Heeler R. Karthik , Prof.S.Karpagarajan, (2014). This paper clearly explained about the safety and control systems in the car developed by Design and Development of Seat Belt Alert System with Ignition Interlocking in Four Wheeler. Day-to-day life we are careless in our safety while driving in vehicles for this we have to introduce some techniques to do these precautions compulsory. Such a new technique is explained in this paper. While driving car wearing seat belt is important that can save our life during accident periods .But most of us are careless to wear seatbelt. Road traffic injuries have been neglected from the global health agenda for many years, despite being predictable and largely preventable. Evidence from many countries shows that dramatic successes in preventing road traffic crashes can be achieved through concerted efforts that involve, but are not limited to, the health sector.

R.Ramkumar et al, (2013). This journal states that, Rapid growth of technology and infrastructure has made our lives easier. The advent of technology has also increased the traffic hazards and the road accidents take place frequently which causes huge loss of life and property because of the poor emergency facilities. Road accidents are one of the major causes of mortality around the world and over 1,300,000 people are killed annually in the road accidents. Most of fatal accidents occur on the roads outside the city. Some of the casualties are killed in the crash moment and the others after the accident, mostly due to late arrival of rescue groups. The late arrival of rescue groups is mostly because of the lack of rapid and timely notice from accident. The aim of our work is to find the vehicle accident location by means of sending a message using a system which is placed inside of vehicle system. So in this work we are using the arduino microcontroller ATMEGA 2560 for cost effective and also for easy understanding. Here we used embedded C programming for better accuracy and GPS and GSM modules which helps to trace the vehicle anywhere on the globe. The exact location of the vehicle is sent to our remote devices (mobile phones) using GSM modem. Proposed system contains single-board embedded system that is equipped with GPS and ZigBee, along with microcontroller that is installed in the SAS vehicle.

Muhammad Adnan Elahi1, Yasir Arfat Malkani, (2014). According to this work Tracking systems were first developed for the shipping industries to determine the position of ships and boats in the sea. Initially passive systems were developed to support in tracking and navigation for location-based applications. For the applications that require real time location information of the vehicle, these systems cannot be employed, because they store the location information in the internal storage that can only be accessed when vehicle is available. Recently, Automatic Vehicle Location (AVL) systems are developed and deployed in numerous environments. These systems are capable of transmitting vehicle’s location information in real time. In these systems, the device installed in the vehicle can transmit the location information in real time to a remote data center, instead of storing into local storage, using some radio network. In this paper, we present the design and implementation of a real time AVL system that incorporates a hardware device installed in the vehicle and a remote Tracking Server (TS).

M. A. M. Razali4, N. M. Z. Hashim, (2013). This journal told that Vehicle Security Alert System is a security system that is designed to protect and alert the user on certain happenings that need ready attention to the car. Vehicle Security Alert System is a vehicle safety system is required at present as the crimes involving the theft of the car or the car breaks rampant today. This system involves the real connection with the conventional alarm system connected to the Programmable Interface Controllers (PIC) and GSM Modem. When the negative situations occur, the car security alarm will activate and if the car door had been opened, a signal will be send to the PIC. Later the PIC will process the data and will transmit the signal to the GSM modem. Here the GSM modem will send a notification SMS to phone the owner of the vehicle immediately. The proposed system is applied for transferring of GSM communication by sending a SMS message to the user's mobile phone. The system is used for car protection in combination with the vehicle security system. In general, the project is fully hardware configuration and categorized into two parts: electronic and telecommunication part. This project is design by using a transmitter, which transmit signals to another device. With a controlling system which defined as PIC microcontroller.

Rupal Shah, Yogesh Sharma , (2016). The main purpose of this study is to understand and establish the extent to which vehicle overloading is happening in a developing country. The phenomenon of vehicle overloading is not new and has been discussed in relation to the adverse effects on vehicle engine, road safety and environment problem. Although much has been said in the context of the more developed countries, in developing countries there has not been much discussion on vehicle overloading. In this study vehicle overloading in a developing country is established. Many types of problems are produced due to overloading. It is found that there is moderate increase in accidents due to overloading or higher weight. An overloaded vehicle is less stable and thus incurs additional risk for the other road users. In this project we are trying to resolve this problem of overloading in bike by allocating overload indicator system which will work based on suspension system of bike. Exceeding a vehicle's maximum permissible weight is not only a danger to the driver and road users; it is an illegal offence which carries with it a range of risks and penalties, from fixed fines to prison sentence. For any business, maximizing efficiency is key to reducing operating cost and improving profit margins. When transporting goods, the temptation to overload a vehicle in a bid to maximize payload and reduce overall fuel costs can be a costly mistake.

Hassan K, Anaelsam and Machuve D, (2013). This work states that current situation for controlling overloading passengers in public buses needs to be improved. There is a need to device a new system which can overcome all this difficulties as the technology is growing we need to utilize it for the development of our country. This may include safety and comfort during the journey, safety at the stop point and terminals, buses travel and stop in the assign routes and terminal. The finding indicate that many deaths and injuries when accident occurs, they causes deaths and injuries mainly if there is passengers overloading or if the passengers are not wearing seat belt or both. Many people lose their lives and some are severally injured when accident occur in the public buses.

Wahid W, Achmad W, (2013). In this thesis the impacts of axle load overloading on freight vehicles toward the increasing of greenhouse gas emission by oxides and carbon. Overloading on vehicles would increase the effort of engine performance so that will cause the increase of fuel consumption. That increasing also would affect the concentration of gas emission from vehicle. This research will discuss about the impact of overloading towards concentration gas emission from heavy freight vehicle, especially oxides of carbon which cause green hose effect, specifically CO and CO2. Due to this air pollution can occur. Air pollution which is a process of inclusion some substance, energy, or other component to ambient air by human activity can causes decreasing of ambient air quality until certain degree which causes the ambient air cannot fulfill its function. Based on the analysis in this study, it can be concluded that change over the axial load freight vehicles comparable correlation with exists emissions. Anthony Nkem Ede analyzed the cumulative damage effects of truck overloads on Nigerian road pavements. Road infrastructure is basic facility needed for the growth and an advancement of any modern economy.

Shanzhen XU, (2011). In this paper, control overloading of the passenger vehicle, an automatic control system based on Microcontroller for overloading passenger vehicle was designed. The system hardware is mainly composed of the sensor circuit, sensor working control circuit, fuel injection control circuit and other components. Sensor circuit mainly consists of the piezoelectric infrared sensor, photosensitive resistance, and piezoelectric infrared signal processing chips and processing circuit. The sensor working control circuit is used to control the sensors by the opening and closing the door. The software of the system was compiled with the microcontroller AT89C51. The front-end detection system has two piezoelectric infrared sensors mounted on both sides of the door (one for the detection of persons getting on the bus, the other one for the off). The system started in time when the door opened. The piezoelectric infrared sensor may detect the infrared emission by the body, which had nothing to do with the dress, so the system is more reliable. When people gets on the bus, infrared sensors detect the number, ECU counts the number and when a person gets off the bus, ECU subtraction the number. Based on the platform of microcontroller AT89C51 microcontroller the passenger overloading control system was designed. Compared with the traditional control overloading methods, it can response fast, saved a lot of manpower, material and financial resources, and can be monitored in real time in the number of passenger, which can control better of overloading of passenger vehicles.

2.2. Summary of Literature review

In this literature review to detection, protection or control the overloaded they use a load sensor on the chassis frame, the vehicle load information accurately and safely used from the single chip microcontroller and the load signal is coming from one home. In this mechanism overload detection, protection or control systems are detecting, control or protect the gross vehicle weight. It is observed that in previous work their system did not detect, control, protect front axle and rear axle load and loads of front wheel left side, front wheel right side, rear wheel left side and rear wheel right side. In load sensor, if the spring remains stack the load sensor had been functioning as a result of wheel unbalance could not be sensed. Therefore, taking into consideration the above gap in previous research on the current thesis work will be focused on solving the identified gaps, such as including of strain gauge, at the leaf spring of all four wheels to achieve effective sensing of unbalance and overload for fast response with alert system and LED display system.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Materials

For designing this system many types of components are used to make it perfectly working. All the components were purchased from different manufacturers. These components show on the Table3.1.

Table 3. 1: Materials required for alert and LED displayed systems.

No	Component	Quantity
1	Actuator	1
2	Circuit And Switch Holder	1
3	Convertors	2
4	DC Motor	1
5	Memory	1
6	Microcontroller	1
7	Power Source(Vehicle Battery/ Auxiliary Battery Or Generator)	1
8	Radio Receiver	1
9	Siren	1
10	Strain Gauge	4
11	Central Processing Unit	1
12	Circuit And Switch Holder	1

3.1.1. Strain Gauge

A strain gauge is constructed by forming a grid made of fine electric resistance wire or photographically etched metallic resistance foil on an electrical insulation base (backing), and attaching gauge leads as shown in Figure 3.1.

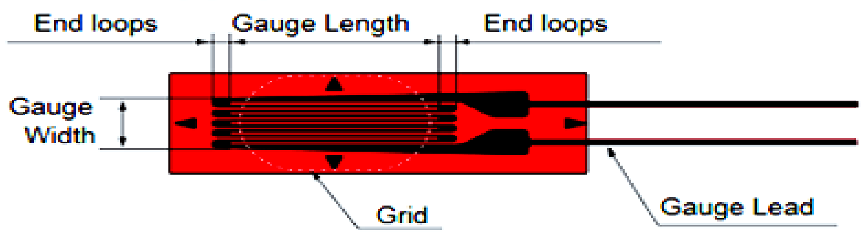


Figure 3. 1: Strain gauge composition (Earl J. Wilson, TB).

3.1.1.1. Strain gauge principles

When strain is generated in a measurement object, the strain is transferred to the resistance wire or foil of the strain gauge via the gauge base (backing). As a result, the wire or foil experiences a resistance change. This change is exactly proportional to the strain as in the equation below. Normally, this resistance change is very small and requires a Wheatstone bridge circuit to convert the small resistance change to a more easily measured voltage change shown in Figure 3.2.

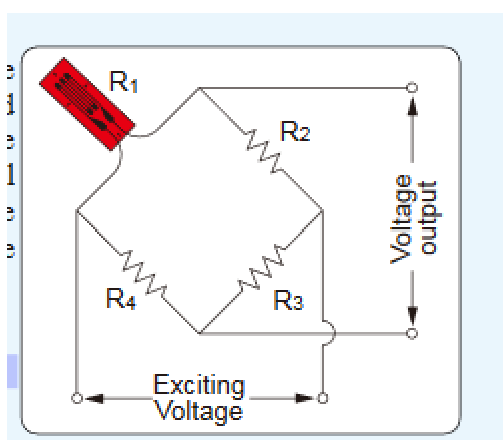


Figure 3. 2: The voltage output of the circuit (Earl J. Wilson, Tb).

$$e = \frac{R_1 R_3 - R_2 R_4}{(R_1 + R_2)(R_3 + R_4)} E$$

where

- e : Voltage output
- E : Exciting voltage
- R_1 : Gauge resistance
- $R_2 \sim R_4$: Fixed resistance

Here, if R=R1=R2=R3=R4 the resistance of the strain gauge changes to R+ΔR due to strain.
A Strain gage (sometimes referred to as a Strain Gauge) is a sensor whose resistance varies with applied force; it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured. When external forces are applied to a stationary object, stress and strain are the result. Stress is defined as the object's internal resisting forces. The strain gage is one of the most important tools of the electrical measurement technique applied to the measurement of mechanical quantities.

3.1.1.2. Structure of strain gages

There are many types of strain gages. Among them, a universal strain gage has a structure such that a grid-shaped sensing element of thin metallic resistive foil (3 to 6μm thick) is put on a base of thin plastic film (15 to 16μm thick) and is laminated with a thin film shown as Figure 3.3.

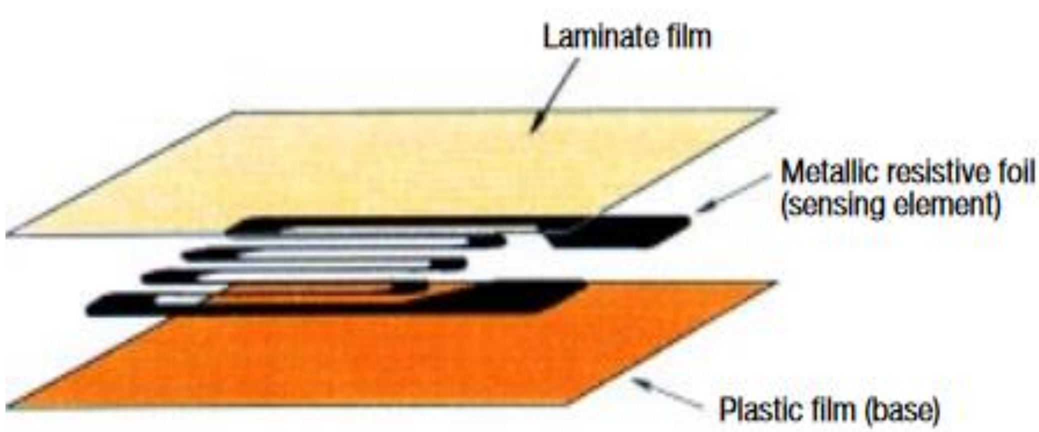


Figure 3. 3: Strain gauge component (Earl J. Wilson, Tb).

3.1.1.3. Selection of instruments for strain measurement

The output voltage from a strain-gage potentiometer circuit or Wheatstone bridges, for elastic strain magnitudes in metals, very small. Electrical amplification is required to bring the signal to a level where it can be used conveniently for indication or recording. To assure satisfactory performance and precision, the entire instrument system, from power supply to recording instrument, should be considered as a unit. The criteria for selecting the individual components of such a system are fixed by the nature of the strain being studied, the type of information required from the system, and the mutual compatibility of the various system components. In the case of small members vibrating at high frequencies, the limitation is more appropriate (apt) to arise from the change in mass due to the presence of the gage and its lead wires. The lead wires must be firmly attached to the gage. Commercial instruments for use with strain gages usually combine several if not all of the components of Figure 3.4, into a single unit. The limitations of such devices should be investigated prior to purchase. For example, the instrument may include an alternating-frequency source of power for the Wheatstone bridge. This can lead to difficulties in the measurement of high-frequency strains. The frequency of the strain being measured (which will modulate the power supply in the bridge circuit) is limited to approximately 10 to 20 percent of the carrier frequency. If the carrier frequency is high enough to overcome this objection, the capacitive unbalance and pickup in the strain-gage leads is apt to be excessive. Strain-gage measurements made in the presence of an intense magnetic field present a special problem since the gage resistance may change as a result of the imposed magnetic field.

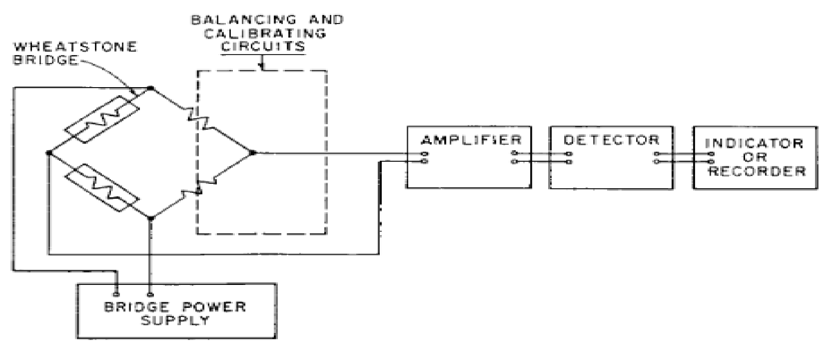


Figure 3. 4: Illustrates in block form the basic elements of a strain-gage instrumentation system (Earl J. Wilson, Tb).

3.1.2. Microcontroller

Microcontroller low- power and high performance CMOS and 8 or 16 bits microcontroller with 8 kb in system programmable flash memory. The devise is manufactured using Atmel's density nonvolatile memory technology and is compatible with the industry standard 80csl instruction set and pin out. Microcontroller is a small, low cost computer on a chip which is usually includes the following components and flow chart shown in Table 3.2 and Figure3.4.

