Mechanism of Avoiding Transport Truck Overloading by using Sensing and Self-controlling System

By

Addisu Bekele Delelegn

A Thesis Submitted to

the Department of Mechanical Engineering

School of Mechanical, Chemical and Materials Engineering

Presented in Partial Fulfillment of the Requirement for Master of Science in

Automotive Engineering

Office of Graduate Studies

Adama Science and Technology University

December, 2022

Adama, Ethiopia

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Advisor: Amana Wako (PhD)

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DECLARATION

I hereby declare that this Master Thesis entitled "Mechanism of Avoiding Transport Truck Overloading by Using Sensing and Self-controlling System" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Addisu Bekele Delelegn	------------------	---------------
Name of the student	Signature	Date

RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled “Mechanism of Avoiding Transport Truck Overloading by Using Sensing and Self-controlling System” prepared under our guidance by Addisu Bekele Delelegn submitted in partial fulfillment of the requirements for Master of Science in automotive engineering. Therefore, we recommend the submission of revised version of the thesis to the department following the applicable procedures.

Amana Wako (PhD)	---------------------	------------------
Major Advisor	Signature	Date

APPROVAL PAGE

We, the advisors of the thesis entitled "Mechanism of Avoiding Transport Truck Overloading by Using Sensing and Self-controlling System" and developed by Addisu Bekele Delelegn; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Amana Wako (PhD)	----------------------	--------------------
Major Advisor	Signature	Date

We, the undersigned, members of the Board of Examiners of the thesis by Addisu Bekele Delelegn have read and evaluated the thesis entitled "Mechanism of Avoiding Transport Truck Overloading by Using Sensing and Self-controlling System" and examined the candidate during open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of Master of Science in Automotive Engineering.

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Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

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ACRONOMY

AADT	Annual average daily traffic
CATIA	Computer aided three dimensional interactive applications
CVO	comertia vehicle over loading
ESALs	Equivalent single axle loads
GPS	Global positioning system
GVW	Gross vehicle weight limit
JICA	Japan international corporation agency
LAL	Legal axle load limit
LCD	Liquid crystal display
MIC	Micro controlle
RTA	Road transport association
SP	Set Point
VDF	Vehicle damage factor
W	Current load on the truck

ABSTRACT

Freight transport is concerned about the basic modes of transportation that are made available for freight to travel from place to place. However, non- developed, developing and developed countries around the world are facing overload as a critical problem Trucks are the most important national transport. As the vehicle gets heavier with over load it brings about the loss of lives, unexpected maintenance costs, destruction of pavements and properties. According to Malaysia road transport statistics, 70% of traffic accidents are caused by trucks overload. The motion of an overloaded vehicle has consequences that facilitate the deterioration of roadway. Controlling overloading is fundamental for the wellbeing of vehicle owners and government from unexpected destruction of property and roads. Due to this reason, sensing and self-controlling mechanism is designed to avoid overload. The materials used, sensors to detect vehicle overload, and then transmits the appropriate data to microcontroller, which transmits the instruction. If the load on the truck is the same as the load that the truck was set to carry, then the truck can be operated at its normal operation. If the load on the truck is at maximum safe load limit, warning systems would be activated and Buzzer provided audio signaling along with yellow LED flashing light which informed the trucks would escaping the safe load limit status and it was about to overload. As the weight on the truck exceeded the set point of the truck load, the system would disable the fuel cut-off solenoid and no fuel would be delivered to the engine. When the vehicle was loaded beyond set point, the system detected reference value of strain and sent a warning signal to the driver. The most optimal strain that could be used as a reference strain for this system would be 1.7. The truck should not be driven beyond the reference strain; otherwise, the vehicle might lose control and became unstable. Therefore, the sensing and self-controlling mechanism reduced the possibility of the trucks rollover by stopping engine and helped to maintain stability under different road conditions to minimize accidents, Properties and pavement damage. The strain fluctuates from 0.260 to 1.469 while trucks decelerating on a level road. And under dynamic condition the strain ranges from 0.161 to 1.7. Overload controlling system would become increasingly important and it would be more secured than other systems to save several things in the developing countries, so once it would implemented in all trucks, it would be possible to control trucks over loading using sensing and self- controlling mechanism.

Key Words: - Overloading, Trucks, Load sensors, Micro controller and Fuel cutting solenoid.

CHAPTER ONE

1. INTRODUCTION

The problems of overloading versatility on the transport industry specially in developing and non- developed countries have initiated to visit the problems of it, and how could the problems should be solved to make the transport system safe from effect of damaging of vehicle parts, road infrastructure, fuel consumptions, air pollution, countries economic losses, traffic accidents and so on. As much as possible designing possible controlling mechanism of over loading in non-developed and developing countries help to minimize the above mentioned problems and facilitates countries growth smoothly and effectively.

1.1. Background and Justification

Now a days logistics industry increase rapidly from time to time, because of this, the question of transport vehicles overloading is becoming more and more serious. Overloaded vehicles would cause extensive damage to the road, traffic accident and huge economic losses to society, which seriously threaten traffic safety (Khaled, 2010). According to statistics, 70% of traffic accidents are caused by vehicles overloading. Therefore, the overloading of transport vehicles has become one of the crucial issues of traffic management.

Even though traditional static weighing system is used to control or detection of over loading it needs to intercept a part of vehicles from the normal traffic flow and weigh them in a static field, it takes a long time and affects the normal traffic (Khaled and Suara, 2013). There are also many unsolved problems in the dynamic weighing technology, such as the small measuring speed range and the large system, which is inconvenient for installation and maintenance (Khaled and Middleton, 2014). Commercial Vehicle overloading on highways a menace; a bane (trouble and makes people unhappy) to the exchequer (the government department that controls public money) having the onus (responsibility) of maintaining the road infrastructure - it is not only increases his expenses but, it is also one of the major causes of road accidents. And, over 50 % of the commercial vehicles plying on our National / State Highways are overloaded. Although there are legal axle load limit/LAL/and gross vehicle weight limit/GVW/ of the vehicles plying on roads, they are violated wickedly by the transporters (Addis, 2013).

The damage by over-loaded vehicles to pavements is exponential. It is believed that the damage caused to a pavement by an axle load twice the standard axle is 16 times the damage incurred by the latter. There are standard legal axle load limit and gross vehicle weight limit but neither are followed by transporters nor enforced stringently by the enforcement authority. Overloading vehicles reduce the design pavement life. Controlling overloading not only prevents premature failure of the pavement but, also brings in monetary benefit to the Concessionaire (a person that has been given concession to sell) (Kishore and Klashinsky, 2010). Controlling overloading reduces accidents; increases speed of vehicles, and require lesser pavement maintenance costs and operating cost.

Freight transport is concerned about the basic transportation that is given to supply commodity for people to travel from place to place. In view of that, trucks are considered as the most important freight transportations service (Hewage & Ranawana, 2017). In the aspect of economics, transportation indicates economic proficiency and basic factor for developing economies. Then effective freight transportation has abundant contributions to the economic growth of one country. Effective transportation achieves equal distribution and social facilitation of human fundamentals mobility. Transport not only benefits the economic mobility of human property, but also it facilitates the rightful sharing of wealth across a given geopolitical region mainly in the form of the mobile factors of production labor, capital and independent enterprise (Ejiogu et al., 2020).

Vehicle overloading defined as when vehicles carry beyond their legal weight. Both developing and developed countries all across the world have been dealing with overloading as an urgent problem. As a result, Overloaded vehicles cause more pavement deteriorations relative to standard loaded vehicles (Jaskula, 2018). Freight transportation has become a serious problem all over the world because it brings upon loss of economies, destruction of properties and unexpected maintenance cost (Sinshaw, 2017).

“People’s Highway Law" clearly provides that vehicle overloading is illegal. Our country have also enacted a series of laws and regulations, local governments have also introduced a large number of files to control overloading of passenger and commercial vehicles, but the effect of any contingent is not obvious. Practice has fully proved that the efforts that came only from policy to control overloading of commercial vehicles is not enough, which made the work of relevant departments seem rather passive. In recent years, automotive electronic control technology has been rapidly developed, and especially the control accuracy, control range, intelligence and networking, etc. have been greatly exceeded (Schuler et al., 2007). In his thesis, based on the different platform of controlling transport vehicles overloading control system would be designed and it would compared with the traditional control overloading methods, it could response fast, saved a lot of manpower, material and financial resources, and could be monitored in real time in the area of allowed weight, which can control better of overloading vehicles (Austroads, 2014).

Usually, pavement life and bearing capacity of expressway and national highway are higher than for a local street. Design life of new flexible pavement is frequently fifteen years and rigid pavement thirty years, which includes regular maintenance and rehabilitation within its service period (Thom et al., 2011). Schedule of maintenance and rehabilitation plan is according to the proportion of vehicle types in the traffic flow (Addis, 2003). Thus, Annual Average Daily Traffic (AADT) of each class of vehicle is a key input to the schedule of maintenance and rehabilitation plan. However, the occurrence of overloading truck traffic induces incorrect estimation in total Equivalent Single Axle Loads (ESALs).

An axle a group of axle or the gross vehicle weight (GVW) limits may be exceeded and mostly several of them together. Most of the overloads are less than 10% above the legal limits, but some large overloads up to 20% and more are found. Heavy vehicle overloads have several adverse consequences: Safety: overloaded vehicles are more dangerous in case of an accident and behave worse with increased instability; Compliance with regulation and fair competition: overloaded vehicles induce unfair competition between transport companies and with alternative transport modes, and have negative impacts on the society and the whole economy; Infrastructure preservation: overloads accelerate infrastructure deterioration and induce high additional repair costs for the society. It is important for those responsible for the maintenance and operation of highway infrastructures to monitor and prevent truck overloading. The additional weight carried by overloaded trucks accelerates the deterioration of the roadway, leading to rutting, fatigue cracking, and in certain cases structural failure. (In a 2019 Transportation Research Board), illegally loaded trucks were estimated to cost United States taxpayers $160 to $670 million per year on the highway system Straus and (Semmens, 2016) conducted a study to quantify state highway damage on the basis of the impacts of overweight vehicles. Each year, millions of dollars of damage associated with life span, design, and maintenance of state highways and structures are attributed to vehicles that exceed state weight limits. They found that for every dollar invested in motor carrier enforcement efforts, there would be $4.50 in pavement damage avoided. It is possible to develop a system that would increase the proportion of noncompliant vehicles subjected to inspection relative to compliant vehicles (Titus, 2019).

The fact of vehicle overloading causes road pavement structural distress and decrease in service life has also been reported by (Mulyono et al. 2010) and an analysis of lost cost of road pavement distress due to overloading freight transportation was also presented (Podborochynski et al., 2011) quantified incremental pavement damage caused by overweight trucks in Saskatchewan, Canada and reported that accelerated damage from truck overloading has decreased the expected performance life of many of the roads increased maintenance and rehabilitation requirements and costs (Campbell et al., 2008). Evaluated crash types and found that a there is moderate increase in accidents rates for higher gross weights. Later reported that the number of fatal truck crashes related increased as rearward amplification increased (Francher et al., 2019). This implies that, other things being equal, significant increases in gross vehicle weight (GVW) would increase the probabilities of the vehicle being involved in a fatal rearward amplification crash. Fatal involvement rates in rollover and ramp-related crashes also increased with increased GVWs. For curve related crashes and crashes in which trucks rear-ended other vehicles, increased GVWs may increase fatal involvement rates, although the trend was not as conclusive as those for rollover and ramp-related accidents.

1.2. Statement of the Problems

Overloading of trucks brought unexpected difficulties and events for most of transport users, pedestrians, property owners, government and on the truck it-self. Over loading became big problem to break off overloaded truck as driver intended, in the same way as the truck got heavier and heavier, the tolerability of stopping the vehicle falls down since brakes over heated and slowed property of braking mechanism is decreased, there for trucks instability increased on various road conditions. Driving an overloaded vehicle on various road conditions could cause instability on the vehicle this leaded to dangerous situation, unless overload controlling mechanism would predicted. Specially nowadays because of the rapid development of logistics industry, the question of transport trucks overloading is becoming more and more serious issues in the developed and non-developed countries; however, in the developed countries had many efforts to control over loading, still it would be continued as a problem. Overloaded trucks cause extensive part damage, destroy the road pavement, traffic accident and huge economic losses to the country. When the loading amount exceeded, the amount of mass increased this effect also increase the kinetic energy of the trucks which seriously threaten traffic safety i.e. when the amount of kinetic energy is more the damage caused by this is high but when the kinetic energy is less the damage also less because of this the seriousness of the problem could be manageable. Whatever overloaded truck transport is an inevitable outcome of economic growth in developing countries, if not the over loading is controlled by any means VDF the damaging effect of over loaded trucks would be greeter from time to time. Even each developed country faced this problem before their economic system became well developed. Since the developed countries worked hard in the area of controlling overload of trucks the situation became under control of manageable system. So, why this overload controlling mechanism needed in developing countries, because from total number of trucks in the road 80% of trucks are over loaded.

1.3. Objectives of the Study

The general objective of this research to develop mechanism of avoiding overloading of transport trucks using sensing and self-controlling mechanism.

1.3.1. Specific Objectives

The general objective of this research would be achieved through the following specific objectives:

- Developed overload avoiding mechanism of transport truck using sensing device and self-controlling system.
- Installed sensing device on suspension system and micro-controller to transmit message to fuel cut solenoid valve to stopped fuel injection in to the engine.
- Made the system give buzzer sound and turned on LED lamp to alarm the driver.

1.4. Significance of the Study

The implication of this study would design of controlling mechanism:

- To decrease parts damage and impacts of load down word.
- To decrease traffic accidents effectively.
- To improve passengers and material safety.
- To minimize spear part loss like (springs suspensions, steering and brake pads), fuel and maintenance cost of the vehicles.
- To increase service life of pavement and bridges.
- To save countries economy.

1.4.1. Beneficiary

- Most of community
- Owner of the property and
- Government

1.5. Scope of the Study

The coverage of this thesis includes each step of designing, simulating through PROTEUS soft ewer, ARDUINO UNO program, load sensors, solenoid valve, fuel pump, trucks and developing electrical circuit.

1.6. Research gab

As I have seen in literature review, all researchers intended to detect vehicle overloading and its effect. However, as a solution, they followed almost the same procedure to accomplish their goals which means, they had decided as a solution to control over loading the best way was weigh in motion (WIM) in different parts of the countries at the entrance and exit of high ways and put the penalty on toll get, on the other hand increase tax. But they would not take in to consideration the capacity of non-developing countries ability to install weighing machine and toll at the entrance and exit of the roads in all parts of the country and the degree of impacts on vehicle parts, traffic accident, road distraction and the computation of drivers and transport companies all researchers who studied overload focused only on explaining about it and detecting overload while the vehicle would reach weighing station and toll get.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. An Overview of Transport Truck Overloading

Few literatures had available on the aspect of controlling of overloading vehicle. Researchers suggested that to control over load changing axle load pattern would be one solution. Two axle vehicles are responsible for maximum damage of the road in developing countries. Many researchers suggested that convert two-axle vehicles into three-axle/four-axle vehicles so that heavy loads to be distributed and reduce damaging effect (Austroads, 2014).

One of the reasons for premature failures and unsatisfactory performance of roads in developing countries is overloading of the commercial vehicles. Although there are legal axle load limit and gross vehicle weight limit of the vehicles plying on roads, they are violated wickedly by the transporters. By overloading, serious consequences are perpetrated (damaged) on the life of the road, the truck and safety of all other road users (Thom et al.,2011).The damage caused by the over loaded vehicles is several times more than that induced by vehicles laden within the legal load limits. So, to compensate the damage of the pavement brings out the whole gamut of implications of overloading and some suggestions to check this overloading or generate additional revenue by penalizing overloading operators for compensating towards accelerated damage caused to pavement.

2.1.1. The Overloaded Heavy trucks Phenomenon

Overloaded truck traffic is a serious problem in many developing countries because it incurs huge costs in terms of maintenance and rehabilitation of damaged road networks (Batelaan, Justin, 2013). Overloaded truck traffic not only causes economic loss but also safety and environmental problems. Many African and Asian countries have been attempting to address this problem in recent years. However, it is an inevitable feature of economic development and expansion. This literature review examines the reasons, background and history of the occurrence of overloading in truck transport. The review was based on journal articles and relevant traffic reports around the world. The literature review was structured as a review of overloading of trucks in developed countries, and review of overloading in developing countries, scrutiny of theory, scrutiny of weight measurement practice, review of safety impacts of truck overloading, and concluding discussion.

In this review, three main points have been identified. First, overloaded truck transport is an inevitable outcome of economic growth (Berthelot et al., 2012). Each developed country faces this problem before their economic system becomes well developed. Second, the problem of overloading cannot be totally eliminated as evidenced by the fact that overloading also exists in the traffic systems of developed countries like the U.S. and Canada. However, the overloading percentage in developed countries is 2 to 5 percent, while in developing countries it can reach as high as 80% of the total number of trucks on the road. Finally, the only way to control this problem is through monitoring, legislation and education. Thus, it is (cleared) revealed that the developed countries invested in road safety education continuously, whereas developing countries require both funding and technology to achieve this.

2.1.2. Overloading of Trucks in Developing Countries

The extent of Highway trucks overloading respect that rapid deterioration of the Anhui province (China) highway pavement is a very common and serious problem, which has occurred early this century (Kapoor and Prozzi, 2015). Southeast University and Nanjing Normal University collaborated to survey and evaluate the overloading status quo and enforcement efficiency with the support of the World Bank. Surveys, which were carried out in six cities, had four major concerns: traffic volume, axle load, freight information and registration information (Ohio et al., 2016). This survey is concerned with the overloading characteristics of the common truck types in Anhui province, so the invalid data was eliminated from the raw data. Thus, the data used for data analysis only included the vehicle class 4, 5, 8, 12, because these four classes are the major components of truck traffic in Anhui province.

Figure 1.Pot holes developed because of heavy vehicles overloaded.

2.1.3. Overloading of Trucks in Developed Countries

Truck overloading in the U.S.A. focused on the relationship between the economic effect of overloading and weight enforcement (Handbook of Highway Maintenance and Rehabilitation, 2002). Stratham studied the economic rationale of vehicle overloading activities when they face weight enforcement (Peng et al., 2005). The study shows that both the intensity of weight enforcement and the level of penalty can deter (prevent) overloading activities. Also, the patterns of weight enforcement practices by the government combine different level of enforcement and penalties (Strathman and Theisen, 2012). In summary, overloading vehicles traffic is concerned around the world in different manner and level, and it is not an unsolvable problem. Most developed countries have invested many resources to control this problem and modifying the road management system to eliminate it continuously. Thus developing countries must identify their unique situation and problems in the overloading vehicles traffic and the most appropriate strategy may be established.

Figure2Examples of overloaded trucks in Malaysia

Figure 3.Over loaded truck in Malaysia and Ethiopia.

In their paper, controlling overloading in BOT projects highlighted reasonable ways to control overloading through strict implementation. Build Operate and Transfer (BOT) projects are project delivery methods in which private sector receives allowance from the public sector, such projects can be used to control overloading as (Bagui et.al.,2ndCTRG) conducted survey on axle load for real project and through that study they concluded that overloading can be controlled by placing heavy restrictions on heavier vehicles and a Weigh in Motion (WIM) system can be integrated along with toll revenue system that will be more effective as WIM can allow high efficiency and through put at toll operations. By study it was found that weigh bridges were economically efficient as weigh bridges can be installed at each end of the road.

Later Mohamed in his study suggested that the weight in motion (WIM) system can function as a vehicle weight sorting tool which can be used in place of static vehicle weight system. Collection of data was done during the study from the developed system so as to explore how WIM system can be effective. The result suggested that WIM system are effective and efficient in the current vehicle weight implementation and hence will be beneficial in generating sufficient revenue. Reducing overloading can be optimal as the accidents reduce and budget for road maintenance also reduces benefitting the public. WIM have proved to be an effective technique to control vehicle overloading and so this technique is integrated with various techniques to make it more efficient and effective in various ways.

To detect the overloaded vehicle, weight sensors are employed on the vehicles suspension. The device automatically detect the over load. Weight Sensors collect data from the springs; pass this data to micro controller normally to be placed at dash board. Micro controller marks the time at that vehicle at that moment. Later that whole data use to completely analyzed and pass message to the vehicle fuel injection control electric system then the injection pump automatically stops the engine from working parallel LCD displayed on dash board to give information to driver Their tracking system has disadvantage that it can be invasion to privacy if any of their technology goes wrong or this system can cause lot of stress to the staff (Cottineau et al., 2015).

The provincial road authorities in South Africa weigh vehicles statica1ly on a regular basis throughout the year. During 1993, almost 95 000 vehicles were weighed at weighbridges throughout the country, of which 40 per cent were overloaded. This is 45 per cent higher than the number of vehicles weighed in 1992. A Vehicle Overloading Management System has been developed by the Division of Roads and Transport Technology, initia1ly in conjunction with the KwaZulu-Natal Department of Transport, for the analysis of weighbridge data. During 1991 the system was implemented in the other provinces in South Africa, so that currently all data is collected in a uniform manner for compilation into a national database.

The program is able to perform various analyses which assist the provinces in identifying problem areas. The output sheet gives detailed information on all vehicles weighed at a specific weighbridge site during a specific period. Another report sheet lists a number of transport companies which operate in each province, together with the number of vehicles weighed from each company and the number that were overloaded. Transport companies guilty of regular overloading can thus be identified. A monthly or annual breakdown of overloading statistics at each weighbridge site can help authorities identify problem routes and thus plan their enforcement strategy. According to studies carried out by (Tailor et al., 2000) in the state of New York (USA), the percentage of overloaded vehicles was reduced from 30% to 2% when enforcement level was increased.

The recent works (Burnos et al., 2008) aim to improve WIM accuracy and solve related legislation problems in order to enable usage of WIM systems for automatic identification of overloaded vehicles and imposing of fines,, which would significantly contribute to efficiency of control a slot of over load identifiers as studied the root causes of trucks over loading are the competition between drivers while loading freight materials, the computations between commodity spread companies, the computation b/n drivers and companies, the distance b/n the project places and stock, the enforcement of bloggers and the wackiness of over load controlling enforcement department and beside this mainly the fast growth of countries economy has played great roll for happing of vehicles over loading and so on. The occurrence of overloaded truck traffic can be evidence of rapid development of an economy. Most of the developing countries emphasis the development of economy, thus support to reform of infrastructure management is limited. As studies show, the number of overloaded vehicles increases when the control of traffic is insufficient. Weigh in Motion (WIM) systems significantly improve control level and contribute to decrease in the number of overloaded vehicles. The damaging effect of overloaded vehicles depends not only on their percentage in total number of trucks, but also on the probability distribution of vehicle loads (Mohammadi et al., 2016).

2.1.4. Effect of Over Loading on Vehicle Parts

If vehicle dimensions, number of axles, and other aspects of the vehicle and component designs were unchanged, substantial increase in gross vehicle weight would lower rollover resistance in steady turns for all trucks, which may lead to more rollover accidents. For existing five-axle doubles, increased weight would also downgrade the rearward amplification behaviors, which may increase the probabilities of rear-trailer overturns during obstacle avoidance or sudden lane change maneuvers. In addition, increased gross weight would require brakes with a higher torque capacity, which, if not provided, would result in trucks that were deceleration limited by brake torque capacity rather than by tire friction levels and fore-aft brake balance without modifications of engines and drive trains, increased truck weights would lead to greater speed reductions on upgrades and greater difficulties for trucks to merge, weave and change lanes on freeways. Other things being equal, increased gross weights may also increase the probabilities of brake overheating on long, steep downhill runs. Any one of these situations can have adverse traffic (delays and congestion) and accident implications (Transportation Research Board, 1990).

