

# RETROFITTING AND USE OF A SENSOR SYSTEM FOR COMPLIANCE OF RULES GOVERNING LOADING LIMITS OF FOUR WHEELERS

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**Abstract** - India has grown a lot in recent times and also its economy is incrementally growing. To hold on to this growth, quality infrastructure is needed which comprises of transportation. Transportation by road is very important in India and is playing a crucial role due to the presence of good quality infrastructure of the road as well as wide geographical network. But it is noted that in order to make quick money the truck owners overload the trucks/lorries over the legal capacity limit. This results in quick wear and tear of the roads, vehicle engine, as well as increasing number of accidents. To prevent such illegal overloading, a device/mechanism has been designed that can tell the driver about overloading and the driver can reduce the excessive load. But, if the driver continues to drive the overloaded vehicle, he will be stopped by the road transport authorities or police and the necessary action will be taken. Also, the system has been developed using a programmed microcontroller and reliability analysis has been conducted to recommend the most reliable control circuit for implementation in the near future

**Key Words:** overloading, reliability analysis, availability, unauthorized driving, radio frequency, Truck retrofitting.

## 1. INTRODUCTION

Roadways are crucial mode of transport in every part of the world. We get so many benefits with the roads, like they take us from one place to another; less time is taken for reaching to various destinations etc. It is vital for those responsible for maintaining and operations of highway structures to inspect and prevent vehicle overloading. The excess load carried by the overloaded damages the roads quickly, leading to fatigue, cracks and in some cases an unexpected failure.

Every year a huge amount of capital is being invested in the construction and maintenance of all the state/national highways by the government. It is known that the overloading of vehicle creates structural distress of roads leading to the reduction of the service life of the road. Due to the overloading of heavy vehicles, there is gradual increase in rate of accidents for higher gross weight. . Due to the increase in the Gross Vehicle Weight (GVW), there are more chances of the truck getting involved in a fatal accident. Increased GVW also leads to more rollover of the vehicles due to change in centre of gravity. Overloaded trucks also affect the dynamics, performance and stability of the engine.

The amount of braking force needed to get the vehicle to a halt increases with more weight. If the design and other important aspects of the vehicle like axle are unchanged, an increase in gross vehicle weight will lower rollover resistance while taking steady turns for all the trucks, which results in more rollover accidents.

For existing four-axle doubles, increased weight would also reduce the rearward amplification behaviours, which might increase the chances of overturns of rear-trailers while suddenly changing the lanes at higher speeds or avoiding obstacles. Also, increased gross weight will require a braking system having higher torque capacity, which, if not provided, will result in an increased stopping distance as a result of which the number of accidents will be more. Heavy vehicle drivers get more driver fatigue especially if it consists of long distance trips and long working hours with limited recovery time. Fatigue caused to the drivers by driving on complex roads had the most negative impact on visual distance estimation and driving behaviour. The drivers of the overloaded truck experience fatigue while driving in such condition compromising other people's safety. The situation may get even worse if the trucks and lorries are overloaded because it becomes difficult to handle an overloaded truck safely as compared to a truck loaded within the legal weight limit.

Thus, truck overloading combined with driver fatigue will reduce the safety of road users in a traffic stream. Having a clear knowledge on vehicle overloading will help the decision makers create more comprehensive and improved policy measures to deal with such problems.

## 2. LITERATURE REVIEW

Arezoo Abolghasem and Abbas Mahmoudabadi, (2013), "Application of Chaos Theory in Trucks Overloading Enforcement", Overloading of trucks is known as one of the most important problems in road transport due to a possible damage of the pavements, as well as, reduced performance of the truck's braking system. Sufficient manpower and correct time scheduling has to be done to conduct the survey of overloaded vehicles; therefore, a correct model is needed to be prepared to determine the number of overloaded trucks at a particular point. In this research work the ratio of overloaded trucks is predicted using the concept of chaos theory. The largest Lyapunov exponent is used to determine the presence of chaos by conducting experiments and collecting data and a conclusion is made that the ratio of

overloaded trucks shows the chaotic behavior. i.e. a comparison is made between the data of the experiment and the results of moving average and simple smoothing methods as per the set criterion of mean square errors. The results also show that the model made using chaos theory is more accurately as compared to other methods including moving average and simple smoothing