Table 3. 2: Components of Microcontroller.

No	Component	Quantity
1	An 8 or16 bits microprocessor (CPU)	1
2	A small amount of RAM.	1
3	Programmable ROM and/or flash memory.	1
4	Input	4
5	output	1
6	Timer and signal generators.	1
7	Analog to Digital (A/D) and Digital to Analogy (D/A) conversion	1

The block diagram of programmable integrated circuit (PIC) is shown on Fig 3.5.

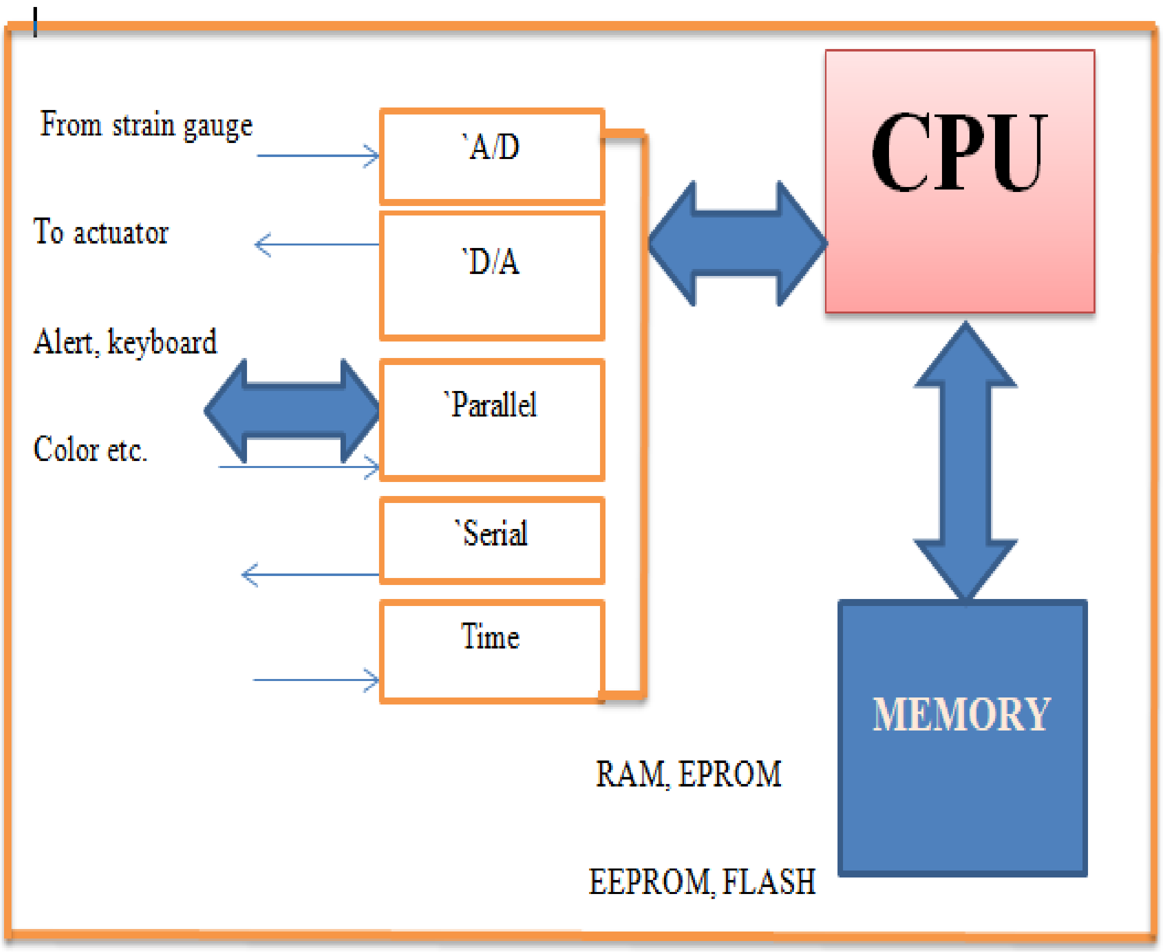


Figure 3. 5: Block diagram of programmable integrated circuit (PIC).

As shown in the figure 3.6 below, the circuit has four logic inputs for four wheels in terms of stain gauge These sensors are EPSL11, EPSL12, EPSL21 and EPSL22 in which they are given to the microcontroller in four ways and from microcontroller it goes to LED and radio receiver.

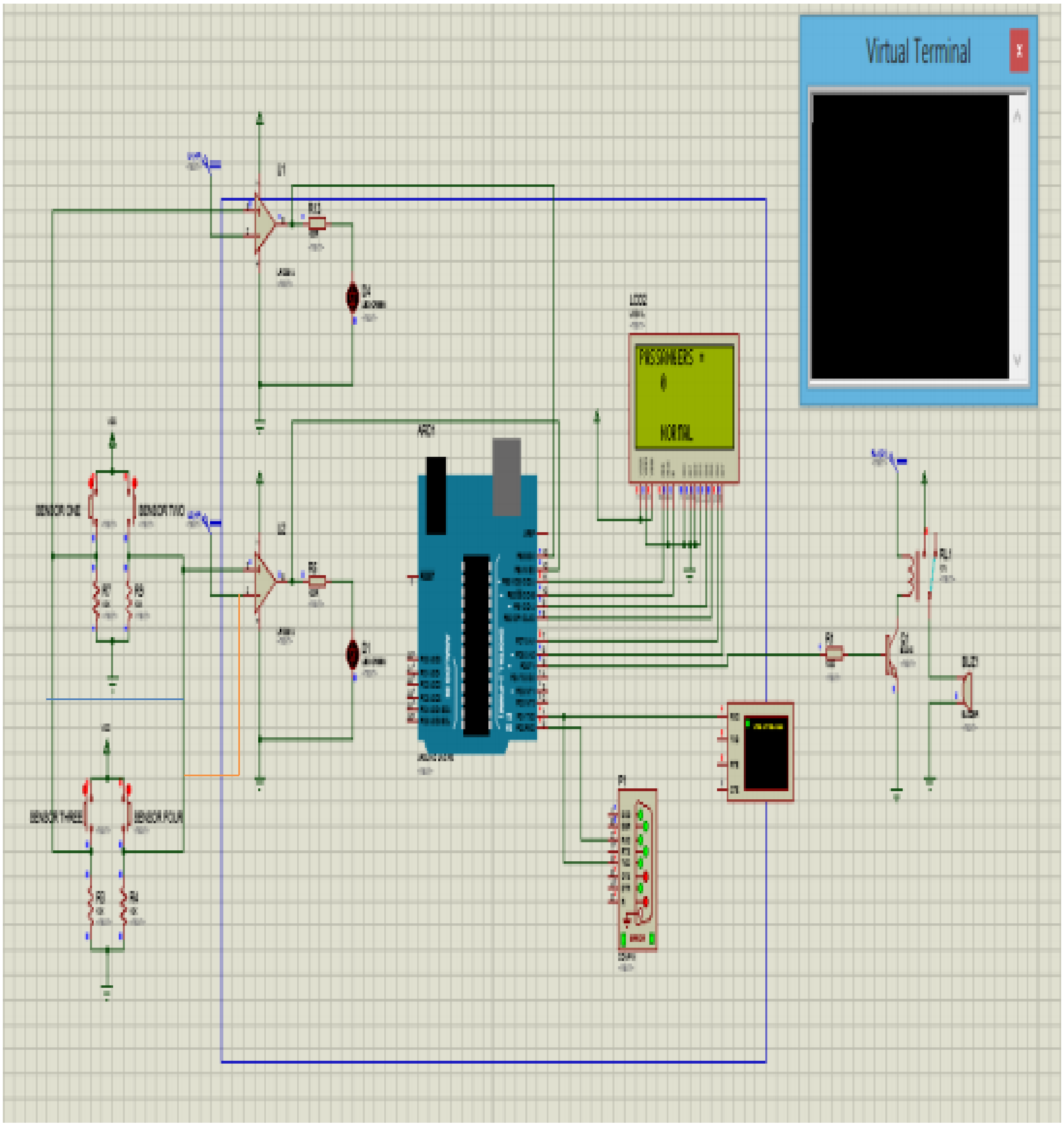


Figure 3. 6: circuit diagram of the system.

3.1.2.1. Converters

There are two basic type of converters, digital-to-analog (DACs or D/As) and analog-to-digital (ADCs or A/Ds). In the case of the ADC, a digital representation of the analog voltage that is applied to the ADCs input is output, the representation proportional to a reference voltage. In both cases the digital word is almost always based on a binary weighted proportion (https://www.electronics).

3.1.2.2. Amplifier

Amplifier is the generic term used to describe a circuit which produces and increased version of its input signal shown as Figure 3.7.

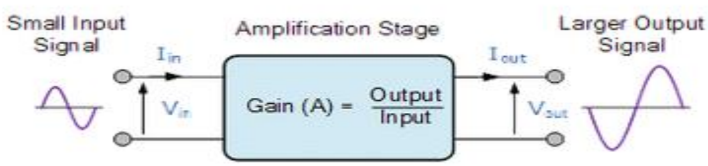


Figure 3. 7: Voltage signal amplifier (https://www.electronics).

3.2. Methods

3.2.1. Introduction

For this study primary and secondary surveys, AUTOCAD, load calculations, C++ languages and MATLAB were used.

Primary survey

Selecting different companies dealing with passenger and freight transport have been identified. From each company 15 persons were selected purposively for questionnaires, the result is attached at appendix.

Secondary survey

Different literature such as journals, internet, textbook, specification…..etc.

3.2.2. Calculation of weight and reaction force in different condition

This study uses the ISO vehicle dynamics system, as shown in Figure 3.8. In order to fully describe the vehicle motion, it is necessary to define two axis systems, which will be referred to as the vehicle-fixed axes and the earth-fixed axes. The equations of motion are derived using the vehicle-fixed axes, whose three principal directions are denoted by xyz, the origin of which is located at the vehicle center of gravity.

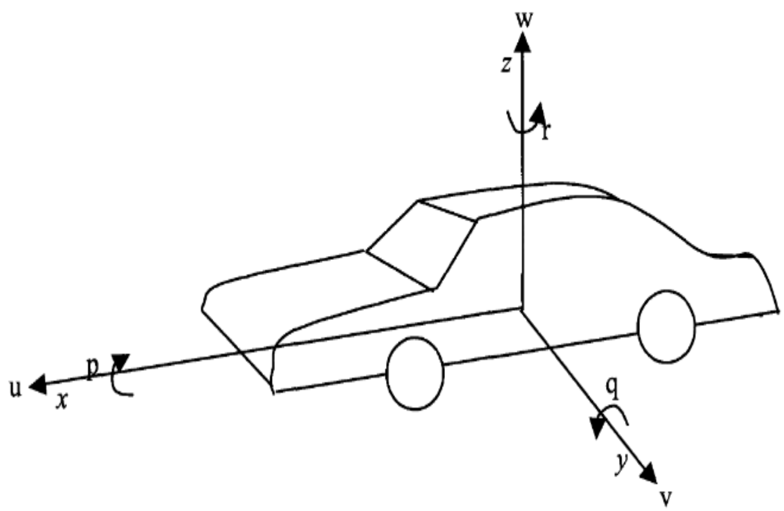


Figure 3. 8: Vehicle dynamics axis system (vehicle dynamic ISO 8855, 1991).

The position of the vehicle is defined as the position of the origin of the vehicle-fixed axes (i.e. the vehicle center of gravity) in an earth-fixed axis system, with principal directions denoted by XYZ, which is considered to be stationary. The point which if the body is hanged from it will stay balanced (leveled as it is on the ground). The specific gravity of the vehicle is not varied depending on vehicle dynamics and the specification of ISUZU-NPR, 2016 model for this work is shown on Table 3.2 and the location of the gravitational force depends on the specification.

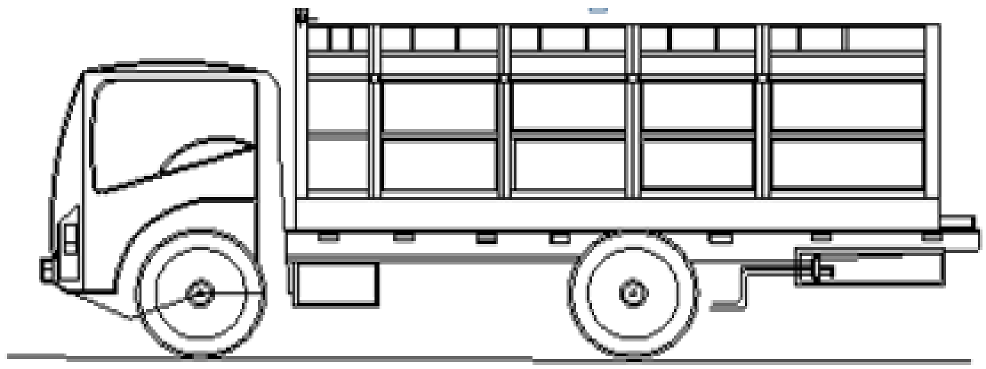
- ✓ **Specification of case car for this Study**

Table 3. 2: ISUZU-NPR, 2016 model specifications

Part Name	Capacity/Type
Front axle reaction force	28923.31N
Rear axle reaction force	57846.62N
Front axle left side reaction force	14461.655N
Front axle right side reaction force	14461.655N
Rear axle left side reaction force	28923.31N
Rear axle right side reaction force	28923.31N
Wheel base	3.55m
Track width	1.5m
Suspension springs	Tapered/Multi-Leaf
Tires specification	205/75R 17.5.
Gross Vehicle weight	86769.94N
Gross Combination Weight	113470.3N
Leaf spring length	1.27m
Leaf spring thickness	0.8cm
Number of leaf spring plate	6
Rear leaf spring	2 part
Front leaf spring	1 part
Stiffness of leaf spring	80 N/mm (80000N/m)

3.2.1.1. Loaded ISUZU- NPR vehicle parked on a level road (model, 2016)

In this condition the value of front axle and rear axle of parked vehicle is given in the specification of ISUZU-NPR. When a car is parked on level pavement, the reaction force, R, under each of the front and rear wheels (specification of ISUZU –NPR, 2016 model) is shown in Fig 3.9.



Front axle	+	Rear axle	=	GVW
28923.31N		57846.62		86769.94N

Figure 3. 9: Weight distribution analysis for loaded ISUZU- NPR vehicle (AUTO CAD).

GVWR/GCWR= $86769.94/113470.30$N

From the specification the front axle is half of the rear axle, because the rear axle have double wheel on left side and right side. The load Carrying capacity of axle is directly proportional to number of tire applied on side wheel.

R_1 = 28923.31N

R_2 = 57846.62N

$R_1 = R_{11} + R_{12}$………………………………..……………………………3.1

$R_2 = R_{21} + R_{22}$ ………………………………………………………………3.2

Where:

R_1 = Front axle reaction force
R_2 = Rear axle reaction force
R_{11} = Front axle left side reaction force
R_{12} =Front axle right side reaction force
R_{21} =Rear axle left side reaction force
R_{22}=Rear axle right side reaction force
d_2 = Rear axle distance from center of gravity
d_1 = Front axle distance from center of gravity
h = Height of center of gravity
m = Mass of vehicle
l = wheel base
C.G = Center of gravity
K = Leaf spring stiffness

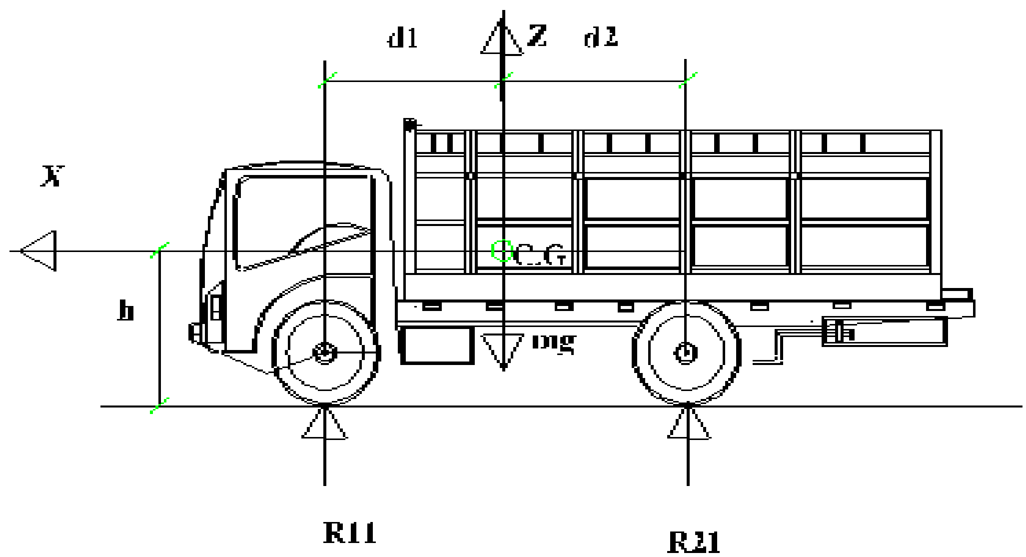


Figure 3. 10: A parked car on level pavement (AUTO CAD).

