Design and Implementation of a Vehicle Monitroring System for Toll Collcection

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Abstract— Vehicle monitoring system for toll collection is a globally accepted system. Initial investment is necessary for the construction and maintenance of the roads and bridges and the initial investment will be paid back over time by user tolls. Fees and tolls may be varied by vehicle type, length or weight of vehicle. Fees or tolls were traditionally collected by hand, by toll gate workers. To cut cost and minimize time delay, many tolls today are collected with some forms of automatic or electronic toll collecting system. In Bangladesh, manual method of toll collection is mostly used. A person collects the tolls according to the list, where how much have to be paid from each category remains enlisted. This is time consuming. Again, in Bangladesh some systems are such that, tolls are charged automatically on the basis of weight of the vehicle, but this system is costly. So, here a system of automatic toll collection on the basis of length of vehicle is designed to reduce manual existence and cost.

Index Terms: Vehicle monitoring, Category, Toll, Road, Micro-controller, LASER, Transmitter.

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1 INTRODUCTION

DURING the last 100 years, most highways have been built, owned, and maintained by governments. However, construction costs for new roads, plus maintenance and enhancements to existing road networks, impose substantial public sector budgetary pressures. Those costs can frequently exceed tax revenue capacity. As a result, governments have been forced to look for alternative funding. One mechanism governments have periodically considered as a means for financing the costs of construction and maintenance of new roads is tolls. [1]. Tolls are a form of user tax that usually pays for the cost of road or bridge construction and maintenance without raising taxes on non-users [2].

Most countries have no toll roads. Where there are toll roads the tolled network typically comprises less than 5 percent of the road network. In most countries with toll roads the private sector has been heavily involved in development of the roads and often thereafter in their operation. The USA, Japan, and France are the key exceptions to this rule, where most toll roads are owned and operated by public corporations.[3]. In Bangladesh, roads and bridges are built by the Government. After building the roads and bridge, the government invites tender to give an Operation and management (O&M) contract against a fee. The O&M operators maintain the bridge and collects toll on behalf of the government.

There are three methods of toll collection available [4]. These are manual, automatic and electronic toll collection system.

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Manual toll collection is most widely used collection method. It requires a toll collector or attendant. Based on the vehicle classification, cash toll is received by the collector. Due to manual intervention, the processing time is highest.

Automatic toll collection is based on the use of Automated Coin Machine (ACM). These accept both coins and tokens issued by the operating agency. Depending on the toll rate, the use of automated coin or token collection instead of manual collection reduces transaction and processing time as well as the operating cost.

Electronic Toll Collection (ETC) is a system that automatically identifies a vehicle equipped with a valid encoded data tag or transponder as it moves through a toll lane or checkpoint. This system is capable of determining if the car is registered or not, and then informing the authorities of toll payment violations, debits, and participating accounts [5].

An ETC system commonly utilizes radio frequency identification (RFID) technology. RFID is a generic term used to identify technologies utilizing radio waves to automatically identify people or objects [6]. RFID technology was first introduced in 1948 [7]. Research on ETC has been around since 1992, during which RFID tags began to be widely used in vehicles to automate toll processes [8].

A complete RFID system consists of a transponder (tag), reader writer, antenna, and computer host. The transponder, better known as the tag, is a microchip combined with an antenna system in a compact package. The microchip contains memory and logic circuits to receive and send data back to the reader [9].

The ETC system is currently being used throughout the world. In the United States alone, various states have implemented an ETC system called E-Z Pass. Other countries that have applied the ETC system are Canada, Poland, the Philippines, Japan and Singapore, among many others.[10]

In Bangladesh, most of the toll plazas are manual. Vehicles enter the plaza and toll is charged and collected by a person. There are some automatic toll plazas also in which toll is charged automatically on the basis of the weight of the vehicle, and a person collects the toll [11]. In this project, a vehicle monitoring system which will calculate toll based on the length of vehicle has been designed to reduce manual assistance in the toll plazas of Bangladesh.

2 METHODOLOGY

The basics of the project is that, here LASER (Light Amplification by Stimulated Emission of Radiation) light is placed in one side of the road and LDR (Light dependent resistor) along with other circuit components is placed on the other side of the road. There are five sets of such arrangements on both sides of the road. LASER light is adjusted such that it directly falls on LDR when there is no vehicle between LASER and LDR.As a result LDR has low resistance and positive input voltage of OP-AMP (OP-AMP 741) is higher than negative input voltage according to voltage divider rule (Voltage division refers to the partitioning of a voltage among the components of the divider.[12]).The output of OP-AMP is fed to base of the transistor (C828) and the transistor is on. The output current discharge to ground and we do not get any output voltage.

When there is vehicle between LASER and LDR there is no light on LDR. So resistance of LDR is increased .Now positive input voltage is lower than negative input voltage according to voltage divider rule and there is no output voltage of OP-AMP. In this condition the transistor remains off and microcontroller gets a voltage. Similar condition is applicable to get output voltage from all the five arrangements.

Now voltages from five arrangement is fed to the microcontroller (PIC16F628A).When microcontroller gets the voltage from 1st set of LASER and LDR (It happens when the vehicles enters between 1st set of LASER and LDR), microcontroller sense the presence of vehicle. Microcontroller will then check for voltages from 2nd, 3rd, 4th and 5th set of LASER and LDR. When it gets voltages from 5th set of LASER and LDR, it will check which another voltage from 2nd, 3rd, 4th and 5th set of LASER and LDR is present at that moment. Depending on it, microcontroller will decide which category of vehicle it is (the category is programmed before inside the microcontroller) and how much have to be charged from the vehicle. Microcontroller will also count how many vehicles under each category have passed through the toll plaza. The charge for different category is given in Table I. The system of counting different types of categories is shown in Fig.1.