The braking system of any truck is designed for the maximum allowable weight indicated on the vehicle documents. The breaking capacity not only depends on the brakes themselves, but also on the tire and suspension performances designed for the maximum allowable weight of the truck. Any weight in excess reduces the braking capacity of a truck, and may even damage the braking system (Jacob and Beaumelle, 2010). As mentioned by (Bixel et al., 2018), vehicle weight is one of the essential parameters in vehicle design study that can affect vehicle driving, braking and handling performance characteristics. Furthermore, most of the time vehicle dynamics influence driver behavior in controlling their vehicles (Wong, 2013). The study by (Saifizul et al., 2011a, 2011b) has also shown that heavy vehicle GVW has direct influence on speed, whether the vehicle travel in a vehicle following situation or in free flow condition.

Vehicle overloading mainly would give rise to the following risks

- The vehicles react unusually when they carry exceeded maximum weights for which they are outlined hence the vehicle become less firm, difficult to lead and takes longer to halt.
- There will be chance of untimely, menacing and overpriced failure to escalate as over loading cause the tires of vehicle to overheat and rapidly wear out which can get worse by time.
- The chances of accident will increase if the driver's work space and control in the over loaded vehicle is decreased.
- Overloaded vehicle's head light will lean upwards at night, glaring the approaching drivers to possible detritus or hindrance on the road.
- The brakes of vehicle as the vehicle is ponderous due to overloading, work hard because of 'the riding of brakes' and hence lose their efficiency to halt the vehicle due to overheating.
- Overloading make the vehicle hard to outdo as vehicle cannot expedite normally.
- When there is stress in the suspension system of vehicle, the infirm point can yield over time.
- If the vehicle is overloaded it leads to high perpetuation cost such as higher fuel exhaustion, brakes, tires and shock absorbers.
- Since the purpose is to cram in as much people as possible into the vehicle, seat belts are often not used with overloading.
- Overloaded vehicles insurance cover may be empty as overloading is illegitimate

Figure 4.Over load Truck in Ethiopia.

2.1.5. Effect of over loading on traffic movement

An overloaded truck is more likely to be involved in an accident, and have more severe consequences, than a legally loaded truck (Jacob and Beaumelle, 2010). The heavier the vehicle, the higher its kinetic energy resulting in greater impact forces and damage – to other vehicles or to the infrastructure – in the event of a crash. An overloaded vehicle is less stable because of the increased height at the center of gravity and more inertia of the vehicle bodies. An overloaded truck will experience loss of motility and maneuverability. The overloaded vehicle becomes under-powered resulting in lower speeds of up-hill slopes as well as the risk of congestion, inefficient engine braking and over speeding on down-hill slopes. Overtaking also takes longer, and thus incurs additional risks for the other road users (Jacob and Beaumelle, 2010). Heavy vehicle drivers are also prone to driver fatigue especially if it involves long working hours and long distance trips with limited recovery time. The monotony of long distance driving task may also increase the effects of fatigue on the driving performance and safety of heavy vehicle drivers showed that fatigued drivers faced greater attention demand, were less alert, and tended to overestimate the distance to roadside traffic signs.

Figure 5.The traffic crudeness b/s of vehicle over loading (hosanna city).

Fatigue caused by driving in complex road environment had the greatest negative impact on driving behavior and visual distance estimation, and the fatigue transfer effect worsened significantly but differently on both driving behavior and performance of fatigued drivers when switching from a complex to a monotonous road environment and vice versa (Liu and Wu,2009).In situations when heavy vehicle drivers experience fatigue due to the factors mentioned above, the traffic safety level on the road may be compromised. It can only get worse if the heavy vehicles are overloaded because the safe handling of an overloaded truck will be more difficult as compared to a non-overloaded truck. Thus, truck overloading in combination with driver fatigue will jeopardize the safety of road users in a traffic stream. As such, the need to identify the occurrence and extent of vehicle overloading, particularly in a developing country has to be acknowledged. Based on a clear understanding of the situation on vehicle overloading, decision makers will be in a better position to formulate more comprehensive and effective policy measures to mitigate the problem. The graph below shows the speed, weight and stopping distance relation.

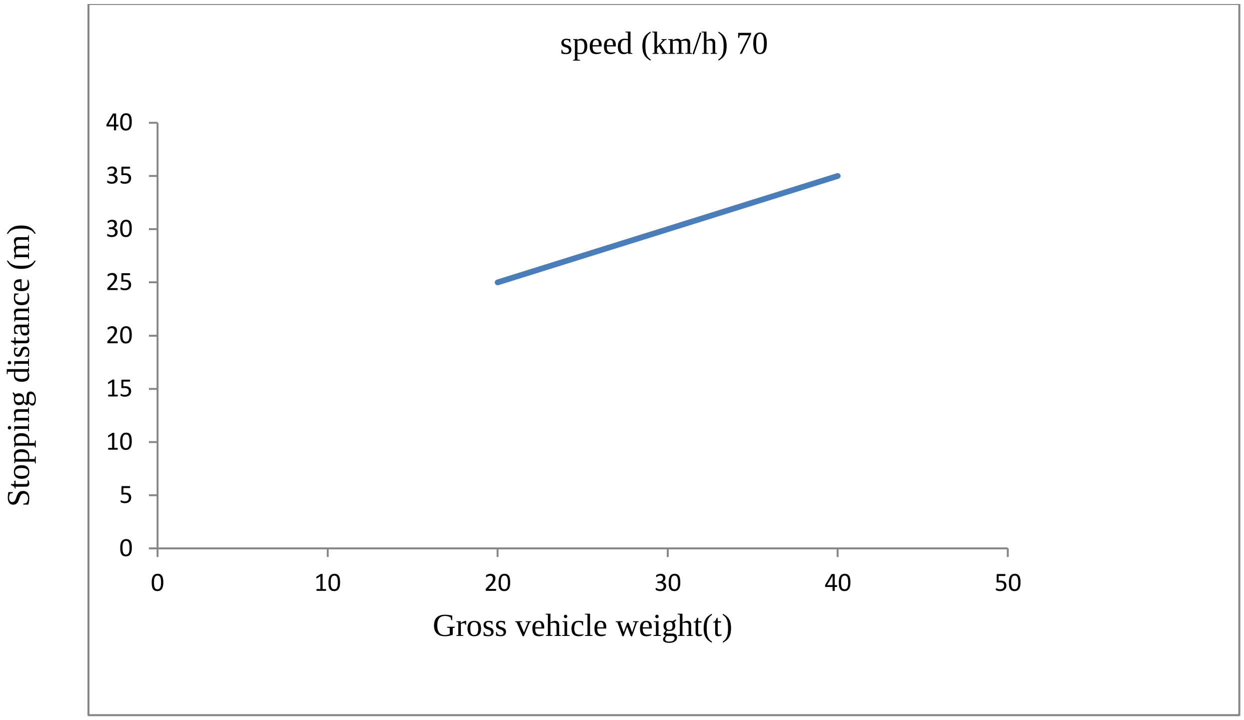


Figure 6.The gross vehicle weight, speed and stopping distance relation.

As we observe on the graph when the weight of the vehicle increase, even if the speed is the same the distance covered to stop vehicle is more, also the reverse condition too true. Sometime, the vehicle designer tried to increase the number of axles to decrease the concentration of load on the specific area and damaging effect of the infrastructure.

2.1.6. Effects of Over Loading on Pavements and Bridges

The simplest statistical value used to describe the problem of vehicle overloading is the percentage of overloaded vehicles in the total number of trucks. It is observed that the percentage of overloaded vehicles is much higher in developing countries and can reach an extremely high level of 80% according to studies of. In developed countries it is in lower range from 10%to 30% (Fiorillo and Ghosn, 2014).Overloaded trucks had much greater potential to cause pavement distress in comparison with properly loaded trucks**.** The damaging effect of overloaded vehicles depends not only on their percentage in total number of trucks, but also on the probability distribution of vehicle loads (Rys et al., 2016), showed that a 1% increase in overweight trucks could cause a 1.8% reduction of pavement life. According to (Al-Qadi et al., 2017) truck overloading causes greater pavement damage on secondary roads with low truck traffic volume.

The phenomena of vehicle overloading contribute to reduction in service period of pavements and bridges as well as an increase in the cost associated with maintaining, upgrading and replacing the highway infrastructure. According to (Pais et al., 2013) the maintenance cost of road calculated per one vehicle is higher by 100% for overloaded vehicles compared to the cost of the same vehicle with legal loads. The infrastructure damage costs should be recovered by proper fee for overloaded vehicles (Dey et al., 2015).The estimated pavement damage cost varies significantly depending on truck traffic volume and highway type. However, the level of damage cost recovery fee depends on the effectiveness of detection of overloaded vehicles and it can be improved by regular vehicle control. Moreover, regular control reduces the percentage of overloaded vehicles. According to studies carried out by (Tailor et al., 2010) in the state of New York (USA), the percentage of over loaded vehicles was reduced from 30%to 2% when enforcement level was increased.

Figure 7.Truck (WIM) station statically in India and over load vehicle in Ethiopia.

The weigh in motion (WIM) system allows improving vehicle control and contribute to decrease in the number of overloaded vehicles. However, in Europe WIM systems are used for vehicle preselect ion and those recognized as potentially overloaded have to be weighed again on legalized static scales. Thus the effectiveness of WIM systems depends significantly on proper localization of the WIM station in road network (ski & Kaszubowski 2016), aim to improve WIM accuracy and solve related legislation problems in order to enable usage of WIM systems for automatic identification of overloaded vehicles and imposing of fines, which would significantly contribute to efficiency of control. An axle a group of axle or the gross vehicle weight (GVW) limits may be exceeded and mostly several of them together. Most of the overloads are less than 10% above the legal limits, but some large overloads up to 20% and more are found. Heavy vehicle overloads have several adverse consequences:

- Safety: overloaded vehicles are more dangerous in case of an accident and behave worse with increased instability;

- Compliance with regulation and fair competition: overloaded vehicles induce unfair competition between transport companies and with alternative transport modes, and have negative impacts on the society and the whole economy;

- Infrastructure preservation: overloads accelerate infrastructure deterioration and induce high additional repair costs for the society.

Design life of new flexible pavement is frequently taken as 5 to 15 years (Nepal Road Standard 2045 BS), which includes regular maintenance and rehabilitation within its service period. Thus annual average daily traffic (AADT) of each class is a key input to the schedule of maintenance and rehabilitation plan. Along Narayanghat-Mugling Road section (AH42), for the direction of Narayanghat – Mugling (S-N), the pavement service life might be reduced by 59.90% due to overloading condition, while for the opposite direction, the service life would not reduce caused by the same factor. Comparison between ESAL with overloaded and standard truck traffic is the important factor to estimate the reduction in pavement service life, because pavement service life is directly driven by traffic load.

The impact of overload conditions on the road pavement showed premature failure, that is, a condition which the damage reduced the life of roads before the design life of the road is reached. Bituminous pavements undergo premature failure much before their design life. The reason may be inappropriate selection of materials, lack of dependable traffic and axle load data and limited information related to distresses for analysis. From the results, it can be concluded that overloaded vehicles on the road are very influential to the reduction in pavement service life.

Load – Road Life relation (Narayan hat – Mugling direction

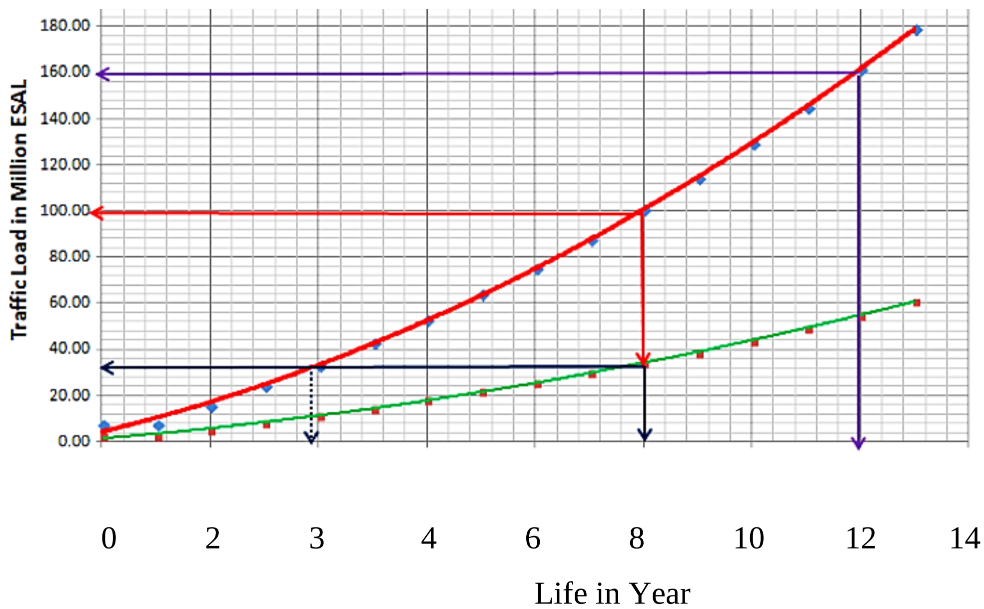


Figure 8. Shows the load – road life relation in standard and overloaded condition

2.1.7. Effects of Over Loading in Country Economy

The major economic impact induced by overloaded truck traffic is unexpected expenditure on pavement investment. Because pavement design is based on normal traffic load and total ESAL, the ESAL caused by overloaded truck traffic is not the expected traffic load in pavement design. As a result, the bearing capacity of pavement is lower than the actual demand. Actual pavement service life therefore cannot reach the original design life. Pavement service life has a direct relationship with net present value of investment. Construction cost for a new pavement is the most direct cost, which occurs when pavement service life is reduced. On the other hand, increase in annual maintenance and rehabilitation costs are the most evident economic loss induced by overloaded truck traffic.

Overloaded truck traffic is an untenable problem around the world. This phenomenon occurs in not only developing countries, but also in developed countries. Extremely high enforcement and inspection are applied to ensure this. Impact of overloaded truck traffic includes economic, social and environmental losses (Stanczyks. D, 2009). The major economic impact by overloaded truck traffic is unexpected expenditure on pavement investment. Because pavement design is based on normal traffic load and total ESAL.

Overloaded truck traffic is not the expected traffic load in pavement design as result; the bearing capacity of pavement is lower than the actual design. Pavement service life has a direct relationship with net present value of investment (Labry et al., 2005). Construction cost for a new pavement is the most direct cost, which occurs when pavement service life is reduced. On the other hand, increase in annual maintenance and rehabilitation costs at the most evident economic loss is induced by overloaded truck traffic. Traffic on a road pavement is characterized by a large number of different vehicle types, and these can be considered in pavement design by using truck factors to transform the damage they apply to the pavement to the damage that would be applied by a standard axle. The truck factors to convert trucks into standard axles or the load equivalent factors to convert axles into standard axles are defined by considering the average loads for each axle. This process includes the vehicles that travel with axle loads above the maximum legal limit.

There are also a substantial number of overloaded vehicles in terms of total vehicle weight. These axles/vehicles cause significant damage to the pavements, increasing the pavement construction and rehabilitation cost. The study revealed that the presence of overloaded vehicles can increase pavement costs by more than 100% compared to the cost of the same vehicles with legal loads. The study of the traffic information allowed the conclusion that heavy vehicles do not circulate with the maximum load defined by law. On average, and depending on the axle position, the load of each axle ranges from 20 to 90% of the maximum legal load. The study concluded that the effect of vehicle loads is diminished by increasing the asphalt layer thickness. The influence of the sub grade on the vehicle loads effect is very low when the primary pavement distress is the fatigue cracking. The study revealed that, for consideration in pavement design, if vehicles are considered to be at their maximum legal weights, the effect of overloaded vehicles on the pavement performance is clearly reduced. However, the presence of overloaded vehicles can increase costs by more than 100% compared to the cost of the same vehicles with legal loads.

2.1.8. Design Effective Controlling Mechanism of Over Loading.

Since overload monitoring or controlling mechanism is very essential, the possible solution must be developed. According to the study healed on over load control system would becoming increasingly important and it is more secured than other systems. So it is completely integrated with vehicles suspensions parts and then control the vehicles/trucks over loading. Controlling method in this research can reduce over loading, crowdedness, fuel consumption, the vehicles unusually reaction when they carry exceeded maximum weights for which they are outlined hence the vehicle become less firm, difficult to lead and takes longer to halt, decrease the tires of vehicle to overheat and rapidly wear out which can get worse by time, overloaded vehicle's head light would lean upwards at night, glaring the approaching drivers to possible detritus or hindrance on the road, the brakes of vehicle as the vehicle is ponderous due to overloading, work hard because of 'the riding of brakes' and hence lose their efficiency to halt the vehicle due to overheating, overloading make the vehicle hard to outdo as vehicle cannot expedite normally, there is stress in the suspension system of vehicle, the infirm point can yield over time and affect shock absorbers it influences sheerings and finally vehicles insurance cover may be empty as overloading is illegitimate.

2.2. Controlling Mechanism Components

2.2.1. Load Senor

A load cell is a force transducer. It changes over a force like strain, pressure, tension, or force into an electrical sign that can be estimated and normalized. As the force applied to the load cell expands, the electrical sign changes relatively. The most well-known kinds of load cell utilized are strain gauges, pneumatic, and hydraulic.

A load cell utilizes to change over mechanical force into a quantifiable electrical yield; anything that should be weighed likely uses a load cell to do as such. Load cells come in various shapes and sizes so they can be added to various hardware and weighting equipment. Mostly; load cells are utilized throughout numerous industries for gauging and force management by taking the force and changing over it into an electrical yield.

- **Kinds of load cells**

Resistive load cells: work on the standard of piezo-resistivity. At the point when a load/force/stress is applied to the sensor, it changes its resistance. This adjustment of opposition prompts an adjustment of output voltage when an input voltage is applied.

Capacitive load cells: work on the standard of progress of capacitance, which is the capacity of a system to hold a specific amount of charge when a voltage is applied to it. For normal parallel plate capacitors, the capacitance is straightforwardly proportional to the amount of overlap of the plates and the dielectric between the plates and conversely relative to the gap between the plates.

- **Working Principle of Resistive Load Cell**

A load cell made utilizing an elastic part (with greatly repeatable deflection patter) to which various strain measures are joined.

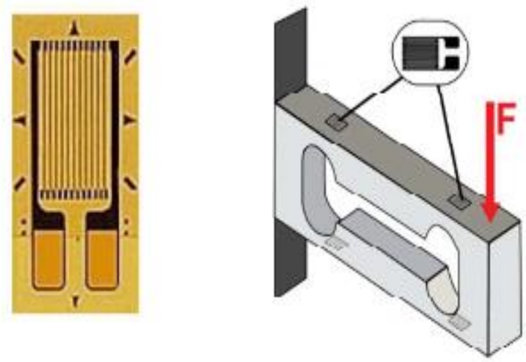


Figure 9.Load Cell

In this specific load cell displayed in the above figure, there are sums of four strain gauges that are attached to the upper and lower surfaces of the load cell.

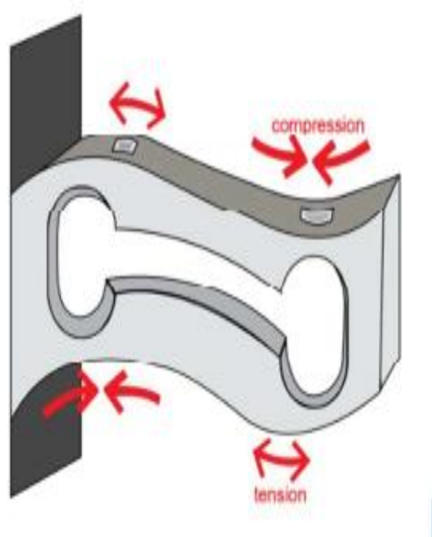
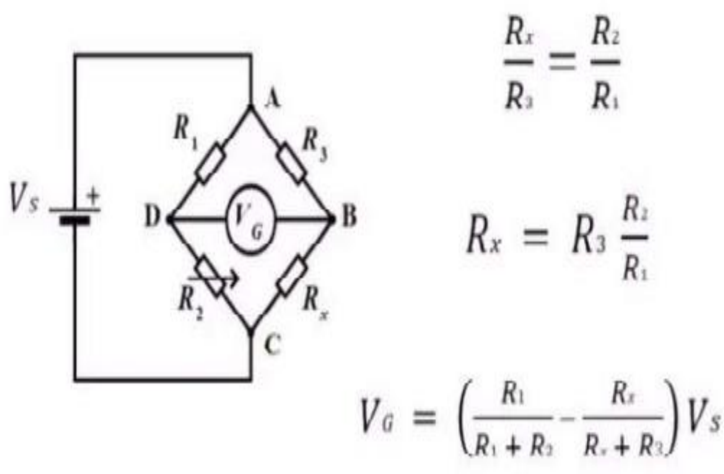


Figure10. Actuated Load Cell

In this specific load cell displayed in the above figure, there are sums of four strain gauges that are attached to the upper and lower surfaces of the load cell. At the point when the load applied to the body of a resistive load cell as displayed over, the flexible part, deflects as shown and makes a strain at those areas because of the stress applied. Thus, two of the strain gauges are in compression, though the other two are in tension. During a measurement, weight acts on the load cells metal spring element and causes elastic deformation of this strain (positive or negative) is changed over into an electrical signal by a strain gauge (SG) installed on the spring component. We utilize the Wheatstone bridge circuit to convert over this adjustment of strain/resistance into a voltage, which is relative to the load.

- **Wheatstone bridge Circuit**

The four strain gauges are arranged in a wheat stone bridge configuration with four separate resistors connected as shown in what called a wheat stone bridge Network. An excitation typically 10V applied to one bunch of corners and the voltage difference is estimated between the other two corners. At equilibrium with no applied load, the voltage output is zero or exceptionally near zero when the four resistors are firmly coordinated in value. That is the reason it is referred to as a balanced bridge circuit.



At the point when the metallic part to which the strain gauges are connected, is stressed by the use of a force, the subsequent strain leads an adjustment of opposition in (at least one) of the resistors. This adjustment of resistance brings about an adjustment of output voltage. This little change in output voltage (typically around 20 m volt of the absolute change in light of full burden) can be estimated and digitized after cautious enhancement of the little mille-volt level signs to a higher abundance 0-5V or 0-10V sign. These load cells have been in need for a long time now, and can give extremely precise readings yet require numerous monotonous strides during the assembling system.

- **Relay module**

A relay module is an electrical switch that is worked by an electromagnet. The electromagnet is enacted by a different low-power signal from a miniature regulator. At the point when enacted, the electromagnet pulls to one or the other open or close an electrical circuit.

Figure 11.Relay Module

The mobile armature is pivoted to the yoke and connected to at least one bunch of the moving contacts. Held in place by a spring, the armature leaves a hole in the magnetic circuit when the relay is de-empowered. While in this point, one of the two arrangements of contacts is shut while the other set remaining parts open.

At the point when electrical flow is passing through a loop, it produces a magnetic field that in turn activates the armature. This development of the portable makes or breaks a linking with the fixed contact. At the point when the relay is de-energized, the arrangements of contacts that were contained, open and break the association as well as the other way around if the contacts were open. When turning off the current to the curl, the armature is returned, forcibly, to its casual position. This force is normally given by a spring; however, gravity can likewise be utilized in specific applications. Most force transfers are fabricated to work in a fast way.

- **Guide for Relay Module with ARDUINO**

A relay is an electrically functioned switch that can be turned on or off, releasing the flow through or not, and can be controlled with low voltages, similar to the 5V given by the ARDUINO pins. Controlling a transfer module with the ARDUINO is just about as straightforward as controlling some other output.

Figure 12.Relay Module

This relay module has two channels (those blue blocks). There are different models with one, four, and eight channels. This module ought to be controlled with 5V, which is fitting to use with an ARDUINO.

- **Relay Pin out**

The following figure demonstrates the relay module pin out.