Wheel base = 3.55m (specification of ISUZU- NPR, 2016 model)

l=d_2+d_1= 3.55m

$R_{11} = R_{12} = \frac{1}{2} mg \frac{d_2}{l}$………………………………………………………….3.3

$R_{21} = \frac{1}{2} mg \frac{a_1}{l}$……...3.4

- ✓ **Steel leaf spring load analysis and calculation.**

Relation between the leaf spring vertical surface strain, Leaf spring vertical deformation, Thickness of the leaf spring, Span leaf spring momentum and the leaf spring is shown as Fig 3.11 (Weigang, 2013).

$$\boldsymbol{\varepsilon} = \frac{\mathbf{6\Delta xh}}{\mathbf{l^2}} \quad \text{………………………………………………………………………}3.5$$

Where:

$\boldsymbol{\varepsilon}$ = Leaf spring surface strain.

Δx= Leaf spring vertical deformation (mm).

h= Thickness of the leaf spring (mm).

l = Span of leaf spring (mm).

Leaf spring surface strain, ε, can be installed in leaf spring strain gauge sensor resistance measured vertical deformation of the leaf spring is,

$$\Delta \boldsymbol{x} = \frac{\boldsymbol{\varepsilon l^2}}{\boldsymbol{6h}} \quad \text{………………………………………………………………………}3.6$$

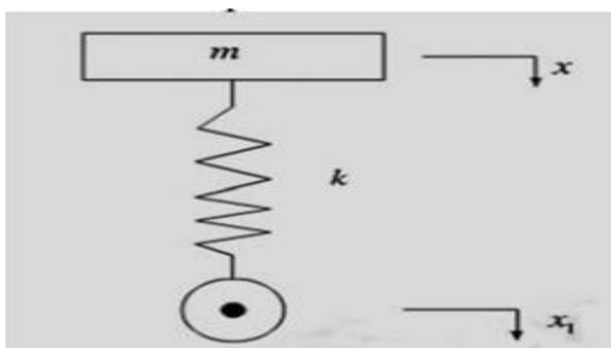


Figure 3. 11: Single-arm suspension system model diagram (Weigang, 2013).

Where:

m = Leaf springs sprung mass (kg).

k = Leaf spring stiffness (N/mm).

x = Sprung mass center of mass displacement (mm).

x_1= Tire deformation (mm).

According to Newton's second law can be obtained:

$$k(x-x_1) = mg \qquad 3.7$$

$$\Delta x=(x-x_1) = \frac{\varepsilon l^2}{6h} \qquad 3.8$$

Because one kind of leaf spring moment span, stiffness and thickness can be fixed, so set the sprung mass correlation coefficient ß $=\frac{l^2}{6hg}$, so the formula m = ß ε can be simplified as:

Therefore :

$$W = R_{11} + R_{12} + R_{21} + R_{22} = (m_{11} + m_{12} + m_{21} + m_{22})g$$

$$= ß(\varepsilon_{11} + \varepsilon_{12} + \varepsilon_{21} + \varepsilon_{22})g = k\,l^2\,\frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{6h} \qquad 3.9$$

$$\varepsilon = \frac{6*mg*h}{kl^2} \qquad 3.10$$

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} \qquad 3.11$$

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} \qquad 3.12$$

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} \qquad 3.13$$

$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} \qquad 3.14$$

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{6*0.08m*14461.65N}{80000N/m*(1.27m)^2}$$

= **0.053797**

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} = \frac{6*0.08m*14461.65N}{80000N/m*(1.27m)^2}$$

= **0.053797**

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{6*0.08m*28923.31N}{80000N/m*(1.27m)^2}$$

= **0.107594**

$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} = \frac{6*0.08m*28923.31N}{80000N/m*(1.27m)^2}$$

= **0.107594**

- ✓ **Longitudinal mass center determination of ISUZU –NPR parked on pavement road.**

To determine the longitudinal position of, C, it should measure the total weight of the car as well as the force under the front or the rear wheels. Figure 3.10, Illustrates a situation in which it is measure the force under the front wheels. Assuming the force under the front wheels $R_{11} and\ R_{12}$, the position of the mass center is calculated by static equilibrium conditions. Where, d_1 is the distance of the car's mass center ,C, from the front axle and d_2 is the distance of ,C, from the rear axle, and l is the wheel base (Reza N. Jazar, www.mohandesyar.com).

$$d_1 = \frac{2l}{mg} R_{22} \qquad 3.15$$

$$= \frac{2*3.55}{8854.45*9.81} * 28923.31$$

$\boldsymbol{d_1}$ = **2. 38m**

$$d_2 = \frac{2l}{mg} R_{11} \qquad 3.16$$

$$= \frac{2*3.55}{8854.45*9.81} * 14461.65\text{N}$$

$\boldsymbol{d_2}$= **1.17m**

Height of the center of gravity determination for loaded ISUZU- NPR vehicle

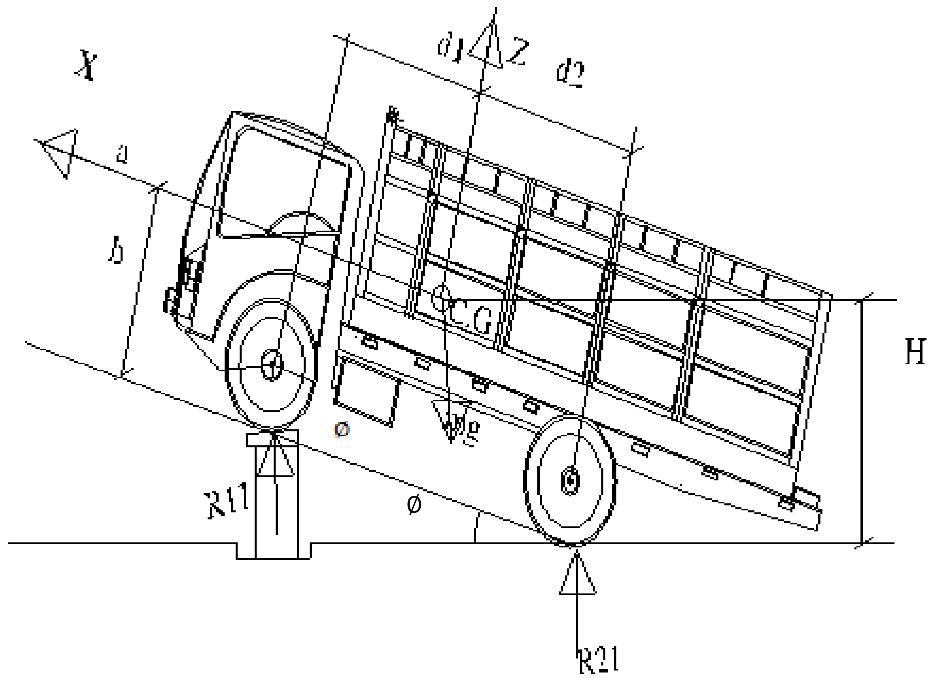


Figure 3. 12: Measuring the force under the wheels to find the height of the center of gravity (AUTO CAD).

To determine the height of center of gravity, C.G, it should measure the force under the front or rear wheels while the car is on an inclined pavement. Experimentally, we use a device such as is shown in Figure 3.12. The car is parked on a level surface such that the front wheels are on a scale jack. The front wheels will be locked and anchored to the jack, while the rear wheels will be left free to turn. The jack lifts the front wheels and the required vertical force applied by the jacks is measured by a strain gauge. Assume that we have the longitudinal position of, C.G, and the jack is lifted such that the car makes an angle, φ, of 10 to 25 degree with the horizontal plane. The slope angle φ is measurable using level meters. Assuming the force under the front wheels is $2R_{11} or\ 2R_{12}$ the height of the mass center can be calculated by using equation 3.17 (Reza N. Jazar, www.mohandesyar.com).

From ISUZU-NPR model the tire specification, 205/75R 17.5.

r= 0.380 m.

$2R_{11} = 28923.31N$

a_2 =1.17m

l =3.55m

φ =15 °

W =mg= 8845.05*9.81= 86769.94N

Therefore:

$$h = r + \left(2\frac{R_{11}}{mg}l - a_2\right)\cot\varphi \quad (3.17)$$

$$= 0.38 + \left(\left(\frac{28923.31N}{8854.45*9.81} * 3.55\right) - 1.17\right)\cot 10^{\circ}$$

h= 0.412m

There are three assumptions in this calculation:

- ✓ The tires are assumed to be rigid disks with radius, r.
- ✓ Fluid shift, such as fuel, coolant, and oil, are ignored.
- ✓ Suspension deflections are assumed to be zero.

Suspension deflection generates the maximum effect on height determination error. To eliminate the suspension deflection, we should lock the suspension, usually by replacing the shock absorbers with rigid rods to keep the vehicle at its ride height.

3.2.1.2. Loaded ISUZU-NPR vehicle is parked on an Inclined Road (model, 2016)

When a car is parked on an inclined pavement as shown in Figure 3.13, the normal force, R, under each of the front and rear wheels, R_1, R_2, is:

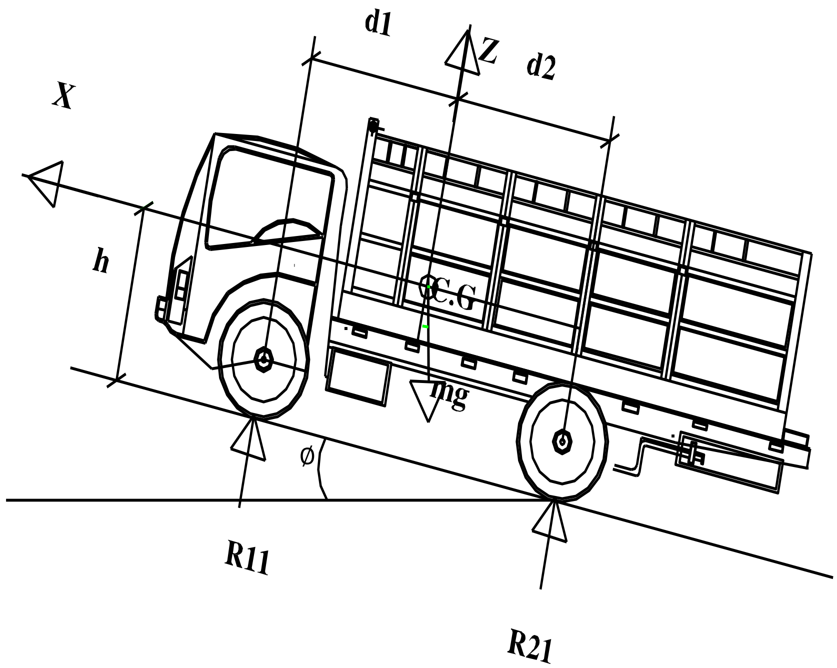


Figure 3. 13: A parked car on inclined pavement (AUTO CAD).

These equations provide the brake force and reaction forces under the front and rear tires. To know reaction forces under the front and rear tires, we give the value of inclination angle (∅) =6.67°(Reza N. Jazar, www.mohandesyar.com).

$$R_{11} = R_{12} = \frac{1}{2} mg \frac{d_2}{l} \cos \emptyset - \frac{1}{2} mg \frac{h}{l} \sin \emptyset \quad \ldots\ldots\ldots\ldots \quad 3.18$$

$$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55} \cos 6.67 - \frac{1}{2} * 86769.94 * \frac{0.45}{3.55} \sin 6.67$$

$R_{11} = R_{12}$ = **<u>13785.5N</u>**

$R_{21} = R_{22} = \frac{1}{2} mg \frac{d_1}{l} \cos \emptyset + \frac{1}{2} mg \frac{\mathrm{h}}{l} \sin \emptyset$ ………………………………..…….. 3.19

$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55} \cos 6.67 + \frac{1}{2} * 86769.94 * \frac{0.45}{3.55} \sin 6.67$

$R_{21} = R_{22} = \underline{\mathbf{29276.05N}}$

W= $\frac{R_{11}+R_{12}+R_{21}+R_{22}}{\cos \emptyset} = \frac{m_{11}+m_{12}+m_{21}+m_{22}}{\cos \emptyset} g$ ……………………….…..……………. 3.20

= ß $\frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{\cos \emptyset} g =$ kl^2 $\frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{6h \cos \emptyset}$ ………………………………..……… 3.21

$$= \frac{13785.5 + 13745.5 + 29276.05 + 29276.05}{\cos 6.67°}$$

= **<u>86123.1N</u>**

$$\varepsilon_{11} = \frac{6\mathrm{h}R_{11}}{kl^2} = \frac{6*0.08\mathrm{m}*13785.5\mathrm{N}}{80000N/m*(1.27m)^2}$$

$= \underline{\mathbf{0.0513}}$

$$\varepsilon_{12} = \frac{6\mathrm{h}R_{12}}{kl^2} = \frac{6*0.08\mathrm{m}*13785.5\mathrm{N}}{80000N/m*(1.27m)^2}$$

$= \underline{\mathbf{0.0513}}$

$$\varepsilon_{21} = \frac{6\mathrm{h}R_{21}}{kl^2} = \frac{6*0.08\mathrm{m}*29276.05\mathrm{N}}{80000N/m*(1.27m)^2}$$

$= \underline{\mathbf{0.1089}}$

$$\varepsilon_{22} = \frac{6\mathrm{h}R_{22}}{kl^2} = \frac{6*0.08\mathrm{m}*29276.05\mathrm{N}}{80000N/m*(1.27m)^2}$$

$= \underline{\mathbf{0.1089}}$

3.2.1.3. Loaded ISUZU-NPR vehicle accelerating on a level road

Friction and cohesion processes are very un trivial, it brings electromagnetic interactions between atoms and molecules on microscopic level as well as surface geometry on macro level – that was another my argument against the statement that acceleration can't be more than g without traction loss – because such complex and heterogeneous process as wheel traction can't have such a simple solution and equal to gravitational force. Observation: If the coefficient of static friction is 0.8, then the tires are still rolling and not skidding (slipping) on the roadway, therefore it is appropriate to use static friction, and not the weaker kinetic friction. Since the friction coefficient is 0.80, then the maximum acceleration that this can produce is 0.80g = 0.8 (9.8 m/sec^2) = 7.84 m/sec^2. (Reza N. Jazar, www.mohandesyar.com).

The problem then states that it takes three seconds to stop at the deceleration rate, so the velocity V = acceleration x time, thus the speed the object is travelling (without skidding) is: V = 3 sec x 7.84 m/sec^2 = 23.52 m/sec = 84.67 km/hr.

When a car is speeding with acceleration on a level road as shown in Figure 3.14, the vertical forces under the front and rear wheels. The value of equation 3.3 and 3.4 is the static load of the vehicle which is standing on level road.