Swapan Bagui, Chiranjeevi Bapanapalli, Atasi Das, (2013) "Controlling Vehicle Overloading in BOT Projects", Commercial Vehicle overloading on highways; causes a harm to the economy of the country in terms of maintenance the road infrastructure - it not only increases the expenditure but, is also causes a large number of road accidents. Over 51 % of the commercial vehicles present on our State/ National Highways are loaded beyond the legal limits. Although there are rules related to the legal axle weight limit and gross vehicle weight (GVW) limit of the vehicles present on roads, they frequently go unnoticed by the transporters. The damage by overloaded vehicles to pavements is accelerated.. There are legal axle weight limit and GVW limit but they are neither followed by transporters nor are they enforced strictly by the respective authorities. Overloading vehicles accelerates the design pavement aging. By controlling overloading the maintenance costs are reduced thereby improving the economy of the country. This paper summarizes the advantages in term of toll revenue for controlling overloading in a Build Operate and Transfer (BOT) Project with a related case study. From the case study, it is noted that the maximum revenue is achieved by permitting vehicle to comply on the road carrying maximum allowable legal weight. Other than the benefits indicated, controlling overloading reduces number of accidents, requires lesser pavement maintenance, increases speed and reduces operating cost of the vehicles. In the end, the possible ways of controlling overloading with strict enforcement are given more importance.

### 3. STUDY OBJECTIVE

The main objective of this project is to develop a new and reliable system on the vehicle by which it will detect the overloading and unauthorized driving on vehicles automatically so that such vehicles on the roads will be reduced or avoided and the accidents caused by the overloaded vehicles will be reduced as well. This new system will allow only authorized or licensed person to drive the vehicle.

In this project a new instrumentation system has been developed with two different control circuits to reduce the overloading of the vehicle. The most reliable system will be recommended. If this particular system is made compulsory in all the commercial vehicles by the Indian government, it will help in minimizing the casualties due to overloaded trucks to a greater extent. Since India is densely populated country and the most frequent mode of transport is considered to be the busses, they are mostly found overloaded. This system can also be used in busses if there is

successful implementation in trucks. In future, more success of the system can be achieved by reducing overloading in passenger trains as well.

### 4. DATA COLLECTION

For this study, the failure rates of various components are collected from their manufacturer's data sheet in order to calculate system availability & reliability using both the control circuits.

COMPONENT	FAILURE RATE	SPECIFICATION
BATTERY	1.99*10 <sup>-6</sup> F/hr	6V, Lead Acid battery
LIMIT SWITCH	117.49 F/ 10 <sup>6</sup> hrs	Single pole single throw (SPST), Resistive load
RF RECEIVER	13.2 F/ 10 <sup>6</sup> hrs	433 MHz receiving frequency with 5V Operating voltage
SIREN	7*10 <sup>-7</sup> F/hr	120dB Direct current
MAGNETIC SENSOR	1*10 <sup>-6</sup> F/hr	Normally Open magnetic switch
RELAY	1.63 F/ 10 <sup>6</sup> hrs	Single pole double throw (SPDT)
MOTOR	68.8 F/ 10 <sup>8</sup> hrs	Viper motor
IN-HOUSE CIRCUIT	1.44*10 <sup>-6</sup> F/hr	UM-606 IC, diodes, transistors
MICROCONTROLLER	1.157 10 <sup>-6</sup> F/hr	Arduino Uno ATmega 328P

Table 1: Data Collection

### 5. WORKING

#### 5.1 Working of the truck

The four wheel vehicle is moved by a DC motor drive through a chain and sprocket mechanism. It consists of a cabin and a tray for carrying load. In normal conditions, when the switch to start the vehicle is put on, it closes the circuit and the current flows through the circuit. For the vehicle to start moving, the motor circuit is to be switched ON. The DC servo-motor that is connected to the rear axle via chain and sprocket mechanism starts to move the wheels of the vehicle. Load carrying trolley has cushioning springs at the 4 ends that are set for a particular load and if overloaded, will press the limit switch to trigger the control circuit which is indicated by a small light on the dash board and sound a buzzer so that it alerts the driver that the vehicle is overloaded.

When the truck is overloaded, it raises the force acting on the springs which tends to compress the springs little by little. Due to the compression, the load carrying tray moves downwards activating the limit-switch. This limit switch sends a signal to the relays activating a small buzzer. The buzzer will be stopped only when the load on the tray is reduced up to the legal limit. If the driver tries to bypass the ignition connection, the vehicle can be started. If the driver tends to move the vehicle with overload, the buzzer sounds continuously which is heard by the driver only.