Figure 13.Relay module pin out

The six pins on the right half of the relay module join high voltage, and the pins on the left side interface the part that requires low voltage the ARDUINO pins.

- **Mains voltage connections**

The high-voltage side encloses two connectors, each with three sockets: common (COM), normally closed (NC), and normally open (NO).

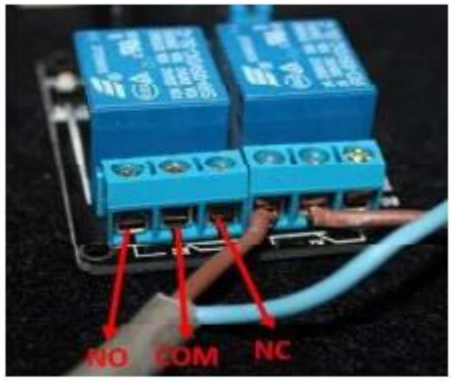


Figure 14.Main voltage connections of the relay module**.**

- **COM**: common pin
- **NC (Normally Closed):** The ordinarily shut design is utilized when it is needed the transfer to be shut default, which means the current is streaming except if you convey a message from the ARDUINO to the relay-off module to open the circuit and stop the current.
- **NO (Normally Open):** the typically open setup works the reverse way around: the relay is consistently open, so the circuit is broken except if you convey a message from the ARDUINO to close the circuit

To light up a lamp periodically, it is smarter to utilize a normally open circuit setup.

- **Pin wiring**

The low-voltage side has a set of four pins and a set of three pins.

Figure 15.Pin Wiring

The set at the right contains of **VCC** and **GND** to power up the module, and input 1 (**IN1**) and input 2 (**IN2**) to regulate the bottom and top relays, respectively.

The second set of pins consists of **GND**, **VCC**, and **JD-VCC** pins. The JD-VCC pin powers the electromagnet of the relay.

The connections between the relay module and the ARDUINO are simple:

- **GND**: goes to ground
- **IN1**: controls the first relay (it will be connected to an ARDUINO digital pin)
- **IN2**: controls the second relay
- **VCC**: goes to 5V
- **ARDUINO**

ARDUINO is an open-source electronics stage based on simple to-utilize hardware and programming. ARDUINO boards can understand inputs - light on a sensor, a finger on a button, or a Twitter message - and transform it into a yield - activating a motor, turning on a LED, distributing something on the web. It is possible to guide board by sending a bunch of guidelines to the microcontroller on the board to do as such utilize the ARDUINO programming language (in view of Wiring), and the ARDUINO Software (IDE), in light of Processing.

Throughout the long term ARDUINO has been the intelligence of thousands of tasks, from regular items to complex logical instruments. An overall local area of producers understudies, specialists, craftsmen, software engineers, and experts - has assembled around this open-source stage, their commitments have amounted to an inconceivable measure of open information that can be of incredible assistance to learners and specialists the same.

When it arrived at a more extensive community, the ARDUINO board began changing to adjust to new requirements and difficulties, separating its proposal from simple 8-bit boards to items for applications, wearable, 3D printing, and embedded atmospheres. All ARDUINO boards are totally open-source, engaging clients to construct them freely and in the end adjust them to their specific requirements. The product, as well, is open-source, and it is becoming through the commitments of clients around the world.

- **ARDUINO board**

There are numerous varieties of ARDUINO boards utilized for various purposes. A few boards appear to be unique from the one underneath, yet most ARDUINO boards most of these components practically speaking. Power (USB / Barrel Jack)

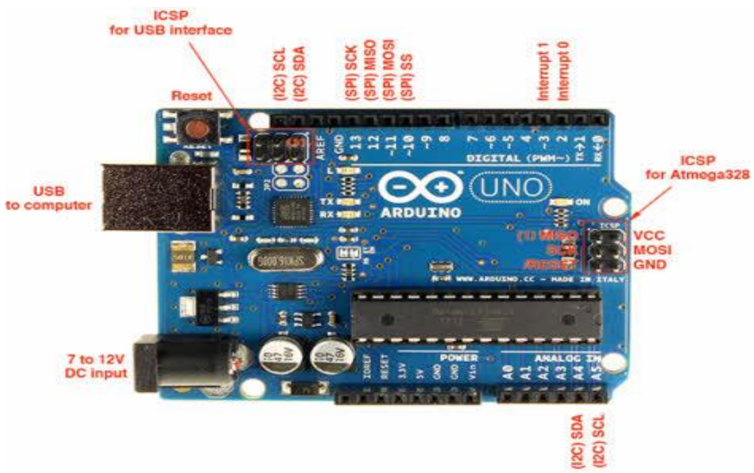


Figure16.ARDUINO Board

Each ARDUINO board needs a way of being associated with a power source. The ARDUINO UNO controlled from a USB link coming from your PC or a divider power supply (like this) that ended in a barrel jack. In the image over the USB, association is named and the barrel jack is marked.

The USB association is likewise how you will load code onto your ARDUINO board. More on the most proficient method to program with ARDUINO can be found in our Installing and Programming ARDUINO instructional exercise.

Do NOT use a power supply more supply than 20 Volts as you will overwhelm (and subsequently obliterate) ARDUINO. The suggested voltage for most ARDUINO models is somewhere in the range of 6 and 12 Volts.

Pins (5V, 3.3V, GND, analogue, Digital, PWM, AREF)

The pins on your ARDUINO are where you associate wires to build a circuit (most likely related to a breadboard and some wire. They ordinarily have black plastic 'headers' that permit you to simply plug a wire squarely into the board. The ARDUINO has a few various types of pins, every one of which named on the board and utilized for various capacities.

GND (3) which can be used to ground your circuit

5V (4) & 3.3V (5): the 5V pin supplies 5 volts of power, and the 3.3V pin supplies 3.3 volts of power. Most of the simple components used with the ARDUINO run happily off of 5 or 3.3 volts.

- **Analogue (6)**: The UNO) is Analogue in pins. These pins can read the signal from an analogue sensor and convert it into a digital value that can be read.
- **Digital (7)**: Across from the analogue pins are the digital pins (0 through 13 on the UNO). These pins can be used for both digital input (like informing if a button is hard-pressed) and digital output (like powering an LED).
- **PWM (8)**: the tilde (~) next to some of the digital pins (3, 5, 6, 9, 10, and 11 on the UNO). These pins act as normal digital pins but can also be used for something called Pulse-Width Modulation (PWM). (https:/www.elprocus.com/atmega328.arduino-uno-board-working and its application).

2.2.2. Load Cell Strain Gauge

Two of the load cells are positioned in tension mode and the other two are positioned in compression mode. When you step onto the scale, the microcontroller takes their outputs and converts them to an aggregate weight value in the selected unit of measurement, and displays that number on a gauge.

2.2.3. Load Cell

Manufactured in US by FUTEK Advanced Sensor technology (FUTEK), a leading load cell manufacturer producing a huge selection of force transducers, utilizing one of the most advanced technologies in the Sensor Industry: Metal foil strain gauge technology. A Force Sensor is defined as a transducer that converts an input mechanical load, weight, tension, compression or pressure into an electrical output signal (load cell definition). Force Sensors are also commonly known as force transducer. There are several types of load_cells based on size, geometry and capacity.

By definition, load cell (or load cell) is a type of transducer, specifically a force transducer. It convertsaninputmechanicalforce suchas load, weight (aka weightsensors), tension, compressio n or pressure (aka pressure_sensors for pressure measurement - What is a pressure sensor?) into another physical variable, in this case, into an electrical output signal that can be measured, converted and standardized. As the force applied to the force sensor increases, the electrical signal changes proportionally. Force Transducers became an essential element in many industries from Automotive, High precision manufacturing, Aerospace & Defence, Industrial Automation, Medical & Pharmaceuticals and Robotics where reliable and high precision load measurement is paramount (i.e. medical load cell). Most recently, with the advancements in Collaborative Robots (Cobots) and Surgical Robotics, many novel force measurement applications are emerging, such as miniature medical sensors for robotic surgery.

2.2.4. Working Principle of Load Cell

Firstly, we need to understand the underlying physics and material science behind the load cell working principle, which is the strain gauge (sometimes referred to as Strain gage). Metal foil strain gage is a material whose electrical resistance varies with applied force. In other words, it converts (or transducers) force, pressure, tension, compression, torque, weight, etc… into a change in electrical resistance, which can then be measured. So, metal foil strain gauge is the building block of force sensor working principle. Weight measurement using Strain Gauge Bridge is also one of the comment applications of this technology.

Strain gauges are electrical conductors tightly attached to a film in a zigzag shape. When this film is pulled, it – and the conductors – stretches and elongates. When it is pushed, it is contracted and gets shorter. This change in shape causes the resistance in the electrical conductors to also change. The strain applied in the load cell can be determined based on this principle, as strain gauge resistance increases with applied strain and diminishes with contraction.

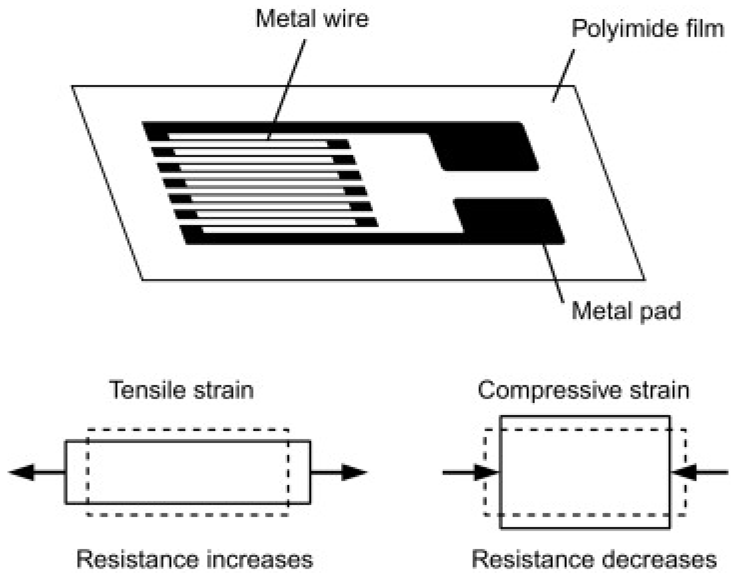


Figure 17.Representative picture of load cell.

Structurally, a force sensor (or transducer) is made of a metal body (also called flexure) to which foil strain gauges are bonded. The sensor body is usually made of aluminium or stainless steel, which gives the sensor two important characteristics:

1. Provides the sturdiness to withstand high loads and
2. Has the elasticity to minimally deform and return to its original shape.

When force (tension or compression) is applied, the metal body acts as a “spring” and is slightly deformed, and unless it is overloaded, it returns to its original shape. As the flexure deforms, the strain gage also changes its shape and consequently its electrical resistance, which creates a differential voltage variation through a Wheatstone bridge circuit. Thus, the change in voltage is proportional to the physical force applied to the flexure.

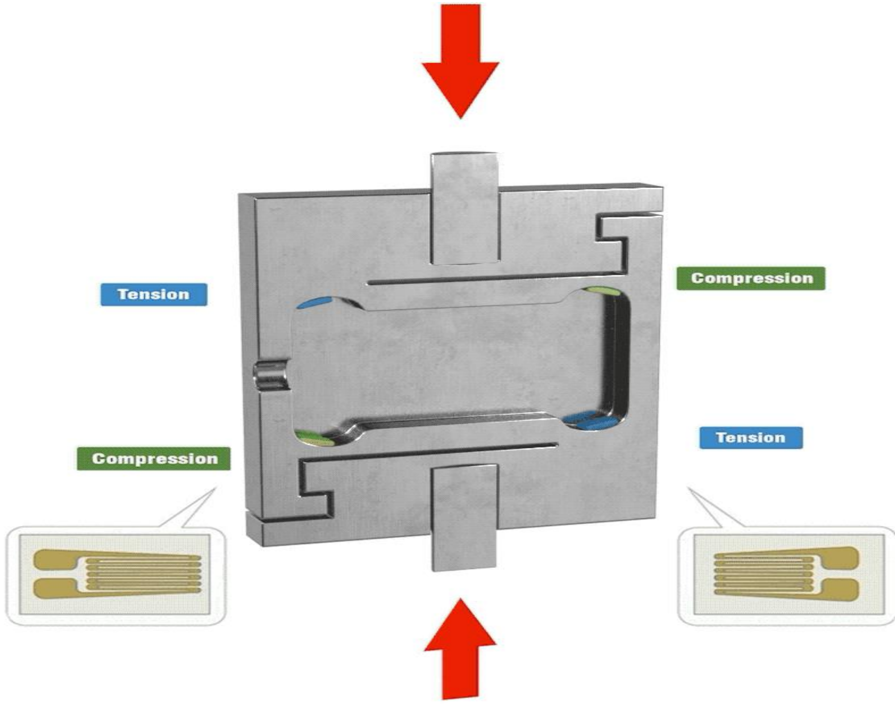


Figure 18 .Strain gage load cells

Metal foil strain gauge load cell sensors (not a draw wire sensor) are the most common technology, given its high accuracy, long term reliability, variety of shapes and sensor geometry and cost-effectiveness when compared to other force measurement technologies. Also, strain gage force measuring sensors are less affected by temperature variations.

- The highest accuracy which may conform to many standards from Surgical Robotics to Aerospace;
- Robust Construction made of either high strength Stainless steel or Aluminum;
- Maintain high performance at the longest possible work life even at the most rigorous conditions. Some load cell designs can go up to billions of fully reversed cycles (lifespan).
- A plethora of geometries and customized shapes, as well as mounting options for *an*y scale any-where.
- A full gamut of selections with capacities ranging from 10 grams to 100,000 pounds.

2.2.5. Types of Load Cells

Although there several technologies to measuring force, we will focus on the most common type of load cell: metal foil strain gauge. Within the types of force sensors, there are a variety of body shapes and geometries, each one catering to distinct applications. Get to know them if you want to buy load cell:

2.2.5.1. In-Line Load Cell

Most commonly referred to as in-line force transducers force sensor with male threads. This style of load force transducer can be used in both pushing and pulling forces applications (aka push-pull load cell). In-line sensors offer high accuracy and high stiffness with minimal mounting clearance needed. They are great for endurance, press in force measurement applications and force measurement sensor for gym workout equipment. Also offered in miniaturized versions as micro load_cell (aka micro force sensor, miniature load cell, miniature force sensor or milligram load cell).

2.2.5.2. Column Load Cell

FUTEK provides a wide range of Canister Load Cells (also known as Column Load Cell) designed for high capacity compression applications such as CNC Machine Vise Clamping Force Test. These models offer robust construction with a capacity ranging from 2,000 to 30,000 lbs. FUTEK has also developed a miniature Load Cell Canister series for applications where size is a critical factor.

2.2.5.3. Load Button

These force transducers have a single flat, raised surface (aka a button) where the compressive force is applied. What's impressive about load buttons is their low_profile load cell design. As small load cells as they are, they are known for their robustness and are used in fatigue applications. Some applications require miniature modes such as the LLB130 subminiature load cell load button. Rolling element bearing load measurement is an application where load buttons are utilized.

2.2.5.4. S Beam Load Cell

With other names including Z Beam Sensor, S Type load cell, the S Beam Load Cell is a tension load cell and compression load cell with female threads for mounting. Sporting high accuracy and a thin beam load cell, compact profile, this force sensor type is great for in-line processing and automated control feedback applications. S Beam Load cells can also be used as a non-contact flow sensor in fluid flow measurement application.

2.2.5.5. Thru Hole Load Cell

Also known as donut load cell or washer load cell, thru hole load cell traditionally have a smooth non-threaded inner diameter used to measure compressive loads that require a rod to pass through its center. One of the primary uses of this sensor type is to measure bolt loading.

2.2.5.6. Pancake Load Cells

Pancake load cell, universal load or shear web load cell have a central threaded hole for measuring loads in either tension or compression. These force transducers are used in applications needing high endurance, high fatigue life, or high-capacity in-line measurements, such as material force testing, load cell for tanks weighing system or crane load cell applications. They are also highly resistant to off-axis loading and are also available as low profile pancake load cell.

2.2.5.7. Rod End Load Cell

Also known as Actuator Load Cell, this load transducer type offers one male thread and one female thread for mounting. The male and female thread combination is well suited in applications where you need to adapt a force sensor into an existing fixture.

2.2.5.8. Bending Beam Load Cell

It offers a slim design making it ideal for OEM applications. Utilized in Compression, the Bending Beam Load Cells can be used to measure force, surface pressure and displacement for OEM applications. With its miniature size, the Cantilever Load Cell is a great selection for tight environments.

2.2.5.9. Single Point Load Cell

Side mounted load cell with a single point design that are specifically made for OEM applications that require high precision or high volume production. Also known as Shear Beam Load cell, these strain gauged based force sensors measure tension and compression and are also known as compact parallelogram sensors, or single point load cell. Side mount load cells such as the LSM Series sensors are a recommended OEM weight measurement solution and are sensors used in bottle_filling plant.Other unique designs are also available such as the load pin load cells (aka load cell pin), seat_belt load cell, and others (https://www.futek.com/how-a-load-cell-works).

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Materials

Materials required for execution of this research work are given below. Software expected to be used for programming and simulating. Sensors are expected to sense loading effect on axles and send messages through circuit to micro controller. Microcontroller also expected to take sensors message from axles caring capacity to give command to fuel controlling solenoid valve. To design this system different material was required. All of them purchased from different manufacturers.

Table 1 Materials required for the design of fuel cut off solenoid for controlling over load on trucks.

No	Component	Quantity	No	Component	Quantity
1	Load cell sensor	1	5	Steeper motor	1
2	ARDUINO UNO system	1	6	Circuit and switch holder	1
3	Buzzer	3	7	LCD display	1
4	Jumper wire	60	8	Light alarm	1

3.1.1. Controller: ARDUINO Microcontroller

ARDUINO UNO is a low-cost, flexible, and easy-to-use programmable open-source microcontroller board that can be integrated into a variety of electronic projects. This board can be interfaced with other ARDUINO boards, ARDUINO shields, and Raspberry Pi boards and can control relays, LEDs, servos, and motors as an output.

3.1.2. ARDUINO UNOAtmega328

The ATmega328 is one kind of single-chip microcontroller formed with Atmel within the mega VR family. The architecture of this ARDUINO UNO is a customized Harvard architecture with 8 bit RISC processor core. Other boards of ARDUINO Uno include ARDUINO Pro Mini, ARDUINO Nano, ARDUINO Due, ARDUINO Mega, and ARDUINO Leonardo.

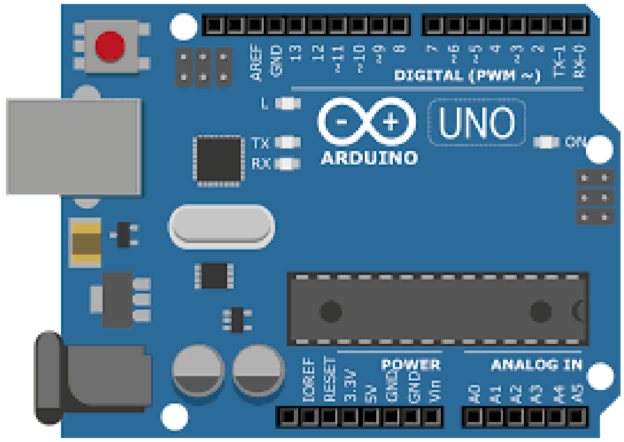


Figure 19.Features of ARDUINO UNO Board

The features of ARDUINO UNOATmega328 include the following.

- The operating voltage is 5V
- The recommended input voltage will range from 7v to 12V
- The input voltage ranges from 6v to 20V
- Digital input/output pins are 14
- Analogue I/p pins are 6
- DC Current for each input/output pin is 40 MA
- DC Current for 3.3V Pin is 50 MA
- Flash Memory is 32 KB
- SRAM is 2 KB
- EEPROM is 1 KB
- +CLK Speed is 16 MHz

3.1.3. ARDUINO UNO Pin Diagram

The ARDUINO UNO board can be built with power pins, analogue pins, ATmegs328, ICSP header, Reset button, power LED, digital pins, test led 13, TX/RX pins, USB interface, an external power_supply. The ARDUINO UNO board description is discussed below.

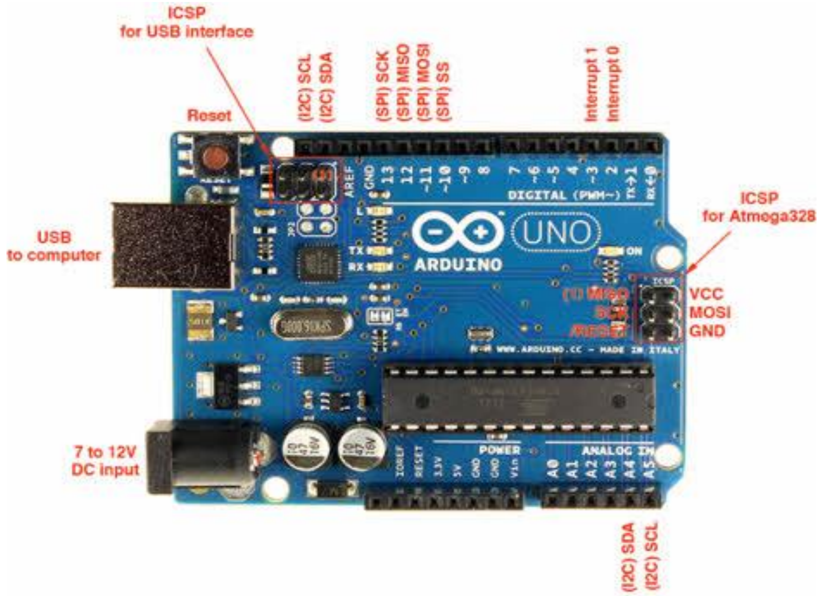


Figure 20.ARDUINO UNO board pin configuration

3.1.4. Power Supply

The ARDUINO UNO power supply can be done with the help of a USB cable or an external power supply. The external power supplies mainly include AC to DC adapter otherwise a battery. The adapter can be connected to the ARDUINO UNO by plugging into the power jack of the ARDUINO board. Similarly, the battery leads can be connected to the vin pin and the GND pin of the POWER connector. The suggested voltage range would be 7 volts to 12 volts.

3.1.5. Input & Output

The 14 digital pins on the ARDUINO UNO can be used as input & output with the help of the functions like pin Mode, digital Write, & Digital Read.

Pin1 (TX) & Pin0 (RX) (Serial): This pin is used to transmit & receive TTL serial data, and these are connected to the ATmega8U2 USB to TTL Serial chip equivalent pins.

Pin 2 & Pin 3 (External Interrupts): External pins can be connected to activate an interrupt over a low value, change in value.

Pins 3, 5, 6, 9, 10, & 11 (PWM): This pin gives 8-bit PWM o/p by the function of analogue Write. SPI Pins (Pin-10 (SS), Pin-11 (MOSI), Pin-12 (MISO), Pin-13 (SCK): These pins maintain SPI-communication, even though offered by the fundamental hardware, is not presently included within the ARDUINO language. Pin-13(LED): The inbuilt LED can be connected to pin13 (digital pin). As the HIGH-value pin, the light emitting diode is activated, whenever the pin is LOW.

Pin-4 (SDA) & Pin-5 (SCL) (I2C): It supports TWI-communication with the help of the Wire library. AREF (Reference Voltage): The reference voltage is for the analogue I/ps with analogue Reference. Reset Pin: This pin is used for reset (RST) the microcontroller.

3.1.6. Memory

The memory of this Atmega328 ARDUINO microcontroller includes flash memory-32 KB for storing code, SRAM-2 KB EEPROM-1 KB.

3.1.7. Communication

The ARDUINO UNOATmega328 offers UART TTL-serial communication**,** and it is accessible on digital pins like TX (1) and RX (0). The software of an ARDUINO has a serial monitor that permits easy data. There are two LEDs on the board like RX & TX which would blink whenever data is being broadcasted through the USB.