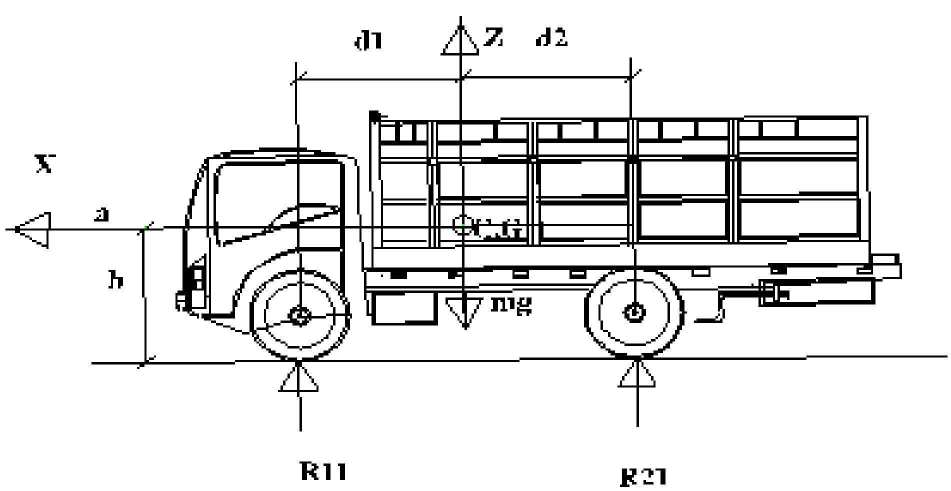


Figure 3. 14: Accelerating Car on a Level Road (AUTO CAD).

The value of equation 3.22 and 3.23 is the load of each wheel accelerating on level road.

$$R_{11} = R_{12} = \frac{1}{2}mg\frac{d_2}{l} - \frac{1}{2}mg\frac{\text{h}}{l}\frac{\text{a}}{g} \text{ ……………………………………….…………….. 3.22}$$

$$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55} - \frac{1}{2} * 86769.94 * \frac{0.45}{3.55} * \frac{7.84}{9.81}$$

$R_{11} = R_{12}$= **<u>11792.54N</u>**

$$R_{21} = R_{22} = \frac{1}{2}mg\frac{d_1}{l} + \frac{1}{2}mg\frac{\text{h}}{l}\frac{\text{a}}{g} \text{…………………………….…..……… 3.23}$$

$$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55} + \frac{1}{2} * 86769.94 * \frac{0.45}{3.55} * \frac{7.84}{9.81}$$

$R_{21} = R_{22}$= **<u>31592.41N</u>**

W= $R_{11} + R_{12} + R_{21} + R_{22} = (m_{11} + m_{12} + m_{21} + m_{22})g$

$$= ß\,(\varepsilon_{11} + \varepsilon_{12} + \varepsilon_{21} + \varepsilon_{22})g = \text{k}l^2\,\frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{6h} \text{……................... 3.24}$$

W= 11792.54N +11792.54N +31592.41N+31592.41N

W=<u>86769.94N</u>

$$\varepsilon_{11} = \frac{6\text{h}R_{11}}{kl^2} = \frac{6*0.08\text{m}*11792.54\text{N}}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.0438}}$$

$$\varepsilon_{12} = \frac{6\text{h}R_{12}}{kl^2} = \frac{6*0.08\text{m}*11792.54\text{N}}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.0438}}$$

$$\varepsilon_{21} = \frac{6\text{h}R_{21}}{kl^2} = \frac{6*0.08\text{m}*31592.41\text{N}}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.117524}}$$

$$\varepsilon_{22} = \frac{6\text{h}R_{22}}{kl^2} = \frac{6*0.08\text{m}*31592.41\text{N}}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.117524}}$$

3.2.1.4. Loaded ISUZU- NPR Accelerating car on an inclined road

You need to have able to accelerate a vehicle anywhere especially up a hill where gravity is pulling against it. If there are any faulty components in the vehicle, then this could make it harder for the engine to work hard enough to push the vehicle up the hill as you attempt to accelerate (Reza N. Jazar, www.mohandesyar.com). The first term, $\frac{1}{2}mg\frac{a_2}{l}$ and $\frac{1}{2}mg\frac{a_1}{l}$, are called static part, and the second ters $\pm\frac{1}{2}mg\frac{\mathrm{h}}{l}\frac{\mathrm{a}}{g}$ = 2669.1N are called dynamic part of normal forces. When a car is accelerating on an inclined pavement with angle , $\emptyset$, as Figure 3.15, the normal force under each of the front and rear wheels, R_1, R_2 would be:

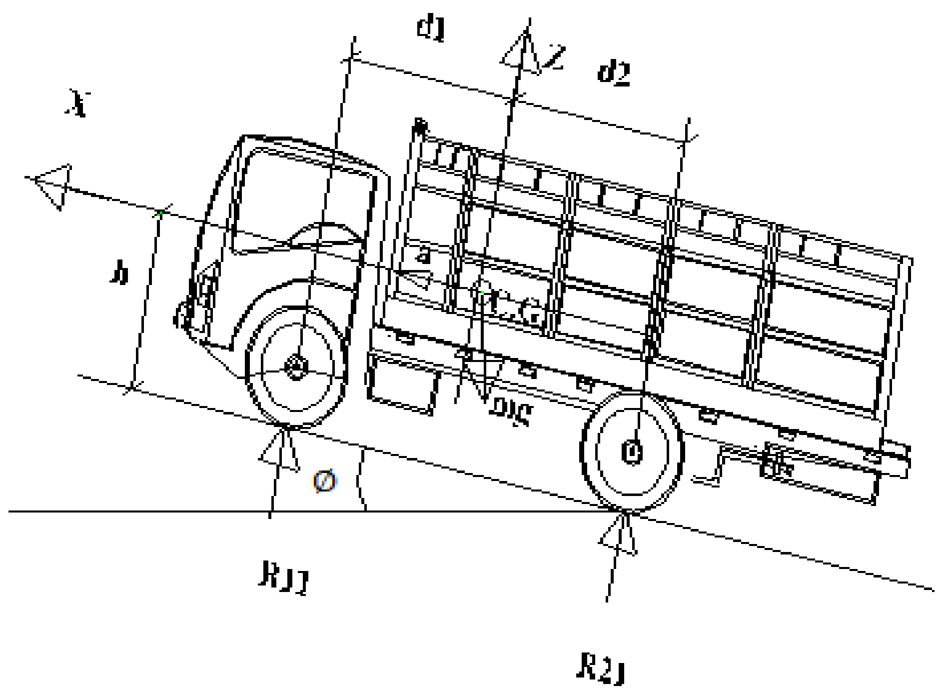


Figure 3. 15: Accelerating car on an inclined road (AUTO CAD).

$$R_{11} = R_{12} = \frac{1}{2}mg(\frac{d_2}{l}\cos\emptyset - \frac{\mathrm{h}}{l}\sin\emptyset) - \frac{1}{2}ma\frac{\mathrm{h}}{l} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ 3.25$$

$$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55}\cos 6.67 \quad - \frac{1}{2} * 86769.94 * \frac{0.45}{3.55}\sin 6.67 \quad 0.5*8854.45*\frac{0.45}{3.55}$$

$R_{11} = R_{12}$=**11116.4N**

$R_{21} = R_{22} = \frac{1}{2}mg(\frac{d_1}{l}\cos\emptyset + \frac{\mathrm{h}}{l}\sin\emptyset) + \frac{1}{2}ma\frac{\mathrm{h}}{l}$…………………………………. 3.26

$= \frac{1}{2} * 86769.94 * \frac{1.17}{3.55} \cos 6.67 + \frac{1}{2} * 86769.94 * \frac{0.45}{3.55} \sin 6.67 + 0.5*8854.45*\frac{0.45}{3.55}$

$R_{21} = R_{22}$=**<u>31945.15N</u>**

W= $\frac{R_{11}+R_{12}+R_{21}+R_{22}}{\cos\emptyset} = \frac{m_{11}+m_{12}+m_{21}+m_{22}}{\cos\emptyset} g$

= ß $\frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{\cos\emptyset} g = kl^2 \frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{6h\cos\emptyset}$…………………………. 3.27

W= $\frac{11116.4+11116.4+31945.15+31945.15}{\cos 6.67}$

=**<u>86709.98N</u>**

$\varepsilon_{11} = \frac{6\mathrm{h}R_{11}}{kl^2} = \frac{6*0.08\mathrm{m}*11116.4\mathrm{N}}{80000N/m*(1.27m)^2}$

= **<u>0.041353</u>**

$\varepsilon_{12} = \frac{6\mathrm{h}R_{12}}{kl^2} = \frac{6*0.08\mathrm{m}*11116.4\mathrm{N}}{80000N/m*(1.27m)^2}$

= **<u>0.041353</u>**

$\varepsilon_{21} = \frac{6\mathrm{h}R_{21}}{kl^2} = \frac{6*0.08\mathrm{m}*31945.15\mathrm{N}}{80000N/m*(1.27m)^2}$

= **<u>0.1509218</u>**

$\varepsilon_{22} = \frac{6\mathrm{h}R_{22}}{kl^2} = \frac{6*0.08\mathrm{m}*31945.15\mathrm{N}}{80000N/m*(1.27m)^2}$

= **<u>0.1509218</u>**

3.2.1.5. Loaded ISUZU-NPR Parked Car on a Banked Road

Figure 3.16: depicts the effect of a bank angle, ∅, on the load distribution of a vehicle. A bank causes the load on the lower tires to increase, and the load on the upper tires to decrease. The reaction forces of front wheel are $\frac{1}{3}$ of GVW and the reaction force rear wheel is $\frac{2}{3}$ of GVW. Front side is symmetrical to opposite side of the wheel and the rear side is symmetrical with the opposite side wheel as shown on Figure 3.16 and the maximum angle banking road averagely 3.5(Reza N. Jazar, www.mohandesyar.com).

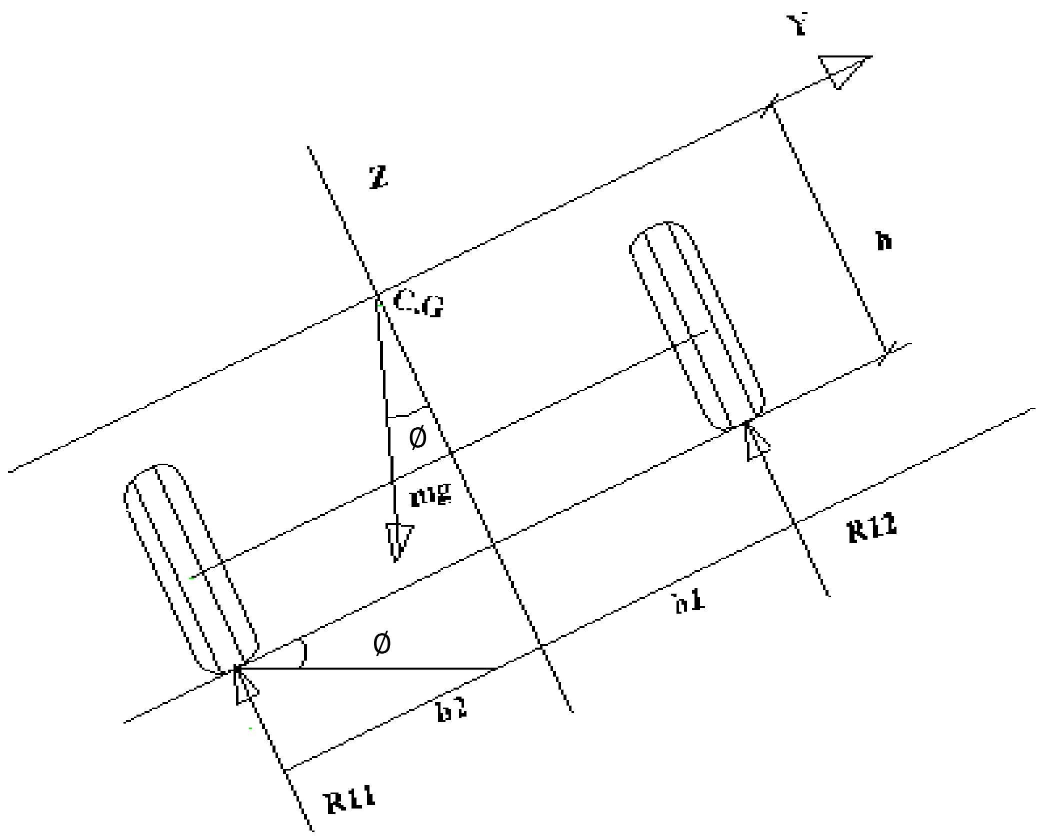


Figure 3. 16: Normal force under the uphill and downhill tire of a vehicle, parked on a banked road.

To calculate the reaction forces under each tire, we may assume the overall lateral force R_{y1}+R_{y2} as an unknown. The solution of these equations provides the lateral and reaction forces under the upper and lower tires.

W= 1.5m

b_2=b_1=$\frac{1}{2}$w = 0.75m

∅=3.5°

h=   0.273m

When a car is parked on a banked pavement, the reaction force, R, under each of the front and rear wheels are:

$$R_{12}=\frac{2}{3}(\frac{1}{2}mg\frac{b_2}{W}*\cos\emptyset - \frac{1}{2}mg\frac{h}{w}\sin\emptyset) \qquad 3.28$$

$$=\frac{2}{3}(\frac{1}{2}*86769.94*\frac{0.75}{1.5}*\cos 3.5° - \frac{1}{2}*86769.94*\frac{0.45}{1.5}\sin 3.5°)$$

R_{12}= **13964.21N**

$$R_{11}=\frac{2}{3}(\frac{1}{2}mg\frac{b_2}{w}\cos\emptyset + \frac{1}{2}mg\frac{h}{w}\sin\emptyset) \qquad 3.29$$

$$=\frac{2}{3}(\frac{1}{2}*86769.94*\frac{0.75}{1.5}*\cos 3.5° + \frac{1}{2}*86769.94*\frac{0.45}{1.5}\sin 3.5°)$$

R_{11}=**14905.98N**

$$R_{22}=\frac{4}{3}(\frac{1}{2}mg\frac{b_1}{w}\cos\emptyset - \frac{1}{2}mg\frac{h}{w}\sin\emptyset) \qquad 3.30$$

$$=\frac{4}{3}(\frac{1}{2}*86769.94*\frac{0.75}{1.5}*\cos 3.5° - \frac{1}{2}*86769.94*\frac{0.45}{1.5}\sin 3.5°)$$

R_{22}=**27928.42N**

$$R_{21}=\frac{4}{3}(\frac{1}{2}mg\frac{b_1}{w}\cos\emptyset + \frac{1}{2}mg\frac{h}{w}\sin\emptyset) \qquad 3.31$$

$$=\frac{4}{3}(\frac{1}{2}*86769.94*\frac{0.75}{1.5}*\cos 3.5° + \frac{1}{2}*86769.94*\frac{0.45}{1.5}\sin 3.5°)$$

R_{21}=**29811.89N**

$$W=\frac{R_{11}+R_{12}+R_{21}+R_{22}}{\cos\emptyset}=\frac{m_{11}+m_{12}+m_{21}+m_{22}}{\cos\emptyset}g$$

$$= ß\ \frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{\cos\emptyset}g= kl^2\ \frac{\varepsilon_{11}+\varepsilon_{12}+\varepsilon_{21}+\varepsilon_{22}}{6h\cos\emptyset} \qquad 3.33$$

$$W= \frac{14905.98+27928.42+13964.21+29811.89}{\cos 3.5}$$

W= <u>86608.09</u> N

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{6*0.08m*14905.98N}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.055545}}$$

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} = \frac{6*0.08m*13964.21N}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.051946}}$$

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{6*0.08m*29811.89N}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.1109}}$$

$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} = \frac{6*0.08m*27928.42N}{80000N/m*(1.27m)^2}$$

$$= \underline{\mathbf{0.13893}}$$

Depending on the specification, the value of R_{21} is carried overload weight. Therefore, when loaded ISUZU –NPR is parked on the banked road the reaction force of each wheels is different; the summation of wheels load is equal to total weight of vehicle divided cos $\emptyset$.