When the vehicle is moving on the road if it comes near to the concerned authorities, the signals transmitted are received by the vehicle through remote radio frequency

receiver circuit that is present within the vehicle (radio remote frequency signals are continuously transmitted by the enforcing authorities or police vehicles of the same frequencies) which is received and the control circuit will send a signal to put on the siren, catching the attention of the authorities or traffic officials to stop the vehicle, impose fines and force the operator to unload the extra load thus making it safer for every person on the roads.

The next feature of this particular project is the license card insertion. In this case we have a normal card with the magnet attached to it, and in actual it will be detecting the magnetic chip present on the license card. Once the card is inserted into the provided slot, the magnet is detected by the sensor which closes ignition circuit by giving an input to the control circuit. Here it is the motor connected to the wheels. If the license card is not inserted, the connection will not be affected, and even if we put on the ignition to start the truck, the vehicle drive motor will not be powered to do so.

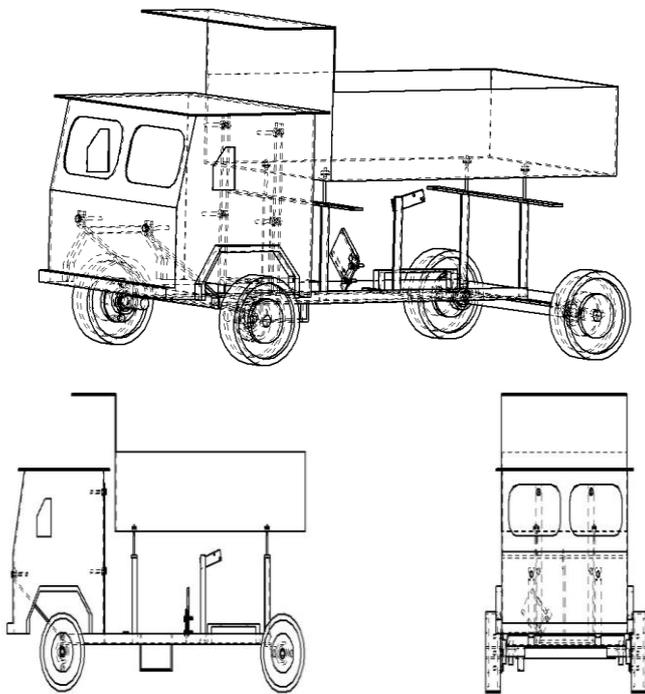


Figure -1: 2-D sketches of the truck

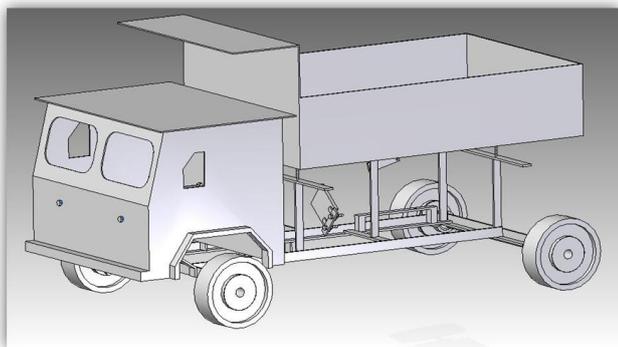


Figure -2: 3-D model of the truck

If any of the parameter is not followed properly, the buzzer will sound and when it comes near the enforcing authorities or check-post, the siren in the vehicle will start that will draw the attention of the authorities who will make the vehicle to stop and impose fines according to law. If the driver when caught near the check post tries to run away with vehicle, or does not stop when asked to, the police from their radio frequency transmitter can stop the fleeing vehicle gradually. The transmitter of the RTO authorities will have a radio frequency that matches with the radio frequency of the vehicle.

## 5.2 Working of the in-house control circuit

### 5.2.1 Overloading initiation circuit

In this circuit we are providing the limit switch below the load holding tray or trolley which is held on springs on the chassis. The tray holds the load properly for the particular weight of the material and if in excess will trigger the limit switch which gives the high state input voltage to IC, UM-606 pin number 7 to give the inverted output at pin number 6 which will trigger the transistor to connect the relay to put on the LED and putting on the buzzer and also activating the radio frequency remote receiver circuit.