A Software Serial library permits for serial communication on ARDUINO UNO digital pins and the ATmega328P supports TWI (I2C) as well as SPI-communication**.** The ARDUINO software contains a wired library for simplifying the utilization of the I2C bus.

3.1.8. Using Principle of an ARDUINO Uno

ARDUINO UNO can detect the surroundings from the input. Here the input is a variety of sensors and these can affect its surroundings through controlling motors, lights, other actuators, etc. The ATmega328 microcontroller on the ARDUINO board can be programmed with the help of an ARDUINO programming language and the IDE (Integrated Development Environment). **ARDUINO projects** can communicate by software while running on a PC.

3.1.9. ARDUINO Programming

Once the ARDUINO IDE tool is installed in the PC, attach the ARDUINO board to the computer with the help of USB cable. Open the ARDUINO IDE & select the right board by choosing Tools–>Board.>ARDUINO Uno, and select the right Port by choosing Tools–>Port. This board can be programmed with the help of an ARDUINO **programming language** depends on Wiring.

To activate the ARDUINO board & flash the LED on the board, dump the program code with the selection of Files–> Examples.>Basics..>Flash. When the programming codes are dumped into the IDE, and then click the button ‘upload’ on the top bar. Once this process is completed, check the LED flash on the board.

3.1.10. High Voltage Protection of USB

The ARDUINO UNO board has a rearrange able poly fuse that defends the USB port of the PC from the over-voltage. Though most of the PCs have their own inner protection, the fuse gives an additional coating of safety. If above 500mA is given to the USB port, then the fuse would routinely crack the connection until the over-voltage is removed.

3.1.11. Physical Characteristics

The physical characteristics of an ARDUINO board mainly include length and width. The **printed circuit board** of the ARDUINO UNO length and width are 2.7 X 2.1 inches, but the power jack and the USB connector will extend beyond the previous measurement. The board can be attached on the surface otherwise case with the screw holes.

3.1.12. Applications of ARDUINO UNOAtmega328

The applications of ARDUINO UNO include the following**.**

- ARDUINO Uno is used in Do-it-Yourself projects prototyping.
- In developing projects based on code-based control

- Development of Automation System
- Designing of basic circuit designs (https://www.elprocus.com/atmega328-ARDUINO-uno-board-working-and-its-applications/).

3.2. Methods

For this study primary and secondary surveys data, ARDUINO UNO programming, PROTEUS soft wear for simulation were used.

3.2.1. Data Collection

- Primary Data Source

Vehicles over loading violation with respect to standard axle's caring capacity with in a specific time data collection on trucks RTA

- Secondary Data Source

Different literatures such as journals, internet, and textbooks were reviewed.

3.3. Overload Analysis for Trucks

Table 2*: Specification of Sino truck model WD15.95C*

Model type and weight	Model type	Model ZZ3257N367C1D
	Curb mass(kg)	12,450
	Gross mass(kg)	25,000
	Front axle load(kg)	7,000
	Rear axle load(kg)	18,000
Dimensions	Length(mm)	8545
	Width(mm)	2496
	Height(mm)	3170
	Wheel base(mm)	(4300+1350)
	Truck width(mm)	1830
	Number of leaf spring(mm)	24
	Weight of leaf spring(kg)	
	Length of leaf spring(mm)	17,400
	Thickness of leaf spring(mm)	500
	Size of tires	1200-R20
	Minimum ground clearance(mm)	314
Engine	Engine type	Water-cooled, in-line, 6-cilyinder, OHC.
	Engine cod	WD15.95C
	Fuel type	Diesel
	Displacement(cm^3)	9726

3.4. Vehicle Overload Analysis

- **Front Axle and Rear Axle Forces**

The payload capacity of a SINOTRUCK is the amount of load, which the vehicle can carry safely. The loading capacity (payload) of the Sino truck is 25ton. SINOTRUCK weight distribution, the front axle is 45% of the gross weight, and the rear axle is 55% of the weight. Loading the vehicle with more weight than payload capacity causes overloading and puts the vehicle more stress on the frame, suspension, and tires than they can handle. When vehicle is parked on level road, the left side and right side of a vehicle are symmetry to each other then again the front side and rear side of this vehicle are not symmetric which in particular refers the distributing of weight within a vehicle is not comparable. Because of parking road conditions and various external factors, the angle of inclination and height of center of gravity could fluctuate. Weight transformation takes place whenever the vehicle is parked on an inclined road thereby wheels' load and axles load can be varied instantly.

- **Loaded Trucks Parked on A Level Road**

When the vehicle parked on a flat paved road, the reaction forces R under each of the front and rear tires are determined in the following way. As shown in the figure below. Front axle carrying capacity is 45% of payload:

Road reaction over the front wheel $(\mathrm{W_1}) = 0.45 \times 25000 \text{ kg} = 11250 \text{ kg}$

Road reaction over the front wheel $(\mathrm{W_2}) = 0.55 \times 25000 \text{ kg} = 13750 \text{ kg}$

$$=\frac{45}{100} \times 25000\mathrm{N}$$

$$= 11250\mathrm{N}$$

When the vehicle is parked on a level road, front axle should tolerate 22500N force. The force applied to each front wheel is 11250 Newton. Rear axle carrying capacity is 55% of payload:

$$=\frac{55}{100} \times 25000\mathrm{N}$$

$$= 12500\mathrm{N}$$

When the vehicle is parked on a level road, front axle should tolerate 25000N forces. The force applied to each front wheel is 12500 Newton.

- **Loaded Trucks Parked On An Inclined Road**

When the vehicle is parked on an inclined road (slope), the reaction force under each wheels are determined.

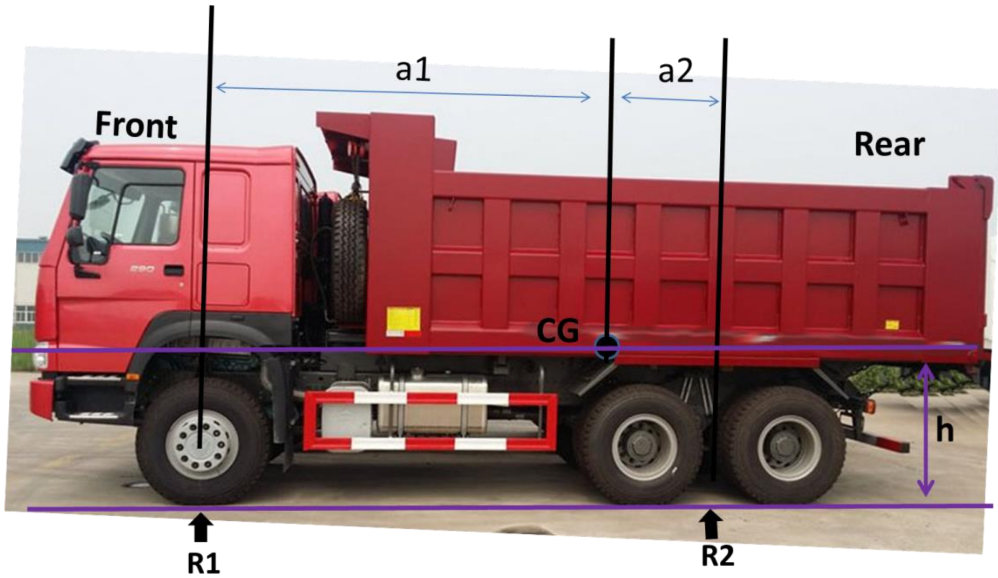


Figure21. A parked truck on level pavement

The value of a_1 and a_2

Where (L) where $l = a_1 + a_2$

$$a_1 = \frac{(l)(R_2)}{mg} = \frac{5.65\text{m} \times 122{,}500\text{N}}{(25{,}000\text{kg} \times 9.81\text{m/s2})}$$

$$= 2.825\text{m}$$

$$a_2 = \frac{(l)(R_1)}{mg}$$

$$\frac{5.65\text{m} \times 110{,}250\text{N}}{(25{,}000\text{kg} \times 9.81\text{m/s2})}$$

$$= 2.54\text{m}$$

To determine the longitudinal point of, C, it should measure the total weight of the vehicle as well as the force under the front or the rear tires. The figure outlines a circumstance where in it estimates the force under the front wheels. Supposing the force under the front wheels R_{11} and R_{12} the position of the mass center is determined by static equilibrium conditions. Where, is the distance of the vehicle's mass center, C, from the front hub and is the distance of, C, from the back axle, and l is the wheelbase (Reza N. Jazar, www.mohandesyar.com).

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 a slanted pavement. The vehicle parked on a level surface such that the front wheels are on a scale jack. The front wheels locked and secured to the jack and the rear wheels left free to turn. The jack lifts the front wheels and the required vertical force applied by the jacks measured by a strain gauge. Consider the longitudinal position of, C.G, and the jack lifted such that the car makes an angle, φ, of 15 to 30 degree with the horizontal plane. The slope angle φ is measurable using level meters (Olma & Yadessa, 2019).

Suspension deflection creates the extreme impact on height determination error. To eradicate the suspension deflection, we should lock the suspension, for the most part by replacing the shock absorbers with inflexible bars to keep the vehicle at its ride height. Dimensions for center of gravity are summarized in table 3.

Table 3. Centre of gravity

Center of gravity	
a_1 is the distance of cars mass center from the front axle	2.825m
a_2 is the distance of cars mass center from the rear axle	2.540m
h height of center of gravity	2.349m

- **Loaded Trucks Parked On An Inclined Road**

When the vehicle is parked on an inclined road (slope), the reaction force under each wheels are determined.

When a vehicle is parked on an inclined pavement as shown in Figure 23 the normal force, R, under each of the front and rear wheels, R_1 and R_2.

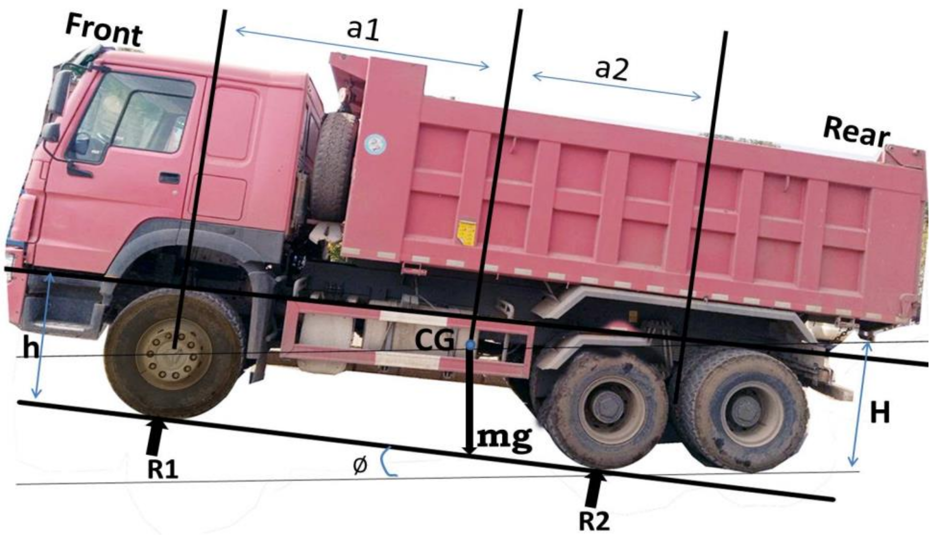


Figure 22.A parked car on inclined pavement

When the vehicle is parked on an inclined pavement as shown in figure 3.3, with an angle ($\emptyset$) the maximum acceleration depends on the friction under the tires. Friction coefficient at the front and rear tires are equal. Maximum inclination angle for that the vehicle can be parked is calculated by the following equation (Reza N. Jazar, *Www.Mohandesyar...*).

3.5. Vehicle Instability Analysis

During a vehicle tends to irregular changes when it is subjected to dynamic and static forces in relation to variety of road conditions refers to instability. Major causes to vehicle instability are uneven weight transformation along with several road conditions and motion of overloaded vehicle through various speed rates.

- **Instability reference point**

Strain occurred in leaf spring with the variation of load throughout the dynamic condition. When a vehicle moves in different road conditions weight transforms from one side to the opposite side of the vehicle in which strain on the leaf spring fluctuates correspondingly. Wheels are supposed to withstand unlimited road profiles and as road condition punctuates hastily wheels are exposed to weight disturbance. On the grounds of this, deformation in leaf spring rises and falls due to weight transformation while the vehicle moves in a variety of road conditions. The instability reference value is the value at which the vehicle starts to become unstable. The optimal strain value that could be safe to drive the vehicle and avoid instability will be observed.

- **Strain and load analysis of leaf spring for SINOTRUCK**

Relation between the leaf spring vertical surface strains, Leaf spring vertical deformity, thickness of the leaf spring, Span leaf spring force shown in Figure.

$$\varepsilon = \frac{6\Delta xh}{l^2}$$

Where

ε = 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,

$$\Delta \mathbf{x} = \frac{\varepsilon l^2}{6h}$$

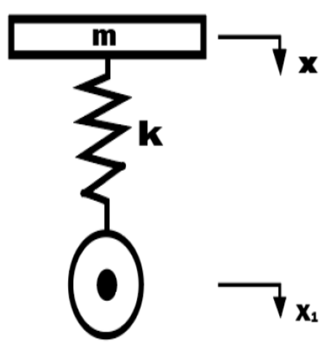


Figure 23.Single-arm suspension system model

Since one kind of leaf spring moment span, stiffness, and thickness can be fixed, so set the sprung mass correlation coefficient ß $= \frac{\varepsilon l^2}{6h}$ so the formula *m* = *ß* can be simplified.

- **Loaded Truck Parked on An Inclined Road**

When a vehicle is parked on an inclined pavement as shown in Figure 3.5, the normal force, R, under each of the front and rear wheels, R_1 and R_2.

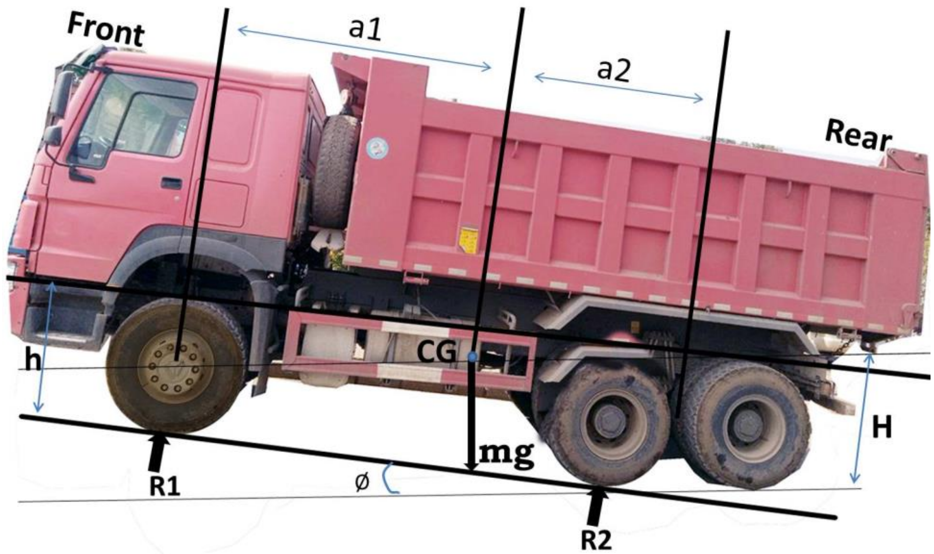


Figure 24.A parked car on inclined pavement

These equations deliver the brake force and reaction forces under the front and rear tires. When the vehicle is parked on an inclined pavement with an angle 30 degree the maximum acceleration depends on the friction under the tires. Friction coefficient at the front and rear tires are equal. Maximum inclination angle for the vehicle can be parked is calculated by the following equation (Reza N. Jazar, *www.Mohandesyar*).

- **Loaded Truck Accelerating on A Level Road**

When a vehicle accelerates on a flat road as shown in figure 3.7, the maximum acceleration for rear-wheel drive calculated as follows:

$$\frac{a}{g} = \frac{a_1 \mu_x}{l - h\mu_x}$$

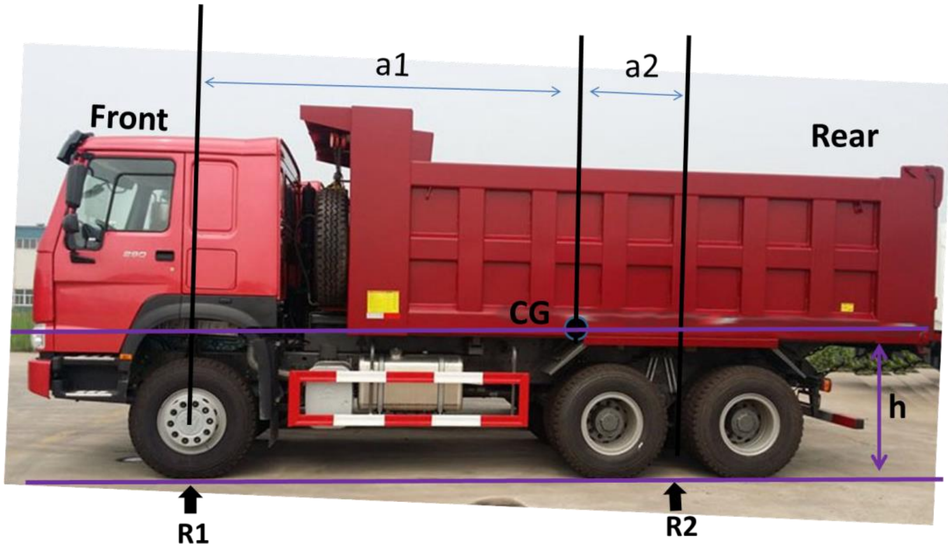


Figure 25.Accelerating car on a level road

- **Loaded Truck Decelerating on a Level Road**

When accelerating a < 0, the normal forces under the front tires are greater than the static load, and under the rear, tires are less than the static load.

- **Loaded Truck Accelerating on an Inclined Road**

When the car starts to move up the hill, gravity pulls against that could make harder for the engine to drive the vehicle up the slope. (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 the static part. And, the second terms $\pm\frac{1}{2}mg\frac{h}{l}\frac{a}{g} = 3346.8$ N are called dynamic parts of normal forces. To know reaction forces under the front and rear tires, Assume inclination angle$(\emptyset) = 30°$.

When the vehicle is moving on an inclined road the appropriate inclination angle should be less than Maximum inclination angle.

In Ethiopia slope of most pavements are less than 30 degree.

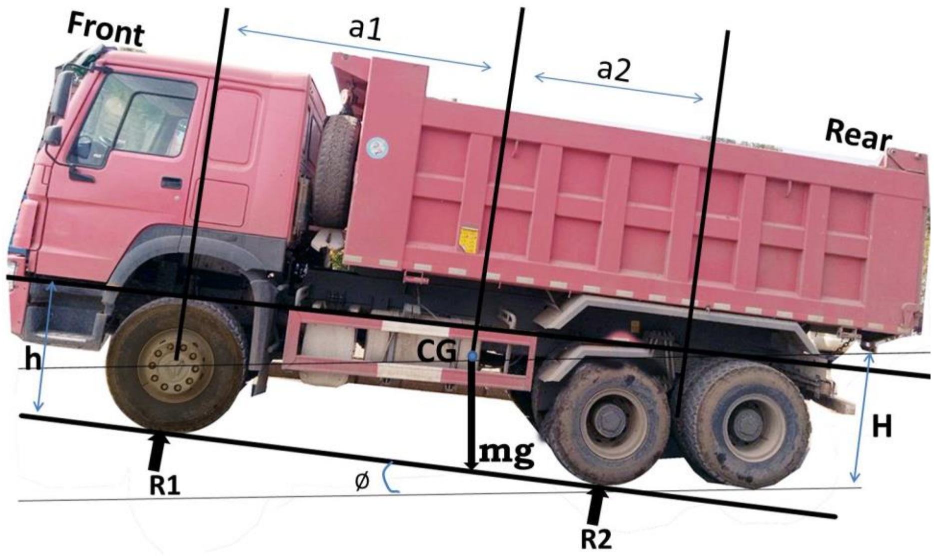


Figure 26.*Over* loaded car accelerating on an inclined road.

When a vehicle is accelerating on slanted asphalt with an angle Ø as Figure shown, the typical force under each of the front and rear tires, R_1 and R_2, would be:

- ## Loaded Truck Moving in a Horizontal Curved Path

If an object is moving along a curved path, the direction of its velocity is changing. Centrifugal force pulls out from the center on a body in circular motion and increases with acceleration. Centrifugal force results in strong outward pull on your vehicle.

Consider the four wheels 11, 12, 21 and 22 of the vehicle taking a turn towards left. The wheels 11 and 21 are inner wheels, whereas 12 and 22 are outer wheels. The center of gravity (C.G) of the vehicle lies vertically above the road surface.

The weight of the vehicle (mg) will be 45% distributed over the front wheels and 55% distributed over the rear wheels which will act downwards. The reaction between the wheel and the road surface of the same magnitude will act upwards.

Road reaction over the front wheel $(\mathrm{W_1}) = 0.45 \times 25000$ kg $= 11250$ kg
Road reaction over the front wheel $(\mathrm{W_2}) = 0.55 \times 25000$ kg $= 13750$ kg

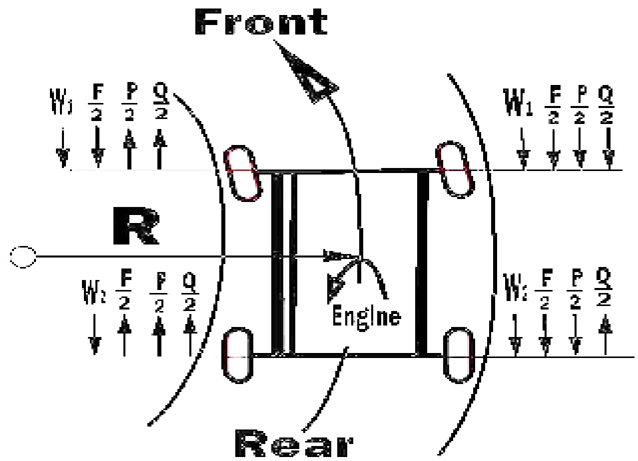


Figure 27.Load distribution on truck moving in a horizontal curved path

From equation (i), we see that there will always be contact between the outer wheels and the road surface because $\frac{W_2}{2}$, $\frac{P}{2}$ and $\frac{Q}{2}$ are vertically upwards. As to have contact between the inner wheels and road surface, the reactions should also be vertically upwards, which is only possible if R_{21} is zero.

Critical speed of a vehicle is the speed at which the vehicle will lose lateral control on the roadway. The speed of this vehicle should not exceed $30\,\frac{\text{km}}{\text{hr}}$ unless the vehicle could lose control of the road, which can cause catastrophic danger. For the stability of the vehicle and better handling, it is highly recommended to accelerate the vehicle below the critical speed. This critical speed was determined at the minimum turning radius of truck, which was taken from the specification. Whenever, the vehicle turns greater than the minimum radius, the vehicle will not expose to problems such as rollover and instability. Since, the driver will be able to manage the vehicle effortlessly.

As the speed of the vehicle drops down form the limiting speed or critical speed, then the vehicle will be capable of avoiding some irritating consequences caused by over speed.