3.2.2. Design of overload alert system for ISUZU-NPR Vehicle

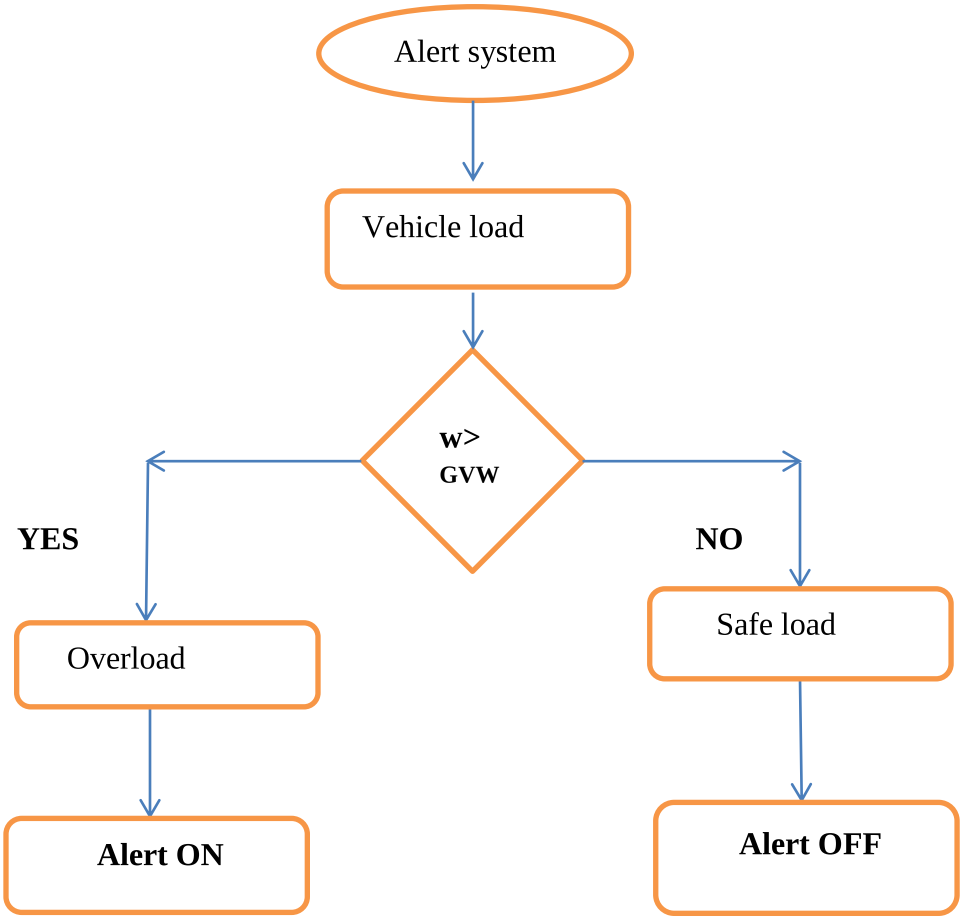


Figure 3. 17: Alert system flow chart for overload ISUZU-NPR vehicle.

CASE 1: If the applied weight is up to 100% of gross vehicle weight then it can be considered as SAFE LOAD. But in this condition front axle or rear axle maybe beyond gross axle weight and if the summation of wheel load is not greater than axle load, the front wheel right side is load greater than front wheel left side and the rear wheel right side is greater than rear wheel left side or vice versa the overload axle or wheel will be displayed on the LED.

CASE 2: If the applied load is 100% it is taken as the signal is sent to alert system, the alert system indicated the safe limit reached.

CASE 3: If the applied load exceeds the threshold then the signal is passed to the alert system, LED and Relay. The relay gets operated and supply is ALERT ON.

3.2.2.1. Design of Programing Code for Overload Alert System (DOLAS)

The **TURBO C++** Programing code of overload alert system for emergency vehicles is described below.

```
// Design of Vehicle Overload Alert System (DOLAS).

#include<iostream.h>

#include<conio.h>

#include<math.h>

#include<fstream.h>

#include<iomanip.h>

 void main()

  {

 Start:

   clrscr();

    char ch1;

// Vehicle Statics:

   float Wgrs,W,ALPHA,l,h,k,EPSL11_per,EPSL12_per,EPSL21_per,EPSL22_per;

   float radcos_ALPHA,EPSL11,EPSL12,EPSL21,EPSL22,delW,Wgrs1,C1,L,R,A,B,C,D;

   const float PI = 3.14;

 ofstream outfile ("OLMA-P2.dat");

 clrscr();

  cout << "\n\n\t\t  Adama Science and Technology University (ASTU) ";

  cout << " \n\t School of Mechanical, Chemical and Materials Engineering (SoMCME) ";
```

```
  cout << " \n\t\t       Department of Automotive Engineering ";
  cout << " \n\t\t\t           Olma Yadessa  ";
  cout << "\n\t\t\t         **************** ";
  cout << " \n\n\t  Design of Overload and Unbalance Alarm System for ISUZI -NPRVehicles
" ;
  cout << "\n ---------------------------------------------------------------------------- ";
  outfile << "\n\n\t\t  Adama Science and Technology University (ASTU) ";
  outfile << " \n\t School of Mechanical, Chemical and Materials Engineering (SoMCME) ";
  outfile << " \n\t\t       Department of Automotive Engineering ";
  outfile << " \n\t\t\t           Olma Yadessa  ";
  outfile << "\n\t\t\t         **************** ";
  outfile << " \n\n\t   Design of Overload and Unbalance Alarm System for ISUZI-NPR
Vehicles " ;
  outfile << "\n ---------------------------------------------------------------------------- ";
  cout <<"\n  Enter the 'gross Weight (Wgrs)' in 'N': ";
  cin >> Wgrs;
  cout <<"\n  Enter the 'gradient (ALPHA)' in 'deg.': ";
  cin >> ALPHA;
  cout <<"\n  Enter the 'span length of leaf spring' in 'mm': ";
  cin >> l;
  cout <<"\n  Enter the 'thickness of leaf spring' in 'mm': ";
  cin >> h;
```

```
cout <<"\n  Enter the 'spring index (k)' in 'N/mm': ";
cin >> k;
cout <<"\n  Enter the 'strain EPSL11)' in '%': ";
cin >> EPSL11_per;
cout <<"\n  Enter the 'strain EPSL12)' in '%': ";
cin >> EPSL12_per;
cout <<"\n  Enter the 'strain EPSL21)' in '%': ";
cin >> EPSL21_per;
cout <<"\n  Enter the 'strain EPSL22)' in '%': ";
cin >> EPSL22_per;
 radcos_ALPHA = ALPHA*(PI/180.0);  Wgrs1 = Wgrs-(0.06*Wgrs);
 EPSL11 = EPSL11_per/100.0; EPSL12 = EPSL12_per/100.0;
 EPSL21 = EPSL21_per/100.0; EPSL22 = EPSL22_per/100.0;
 C1 = (l*l*k)/(6.0*h);
  W = C1*((EPSL11+EPSL12+EPSL21+EPSL22)/radcos_ALPHA);  delW = W-Wgrs;
  cout << setprecision(4)<< "\n\n  EPSL11 = "<<EPSL11_per<<" % ";
  cout << setprecision(4)<< " ;  EPSL12 = "<<EPSL12_per<<" % ";
  cout << setprecision(4)<< " ;  EPSL21 = "<<EPSL21_per<<" % ";
  cout << setprecision(4)<< " ;  EPSL22 = "<<EPSL22_per<<" % ";
  cout << setprecision(4)<< "\n\n\t    W = "<<W<<" N";
  cout << setprecision(4)<< "\n\t Wgrs = "<<Wgrs<<" N";
```

```
if ( W < Wgrs1)
 {
   cout <<"\n\n  'Safe Loading.': ";
   getch();
    }
if ( W > Wgrs1 && W < Wgrs)
 {
   cout <<"\n\n  'Maximum Loading. 'Yellow' Warning !': ";
   getch();
    }
 if ( W >= Wgrs)
  {
   cout <<"\n\n  'Alert !  Overloading.' ";
   cout << setprecision(3)<< "\n\t    excess load = "<<del W<<" N ";
   getch();
    }
cout << "\n\n  Press 'Enter' twice, to 'proceed'.... ";
getch();
getch();
getche();
 }
```

3.2.3. Design of unbalanced Load Display System for ISUZU-NPR Vehicle

This pallet should have been packed against the vehicle's head board with additional restraining ropes to secure the load. Alternatively it could have been repacked to half its height. Regarding this image the center of height of gravity is it become high, if the center of height of gravity of any car become high, the front side of vehicle during up hilling and rear side of vehicle at during downhill become loose the ground easily. .

Figure 3. 18: Unbalanced load (poor loading) and load restraint practices.

If this load was lost the consequence could be catastrophic for nearby road users. The Load Restraint Guide advises that steel on steel should be avoided as there is insufficient friction between load and deck. This pallet should have been packed against the vehicle's head board with additional restraining ropes to secure the load, but load of two side of vehicle is not equal. Alternatively it could have been repacked to half its height. In an emergency braking situation or crash the load was not secured effectively to avoid loss onto the road or intrusion into the driver's cabin, either of which could have caused serious injury or death.

3.2.3.1. **Unbalance System Flow Chart**

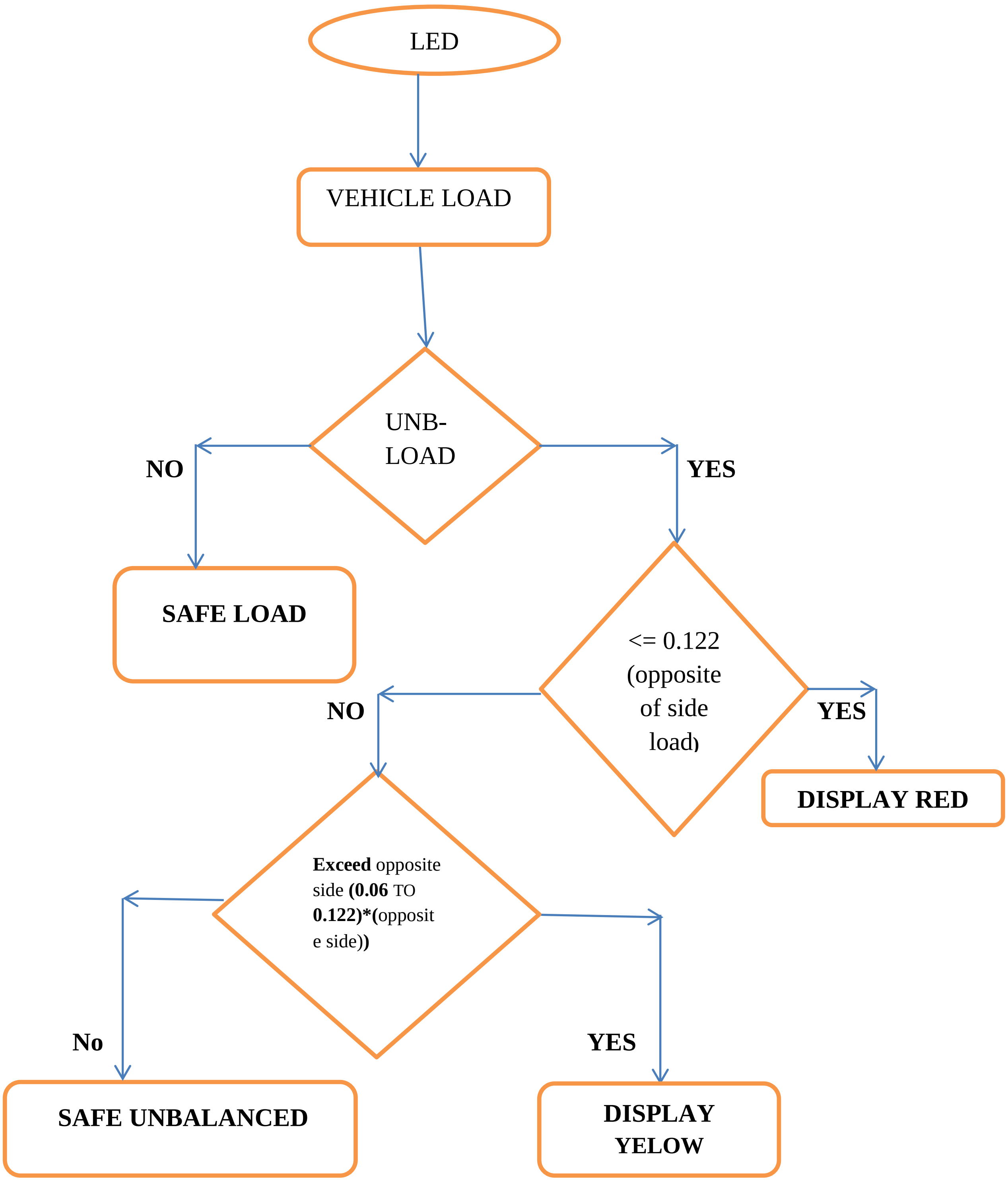


Figure 3. 19: LED system flow chart for unbalance load of ISUZU-NPR vehicle.

The design of the vehicle consists of Gross Vehicle Weight (GVW) and Kerb Weight (KW) specifications which are given to the load system. Then compare the applied load with the wheel load of opposite side.

CASE 1: If the applied load wheel is exceed up to 0.6 times opposite side wheel($R_{11} <= R_{12} + (0.06)R_{12}$ or $R_{21} <= R_{22} + (0.06)R_{22}$ and vice versa) it can be considered as **SAFE** unbalance

CASE 2: If the applied load is between 0.06 to 0.12 times opposite side wheel ($R_{11} = R_{12} + (0.061 \text{ to } 0.122)R_{12}$ or $R_{21} = R_{22} + (0.061 \text{ to } 0.122)R_{22}$ and vice versa) it can be considered asunbalance load and the signal is sent to LED, the LED glows indicating the safe limit ended and is also displayed on the **YELOW** (Unbalancing)

CASE 3: If the applied load is exceed greater than 1.22 times opposite side wheel ($R_{11} = R_{12} + (> 0.122)R_{12}$ or $R_{21} = R_{22} + (> 0.122)R_{22}$ and vice versa) it can be considered as unbalance load and the signal is sent to LED, the LED glows indicating the safe limit ended and is also displayed on the **RED (**Unbalanced**)**.