### 5.2.2 Circuit for switching ON siren

There will be a transmitter provided to the enforcing authorities, whether at vehicle or police station, which will be transmitting radio frequency signals continuously all around. When the overloaded vehicle is moving in the range, the overloading circuit which has already put the RF receiver circuit ON will receive the signals and automatically put ON the siren within the vehicle. If the driver tries to switch off the siren, the drive will be blocked. The transmitted signals on being received by the receiver circuit will trigger the connection to the transistors on the vehicle to energize the relay to put ON the siren. We are using 40 MHz frequency in this project.

In this project AC current is used to charge the batteries to run the vehicle. In this case a 220V AC supply is stepped down to 12V supply using a step-down transformer. It uses a bridge rectifier to convert 12V supply to 5V supply which is used to charge the batteries. The circuit for charging is shown in below figure. The batteries are charged for 6-7 hours and it can be used for 45 minutes of continuous working.

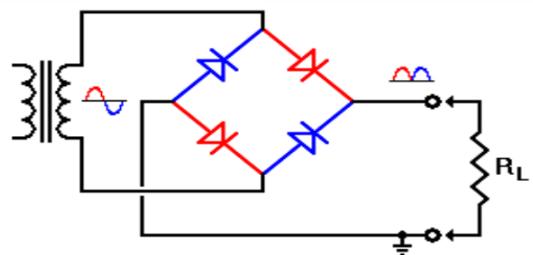


Figure -3: Circuit to step down the voltage from AC to DC

### 5.3 Working of Microcontroller

#### 5.3.1 Overloading initiation circuit

The limit switch is taken as the input for detecting the overloading. When it is pressed due to an overload, it sends the signal to pin 4 of the microcontroller. The microcontroller sends a signal to the buzzer from pin 5 which indicates the driver that the truck is overloaded. If he reduces the load then limit switch is not pressed and no signal is sent to the controller but if he continues to drive the overloaded vehicle then the signal from the transmitter will be received by the receiver present in the truck. The receiver sends the signal to the controller through pin 12 and as a response the microcontroller sends a signal to the siren through pin 6. The sound of the siren is high enough for the police to hear and they can stop the truck to take the necessary actions. If the driver tries to flee away then with the help of a switch the motor can be stopped.

#### 5.3.2 License card circuit

When the driver inserts a license card into the slot provided, the magnetic sensor sends a signal to the microcontroller through pin 2. On detection of the license card, the microcontroller sends a signal through pin 3 to the relay to start the motor. If the card is not inserted, no signal will be sent and no action will take place.

## 6. AVAILABILITY & RELIABILITY ANALYSIS

The circuit diagram used for conducting the analysis is shown below:-

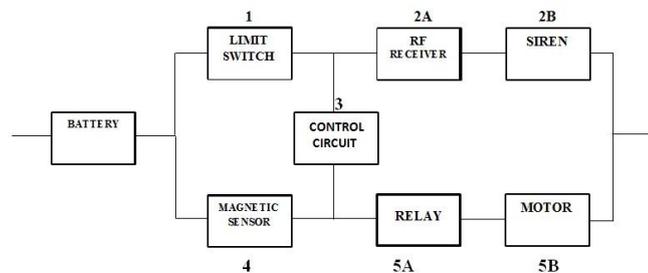


Figure -4: Reliability analysis block diagram

### 6.1 Calculating System Availability

The availability of the system is calculated using the following formulae:-

If the components are connected in series, the formula is:

$$A = A_x \cdot A_y$$

Where,

$A_x$  → Availability of component x

$A_y$  → Availability of component y

If the components form a bridge circuit, the formula is:

$$A_b = 2A_1 A_2 A_3 A_4 A_5 + A_2 A_3 A_4 + A_1 A_3 A_5 + A_2 A_5 + A_1 A_4 - A_2 A_3 A_4 A_5 - A_1 A_2 A_3 A_4 - A_1 A_2 A_3 A_5 - A_1 A_3 A_4 A_5 - A_1 A_2 A_4 A_5$$

Where,

$$A_2 = A_{2A} A_{2B} \text{ \& } A_5 = A_{5A} A_{5B}$$

Applying the appropriate availability formula to the circuit, the system availability is 98.96 for both the control circuits (in-house circuit & microcontroller).

### 6.2 Calculating System Reliability

The reliability analysis is done for a period of 100000 Hrs.