3.6. Overload Detecting and Controlling System of Trucks

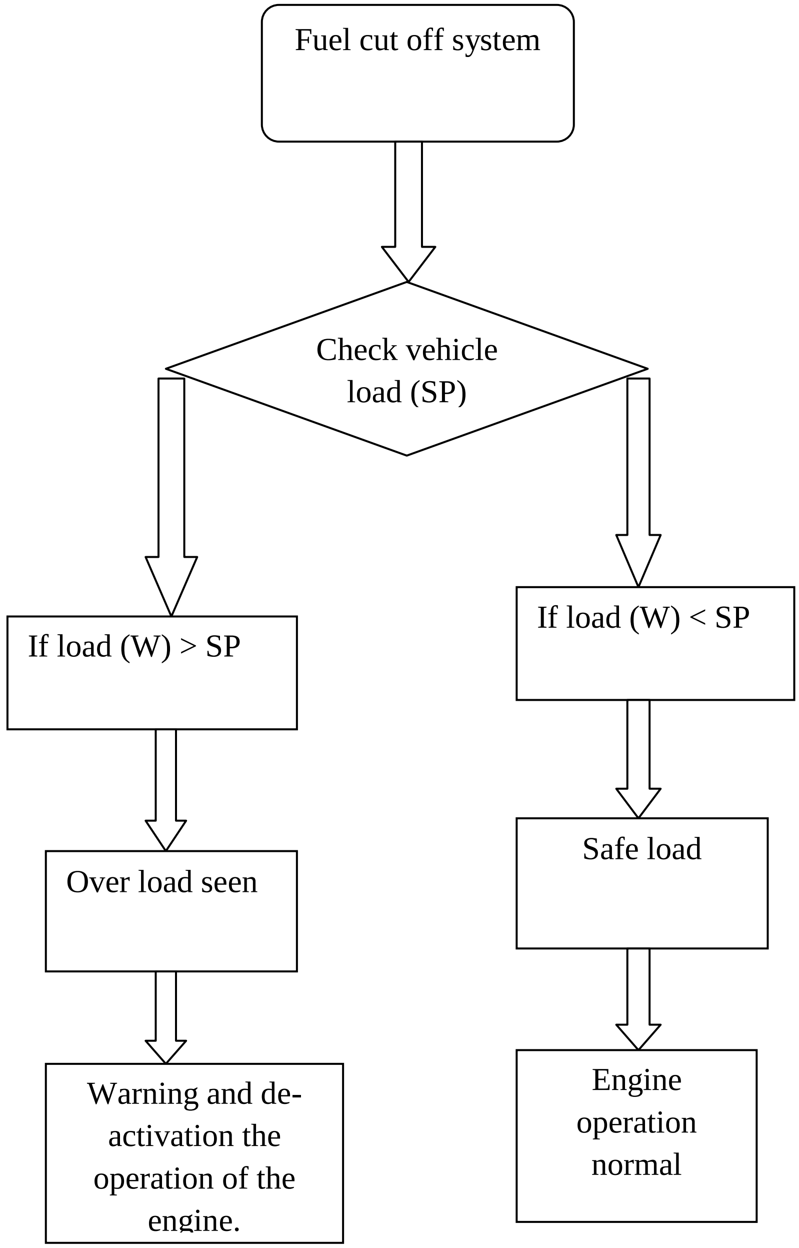


Figure 28.Block diagram of overload detecting and controlling system of truck.

CASE 1: If the weight of the load that the vehicle is carrying (W) is less than the payload of the vehicle (SP), considered as safe for the vehicle.

CASE 2: If the applied load (W) to the vehicle is equal to the payload (SP) of the vehicle, at this point the vehicle possesses maximum safe load limit. Warning signals would turn on with yellow LED, which notifies the vehicle is escaping safe load limit status, and pending to overload.

CASE 3: If the applied load (W) exceeds the payload (SP) of the vehicle, therefore overload detected through the system. The fuel cut off solenoid activated and that cause fuel not to deliver. Besides, the fuel supply terminated which disables the engine to operate and generate power and the vehicle would be unable to move and warning signal turn on with red LED, which notifies the load escaping safe load limit status and completely pending to over load and also as a case 2 buzzing alarm with red lamp.

Load cell

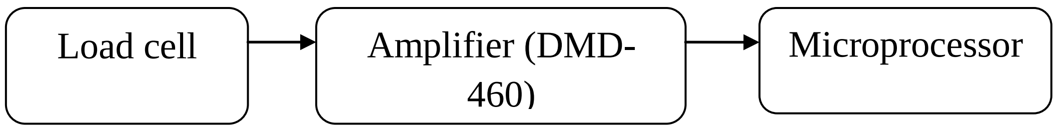


Figure 29.Flow chart

The load cell is connected with the DMD-460 Load cell amplifier wires as shown in figure 3.12. Amplifier (DMD-460) used to boost the voltage output from the load cell to a value great enough that the ARDUINO could read it as an analogue input. This system emphasis about detecting and controlling overload utilizes four load sensors as an input to microprocessor. The load sensor is mounted on suspension system with shaft which had been connected with axles under the frame of the truck. As the vehicle is loaded, the load sensors sense/reads the amounts of load applied to the vehicle and transmit to load cell.

- **Amplifiers (DMD-460)**

The DMD-460 Series bridge amplifiers are self-contained, AC or DC-powered, signal-conditioning modules for strain gages, load cells. The DMD-460 contains a precision differential instrumentation amplifier with voltage output.

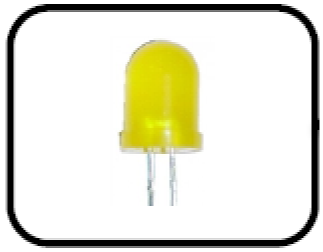
- **LCD display**

LCD connected to the microcontroller. It is an excellent way for a microcontroller to present visible information about vehicle overloading status. After the microcontroller recognized that the vehicle is overloaded then the information will be sent to LCD is displayed to alert the driver about the available information regarding overloading. Therefore, the driver will read this significant information then the driver will take immediate action.

- **LED**

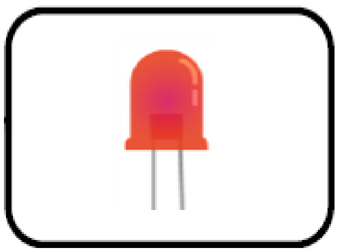
LED alerts the driver about the overloading condition of the vehicle. This LED blinks when the vehicle approaches the optimum load. Blinking notify warning to the driver about the loading condition of the vehicle. Then the driver will take the warning light under consideration.

Therefore, based on the warning light the situation will be under the driver‘s reaction and responsibility. Two fundamental LED lights light up considering the vehicle's weight status and provide significant information to a driver.



Warning lamp

- **Yellow LED**: it is a signal that notifies the driver to a pending to overload and warning.



Stopping lamp

- **Red LED**: it is a signal that notifies the vehicle is already overloaded. Thereafter, the vehicle must come to a complete stop. Additionally, fuel flow terminated as soon as the red LED lights.
- **Fuel cut-off solenoid valve**

A solenoid valve is an electromechanical valve controlled by an electric current. The electric current runs through a solenoid, which is a wire coil wrapped around a metallic core. A solenoid creates a controlled magnetic field when an electrical current passed through it. This magnetic field affects the state of the solenoid valve, causing the valve to open or close.

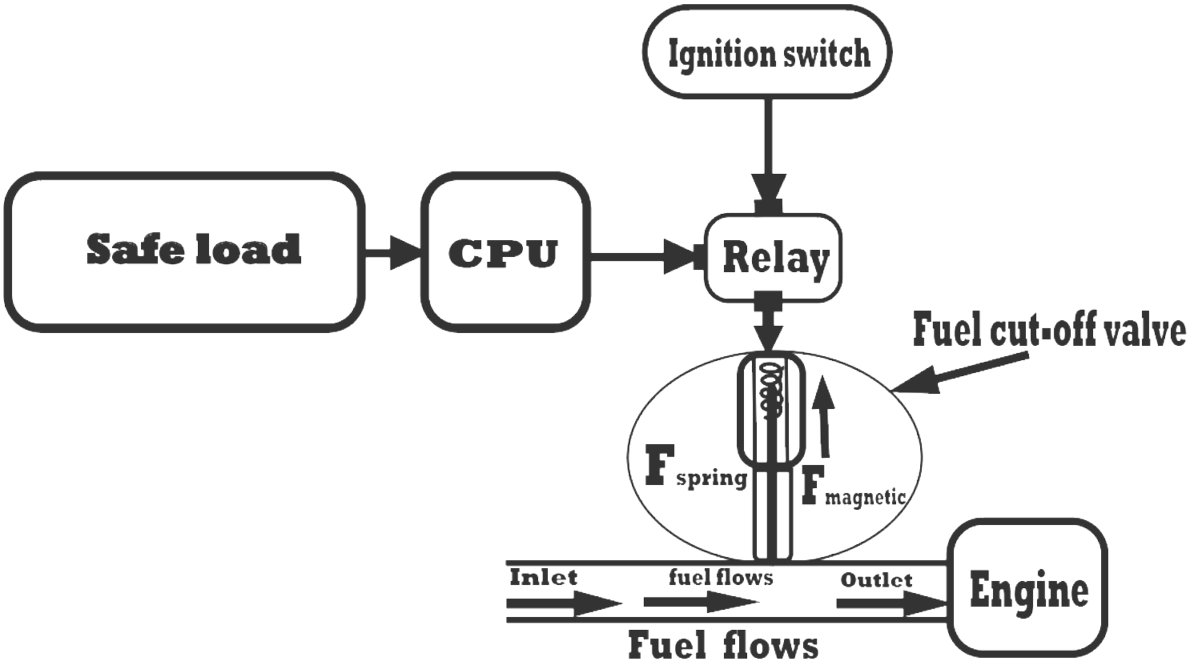


Figure 30.Fuel cut off valve activate

Whenever the vehicle is overloaded, CPU system gives instructions towards the relay in order to interrupt current flow into the direction of the solenoid valve. The electrical current running to the solenoid interrupted, causing the solenoid valve to close and shut off the supply of diesel fuel to the engine as shown in figure 32.

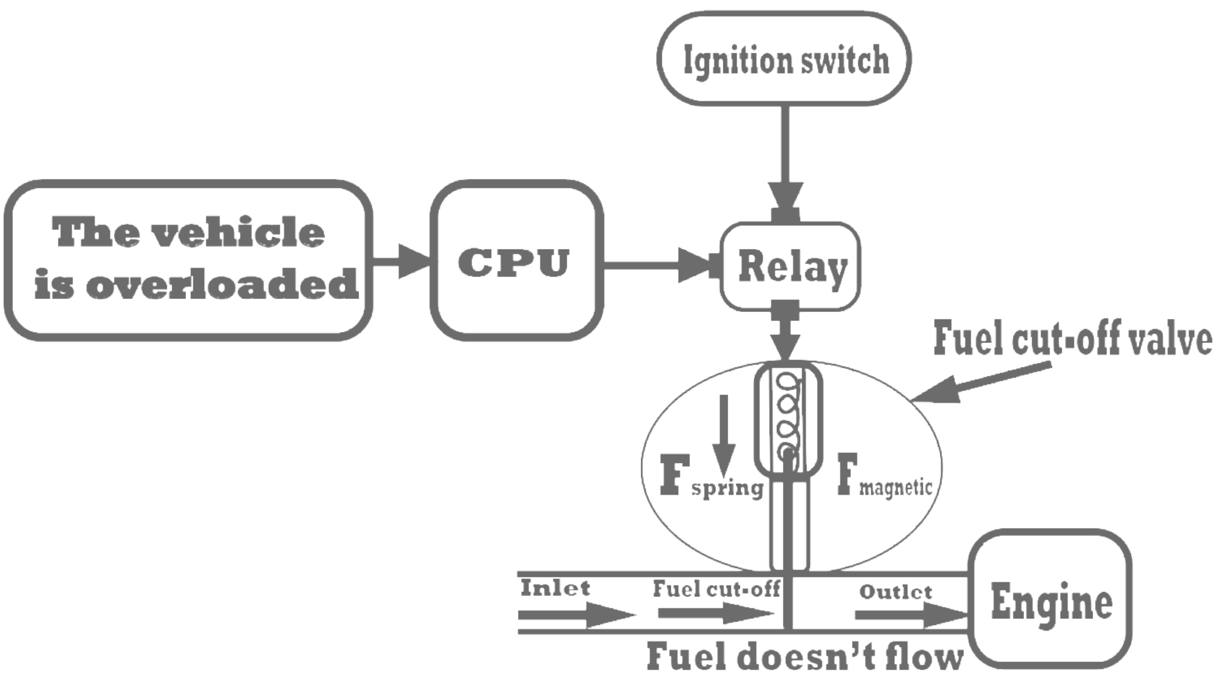


Figure 31.Fuel cut off deactivated

Whenever the system is disabled, CPU system gives instructions towards the relay causing the solenoid valve to close and shut off the supply of the engine.

- **Buzzer**

There are several ways of conveying between the client and an item. Perhaps the ideal way is sound correspondence utilizing a buzzer IC. Therefore, during the plan cycle, seeing a few innovations with setups is extremely useful. Thus, this article examines an outline of a sound flagging gadget like a beeper or a signal and its working with applications.
Sound is Vibrations that moves through the air or another medium and can be heard when they come to at an individual's or alternately creature's ear. A buzzer or beeper is a signaling device, which produces sound. It might be mechanical, electromechanical, or piezoelectric.

A sound signaling device like a beeper or signal might be electromechanical, piezoelectric, or mechanical sort. The principle capacity of this is to change the sign from sound over to sound. For the most part, it is powered through DC voltage and utilized in clocks, caution gadgets, printers, alerts, PCs, and so forth in light of the different plans, it can create various sounds like caution, music, ringer and alarm.

Figure 32.Buzzer

The pin setup of the signal is displayed below. It incorporates two pins specifically positive and negative. The positive terminal of this is addressed with the '+' image or a more drawn out terminal. This terminal is controlled through 6Volts while the adverse terminal is addressed with the '- 'image or short terminal and it is associated with the GND terminal.

Two axel vehicles over loading violation with respect to standard axle's caring capacity with in a specific time data collection as primary source on trucks

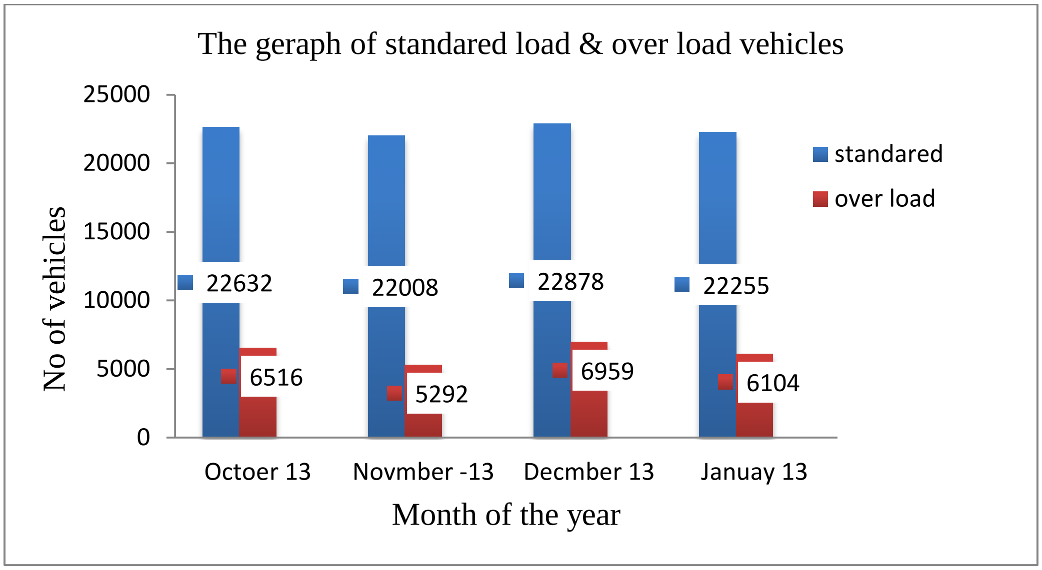


Figure33. (GVW) violation cases by month of the year (Oct 2013 - Jan 2013)

Even though the types of heavy vehicles/trucks may be classified by the number of axles, namely from the 2-axle up to the 5-axle trucks, the 2-axle trucks make up almost 62% of the total heavy vehicle population followed by 3-axle trucks, 20% and 4-axle trucks, 16.6% while the 5-axle trucks forms only around 1.4%. There for, the focus in this paper is mainly on the 2-axle trucks because they form the majority of the truck population in a traffic stream. In average it may be observed that the 2-axle trucks forms more than 62% of the total truck volume, of the GVW violation comes from heavy trucks as observed from the data. On the other hand, the occurrence of truck overloading for the four months period (October 2013 to January 2013) is illustrated in Figure 10. It is quite apparent that the pattern of over loading of truck is similar and consistent throughout the four months period trucks recording the highest number of violations. This finding could assist the planning of weight controlling and enforcement program priorities (RTA report, 2014 E.C).

Although the GVW violation rate may be considered rather high, what is more alarming is the range of GVW values and degree of overloading beyond the allowable limit for each months of heavy commercial vehicles data shows as we can see in(Figure 10). It can be observed that there are cases that the actual GVW is almost double the permissible GVW allowed by law for the particular commercial vehicle category. This phenomenon is probably non-existent in the developed countries but in developing countries this could be quite common. The significantly high GVW beyond the permissible level for each commercial vehicle category would be a cause of major concern especially in terms of the capability of handling the extra heavy commercial vehicle in emergency situations. As such, the extra heavy commercial vehicle may be hazardous and could compromise the safety of other road users should such situations arise. In addition, the fuel consumption of the extra heavy commercial vehicle will increase significantly and the final carbon footprint attributed to this extra heavy commercial vehicle will be higher than what it should be if the permissible GVW was abided to.

Amount of overload vehicles related with standard load in(%)

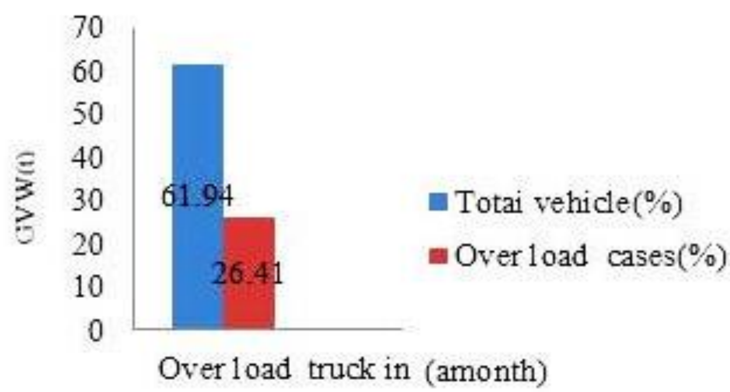


Figure 34 .Graph of weighed no of vehicles with (%) and overload vehicles (%) in 1 month

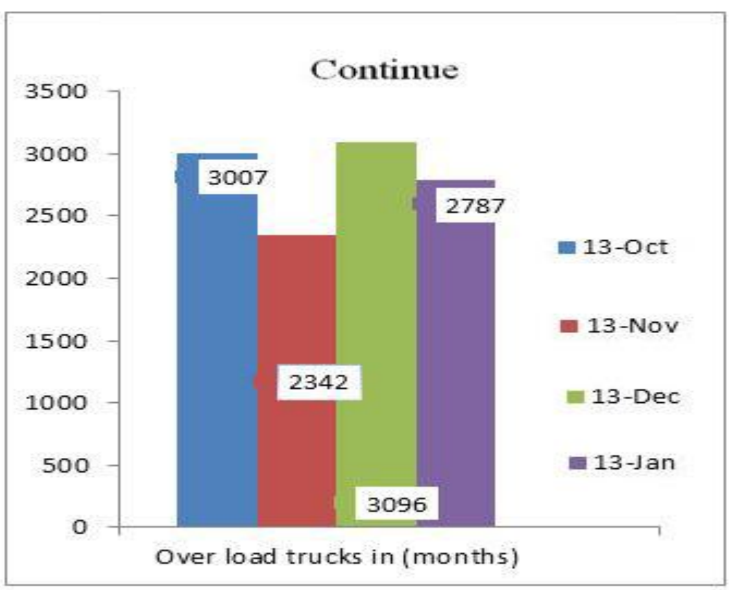


Figure 35.Graph of weighed no of overloaded trucks at study location

The extra heavy commercial vehicle would also have significantly higher axle loads beyond the permissible axle load (which is usually used in pavement design) which would increase the pavement deterioration significantly and shorten the pavement life well below what it was designed for. This is because the damage factor of the pavement surface is to the fourth power of the axle load.

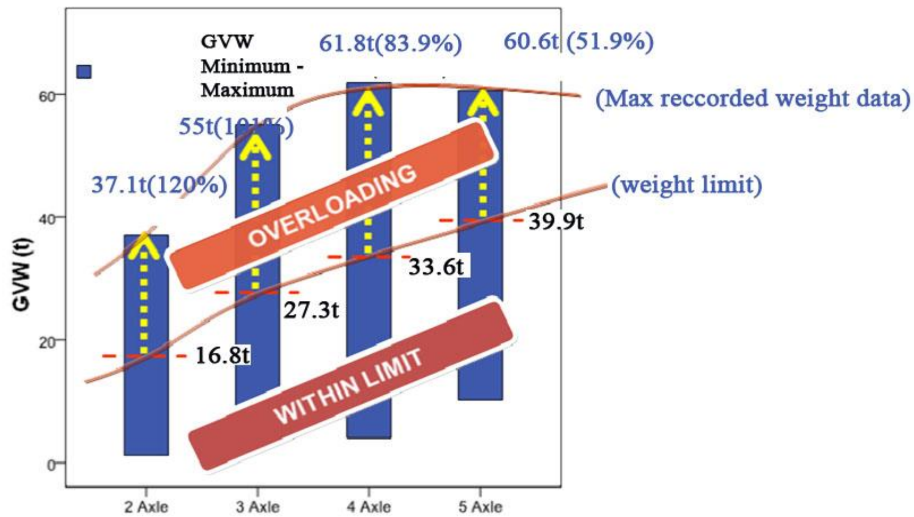


Figure 36.The relation of GVW and no of axles of over load Trucks

CHAPTER FOUR

4. Result and Dissociation

4.1. Overload results and discussion

The load sensor, contributed overload detection system which made it possible to detect the overloaded truck and transfer the relevant data to the micro-controller after the overload signal obtained. The system showed that overloaded vehicles could be accurately detected by this system, which has a very good practical prospect.

4.2. Static reaction force under the wheels

The set point of truck is the amount of load, which the truck can carry safely. Loading the truck with more weight than set point capacity caused overloading and put the vehicle more stress on the frame, suspension, and tires than they could handle. If the applied load (W) to the vehicle is equal to the payload weight (SP) of the vehicle, at this point the vehicle possesses maximum safe load limit. Warning signals would turn on with yellow LED, which notifies the vehicle, is escaping safe load limit status and pending to overload but still engine had function. If the load on the truck became exceeding from maximum set point warning signals would turn on with red LED which notifies the vehicle, is gone beyond safe load limit status, so buzzer provides an audio signaling along as if the applied load, (W) exceeds the payload weight (SP) of the truck, accordingly overload detected by the system. The fuel cut of the solenoid would be deactivated that causing fuel not to delivered. In addition to this, the fuel supply would be discontinuing which inactivates engine to generate power. When vehicle is parked on level road, the left side and right side of a vehicle are symmetry to each other then again the front side and rear side of this vehicle are not symmetric which in particular refers the distributing of weight within a trucks isn’t comparable. Because of parking road conditions and various external factors, the angle of inclination and height of center of gravity could fluctuate. Weight transformation takes place whenever the vehicle parked on an inclined road thereby wheels load and axles load varied instantly. However, the gross weight of a vehicle does not transform accordingly, which considered as safe load. Static reaction forces under each wheel are summarized in table 4.