3.2.3.2. Design of Programing Code for unbalance LED display system

The **TURBO C++** Programing code of unbalance LED display system for emergency vehicles is described below.

```
// DESIGN OF UNBALANCED LED DISPLAY SYSTEM.

#include<iostream.h>

#include<conio.h>

#include<math.h>

#include<fstream.h>

#include<iomanip.h>

 void main()

  {

 Start:

   clrscr();

    char ch1;

// Vehicle Statics:

   float
Wgrs,A,B,C,D,R,L,W,ALPHA,l,h,k,EPSL11_per,EPSL12_per,EPSL21_per,EPSL22_per;

   float radcos_ALPHA,EPSL11,EPSL12,EPSL21,EPSL22;

   const float PI = 3.14;

 ofstream outfile ("OLMA-P1.dat");

 clrscr();
```

```
cout << "\n\n\t\t  Adama Science and Technology University (ASTU) ";

cout << " \n\t School of Mechanical, Chemical and Materials Engineering (SoMCME) ";

cout << " \n\t\t       Department of Automotive Engineering ";

cout << " \n\t\t\t           Olma Yadessa  ";

cout << "\n\t\t\t         **************** ";

cout << " \n\n\t  Design of Overload and Unbalance Alarm System for ISUZU-NPR Vehicles
" ;

cout << "\n ---------------------------------------------------------------------------- ";

outfile << "\n\n\t\t  Adama Science and Technology University (ASTU) ";

outfile << " \n\t School of Mechanical, Chemical and Materials Engineering (SoMCME) ";

outfile << " \n\t\t       Department of Automotive Engineering ";

outfile << " \n\t\t\t           Olma Yadessa  ";

outfile << "\n\t\t\t         **************** ";

outfile << " \n\n\t   Design of Overload and Unbalance Alarm System for ISUZU-NPR
Vehicles " ;

outfile << "\n ---------------------------------------------------------------------------- ";

cout <<"\n  Enter the 'gross Weight (Wgrs)' in 'N': ";

cin >> Wgrs;

cout <<"\n  Enter the 'gradient (ALPHA)' in 'deg.': ";

cin >> ALPHA;

cout <<"\n  Enter the 'span length of leaf spring' in 'mm': ";

cin >> l;
```

```
cout <<"\n  Enter the 'thickness of leaf spring' in 'mm': ";

cin >> h;

cout <<"\n  Enter the 'spring index (k)' in 'N/mm': ";

cin >> k;

cout <<"\n  Enter the 'strain EPSL11)' in '%': ";

cin >> EPSL11_per;

cout <<"\n  Enter the 'strain EPSL12)' in '%': ";

cin >> EPSL12_per;

cout <<"\n  Enter the 'strain EPSL21)' in '%': ";

cin >> EPSL21_per;

cout <<"\n  Enter the 'strain EPSL22)' in '%': ";

cin >> EPSL22_per;

 radcos_ALPHA = ALPHA*(PI/180.0);

 EPSL11 = EPSL11_per/100.0; EPSL12 = EPSL12_per/100.0;

 EPSL21 = EPSL21_per/100.0; EPSL22 = EPSL22_per/100.0;

  W = ((l*l*k)/(6.0*h*radcos_ALPHA))*(EPSL11+EPSL12+EPSL21+EPSL22);

  L=(EPSL11+EPSL21);

  R=(EPSL12+EPSL22);

  A=L+0.06*L;

  B=L+0.12*L;

  C=R+0.06*R;
```

```
  D=R+0.12*R;
  cout << setprecision(3)<< "\n\n\t W = "<<W<<" N";
  cout << setprecision(3)<< "\n\t Wgrs = "<<Wgrs<<" N";
 if ( L <=C)
  {
   cout <<"\n\n  'Safe Unblance.': ";
   getch();
    }
  if (C < L< D )
   {
   cout <<"\n\n  'YELOW, L UNBALANCING.': ";
   getch();
    }
if (L >= D)
 cout <<"\n\n 'RED, L unbalance.':";
 getch ();


 if (A < R <B)
 {
 cout<<"\n\n 'YELLOW, R UNBALANCING.':";
 getch();
```

```
}

cout << "\n\n  Press 'Enter' twice, to 'proceed'.... ";

getch();

getch();

getche();

 }
```

3.4. The Systems Hardware and Software of the Overload and Unbalance

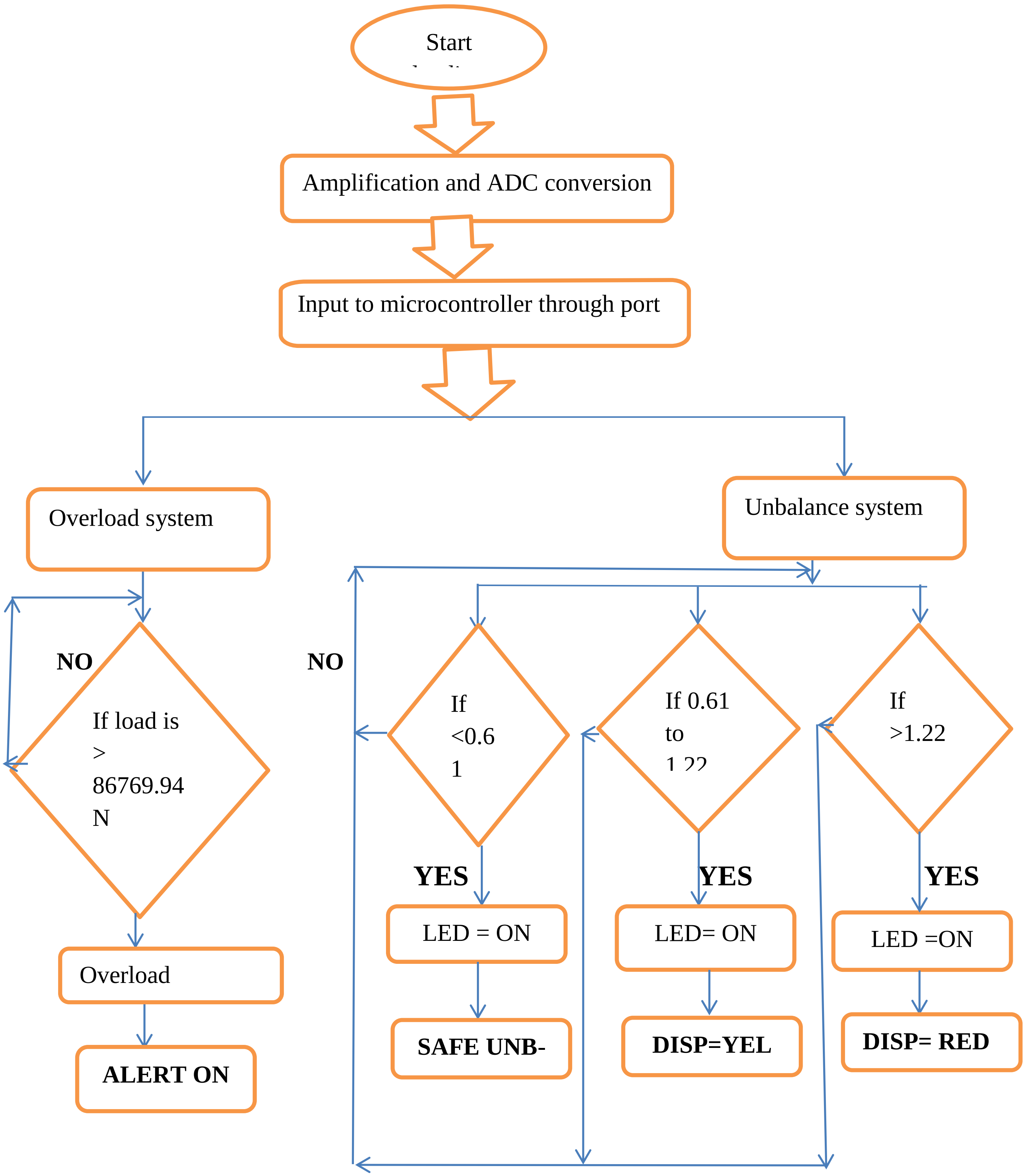


Figure 3. 20: Flow chart of the overload and unbalanced system**.**

Overall system architecture Compass vehicle networking based on real-time monitoring system overloaded trucks, including truck overload detection terminal 4 suspension load detecting CAN node, the owner of the terminal composition. The thesis model that guided this study is shown in the Figure 3.21.

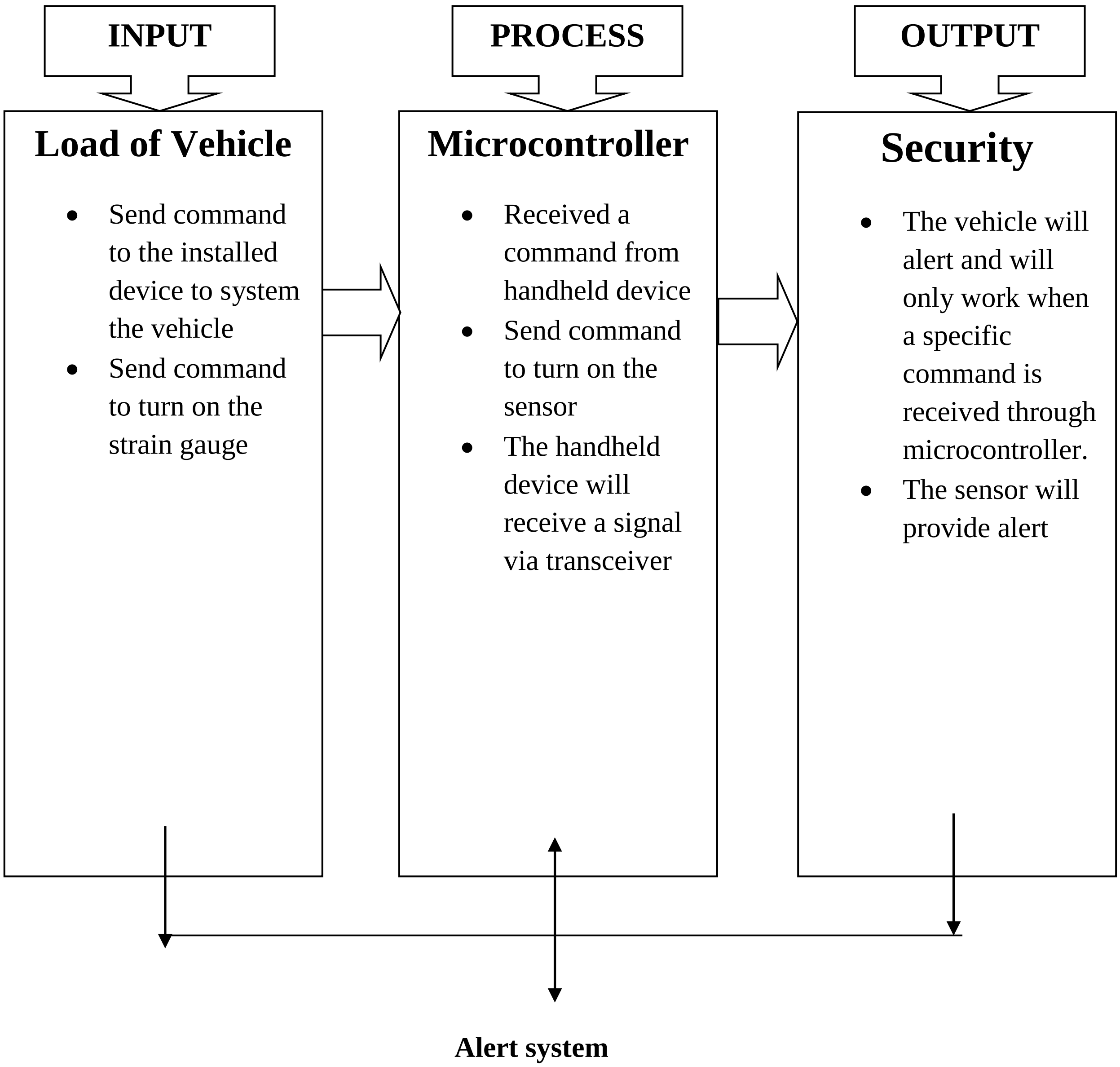
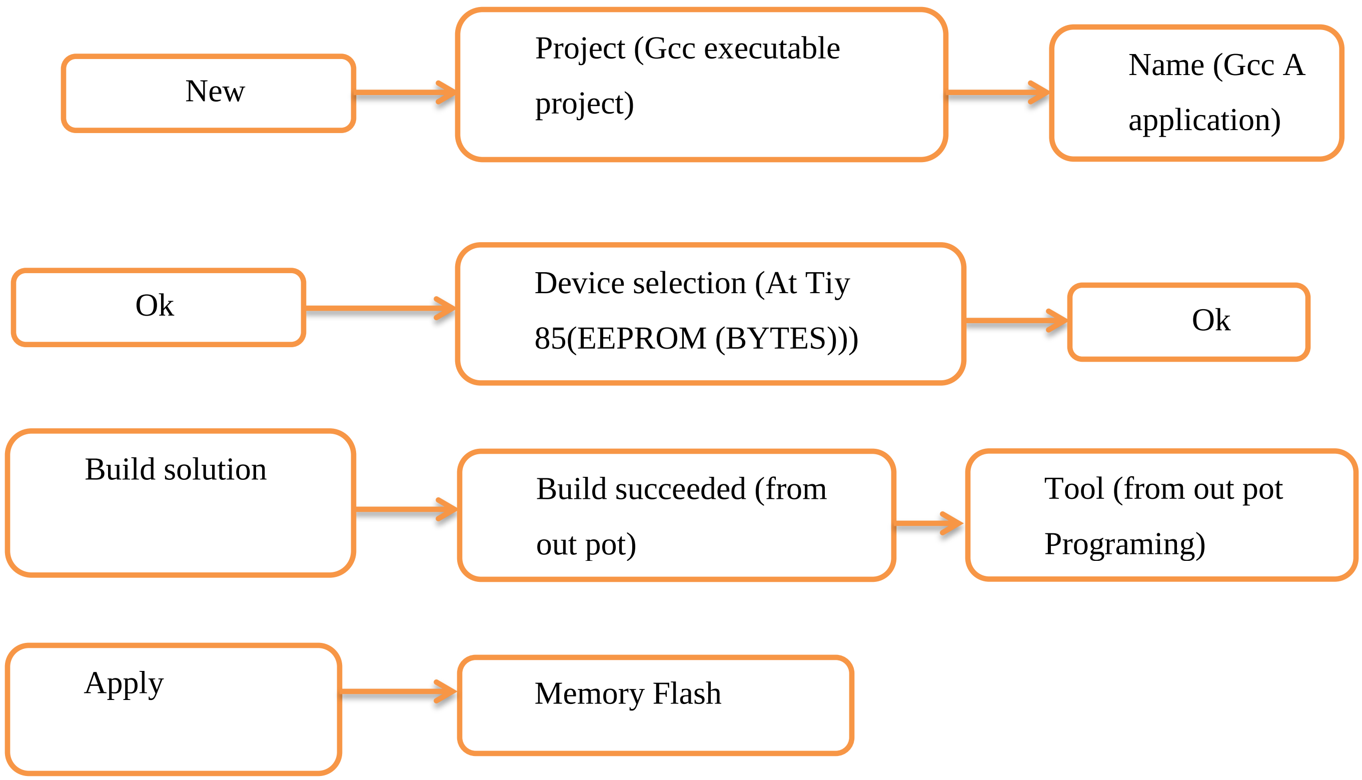


Figure 3. 21: It follows the Input-Process-Output approach.

The code of **turbo c++** is not uploading in to arduino microcontroller purely like arduino code. It needs the following progression as shown on following flow chart.

Procedures of code connect in to microcontrollers



CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Result

Table 4. 1: Calculated results of weight and reaction force.

No	Vehicle Situation	W	R_{11}	R_{12}	R_{21}	R_{22}
1	Vehicle parked on a level road	86769.94N	14461.65N	14461.65N	28923.3N	28923.3N
2	Parked on an Inclined Road	86123.1N	13785.5N	`13785.5N	29276.05N	29276.05N
3	Vehicle accelerating on a level load	86769.94N	11792.54N	11792.54N	31592.41N	31592.41N
4	Accelerating car on an inclined road	86709.98N	11116.4N	11116.4N	31945.15N	31945.15N
5	Parked car on a banked road	86608.09 N	14905.98N	13964.21N	29811.89N	27928.42N

The carrying capacity of ISUZU-NPR previously known, the left and right side of a vehicle is symmetry and the front and rear side of this vehicle is not symmetric when vehicle is parked on level road. Depend on vehicle situation the weight, wheel loads, and axles load of vehicles are different be subject to vehicle position. In this state, when the angle of bank, acceleration, angle of inclination and height of center of gravity fluctuated the weight of a vehicle is varied and not more than gross weight. Wheels load and axles load value is varied because the load is transferred from one wheel to another wheel or from one axle to another axle.

Table 4. 1: Calculation results of strain gauge**.**

No	**Vehicle Situation**	ε_{11}	ε_{12}	ε_{21}	ε_{22}
1	Vehicle parked on a level road	0.053797	0.053797	0.107594	0.107594
2	Parked on an Inclined Road	0.0513 6	0.0513 6	0.10897	0.10897
3	Vehicle accelerating on a level load	0.043856	0.043856	0.117524	0.117524
4	Accelerating car on an inclined road	0.041353	0.041353	0.1509218	0.1509218
5	Parked car on a banked road	0.055545	0.051946	0.13893	0.11090

When the reaction force applied to the wheels, the values of strains are varied with reaction force and the strain gauge signals are varied with strain values.