The system reliability is calculated using the following formulae:-

If the components are connected in series, the formula is:

$$R_s = R_A R_B$$

Where,

$R_A$  → Reliability of component A

$R_B$  → Reliability of component B

If the components form a bridge circuit, the formula is:

$$R_b = 2R_1 R_2 R_3 R_4 R_5 + R_2 R_3 R_4 + R_1 R_3 R_5 + R_2 R_5 + R_1 R_4 - R_2 R_3 R_4 R_5 - R_1 R_2 R_3 R_4 - R_1 R_2 R_3 R_5 - R_1 R_3 R_4 R_5 - R_1 R_2 R_4 R_5$$

Where,

$$R_2 = R_{2A} \cdot R_{2B} \text{ \& } R_5 = R_{5A} R_{5B}$$

Applying the appropriate reliability formulae to the circuit, the system reliability using in-house control circuit is 70.68%.

Replacing the control circuit with the microcontroller the system reliability is 80.93%.

## 7. RELIABILITY IMPROVEMENT

The reliability of the system consisting of the microcontroller is selected and recommended as it has a higher reliability as compared to the in-house circuit. Further the system reliability is improved by calculating the importance of each component in the system and thereby adding another identical component in standby mode to the most important component. The formula for calculating static reliability importance is as follows:

$$I_{R_i} = \frac{\partial R_s}{\partial R_i}$$

Where,

$I_{R_i}$  → Reliability importance of component i.

$R_s$  → System reliability

$R_i$  → Reliability of component i.

$$R_s = R_{battery} * R_b$$

The static reliability importance graph is plotted as follows:

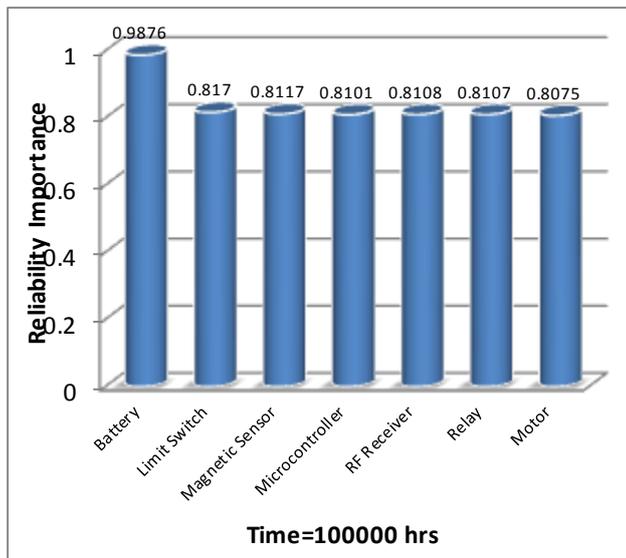


Chart -1: Static reliability importance diagram

From the above graph it can be seen that the static reliability importance for the battery is higher than rest of the components. Hence another battery is added in standby mode with a reliable switching mechanism which will come into play if the other battery fails.

### 8. IMPROVED SYSTEM RELIABILITY

The formula used for calculating reliability of two identical components connected in standby mode is as follows:

$$R_{std}(t) = \sum_{i=0}^m \left( \frac{(\lambda t)^i e^{-\lambda t}}{i} \right)$$

Where,

$R_{std}(t)$  → Standby system reliability at time t

m → Total number of standby units

$\lambda$  → Unit constant failure rate

Using the above formula, with the addition of another battery in standby mode the system reliability is improved from 80.93% to 97.03%.

### 9. RESULTS & RECOMMENDATIONS

Control Circuit	AVAILABILITY	RELIABILITY
In-house built	98.96%	70.68%
Microcontroller	98.96%	80.93%

Table -2: Availability & reliability values

- Microcontroller is recommended as the control circuit.
- Battery is proved to be the most important component considering its failure rate and position in the circuit
- The reliability of the system after adding another battery in standby mode is improved from 80.93% to 97.03%.

### 10. ADVANTAGES

- Very less police enforcing required.
- Less cost in monitoring.
- No mistakes in enforcing and monitoring.
- Reduces road accidents by making proper and safe ride on roads
- Accident prevention means saving of property and lives.
- Reduces wear and tear of the vehicles engine.
- Useful in controlling the vehicle emissions.

### 11. CONCLUSIONS

The conclusions of this study are summarized as follows:

- Significant GVW violation involving overloading of commercial vehicles are monitored.
- Overloading not only causes premature pavement damage (which in turn may contribute to accidents) but it is also hazardous to the other people on the roads.
- Monitoring and enhancing enforcement of weight limits on heavy vehicles may be a step in the right direction to reduce casualties
- Microcontroller is used as control circuit considering the system reliability.

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