Table 4.the analysis result of static reaction force under the wheel

Road condition	Front wheels		Rear wheels		Total weight
	R_{11}	R_{12}	R_{21}	R_{22}	
Level road	11250N	11250N	12500N	12500N	47500N
Inclined road	22228N	22228N	30233N	30233N	64922N

Strain values and reaction forces under each wheel

The condition of leaf spring exposed to strain with the variation of load throughout the dynamic journey of trucks. When a truck moved in different road conditions weight transformed from one side to the opposite side of the vehicle in which strain on the leaf spring fluctuated correspondingly. Integrated strain gauges with leaf springs attained the proportional strain value during vehicle operation. Wheels are supposed to withstand unlimited road profiles and as road condition punctuates hastily wheels exposed to weight disturbance. Wheels might also lose their contact with the road as the vehicle is accelerating upon a curved path and the other wheels hold out the total weight transformed. On the grounds of this, deformation in leaf spring raised and falls due to weight transformation while the vehicle moved in a variety of road conditions. At the time that a vehicle is travelling along different road conditions, strain values for every wheel of the vehicle are summarized in the following tables. In addition, strain value of leaf spring obtained during static condition, which helped to understand overload status, and stability condition of the vehicle. When a vehicle moved across different road conditions, weight shifted from one side to the opposite side of the vehicle. As the strain on the leaf spring changed, the vehicle's motion changed correspondingly.

Strain value for front wheel (ε_{11}) under static and dynamic condition;

Front wheel experiences different road conditions and the corresponding deformation on the leaf spring fluctuates according to road conditions. Results for static and dynamic conditions are shown in Table 5.

Table 5.Strain value for front wheel (ε_{11}) under static and dynamic condition

Loaded truck			
	Front wheel(R_{11})	Load at front wheel(R_{11})	Strain value(ε_{11})of front leaf spring
Static condition(When the vehicle is parked)	Level road	11250N	0.403
	Inclined road	22228N	O.398
Dynamic condition(when vehicle is in motion)	Accelerating at level road	21658.9N	O.393
	Decelerating at level road	156093N	0.283
	Accelerating at inclined road	14372N	0.260
	Decelerating at inclined road	81309N	1.469

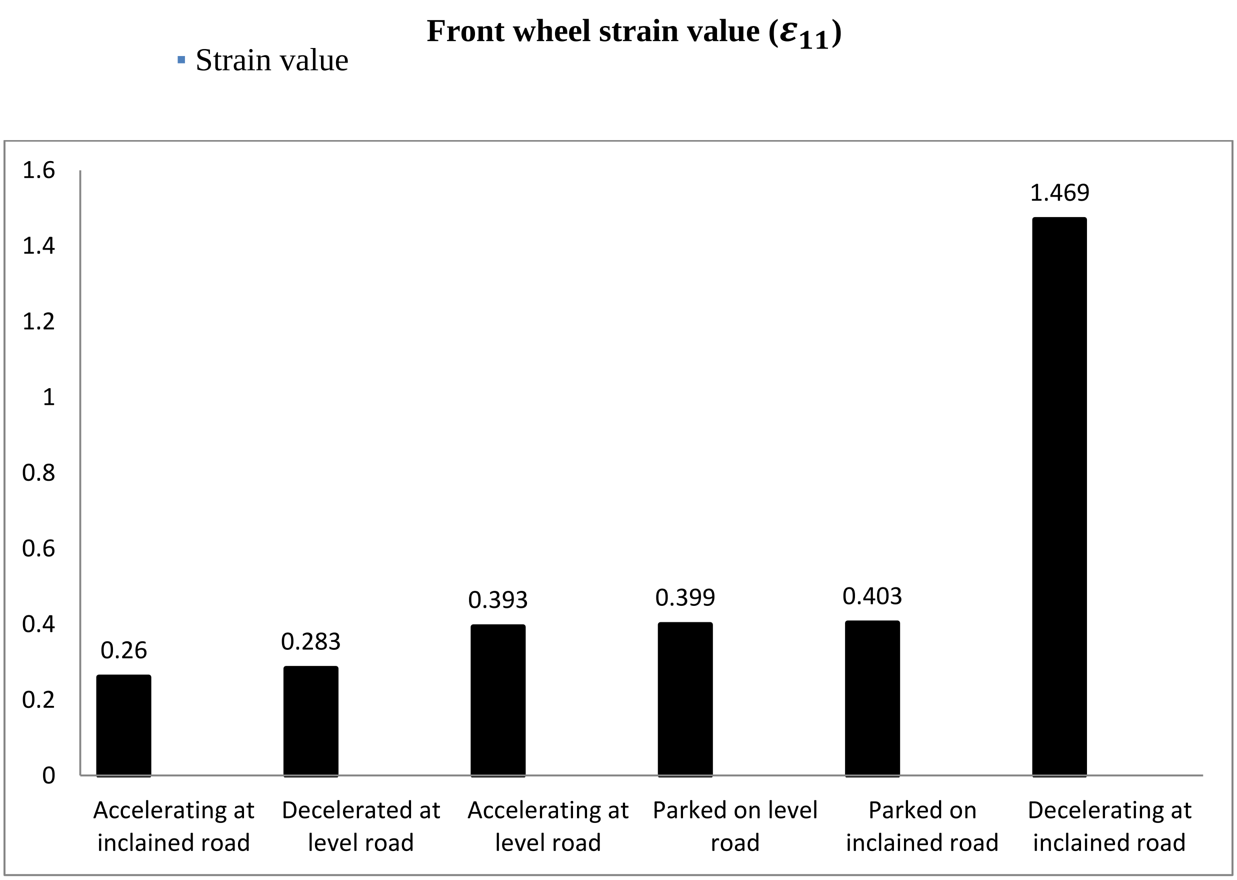


Fig 37.Strain value for front wheel (ε_{11}) under static and dynamic condition.

When the vehicle turned on its minimum turning radius upon a curved path, then the leaf spring of the truck had showed least deformation than the deformations throughout different road conditions. This indicated that when the vehicle turns on a curved path and the weight of the vehicle shifted out from the inner front wheel to the outer front wheel due to centripetal force. However, this leaf spring remains extremely deformed while decelerating on a level road. The strain fluctuates from 0.260 to 1.469. The maximum strain value during decelerating does not have an impact on the truck as it showed that the driver is having full handling over the vehicle's speed.

Strain value for front wheel (ε_{12}) under static and dynamic condition;

Front-wheel experienced different road conditions and the corresponding deformation on leaf spring fluctuated depending on various road conditions. Results for static and dynamic conditions are shown in Table 6.

Table 6.Strain value for front wheel (ε_{12}) under static and dynamic condition

Loaded truck			
	Rear wheel(R_{12})	Load at rear wheel(R_{12})	Strain value(ε_{12}) of front leaf spring
Static condition(When the vehicle is parked)	Level road	55125N	0.399
	Inclined road	22228N	0.403
Dynamic condition(when vehicle is in motion)	Accelerating at level road	21658.9N	0.393
	Decelerating at level road	8915N	0.283
	Accelerating at inclined road	14372N	0.260
	Decelerating at inclined road	82309N	1.469

Front wheel strain value ($\boldsymbol{\varepsilon_{12}}$)

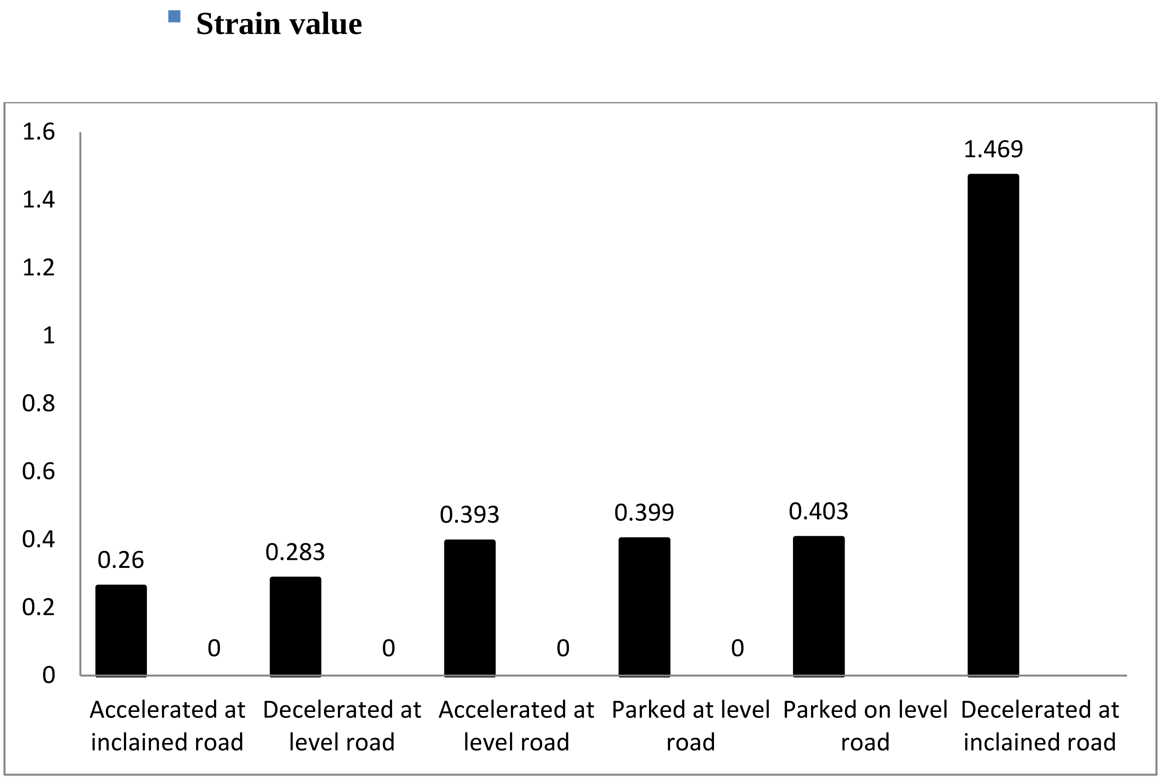


Fig 38.Strain value for front wheel $(\boldsymbol{\varepsilon_{12}})$ under static and dynamic condition.

When the vehicle turns at its minimum turning radius upon a curved level path then the strain value does not experience deflection. The weight of the vehicle shifted out from the inner rear wheel to the outer rear wheel. Conversely, this leaf spring remains exceedingly deformed while the vehicle is accelerating at an inclined road. The value of strain fluctuates between 0.260 and 1.469. While the vehicle is accelerating on a curved path, the leaf spring comes across with no deflection. This specifies that the wheel has lost contact with the ground and the vehicle is accelerating at a critical speed. The vehicle should not drive above the critical speed otherwise; the vehicle could lose control and exposed to instability, which might results catastrophic consequences such as to roll over.

Strain value for rear wheel (ε_{21}) under static and dynamic condition;

Rear- wheel experiences different road conditions and the corresponding deformation on the leaf spring fluctuates according to road conditions. Results for static and dynamic conditions are shown in Table 7.

Table 7.Strain value for rear wheel (ε_{21}) under static and dynamic condition

Loaded truck			
	Rear wheel(R_{21})	Load at rear wheel(R_{21})	Strain value(ε_{21}) of rear leaf spring
Static condition(When the vehicle is parked)	Level road	55,125N	1.000
	Inclined road	30233N	0.548
Dynamic condition(when vehicle is in motion)	Accelerating at level road	94780.98N	1.719
	Decelerating at level road	8915.7N	0.161
	Accelerating at Inclined road	81309N	1.475
	Decelerating at Inclined road	86566N	1.564

Rear- wheel strain value (ε_{21}) strain value

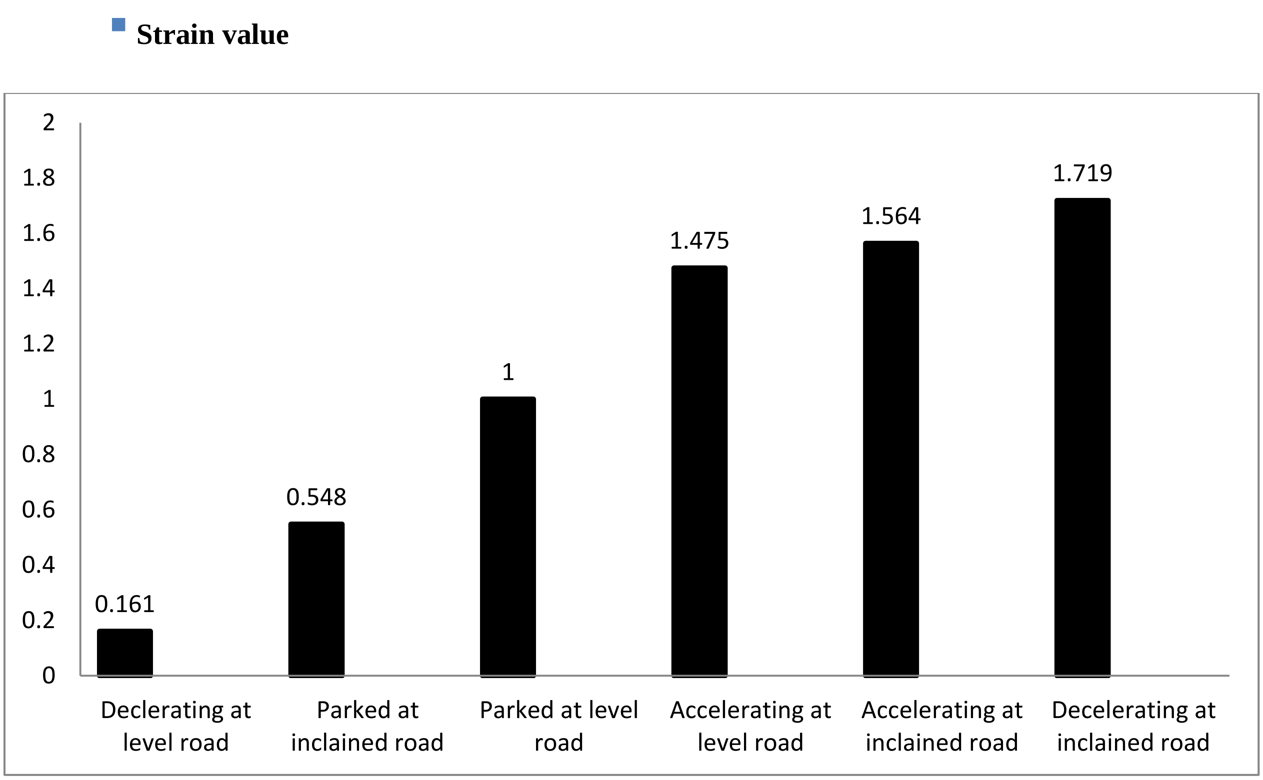


Fig 39. Strain value for rear wheel ($\boldsymbol{\varepsilon_{21}}$) under static and dynamic condition.

When the vehicle accelerates at an inclined road then the leaf spring integrated into the wheel experiences the least deformation value than the deformations all the way through different road conditions. On the other hand, this leaf spring extremely deformed while the vehicle is turning on a curved path. The strain ranges from 0.161 to 1.564**.** There is wide strain variation between the lowest and the highest value, which conforms that the wheel is undergoing inestimable instabilities as the road conditions are exchanging suddenly.

Strain value for rear wheel under static and dynamic condition

Rear wheel experiences different road conditions and the corresponding deformation on the leaf spring fluctuates according to road conditions. Results for static and dynamic conditions are shown in Table 8.

Table 8.Strain value for rear wheel (ε_{22}) under static and dynamic condition

Loaded truck			
	Rear wheel(R_{22})	Load at rear wheel(R_{22})	Strain value(ε_{22}) of rear leaf spring
Static condition(When the vehicle is parked)	At level road	61.250N	1.11
	At inclined road	30233N	0.548
Dynamic condition(when vehicle is in motion)	Accelerating at level road	94780.98N	1.719
	Decelerating at level road	8915.7N	0.161
	Accelerating at Inclined road	81309N	1.475
	Decelerating at Inclined road	86566N	1.564

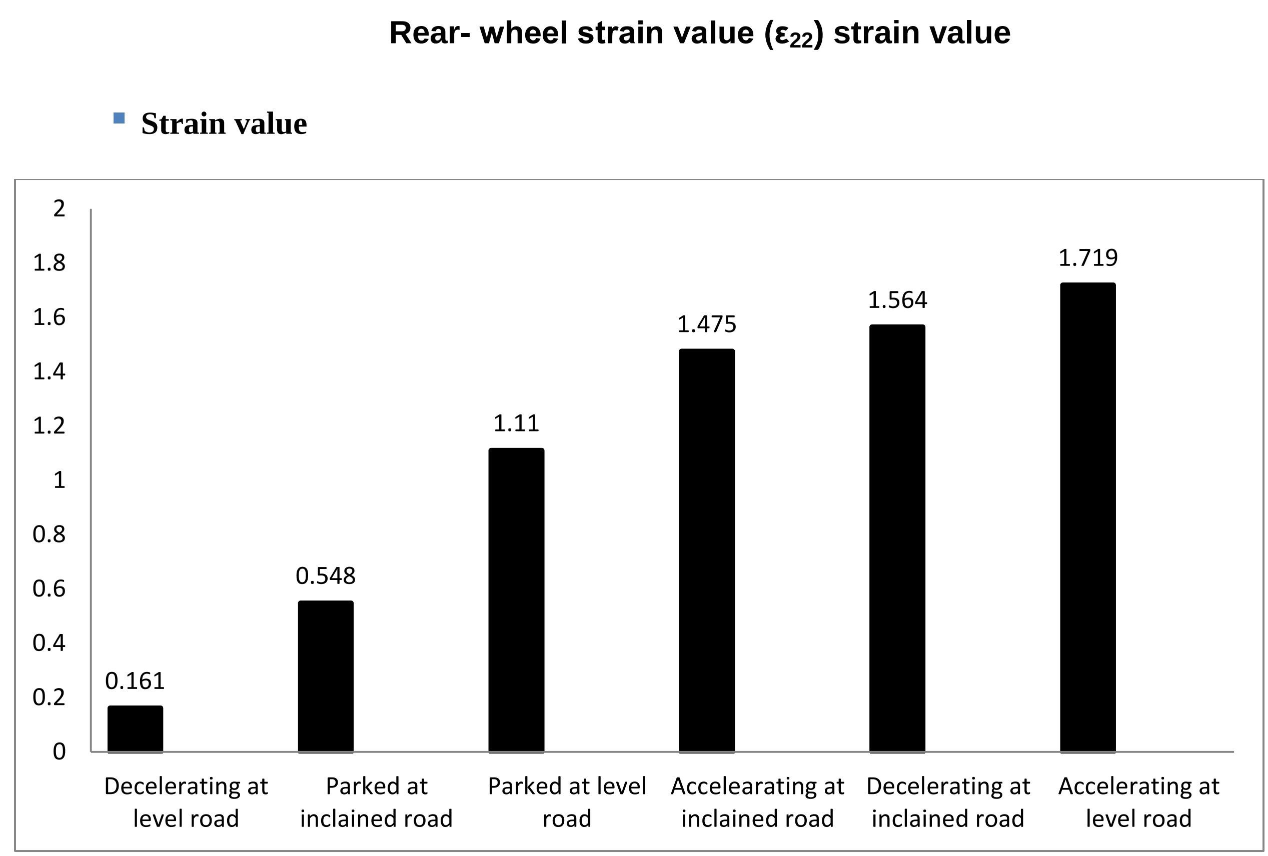


Fig 40. Strain value for rear wheel ($\boldsymbol{\varepsilon_{22}}$) under static and dynamic condition.

The least deformation is when the vehicle decelerates on a level road, which clearly implies driver is regulating the speed of the vehicle. On the other hand, the leaf spring is extremely deformed and distorted while the vehicle is turning on a curved path. The strain ranges from 0.161 to 1.719. There is extensive strain variation between the lowest and the highest strain value, which conforms that the wheel is undergoing inestimable instabilities as the road conditions are exchanging continuously. Therefore, it is highly recommended to limit the speed during the time that the vehicle is turning in a curved path in order to moderate stability. The strain value attained while the vehicle moves at a maximum safe speed through a curved path adjusts the instability reference point of the vehicle.

CASE 1: If the strain value of one of the leaf springs is less than the specified reference value 1.719, the vehicle moves under stable conditions. Relative to the accelerating truck speed, the weight transformation from one side of the vehicle to the other side of the vehicle achieves a safe and stable movement.

CASE 2: If the strain value of one of the leaf springs is equal to a predetermined reference value of 1.719, then the truck instability reaches the maximum safe limit and the warning signals activated with yellow LED light that notifies the driver that the truck is in a state of instability.

CASE 3: If the strain value of one of the leaf springs exceeds the specified reference value 1.719 to a certain extent, the truck would became unstable.

4.3. Protus soft wear results

Parameters used

Sino Track

- Maximum load to carry 135 quintal or 13700 Kg
- Tolerance load to carry 3 quintal or 300Kg allowance

In addition, this system is applicable for any types of car by adjusting the maximum allowable load by set point and it is practically implemented with small cost and integrating with engine locking system. This system has two sensor for more reliable and accuracy purpose.

4.3.1. Case I

If the load (W<SP) is lower than the maximum allowed load as you could see in the picture the below LCD displays the amount of weight exist in the Sino track and the fuel pump is running and the green LED indicates the load is under and normal.

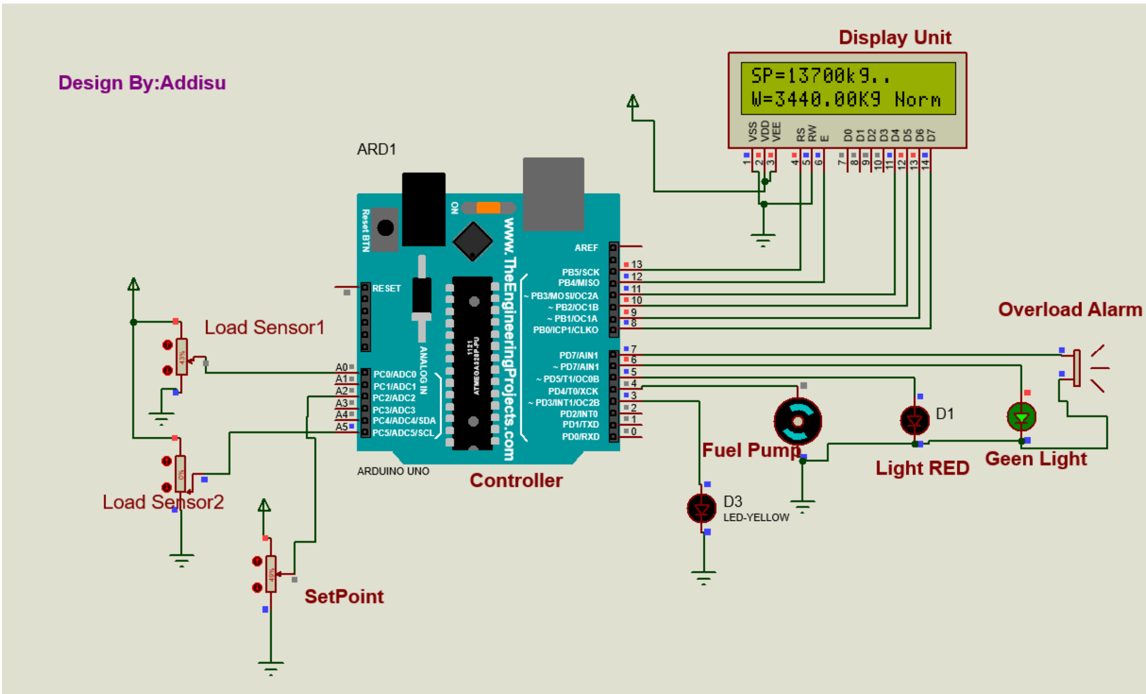


Figure 41.The image of safe truck load system.

4.3.2. Case II

If the load a little bit more than set point (W>SP) in the maximum tolerable weight that means it warning is seen on LCD with yellow LED light blowing.