4.1.1. Loaded ISUZU- NPR Accelerating Car on a Level Road

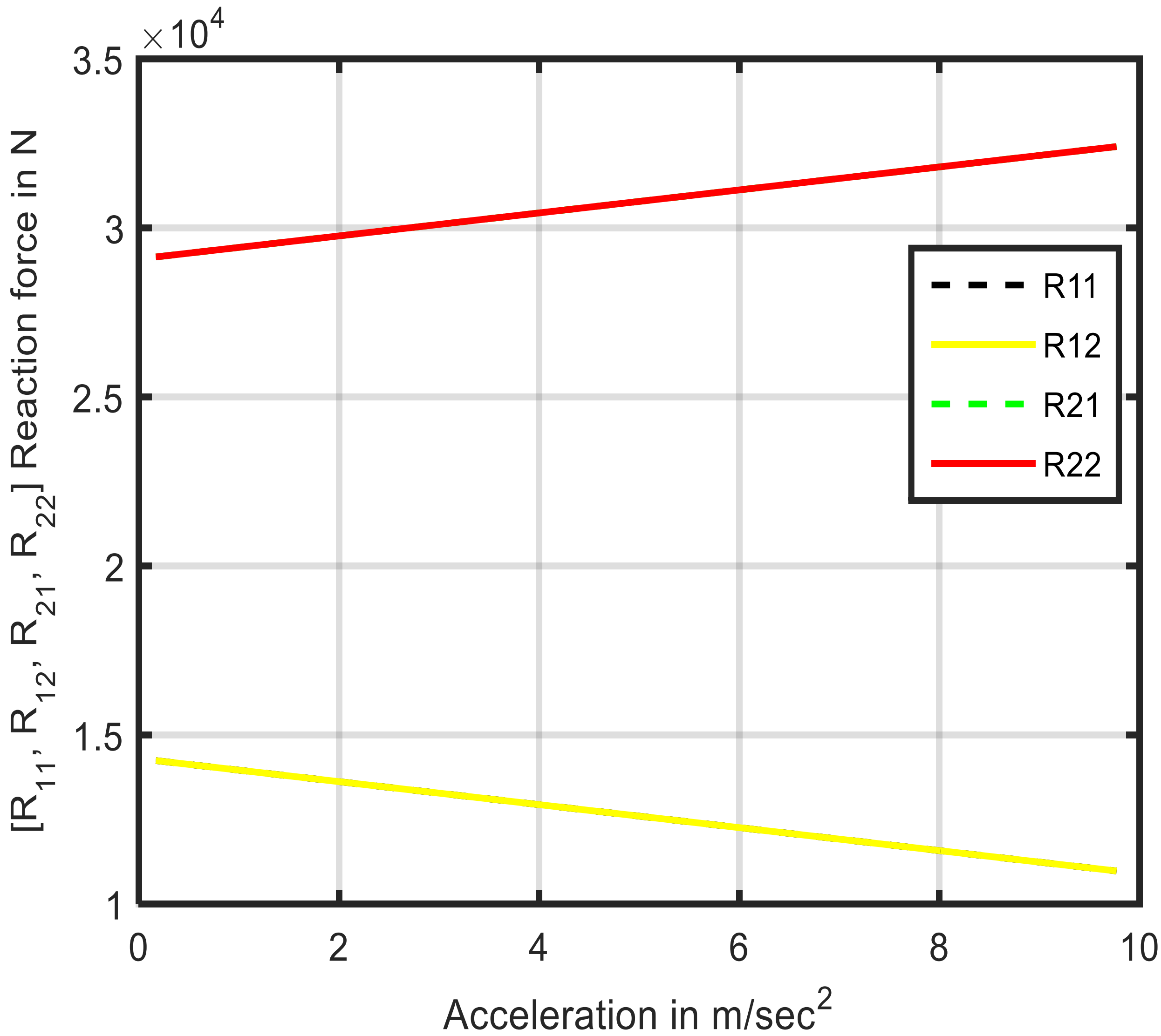


Figure 4. 1: Accelerating Car on a Level Road [MATLAB].

In this situation the result of the front wheel right side and front wheel left side are dropped, when the vehicle's acceleration is increasing and the rear side of wheels becomes increase with acceleration.

4.1.2. Height of center of gravity determination

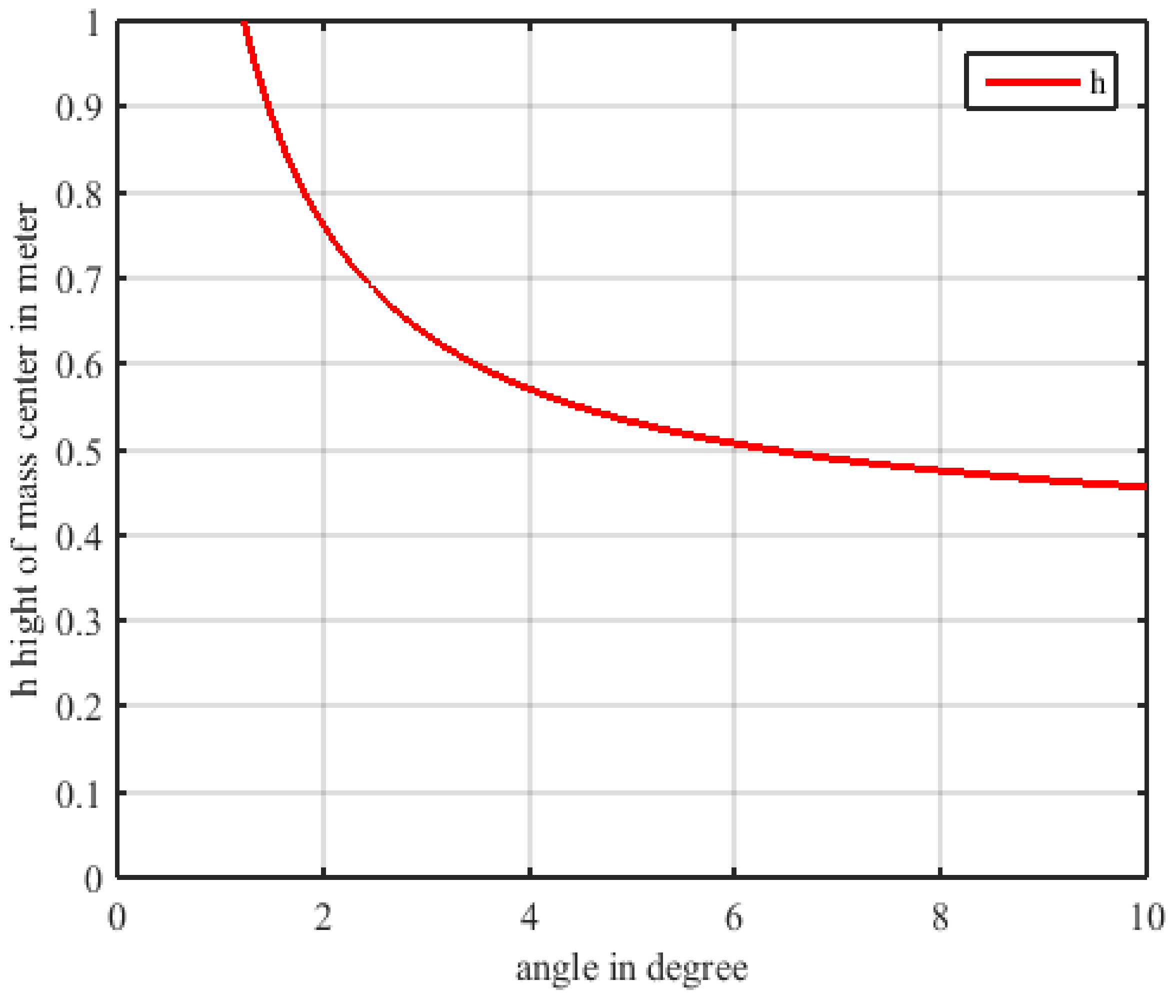


Figure 4. 2: Height of center of gravity determination at 10 final degree of inclination [MATLAB].

The height of the center of gravity (C.G) of the vehicle is depending on the radius of wheel, wheel base, reaction force ($R_{11} or\ 2R_{12)}$ and the angel of the vehicle tilted up. Height of center of gravity (C.G) is directly proportional to the radius of the tire and inversely proportional to inclination angle.

4.1.3. Loaded ISUZU- NPR parked car on an inclined road

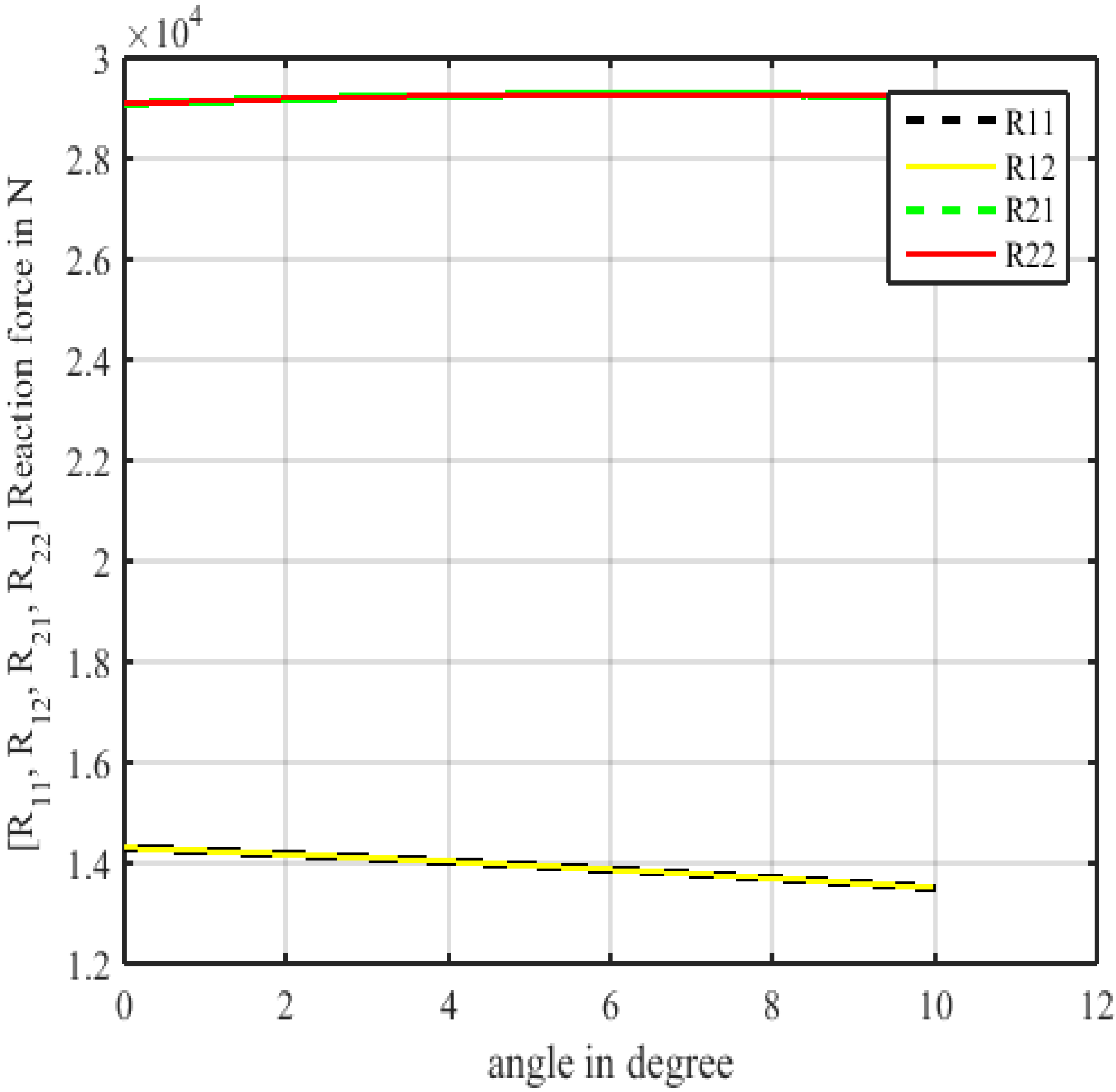


Figure 4. 3: Parked car on an inclined road at angle of 10 degree.

When the vehicle is parked on an inclined road, wheel load of the right side and left side are equal and their load shifted into the rear axle of wheels and rear wheel load are increasing. If the angle of inclination increases further, the wheel load of front and rear are decreasing and lose the ground contact and the vehicle is filled down

4.1.4. Loaded ISUZU-NPR Parked Car on a Banked Road

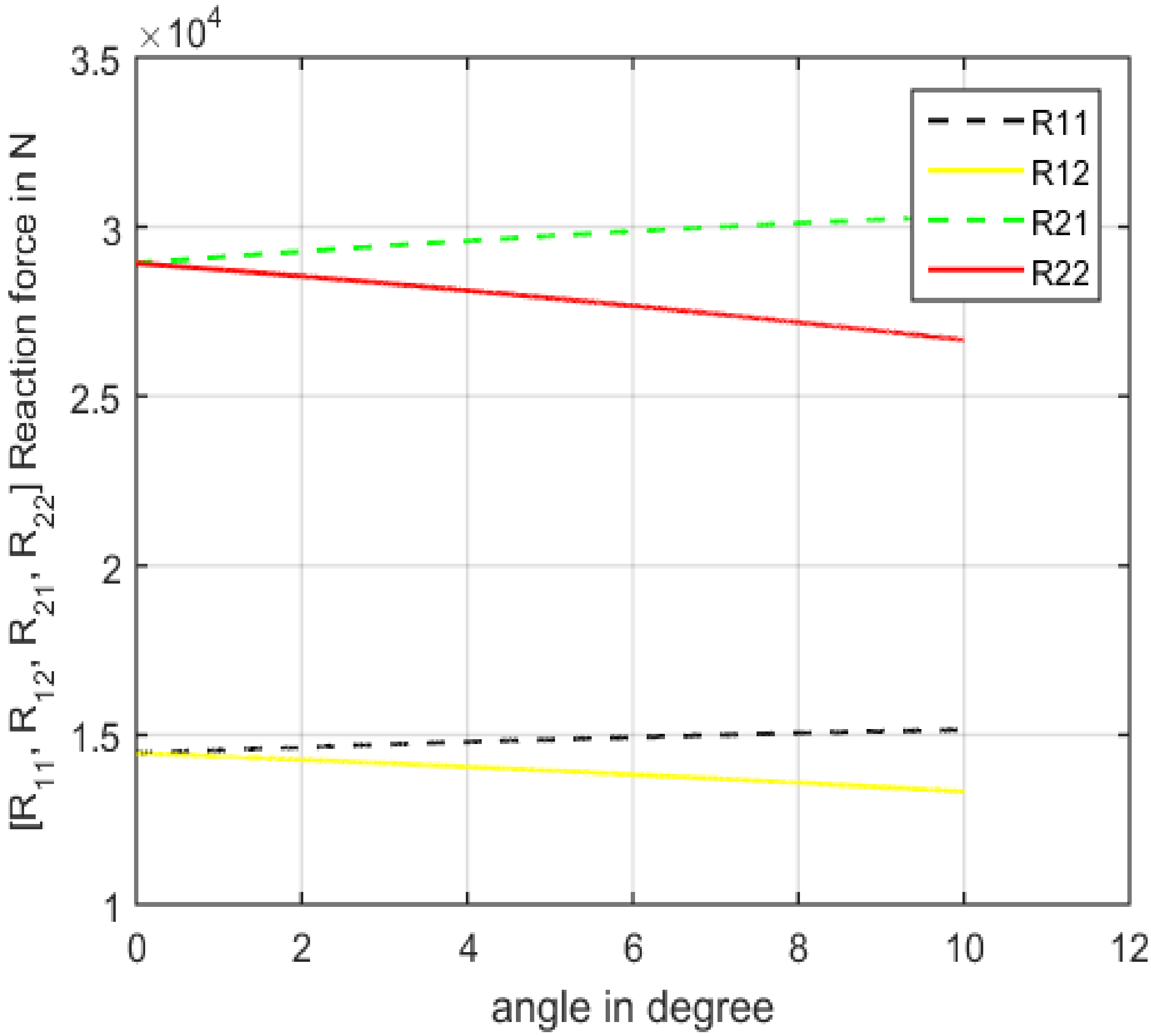


Figure 4. 4: Parked car on a banked road at angle of 90 degree.

The situations where the vehicle parked on a banked road, the reaction force of each wheel are different. The reaction force of external side wheels transferred to lower side wheels. Hence, the reaction force of upper side wheels becomes decreased, when the angle of banked road is increased and the reaction force of internal side wheels becomes increased with angle. Therefore, overload of wheels or the overload of axle and unbalance load can be happened on a vehicle wheel.