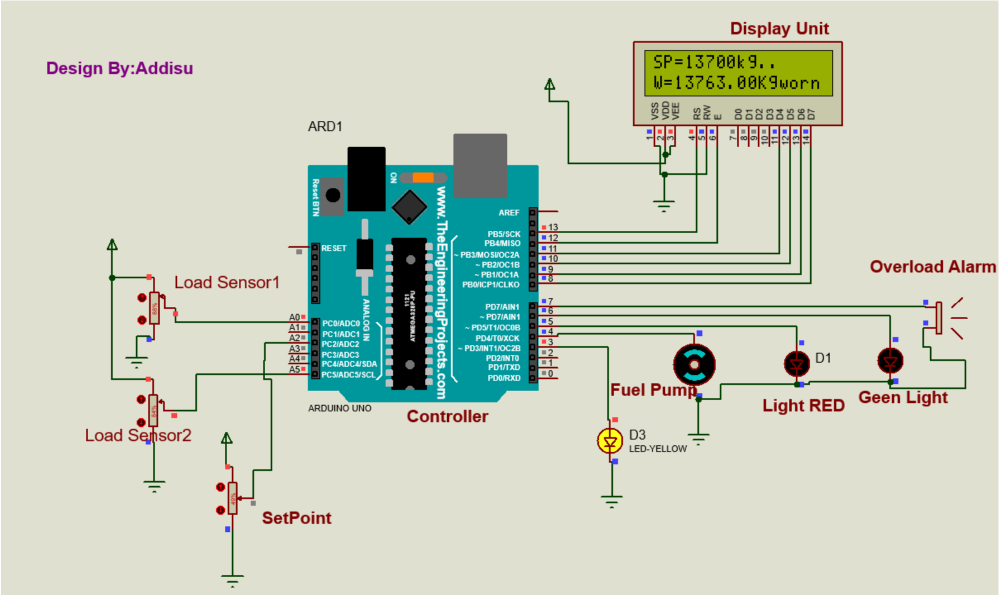


Figure 42.The image of overload and warning system.

4.3.3. Case III

If the load is above the maximum allowed weight (W>SP) automatically engine stopped its operating function with red LED light and buzzer give sound in the form of alarm countinousely.

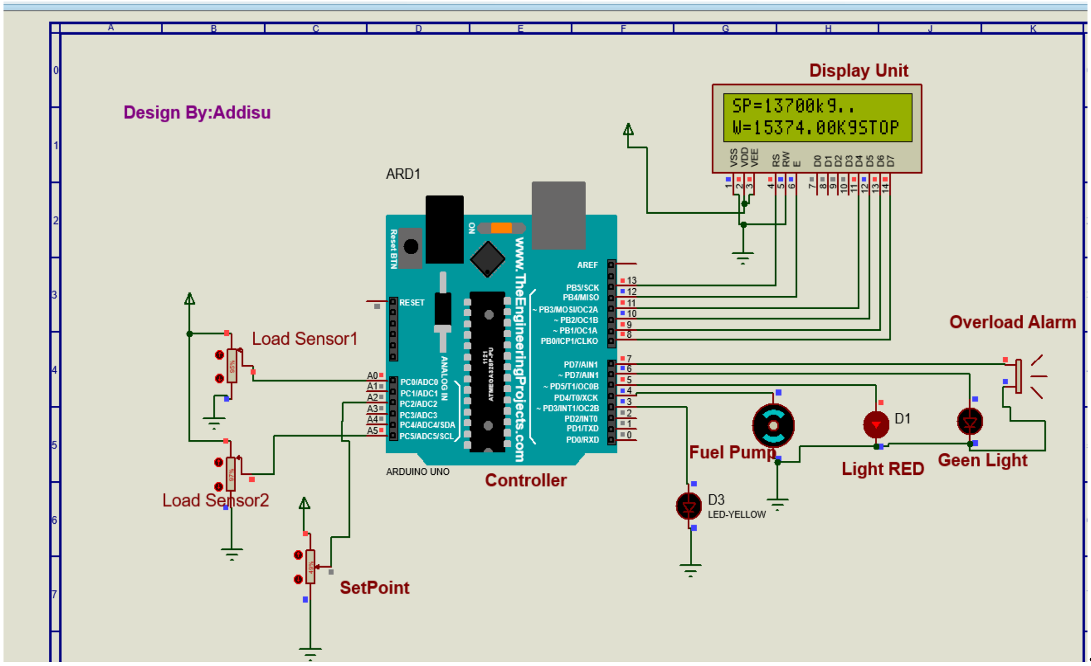


Figure 43.The image of overload and controlling system.

In the case (I)

As you could see in the figure the LCD displays the amount of weight/set point exist in the Sino track and the fuel pump is running and the green led indicates the load would under and normal condition.

In the case (II)

If the load would have been in the maximum tolerable weight that means it could have been above the load but it would in the warning and the fuel pumped to operate the engine the yellow led indicates warning even if not recommended and it didn't bring damage.

In the case (III)

This case would be the fuel pump is stopped it never be pumping unless the load is subtracted. The Red Led is blinking and the Buzzer is running to alarm the driver to subtract the load. The LCD display the exact amount of weight added to the car.

CHAPTER FIVE

5. Conclusion and Recommendation

5.1. Conclusion

Overload monitoring or controlling system is becoming increasingly important and it is more secured than other systems to save several things in the developing countries. It is completely integrated, so that once it is implemented in all vehicles, then it is possible to control the vehicles/trucks over loading. By using sensors, circuits, Microcontroller and solenoid valve as controlling device for transportation system.

Controlling method in this research can reduce over loading and related problems such as crowdedness, fuel consumption, the vehicles unusually reaction when they carry exceeded maximum weights for which they are outlined hence the vehicle become less firm, difficult to lead and takes longer to halt, decrease the tires of vehicle to overheat and rapidly wear out which can get worse by time, overloaded vehicle’s head light will lean upwards at night, glaring the approaching drivers to possible detritus or hindrance on the road, the brakes of vehicle as the vehicle is ponderous due to overloading, work hard because of ‘the riding of brakes’ and hence lose their efficiency to halt the vehicle due to overheating, overloading make the vehicle hard to outdo as vehicle cannot expedite normally, there is stress in the suspension system of vehicle, the infirm point can yield over time and affect shock absorbers it influences steering and finally vehicles insurance cover may be empty as overloading is illegitimate and car accident in transportation system.

In the result shown in chapter four, if the load on the truck is above the required, the buzzer alarm start sounding with blinking yellow light. If the driver adjust his loading effect in set point manner the engine works properly as usual with blinking green light for correctness, unless this situation is fulfilled the sensors transmit messages for the condition of load from axels immediately Microcontroller control automatically sends the message to the solenoid valve to stop fuel from interring to injection pump to stop engine working. This system has many advantages such as large capability, convent for all vehicles, low operation costs ones it is installed, effective, Strong and the system also very convenient to install when compared with the traditional control methods, the control system designed in this paper responses quickly and it can save a lot of manpower, material and financial resources.

5.2. Recommendation

Following recommendations can help to control the overloading.

1. As overloading is increasing, it has to be controlled by adapting or using self-controlling mechanisms of vehicles/ trucks.
2. Use of networking technology like GPS and MOBAIL phone with vehicles should be encouraged for better and effectiveness of control overloading.
3. Besides this rules and regulations have been sated properly for effective control of over loading. Effective means of managing truck overloading is not unitary. It must be combined with monitoring, inspection, enforcement and punishment as a complete. So fines must be associated with intensified enforcement when considered in further strategy recommendations.
4. Training must be mandatory for property owners, drivers, bloggers and another stack holder since over loading is a contributor for different risks.
5. Another technological remedies and solutions should be encouraged, because such kind of situations helps to develop countries economy by reducing unnecessary distractions.

6. REFERENCES

Abaza, Khaled A. (2000). Optimum Flexible Pavement Life-Cycle Analysis Model. Journal of transportation Engineering / November / December 2002:9.

Abaza, Khaled A and A. M. Suara. (2015). the structural wear of road pavements: an assessment of the fourth power law on the A1 (M) motorway in County Durham. Engrs Transp: 9.

Abaza, Khaled A and J.Middleton. (2004). the effect of dynamic loading on road pavement Wear: a study of the relationship between road profiles and pavement wear on an instrumented test road. Engrs Transp: 12.

Addis, R. R. (2003). International collaboration in accelerated pavement testing. Engrs Transp: 12.

Aman Kishore and Rod Klashinsky. (2010). Prevention of Highway infrastructure damage through commercial vehicle weight enforcement. In Annual Indian Road Congress (IRC) Session. Calcutta.

Hewage.D. & Ramayana, H. (2017). Factors Affecting the Service Quality in Public Bus Transportation in Sri Lanka.

Ejiogu, Okechuku, E., Madonsela, N. S., & Adetunla, A. (2020). The effect of transportation infrastructure on economic development. Proceedings of the International Conference on Industrial Engineering and Operations Management, 59(February), 1213–1220.

Richard E. Schuler. et al (1997). The economic impacts of a divisible-load permit system for heavy vehicles. Transpn Res.-A 32:13.

Austroads. (2014). Pavement design: a guide to the structural design of road pavements, Pavement technology series.

Thom N. H. et al (2011). The use of weigh-in-motion data in pavement design. Transport 147:10.

Batelaan, Justin. (2013). A thin-walled, dual-curved, steel band wheel with inherent spring suspension for use on heavy vehicles. Thin-Walled structure 41:12.

Curtis Berthelot et al (2012). The importance of commercial vehicle weight enforcement in safety and road asset management. In Traffic Technology International annual Review. Canada.

Cottineau, L-M., Hornych, P., Jacob, B., Schmidt, F., Dronneau, R., Kelin, E. (2015).

Tailor B., Bergan A., Lindgren N., Berthelot C., 2000. The Importance of commercial vehicle weight enforcement in safety and road asset management. s

American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS**) 2019**) Volume 58, No 1, pp 159-181

Burnos P., Rys D., 2017. The Effect of Flexible Pavement Mechanics on the Accura of Axle Load Sensors in Vehicle Weigh-in-Motion Systems, Sensors, vol.17,

Mohammadi J., Shah N., 1992. Statistical evaluation of truck overloads. Journal of Transportation Engineering, 118, 651-665.

(https://www.futek.com/how-a-load-cell-works).

Zhao Y., Tan Y., Zhou C., 2012. Determination of axle load spectra based on percentage of overloaded trucks for mechanistic-empirical pavement design. Journal of Road Materials and Pavement Design, Vol. 13, nr 4, 850-863, 2012.

Fiorillo G., Ghosn M., 2014. Procedure for statistical categorization of overweighs vehicles in a WIM database. Journal of Transportation Engineering, 140(5).

Al-Qadi I., Ouyang Y., Wang H., Meidani H., Gungor O. E., Petit A., Zhao J., Qiu J.,(2017) development of Overweight Vehicle Permit Fee Structure in Illinois.

Dey, K., Chowdhury, M., Wiecek, M., and Dunning, A., 2015. Infrastructure Damage Cost-Recovery Fee for Overweight Trucks: Tradeoff Analysis Framework. Journal of transportation engineering.

Oskar ski J., Kaszubowski D., 2016. Implementation of Weigh-in-Motion system in freight raffic management in urban areas. 2nd International Conference Green Cities - Green Logistics for Greener Cities, Transportation Research Procedia, vol.16, 449-463

Stanczyk, D. (2009). Etalon age automatique des stations de pesage. *Acte de la journée national pesage en marche*. LCPC, Paris.

Labry, D., Dolcemascolo, V., Jacob, B. and Stanczyk, D. (2005). Piezoelectric Sensors for Weigh-inmotion: Sensor Behaviour Analysis and Recommendation. In Post-Proceedings Of the 4thInternational Conference on Weigh-In-Motion. February 20-22,
DANIEL, L. (2013). October, 2013 Addis Ababa, Ethiopia.

Dr. Bayan M. Sabbar1, A. I. A. (2016). GPS-GPRS Control and Tracking System for fuel trucks via Processing of Travelling Information. IJCSET Dec, 7(6), 1002–1011.

Ejiogu, Okechuku, E., Madonsela, N. S., & Adetunla, A. (2020). The effect of transportation infrastructure on economic development. Proceedings of the International Conference on Industrial Engineering and Operations Management, 59(February), 1213–1220.

Gurjar, S. S., & Mishra, R. (2019). Vehicle Overloading Detection and Protection using Raspberry Pi and IOT Application. 10098–10104.

https://doi.org/10.15680/IJIRSET.2019.0810033

Hadiwardoyo, S. P., Sumabrata, R. J., & Berawi, M. A. (2012). Tolerance Limit for Trucks with Excess Load in Transport Regulation in Indonesia. MAKARA of Technology Series, 16(1). https://doi.org/10.7454/mst.v16i1.1336

Hewage, D., & Ranawana, H. (2017). Factors Affecting the Service Quality in Public Bus Transportation in Sri Lanka Factors Affecting Service Quality in Public Bus

Transportation in Sri Lanka. Proceedings of 8th International Research Conference, KDU, Published November 2015, August 2015, 103–109.

Hu, S., Kong, M., & She, C. (2017). Design of vehicle overload detection system based on geophone. Journal of Physics: Conference Series, 887(1).

https://doi.org/10.1088/1742- 6596/887/1/012021 Page | 90

Jihanny, J., Subagio, B. S., & Hariyadi, E. S. (2018). The analysis of overloaded trucks in Indonesia based on weigh in motion data (east of sumatera national road case study). MATECWebof Conferences, 147, 1–6.

https://doi.org/10.1051/matecconf/201814702006

Karim, M. R., Abdullah, A. S., Yamanaka, H., & Abdullah, A. S. (2013). Degree of Vehicle Overloading and its Implication on Road Safety in Developing Countries. 3(12), 20–32. Kattimani, H. D., Meghana, N. R., Nagashree, B., Munegowda, S., & Vijayalakshmi, S. (2017) Vehicular Overload Detection and Protection .‖ 119–122.

KIBRET, G. (2015). School Of Graduate Studies Truck Overload Fine Rationalization On Ethiopian Primary Roads A Case Study On Addis Ababa -Adama Expressway A thesis submitted to the School of Graduate Studies of. July.

Kishore, L., & Raja, A. (2015). Advanced Vehicle Tracking System Using ARM7. 4(1), 14–20.

Matsagar, V. (2015). Advances in structural engineering: Materials, volume three. Advances inStructural Engineering: Materials, Volume Three, January 2015, 1619–2647.

https://doi.org/10.1007/978-81-322-2187-6

Dr. Bayan M. Sabbar1, A. I. A. (2016). GPS-GPRS Control and Tracking System for Fuel trucks via Processing of Travelling Information. IJCSET Dec, 7(6), 1002–1011.

Ejiogu, Okechukwu, E., Madonsela, N. S., & Adetunla, A. (2020). The effect of transportation infrastructure on economic development. Proceedings of the International Conference on Industrial Engineering and Operations Management, 59(February), 1213–1220.

Hadiwardoyo, S. P., Sumabrata, R. J., & Berawi, M. A. (2012). Tolerance Limit for Trucks with

Excess Load in Transport Regulation in Indonesia. MAKARA of Technology Series, 16(1). https://doi.org/10.7454/mst.v16i1.1336

Hewage, D., & Ranawana, H. (2017). Factors Affecting the Service Quality in Public Bus transportation in Sri Lanka Factors Affecting Service Quality in Public Bus transportation in Sri Lanka. Proceedings of 8th International Research Conference, KDU, Published November 2015, August 2015, 103–109.

Hu, S., Kong, M., & She, C. (2017). Design of vehicle overload detection system based on geophone. Journal of Physics: Conference Series, 887(1).https://doi.org/10.1088/1742-6596/887/1/012021

Jacob, O. O., Callistus Chukwudi, I., Oforegbunam Thaddeus, E., & Agwu, E. E. (2020). Estimation of the Impact of the Overloaded Truck on the Service Life of Pavement Structures in Nigeria. International Journal of traffic and transportation engineering, 2020(2), 41–47. https://doi.org/10.5923/j.ijtte.20200902.03

Jaskula, P. (2018). Effect of Overloaded Vehicles on Whole Life Cycle Cost of Flexible Pavements. July, 0–15. https://doi.org/10.1007/978-3-319-95789-0

Jihanny, J., Subagio, B. S., & Hariyadi, E. S. (2018). The analysis of overloaded trucks in Indonesia based on weigh in motion data (east of sumatera national road case study). https://doi.org/10.1051/matecconf/201814702006

Karim, M. R., Abdullah, A. S., Yamanaka, H., & Abdullah, A. S. (2013). Degree of Vehicle Overloading and its Implication on Road Safety in Developing Countries. 3(12), 20–32.

Kattimani, H. D., Meghana, N. R., Nagashree, B., Munegowda, S., & Vijayalakshmi, S. (2017). Vehicular Overload Detection and Protection.‖ 119–122.

KIBRET, G. (2015). School Of Graduate Studies Truck Overload Fine Rationalization On Ethiopian Primary Roads A Case Study On Addis Ababa -Adama Expressway A thesis submitted to the School of Graduate Studies of. July.

Kishore, L., & Raja, A. (2015). Advanced Vehicle Tracking System Using ARM7. 4(1), 14–20.

Matsagar, V. (2015). Advances in structural engineering: Materials, volume three. Advances in Structural Engineering: Materials, Volume Three, January 2015, 1619–2647. https://doi.org/10.1007/978-81-322-2187-6

Noman, A. T., Hossain, S., Islam, S., Islam, M. E., Ahmed, N., & Mahmud Chowdhury, M. A. (2019). Design and implementation of microcontroller based anti-theft vehicle security system using GPS, GSM and RFID. 4th International Conference on Electrical engineering and information and Communication Technology, ICEEiCT 2018, February 2019, 97–101. https://doi.org/10.1109/CEEICT.2018.8628051

Odonkor, E. N., & K. Ofosu, W. (2020). Design and Construction of Vehicle Loading Monitoring System Using Load Sensor and GSM. International Journal of Applied Science and Technology, 10(1). https://doi.org/10.30845/ijast.v10n1p1

Olufemi Jacob, O., Callistus Chukwudi, I., Oforegbunam Thaddeus, E., & Ejem Agwu, E. (2020). Analysis of the Extent of Overloading on the Nigerian Highways. International Journal of Transportation Engineering and Technology, 6(1), 22.

https://doi.org/10.11648/j.ijtet.20200601.14 Pa

Reddy, R. (2015). Analysis of Overloading Prevention System in Trucks. International Journal on Emerging Technologies, 6(2), 224–228.

Rievaj, V., Vrábel, J., Synák, F., & Bartuška, L. (2018). The Effects of Vehicle Load on Driving characteristics. Advances in Science and Technology Research Journal, 12(1), 142–149. https://doi.org/10.12913/22998624/80896

Rys, D., & Jaskula, P. (2019). Effect of Overloaded Vehicles on Whole Life Cycle Cost of Flexible Pavements. Sustainable Civil Infrastructures, July, 104–117.

https://doi.org/10.1007/978-3-319-95789-0_10

S, J. G., & Vignesh, M. (2019). Truck Weighing Based on the Suspension of the Vehicle. May, 6678–6682. Sara Behailu. (2016). Addis Ababa Institute of Technology School Of Civil and environmental Engineering Evaluation of Vehicle Overload Control System on major road corridors in Ethiopia a thesis in road and transport engineering. Shah, P. B., & Nepali, B. B. (2020).

Impact of Overloaded Vehicles on Flexible Pavement: Case Study of Belhiya-Butwal Road in Nepal. 17(5), 49–61.

Appendices

Longitudinal center of mass for trucks

Where

R_1= Front axle reaction force

R_2 = Rear axle reaction force

R_{11} = Front axle right side reaction force

R_{12} = Front axle left side reaction force

R_{21} = Rear axle right side reaction force

R_{22} = Rear axle left side reaction force

a_1 = the distance of the car‘s mass center from the front axle

a_2 = the distance of the car‘s mass center from the rear axle

h = Height of center of gravity

m= Mass of the vehicle

l = Wheel base

C.G = Center of gravity

K = Leaf spring stiffness

r= radius of the wheel

The gross weight of the vehicle is 245000N. The 45% of the total weight of the vehicle is distributed to the front axle and 55% of the total weight is distributed to the rear axle.

Front axle load (R_1) = 110250 N or 11250 kg

Rear axle load (R_2) = 122500N or 12500 kg

(Gross vehicle weight)GVW = Front axle load (R_1) + Rear axle load (R_2)

GVW = 110250N + 122500N = 245000N

Front axle load (R_1) = (Front left wheel load) R_{11} + (Front right wheel load) R_{12}

(Front left wheel load) R_{11} = (Front right wheel load) R_{11} = 55125N

Rear axle load (R_2) = (Rear left wheel load) R_{21} + (Rear left wheel load) R_{22}

(Rear left wheel load) R_{21} = (Rear left wheel load) R_{22} = 61250N

The value of a_1 and a_2

Where (L) wheel base

$l = a_1 + a_2$

$$a_1 = \frac{(l)(R_2)}{mg}$$

$$= \frac{5.65\text{m} \times 122{,}500\text{N}}{(25{,}000\text{kg} \times 9.81\text{m/s2})}$$

=2.825m

$$a_2 = \frac{(l)(R_1)}{mg}$$

$$\frac{5.65\text{m} \times 110{,}250\text{N}}{(25{,}000\text{kg} \times 9.81\text{m/s2})}$$

=2.54m

From truck, model the tire specification, 1200−R20

r = 0.628m

$2R_{11} = 110250\text{N}$

$a_2 = 2.54\text{m}$

l = 5.65m

$\varphi = 15^0$

W = mg

= 25000kg x 9.81m/s2

245000N

There for

$$h = (r) + \left(2\frac{R11}{mg}l - a2\right)\cot\emptyset$$

$$= (628\text{m}) + \left(2\frac{110{,}250\text{N}}{245{,}000\text{kgx}9.81\text{m/s2g}} \times 5.65\text{m} - 2.54\text{m}\right)\cot 15$$

h=2349mm

There are three assumptions in this calculation:

The tires are thought to be rigid disks with radius, r.

Fluid shift, such as fuel, coolant, and oil ignored.