4.1.5. Programing language results

Overload programing language results

If the applied weight is up to 100% of gross vehicle weight then it can be considered as SAFE LOAD. But in this condition front axle or rear axle maybe beyond gross axle weight and if the summation of wheel load is not greater than axle load, the front wheel right side is load greater than front wheel left side and the rear wheel right side is greater than rear wheel left side or vice versa the overload axle or wheel will be displayed on the LED and if the applied load is 100% it is taken as the signal is sent to alert system, the alert system indicated the safe limit ended. If the applied load exceeds the threshold then the signal is passed to the alert system, LED and Relay. The relay gets operated and supply is ALERT ON.

Unbalance programing language results

If the applied load wheel is exceed up to 0.6 times opposite side wheel($R_{11} <= R_{12} + (0.06)R_{12}$ or$R_{21} <= R_{22} + (0.06)R_{22}$ and vice versa) it can be considered as **SAFE** unbalance and the applied load is between 0.06 to 0.12 times opposite side wheel ($R_{11} = R_{12} + (0.061 \text{ to } 0.122)R_{12}$ or$R_{21} = R_{22} + (0.061 \text{ to } 0.122)R_{22}$ and vice versa) it can be considered as unbalance load and the signal is sent to LED, the LED light indicating the safe limit ended and is also displayed on the YELOW (Unbalanc1ng). If the applied load is exceed greater than 1.22 times opposite side wheel ($R_{11} = R_{12} + (> 0.122)R_{12}$ or$R_{21} = R_{22} + (> 0.122)R_{22}$ and vice versa) it can be considered as unbalance load and the signal is sent to LED, the LED light indicating the safe limit ended and is also displayed on the **RED** **(**Unbalanced).

CHAPTER FIVE

CONCLUSIONS AND RECOMENDETIONS

5.1. Summary

The main purpose of this study is to understand and establish the extent to which vehicle overload and unbalanced load is happening in a developing country. A vehicle overloaded and unbalance is less stable and thus incurs additional risk for the other road users. Exceeding a vehicle's maximum permissible weight is not only a danger to the driver and road users; it is an illegal offense which carries with it a range of risks and penalties, from fixed fines to prison sentence. When transporting goods, the temptation to overload and unbalance of a vehicle in a bid to maximize payload and reduce overall fuel costs can be a costly mistake. Overloading and unbalance vehicles significantly increase fuel consumption and tires are more prone to wear, steering becomes more difficult to control, vehicles take longer to react to braking and high centrifugal force at the position of unbalance load or poor load. This can dramatically affect vehicle handling, increase daily wear and tear and increase the likelihood of a costly and potentially fatal accident. In this study it is trying to resolve this problem of overloading and unbalance in a vehicle by allocating overload and unbalance alert system for ISUZU- NPR vehicles. The system of this thesis is to alert or LED display the function it need hardware like a strain gauge each of the wheel where friction load applied on ISUZU- NPR. Strain gauge is constructed by forming a grid made of fine electric resistance wire or photographically etched metallic resistance foil on an electrically insulating base (backing), and attaching gauge leads. The system included four strain gauges found at each suspension or mounted to under the leaf spring of the front leaf spring and rear leaf spring interface circuit with microcontroller.

Microcontroller is low- power and high performance CMOS and 8 or 16 bits microcontroller with 8 kb in system programmable flash memory. An 8 or16 bits microprocessor (CPU), A small amount of RAM, Programmable ROM and/or flash memory, Parallel and /or serial I/O, Timer and signal generators, Analog to Digital (A/D) and Digital to Analogy (D/A) conversion. The software of the alert system designed in c++ assembly language. Comparing with the previous methods, the system designed in this paper respond quickly of total gross weight vehicle by using alert system and display the status of the front or rear axle load, loads of each wheel and unbalanced load by using LED display system.

5.2. Conclusions

- Applied weight is up to 100% of gross vehicle weight then it can be considered as SAFE LOAD.
- Applied weight is greater than gross vehicle weight, the microcontroller considered as overload and the relay operated and supply is ALERT ON.
- The applied load wheel is exceeding up to 0.6 times opposite side wheel($R_{11} <= R_{12} + (0.06)R_{12}$ or$R_{21} <= R_{22} + (0.06)R_{22}$)and vice versa it can be considered as **SAFE (**unbalance).
- The applied load is between 0.06 to 0.12 times opposite side wheel ($R_{11} = R_{12} + (0.061 \text{ to } 0.122)R_{12}$ or$R_{21} = R_{22} + (0.061 \text{ to } 0.122)R_{22}$) and vice versa it can be considered as unbalance load and LED display **YELOW** (Unbalancing).
- The applied load is exceed greater than 1.22 times opposite side wheel ($R_{11} = R_{12} + (> 0.122)R_{12}$ or$R_{21} = R_{22} + (> 0.122)R_{22}$)and vice versa it can be considered as unbalance load and the LED display **RED (**Unbalanced).

5.3. Recommendations

The hardware of these systems is very difficult to doing the prototype, In case of financial problem. It would like to recommend the future researcher should continue to work in this direction and control system of my title and try to reduce overload and unbalance problem and it recommends that all Automobile companies to apply this system for all vehicles.

5.4. Future Works

The researcher can be extended in the future in following area.

1. Design of overload and unbalance control system for vehicle
2. Code of the system is preferable to write on Arduino software.
3. Simulink of power system special for electromechanical, autotronics or power engineering department students.

5.5. Limitations

There was a limitation to find out the literature has done on this title.

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APPENDIX

1. %MATLAB code for the height mass center determination

```
clear all; close all;
%Initial condition
d1=2.38; %In meter
d2=1.17; %In meter
W=86769.94; %weight, gross vehicle weight in N
w=1.5; %In meter
r= 0.380; %In meter
L = a1+a2; %In meter
R11=14461.655; %in Newton
%Initiation
phi_deg=0;
phi_deg1=0;
d_phi=1e-4;%unit step increment
phi_deg_final=10;% final degre
x=1;
n=1;
while(phi_deg<phi_deg_final),
  phi_rad=phi_deg*2*pi/360;
h=r+((2*R11*L/W)-a2)*cot(phi_rad);
phi_deg=phi_deg+d_phi;
phi_deg1=phi_deg1+d_phi;

if x>16,
hn(n)=h;
phi_degn(n)=phi_deg;
   n=n+1;
   x=1;
end
```

```
  x=x+1;
end
figure(1);
plot(phi_degn,hn,'r','LineWidth',2);
set(gca,'FontSize',12)
axis([0 10, 0 1]);%set(gca,'xticklabel',[]);
legend('h')
grid
xlabel('angle in degree')
ylabel('h height of mass center in meter','FontSize',12)
```

2. %MATLAB code for the Parked car on an inclined road

```
clear all; close all;
%Initial condition
d1=2.38; %In meter, is distance between center of gravity and front axle
d2=1.17; %In meter, is distance between center of gravity and rear axle
m=8845.05; %In Kg, mass of permissible capacity for vehicle
g=9.81; %gravitational force
w=1.5; %In meter
b1=0.75; %In meter
b2=0.75; % In meter
h= 0.273; %In meter
r= 0.380; %In meter
L = d1+d2; %In meter, L is wheel base.
%Initiation
phi_deg=0;
phi1_deg=0;
d_phi_deg=1e-4;% unit step increment
phi_deg_final=10;% Final degree of inclination.
x=1;
n=1;
while(phi_deg<phi_deg_final),
phi_rad=phi_deg*2*pi/360;
R11=0.5*(((m*g*d2)/L)*cos(phi_rad))-0.5*(((m*g*h)/L)*sin(phi_rad));
R12=R11;
R21=0.5*((m*g*d1)/L)*cos(phi_rad)+0.5*(m*g*h/L)*sin(phi_rad);
R22=R21;
phi_deg=phi_deg+d_phi_deg;
phi1_deg=phi1_deg+d_phi_deg;
if x>16,
   R11n(n)=R11; %
   R12n(n)=R12;
```

```
R21n(n)=R21;
R22n(n)=R22;
phi_degn(n)=phi_deg;
    n=n+1;
    x=1;
end
  x=x+1;
end
figure(1);
plot(phi_degn,R11n,'k--',phi_degn,R12n,'y',phi_degn,R21n,'g--
',phi_degn,R22n,'r','LineWidth',1.5);
set(gca,'FontSize',12)
axis([]);% set(gca,'xticklabel',[]);
legend('R11','R12','R21','R22')
grid
xlabel('angle in degree')
ylabel('[R_1_1, R_1_2, R_2_1, R_2_2] Reaction force in N','FontSize',12)
```

3. %MATLAB code for the Accelerated car on a level road

```
clear all; close all;
%Initial condition
d1=2.38; %In meter, is distance between center of gravity and front axle
d2=1.17; %In meter, is distance between center of gravity and rear axle
m=8845.05; %In Kg
g=9.81; %gravitational
w=1.5; %In meter
b1=0.75; %In meter
b2=0.75; % In meter
h= 0.273; %In meter
r= 0.380; %In meter
L = d1+d2; %In meter
%Initiation
a=0;
a1=0;
d_a=1e-2;%unit step increment
a_final=9.1;% Final acceleration
x=1;
n=1;
while(a<a_final),
R11=0.5*(m*g*d2/L)-0.5*(m*g*h*a/(L*g));
R12=R11;
R21=0.5*(m*g*d1/L)+0.5*(m*g*h*a/(L*g));
R22=R21;
a=a+d_a;
a1=a1+d_a;
if x>16,
   R11n(n)=R11; %
   R12n(n)=R12;
R21n(n)=R21;
```

```
R22n(n)=R22;
an(n)=a;
    n=n+1;
    x=1;
end
  x=x+1;
end
figure(1);
plot(an,R11n,'k--',an,R12n,'y',an,R21n,'g--',an,R22n,'r','LineWidth',1.5);
set(gca,'FontSize',12)
axis([]);% set(gca,'xticklabel',[]);
legend('R11','R12','R21','R22')
grid
xlabel('Acceleration in m/sec^2')
ylabel('[R_1_1, R_1_2, R_2_1, R_2_2] Reaction force in N','FontSize',12)
```

4. %MATLAB code for the Vehicle on a banked road

```
clear all; close all;
%Initial condition
d1=2.38; %In meter, is distance between center of gravity and front axle
d2=1.17; %In meter, is distance between center of gravity and rear axle
m=8845.05; %In Kg
g=9.81; % gravitational
w=1.5; % In meter
b1=0.75; %In meter
b2=0.75; % In meter
h= 0.273; %In meter
r= 0.380; %In meter
L = d1+d2; %In meter
%Initiation
phi_deg=0;
phi_deg1=0;
d_phideg=1e-4;%unit step increment
phi_deg_final=10;% Final acceleration
x=1;
n=1;
while(phi_deg<phi_deg_final),
 phi_rad=phi_deg*2*pi/360;
R11=0.5*(((2/3)*m*g*b2)/w)*cos(phi_rad)+0.5*(((2/3)*m*g*h)/w)*sin(phi_rad);
R12=0.5*(((2/3)*m*g*b2)/w)*cos(phi_rad)-0.5*(((2/3)*m*g*h)/w)*sin(phi_rad);
R21=0.5*(((4/3)*m*g*b1)/w)*cos(phi_rad)+0.5*(((4/3)*m*g*h)/w)*sin(phi_rad);
R22=0.5*(((4/3)*m*g*b1)/w)*cos(phi_rad)-0.5*(((4/3)*m*g*h)/w)*sin(phi_rad);
phi_deg=phi_deg+d_phideg;
phi_deg1=phi_deg1+d_phideg;
if x>16,
    R11n(n)=R11; %
```

```
   R12n(n)=R12;
R21n(n)=R21;
R22n(n)=R22;
phi_degn(n)=phi_deg;
   n=n+1;
   x=1;
end
 x=x+1;
end
figure(1);
plot(phi_degn,R11n,'k--',phi_degn,R12n,'y',phi_degn,R21n,'g--',phi_degn, R22n, 'r','Line Width', 1.5);
set(gca,'FontSize',12)
axis([]);% set(gca,'xticklabel',[]);
legend('R11','R12','R21','R22')
grid
xlabel('angle in degree')
ylabel('[R_1_1, R_1_2, R_2_1, R_2_2] Reaction force in N','FontSize',12)
```

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

A Questionnaire Sample for Vehicle Company Manager, Worker and Other

Dear participant, I am master graduate student of Automotive Engineering Department at Adama Science and Technology University. I am studying design of overload and unbalance alert system for Isuzu cargo vehicle, for the fulfillment of my master's degree. Frist of all I would like to give thanks to you for giving me your due attention and precious time as well as willingness and participation in filling this questionaries' that address may addresses my study mention above. Your suggestion and comments are helpful for my work and should be without any influence. That information your provided is used for the educational purpose therefore, you will keep secret and confidential on the answer.

The objective of this study is to minimize accident causes of overload and unbalance load and the result of the study would be used as a model to other vehicle. Finally my study will be fulfilled for this purpose expecting useful information's, I like ask you to fill this questionnaire depending on you feeling and understanding.

General direction

- ✓ In any part of questionnaire, you are not required to write your name.
- ✓ For closed ended questions put (x) mark against the appropriate answer.
- ✓ For open ended questions give brief answer in the space provided.

Thank you in advance for taking time to participate in this study

Part I.: Demographic profile

Please tick(x) in the appropriate box

1. Sex Female ☐ male ☐

2. Age

20-25 years old ☐ 26-35 years old ☐

36-45 years ☐ ☐ 46-55 years old

56 above ☐

3. Highest educational attainment

Diploma ☐ Degree ☐ Masters ☐ PHD ☐

5. Work experience

≤ Two years ☐ 3-5 years ☐

6-10 years1 ☐ 10 and above years ☐

Part II. Question related to accident because of overload and unbalance load.

For the following questions put' (X)' mark in the box in front of the choice.

1. Have you ever seen a car accident?
   a. Yes ☐ b. No ☐
2. If your answer for question number 1 is yes, on which vehicle type is it frequently noticed?
   a. Public Bus ☐ b. Cargo Vehicles ☐
3. Among the car accidents caused by external causes, which cause is frequently noticed:
   a. Environmental cause ☐ b. Vehicle technical problems ☐
   b. Because of natural laws. ☐
4. On which vehicle type do we see vehicles carrying above the permissible load?
   a. On public Buses ☐ b. On Cargo vehicles ☐
5. On which type vehicle do the traffic police take measures due to loading beyond the permissible capacity?
   a. On public Buses ☐ b. On Cargo vehicles ☐
6. For what reason do you think?

   ____

   ____

   ____
7. How much do you think that loading a vehicle exposes for accident?
   a. Very much ☐ c. Less ☐
   b. Very less ☐ d. Doesn't expose to accident at all ☐
8. In which vehicle type do we see more frequently improper way of loading the vehicle?
   a. On public Buses ☐ b. On Cargo vehicles ☐
9. What do you think the consequences of improper vehicle loading to be?

   ____

   ____

   ____
10. Is there any means by which we can know whether the vehicle is over loaded or not?
    a. Yes ☐ b. No ☐

11. If your answer to question number 10 is yes, how?

____

____

____

12. Does geographical topography expose vehicles for accident?

a. Yes ☐ b. No ☐

13. How can we minimize accidents coming due to geographical topography?

____

____

____

14. In which vehicle type have you ever seen a car accident?

a. Heavy vehicle ☐ b. Light vehicle ☐

Table A. 1: Questioners Assessments results.

No.	Name of company/office	No of questioner paper	public Buses in %	Cargo vehicles in %	Heavy Truck in%	Light truck in %
1	Bishoftu Automotive And Engineering Industry	15	37	63	71	29
2	Awash Insurance Company	15	42	58	24	76
3	Ambesa City Bus	15	53	47	41	59
4	Oromiya Transport Authority Traffic Agency Office	15	39	61	33	67
		Average	**43**	**57**	**42**	**58**

Figure A. 1: Front Body of ISUZU- NPR, 2016 Model.

Figure A. 2: chassis frame of ISUZU- NPR vehicle.