Suspension deflections assumed zero.

$$\tan(\emptyset) = \frac{a_2\mu_x}{l - h\mu_x}$$

$$\tan(\emptyset) = \frac{\frac{2.54\text{m}}{\text{s2}} \text{ x } 0.85}{5.65m - (2.349m \text{ x } 0.85)}$$

$$\tan(\emptyset) = 0.59$$

$$\emptyset = \tan(0.59)$$

$$\emptyset = 30 \text{ degree}$$

When the vehicle is carrying the maximum load (payload) on inclined road, the reaction forces under each wheel are calculated as follow.

$$\mathrm{R}_{11} = \mathrm{R}_{12} = \frac{1}{2} mg \left(\frac{a_2}{l} \cos\emptyset\right) - \frac{1}{2} mg \frac{h}{l} \sin\emptyset$$

$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2}) \left(\frac{2.54\text{m}}{5.65\text{m}} \cos 30\right) - \frac{1}{2}(25{,}000\text{kg} \times 9.8\text{m/s2}) \frac{2.349m}{5.65\text{m}} \sin 30$$

$$\mathrm{R}_{11} = \mathrm{R}_{12} = 22228 \text{ N}$$

$$\mathrm{R}_{21} = \mathrm{R}_{22} = \frac{1}{2} mg \left(\frac{a_1}{l} \cos\emptyset\right) + \frac{1}{2} mg \frac{h}{l} \sin\emptyset$$

$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2}) \left(\frac{2.825\text{m}}{5.65\text{m}} \cos 15\right) + \frac{1}{2}(25{,}000\text{kg} \times 9.8\text{m/s2}) \frac{2.349m}{5.65\text{m}} \sin 30$$

$$\mathrm{R}_{21} = \mathrm{R}_{22} = 30233\text{N}$$

Strain and load analysis of leaf spring for SINOTRUCK

$$\varepsilon = \frac{6\Delta xh}{l^2}$$

Where

ε = 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,

$$\Delta \mathbf{x} = \frac{\varepsilon l^2}{6h}$$

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:

$$K\ (x - x_1) = mg$$

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

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

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

$$W = ß\ (\ \varepsilon_{11} + \ \varepsilon_{12} + \ \varepsilon_{21} + \ \varepsilon_{22})g$$

$$Kl^2\ (\frac{(\ \varepsilon_{11} + \ \varepsilon_{12} + \ \varepsilon_{21} + \ \varepsilon_{22})}{6h}$$

$$\varepsilon = \frac{6mgh}{Kl^2}$$

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

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

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

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

Calculation of strain values and reaction force under static condition

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 22228 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2}$$

$$= \ 0.403$$

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} \quad = \frac{(6 * 2.349m * 22228 \text{ N})}{24330 \text{ N/m} * (5.65 \text{ m})^2}$$
$$= 0.403$$
$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} \quad = \frac{(6 \times 2.349\text{m} \times 30233 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2}$$
$$= 0.548$$
$$\varepsilon_{22} = \frac{6hR_{21}}{kl^2} \quad = \frac{(6 \times 2.349 \text{ m} \times 22228 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2}$$
$$= 0.548$$
$$\mathrm{R}_{11} = \mathrm{R}_{12} = \frac{1}{2}mg\left(\frac{a_2}{l}\cos\emptyset\right) - \frac{1}{2}mg\frac{h}{l}\sin\emptyset$$
$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2})\left(\frac{2.54\text{m}}{5.65\text{m}}\cos 30\right) - \frac{1}{2}(25{,}000 \times 9.8\text{m/s2})\frac{2.349m}{5.65\text{m}}\sin 30$$
$$\mathrm{R}_{11} = \mathrm{R}_{12} = 22228 \text{ N}$$
$$\mathrm{R}_{21} = \mathrm{R}_{22} = \frac{1}{2}mg\left(\frac{a_1}{l}\cos\emptyset\right) + \frac{1}{2}mg\frac{h}{l}\sin\emptyset$$
$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2})\left(\frac{2.825\text{m}}{5.65\text{m}}\cos 15\right) + \frac{1}{2}(25{,}000 \times 9.8\text{m/s2})\frac{2.349m}{5.65\text{m}}\sin 30$$
$$\mathrm{R}_{21} = \mathrm{R}_{22} = 30233\text{N}$$

$$\mathrm{W} = \frac{\mathrm{R11} + \mathrm{R12} + \mathrm{R21} + \mathrm{R22}}{\cos\emptyset}$$

$$= \frac{22228 \text{ N} + 22228 \text{ N} + 30233\text{N} + 30233 \text{ N}}{\cos 30}$$
$$= 245249.99\text{sN}$$
$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349\text{m} \times 22228 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2} = 0.403$$
$$\varepsilon_{12} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 22228 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2} = 0.403$$
$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{(6 \times 2.349m \times 30233 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2} = 0.548$$
$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} = \frac{(6 \times 2.349m \times 30233 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2} = 0.548$$

Loaded truck accelerating on a level road

$$\frac{a}{g} = \frac{a_1\mu_x}{l - h\mu_x}$$
$$\frac{a}{g} = \frac{2.825\text{m/s2} \times 0.85}{5.65\text{m} - (2.349\text{m} \times 0.85)}$$

$$a = 0.734 \times 9.81\text{m/s2} = 6.44\text{m/s2}$$

The minimum time that it requires to stop at deceleration rate is 5.11 s.

$$\text{Velocity} = \text{acceleration} \times \text{time}$$
$$= 6.44\ \text{m/s2} \times 5.11\ \text{s} = \ \text{m/s} = 32.9\ \text{km/hr.}$$

$$\text{R}_{11} = \text{R}_{12} = \frac{1}{2}mg\frac{a_2}{l} - \frac{1}{2}mg\frac{h}{l}\frac{a}{g}$$

$$= \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.540\text{m}}{5.65\text{m}} - \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.349\text{m}}{5.65\text{m}} \times \frac{6.44\text{m/s2}}{9.81\text{m/s2}}$$

$R_{11} = R_{12} = \underline{21658.9\text{N}}$

$$\text{R}_{21} = \text{R}_{22} = \frac{1}{2}mg\frac{a_1}{l} + \frac{1}{2}mg\frac{h}{l}\frac{a}{g}$$

$$= \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.825\text{m}}{5.65\text{m}} + \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.349\text{m}}{5.65\text{m}} \times \frac{6.44\text{m/s2}}{9.81\text{m/s2}}$$

$R_{21} = R_{22} = \underline{94780.55\text{N}}$

$$\text{W} = \text{R}_{11} + \text{R}_{12} + \text{R}_{21} + \text{R}_{22}$$

W=2×21658 +2×94780.55

= $\underline{232877\text{N}}$

$$\boldsymbol{\varepsilon} = \frac{6hR}{\text{k}l^2}$$

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349\ \text{m} \times 21658\ \text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2}$$

= 0.393

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} \quad = \frac{(6 \times 2.349m \times 21658\ \text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2}$$

$$= 0.393$$

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} \quad = \frac{(6 \times 2.349\text{m} \times 94780.55\ \text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2}$$

$$= 1.719$$

$$\varepsilon_{22} = \frac{6hR_{21}}{kl^2} \quad = \frac{(6 \times 2.349\ \text{m} \times 94780.55\ \text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2}$$

$$= 1.719$$

Loaded truck decelerating on a level road

When accelerating a < 0, the normal forces under the front tires are greater than the static load, and under the rear, tires are less than the static load.

$$\text{R}_{11} = \text{R}_{12} = \frac{1}{2}mg\frac{a_2}{l} + \frac{1}{2}mg\frac{h}{l}\frac{a}{g}$$

$$= \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.540\text{m}}{5.65\text{m}} + \frac{1}{2}(25000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.349\text{m}}{5.65\text{m}} \times \frac{6.44\text{m/s2}}{9.81\text{m/s2}}$$

$\text{R}_{11} = \text{R}_{12} = \underline{156093\text{N}}$

$$\text{R}_{21} = \text{R}_{22} = \frac{1}{2}mg\frac{a_1}{l} - \frac{1}{2}mg\frac{h}{l}\frac{a}{g}$$

$$= \frac{1}{2}(25{,}000\text{kg}) \times 9.81\text{m/s2} \times \frac{2.825\text{m}}{5.65\text{m}} - \frac{1}{2}(25{,}000\text{kg})9.81\text{m/s2} \times \frac{2.349\text{m}}{5.65\text{m}} \times \frac{6.44\text{m/s2}}{9.81\text{m/s2}}$$

$\text{R}_{21} = \text{R}_{22} = 8915.7\text{N}$

$$\text{W} = \text{R}_{11} + \text{R}_{12} + \text{R}_{21} + \text{R}_{22}$$

$= \underline{49049\text{N}}$

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349\ \text{m} \times 15609\ \text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2}$$

$=0.283$

$$\varepsilon_{12} = \frac{6hR_{12}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 15609 \text{ N})}{24330 \text{ N/m} \times (5.65\text{m})^2}$$

=0.283

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 8915 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2}$$

$$= 0.161$$

$$\varepsilon_{22} = \frac{6hR_{21}}{kl^2} \quad = \frac{(6 \times 2.349 \text{ m} \times 8915 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2}$$

$$= 0.161$$

Loaded truck accelerating on an inclined road

$$\mathrm{R}_{11} = \mathrm{R}_{12} = \frac{1}{2}mg\left(\frac{a_2}{l}\cos\emptyset - \frac{h}{l}\sin\emptyset\right) - \frac{1}{2}ma\frac{h}{l}$$

$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2})\left(\frac{2.54\text{om}}{5.65\text{m}}\cos 30 - \frac{2.349\text{m}}{5.65\text{m}}\sin 30\right) - \frac{1}{2}(25{,}000\text{kg} \times 6.44\text{m/s2})\frac{2.349\text{m}}{5.65\text{m}}$$

$$= 14372 \text{ N}$$

$$\mathrm{R}_{21} = \mathrm{R}_{22} = \frac{1}{2}mg\left(\frac{a_1}{l}\cos\emptyset + \frac{h}{l}\sin\emptyset\right) + \frac{1}{2}ma\frac{h}{l}$$

$$= \frac{1}{2}(25{,}000\text{kg} \times 9.81\text{m/s2})\left(\frac{2.825\text{m}}{5.65\text{m}}\cos 30 + \frac{2.349\text{m}}{5.65\text{m}}\sin 30\right) + \frac{1}{2}(25{,}000\text{kg} \times 6.44\text{m/s2})\frac{2.349\text{m}}{5.65\text{m}}$$

= 81309N

$$\mathrm{W} = \frac{\mathrm{R11} + \mathrm{R12} + \mathrm{R21} + \mathrm{R22}}{\cos\emptyset}$$

$$= \frac{14372\text{N} + 14372\text{N} + 81309\text{N} + 81309\text{N}}{\cos 30}$$

=220965N

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 14372 \text{ N})}{24330 \text{ N/m} \times (5.65 \text{ m})^2} = 0.260$$

$$\varepsilon_{12} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349 \text{ m} \times 14372 \text{ N})}{24330 \text{ N/m} \times (4.7 \text{ m})^2} = 0.260$$

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{(6 \times 2.349m \times 81309\ \mathrm{N})}{24330\ \mathrm{N/m} \times (5.65\ \mathrm{m})^2} = 1.475$$

$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} = \frac{(6 \times 2.349m \times 81309\ \mathrm{N})}{24330\ \mathrm{N/m} \times (5.65\ \mathrm{m})^2} = 1.475$$

Loaded truck decelerating on an inclined road

$$\mathrm{R}_{11} = \mathrm{R}_{12} = \frac{1}{2}mg\left(\frac{a_2}{l}\cos\emptyset - \frac{h}{l}\sin\emptyset\right) + \frac{1}{2}ma\frac{h}{l}$$

$$= \frac{1}{2}(25{,}000\mathrm{kg} \times 9.81\mathrm{m/s2})\left(\frac{2.540\mathrm{m}}{5.65\mathrm{m}}\cos 15 - \frac{2.349\mathrm{m}}{5.65\mathrm{m}}\sin 15\right) + \frac{1}{2}(25{,}000\mathrm{kg} \times 6.44\mathrm{m/s2})\frac{2.340\mathrm{m}}{5.65\mathrm{m}}$$

=<u>81309N</u>

$$\mathrm{R}_{21} = \mathrm{R}_{22} = \frac{1}{2}mg\left(\frac{a_1}{l}\cos\emptyset + \frac{h}{l}\sin\emptyset\right) + \frac{1}{2}ma\frac{h}{l}$$

$$= \frac{1}{2}(25{,}000\mathrm{kg} \times 9.81\mathrm{m/s2})\left(\frac{2.825\mathrm{m}}{5.65\mathrm{m}}\cos 15 + \frac{2.349\mathrm{m}}{5.65\mathrm{m}}\sin 15\right) + \frac{1}{2}(25{,}000\mathrm{kg} \times 6.44\mathrm{m/s2})\frac{2.349\mathrm{m}}{5.65\mathrm{m}}$$

=86566N

$$\mathrm{W} = \frac{\mathrm{R11} + \mathrm{R12} + \mathrm{R21} + \mathrm{R22}}{\cos\emptyset}$$

$$= \frac{81309\ \mathrm{N} + 81309\ \mathrm{N} + 86566\mathrm{N} + 86566\ \mathrm{N}}{\cos 30}$$

=387690N

$$\varepsilon_{11} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349\ \mathrm{m} \times 81309\ \mathrm{N})}{24330\ \mathrm{N/m} \times (5.65\mathrm{m})^2} = 1.469$$

$$\varepsilon_{12} = \frac{6hR_{11}}{kl^2} = \frac{(6 \times 2.349\ \mathrm{m} \times 81309\ \mathrm{N})}{24330\ \mathrm{N/m} \times (5.65\ \mathrm{m})^2} = 1.469$$

$$\varepsilon_{21} = \frac{6hR_{21}}{kl^2} = \frac{(6 \times 2.349m \times 86566\text{N})}{24330\ \text{N/m} \times (5.65\ \text{m})^2} = 1.564$$

$$\varepsilon_{22} = \frac{6hR_{22}}{kl^2} = \frac{(6 \times 2.349m \times 86566\text{N})}{24330\ \text{N/m} \times (5.65\text{m})^2} = 1.564$$

Loaded truck moving in a horizontal curved path

Let

Mass of the vehicle = 25000kg

Weight of the vehicle= 25000kg × 9.81m/s 2 = 245255N

Radius of the wheels in meters(r_w) = 0.628m

The minimum radius of curvature(R) = 16m

Height of center of gravity (h) = 0.628m

Width of the track = 2.96m

Dimensions Measured at Truck Garage

Mass of one of the wheels $(m_w) = 65$ kg

Mass of flywheel $(m_F) = 44.5$ kg

Mass of crankshaft $(m_c) = 45$ kg

Diameter of flywheel $= 1.24$ m

Radius of flywheel $(\text{r}_\text{f}) = 0.62$ m

Mass of moment of inertia of one of the wheels in $\text{kg} - \text{m}^2 (I_W)$

$$I_W = m_w$$

$$\begin{aligned} I_W &= m_w \text{I}^2 \\ &= (65\text{kg}) \times (0.628\ \text{m})^2 \\ &= 25.634\text{kg} - \text{m}^2 \end{aligned}$$

Mass moment of inertia of the rotating parts of the engine in $\text{kg} - \text{m}^2 (\text{I}_\text{E})$

$$I_E = m_E \text{I}^2$$

$$\omega_E = \frac{2\pi N}{60}$$

$$✓\omega_E = \frac{2\pi N}{60}$$
$$= \frac{2\pi \times 1600}{60}$$
$$= 167.55\frac{rad}{s}$$

Road reaction over the front wheel $(\mathrm{W}_1) = 0.45 \times 25000\ \mathrm{kg} = 11250\ \mathrm{kg}$

Road reaction over the front wheel $(\mathrm{W}_2) = 0.55 \times 25000\ \mathrm{kg} = 13750\ \mathrm{kg}$

Angular velocity of precession $\left(\omega_p\right) = \frac{v}{R}$

$$= \frac{v}{16m} = 0.0625\mathrm{v}\frac{rad}{s}$$

Therefore, Gyroscopic couple due to 4 wheels,

$$C_W = 4(I_w) \times (\omega_w) \times \left(\omega_p\right)$$
$$C_W = 4(I_w) \times (\omega_w) \times \left(\omega_p\right)$$
$$= 4 \times 25.634\mathrm{kgm}^2 \times 1.594\mathrm{v}\frac{rad}{s} \times 0.0625\mathrm{v}\frac{\mathrm{rad}}{\mathrm{s}}$$
$$= 10.2\mathrm{v}^2$$

$$C_E = I_E \times \omega_{\mathrm{W}} \times \omega_p)$$
$$= 34.43\mathrm{kgm}^2 \times 1.59\mathrm{v}\frac{\mathrm{rad}}{\mathrm{s}} \times 0.0625\mathrm{v}\frac{\mathrm{rad}}{\mathrm{s}}$$
$$= 3.41\mathrm{v}^2$$
$$\frac{p}{2} = \frac{c_{\mathrm{W}}}{2x'}, \frac{p}{2} = \frac{10.12\mathrm{v}^2}{2 \times 2.96m} = 1.7\mathrm{v}^2$$
$$\frac{F}{2} = \frac{C_R}{2b},\ \frac{F}{2} = \frac{359\mathrm{v}}{2 \times 1.59} = 112\mathrm{v}$$

Now let us consider the effect of centrifugal couple acting on the car.

$$\mathrm{Fc}_{\mathrm{c}} = \frac{mv^2}{R}$$

$$\mathrm{C}_0 = \mathrm{Fc} \times \mathrm{h}$$

$$\mathrm{Fc_c} = \frac{mv^2}{R}$$

$$= \frac{25000kgv^2}{16m} = 1562v^2$$

$$\mathrm{C_0} = \mathrm{Fc} \times \mathrm{h}$$

$$= 1562v^2 \times 0.628\mathrm{m}$$

$$= 980.93v^2m$$

$$\frac{Q}{2} = \frac{c_O}{2\mathrm{x}}$$

$$\frac{p}{2} = \frac{c_\mathrm{W}}{2x'}$$

$$\frac{F}{2} = \frac{C_R}{2b}$$

$$\frac{Q}{2} = \frac{c_O}{2\mathrm{x}}$$

$$\frac{Q}{2} = \frac{488.66v^2}{2 \times 2.96\mathrm{m}}$$

$$\frac{Q}{2} = 82.54v^2/m$$

Load on the front wheel 1 (R 11)

$$\mathrm{R_{11}} = 6875 + 112\mathrm{v} - 82.54v^2 - 1.709v^2$$

$$\mathrm{R_{11}} = -84.249v^2 + 112\mathrm{v} + 6875$$

$$=-84.294(8.3)^2 +112*8.3 +6875$$

$$=2000.68\mathrm{N}$$

Load on the front wheel 2 (R_{12})

$$\mathrm{R_{12}} = \frac{W_2}{2} + \frac{F}{2} + \frac{Q}{2} + \frac{P}{2}\mathrm{R_{11}} = \frac{W_2}{2} + \frac{F}{2} - \frac{Q}{2} - \frac{P}{2}$$

$$\mathrm{R_{12}} = 6875 + 112\mathrm{v} + 82.54v^2 + 1.709v^2$$

$$\mathrm{R_{12}} = +84.249v^2 + 112\mathrm{v} + 6875$$

=13608N

Load on the rear wheel 3 (R $_{21}$)

$$R_{21} = \frac{W_2}{2} - \frac{F}{2} - \frac{Q}{2} - \frac{P}{2}$$

$$R_{21} = 6875 - 112v - 84.249v^2$$

$$R_{21} = -84.249v^2 - 112v + 6875$$

=141.486N

Load on the rear wheel 4 (R $_{22}$)

$$R_{22} = \frac{W_2}{2} + \frac{F}{2} + \frac{Q}{2} - \frac{P}{2}$$

$$R_{22} = 6875 + 112v - 80.84v^2$$

$$R_{22} = -80.84v^2 + 112v + 6875$$

=2235.53N

$$\frac{W_2}{2} - \frac{F}{2} - \frac{Q}{2} - \frac{P}{2}$$

$$\frac{F}{2} + \frac{Q}{2} + \frac{P}{2} \leq \frac{W_2}{2}$$

$$112v + 82.54v^2 + 1.709v^2 \leq 6875$$

$$84.23v^2 + 112v - 6875 \leq 0$$

$$112v + 82.54v^2 + 1.709v^2 \leq 6875$$

$$84.23v^2 + 112v - 6875 \leq 0$$

$$V \leq \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$V \leq \frac{-112 \pm \sqrt{(112) - 4 \times 84.23 \times (-(-6875))}}{2 \times 84.23}$$

$$V \leq 8.3\frac{m}{s} = 8.3\frac{m}{s} \times \frac{3600}{1000}$$

$$V \leq 30\frac{km}{hr}$$

Arduino code for overload and instability control

```
#include <SoftwareSerial.h>
#include <LiquidCrystal.h>
#include <TinyGPS.h>
SoftwareSerial my Serial (3, 4);
//long lat, lon; // create variable for latitude and longitude object
Float lat, lon; // create variable for latitude and longitude object
SoftwareSerial gpsSerial (5, 6);//rx,tx
Liquid Crystal lcd (13, 12, 11, 10, 9, 8);
Tiny GPS gps; // create gps object
float load1=0;
float load2=0;
float straingage_value=0.0;
Void setup ()
{Pin Mode (7, OUTPUT);
Pin Mode (6, OUTPUT);
Pin Mode (2, OUTPUT);
Digital Write (7, LOW);
Digital Write (2, LOW);
Serial. Begin (9600);
Serial.println ("The GPS Received Signal :");
Gps Serial. Begin (9600); // connect gps sensor
lcd. Begin (16, 2);
my Serial. Begin (9600); // Setting the baud rate of GSM Module
// Setting the baud rate of Serial Monitor (Arduino)
delay (100);
lcd.setCursor (1, 0);
lcd. Print (" Processing... ");
}
Void loop ()
{load1=analog Read (A0);
load2=analog Read (A1);
```

```
straingage_value=map (analog Read (A2), 0, 1023, 0,255);
if (load1 >500 && load1 <900)//the way is = wp
{digital Write (7, HIGH);
Digital Write (2, LOW);
lcd.setCursor (1, 0);
lcd. Print ("Warning! The car is safe load limit ");
}
else if (load1>900)//wa>wp
{digital Write (7, HIGH);
Digital Write (2, HIGH);
Send Message ();
gsm ();
lcd.setCursor (1, 0);

lcd.print("overload is detected "data sent" ");
}
else if (straingage_value>30)
{
Digital Write (7, HIGH);
lcd.setCursor (1, 0);
lcd.print ("Warning' 'Instability is detected' ");
}
else//WA<wp safe load
{digital Write (7, LOW);
Digital Write (2, LOW);
lcd.setCursor (1, 0);
lcd.print (" SAFE LOAD ");
gsm ();}
if (Serial. Available ()>0)
{if (gps. Encode (gpsSerial.read ()))// encode gps data
{
```

```
gps.f_get_position (&lat, &lon); // get latitude and longitude
// display position
lcd. Clear ();
lcd.setCursor (1, 0);
lcd.print ("GPS Signal");
lcd.setCursor (1, 0);

lcd.print ("LAT :");
lcd.setCursor (5, 0);
lcd.print (lat);
Serial. Print (lat);
Serial. Print (" ");
Serial. Print (lon);
Serial. Print (" ");
lcd.setCursor (0, 1);
lcd.print (", LON :");
lcd.setCursor (5, 1);
lcd.print (lon);
}
String latitude = String (lat, 6);
String longitude = String (lon, 6);
Gps Serial.println (latitude+";"+longitude);
Delay (1000);}
Switch (Serial. Read ())
{
Cases':
Send Message();
Break;
case 'r':
RecieveMessage ();

break;
```

```
}
If (mySerial. Available ()>0)
Serial. Write (mySerial. Read ());
}
void Send Message()
{
mySerial.println ("AT+CMGF=1"); //Sets the GSM Module in Text Mode
delay (1000); // Delay of 1000 milli seconds or 1 second
mySerial.println ("AT+CMGS=\"+251920140419\"\r"); // Replace x with mobile number
delay (1000);
mySerial.println ("I am SMS from Customer Module");// The SMS text you want to send
delay (100);
mySerial.println ((char) 26);// ASCII code of CTRL+Z
delay (1000);
mySerial.println ("car one with targa A2343A is overloaded");// The SMS text you want to send
Delay (100);
mySerial.println ("locations");// The SMS text you want to send
mySerial.println ("Country, Ethiopia");// The SMS text you want to send
mySerial.println ("Latitude=8.514477");
mySerial.println ("Longitude=39.269257");
mySerial.println ("DMS Lat = 8° 30' 52.1172" N");

mySerial.println ( "DMS Long =39° 16' 9.3252" E");
mySerial.println ("UTM Easting =529,633.62");
mySerial.println ("UTM Northing = 941,185.11");
delay (100);
}
Void RecieveMessage ()
{
mySerial.println ("AT+CNMI=2, 2, 0, 0, 0"); // AT Command to receive a live SMS
delay (1000);
}
Void gsm ()
```

```
{gpsSerial.println ("locations");// The SMS text you want to send
Serial.println ("Country, Ethiopia");// The SMS text you want to send
Serial.println ("Latitude=8.514477");
Serial.println ("Longitude=39.269257");
Serial.println ("DMS Lat = 8° 30' 52.1172" N");
Serial.println ( "DMS Long =39° 16' 9.3252" E");
Serial.println ("UTM Easting =529,633.62");
Serial.println ("UTM Northing = 941,185.11");}
```