Table: 1
The toll of different categories of vehicles

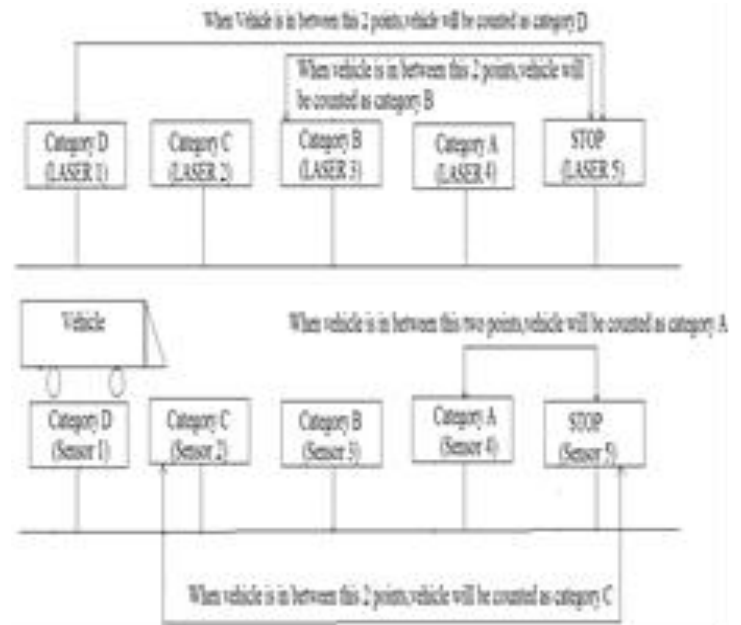| Category	Charge(Taka)
A	10
B	25
C	50
D	100

Fig.1: System of counting of different types of categories.

3 SYSTEM DESIGN

In the complete block diagram (Fig.2), there are five sets of transmitter and receiver. When the vehicle enters, the vehicle monitoring system, at first it cuts the LASER between transmitter 1 and receiver 1, micro-controller gets a voltage and step 1 is shown in the display. In the similar way, it cuts the LASER between second set of transmitter and receiver, third set of transmitter and receiver, fourth set of transmitter and receiver and step 2, step 3 and step 4 are shown in the display respectively. At last, when it cuts the LASER between transmitter 5 and receiver 5, depending on the position of the back wheel of vehicle, it shows vehicle type and toll. For example,

A. Block Diagram:

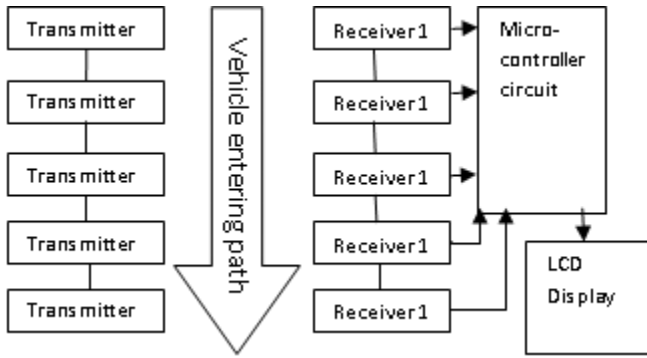The whole system can be represented by a block diagram which is displayed in Fig.2

Fig.2: Complete block diagram of vehicle monitoring system for toll collection.

when the front wheel of a vehicle is in between transmitter 5 and receiver 5, then if the back wheel of the vehicle is in between transmitter 3 and receiver 3, it shows category B and toll 25 taka.

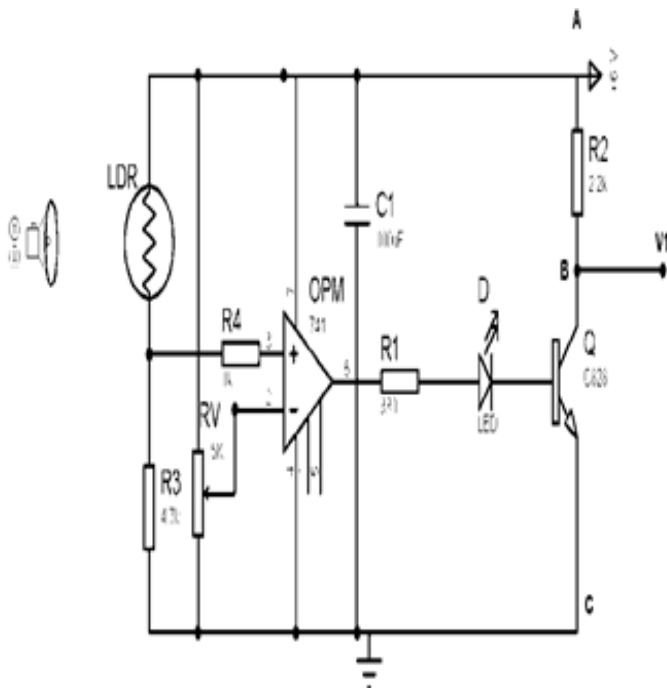**B.** *Transmitter and Sensor Circuit:*

Fig.3: Transmitter and sensor Circuit

In sensor circuit, 4.7 kΩ, 2 kΩ, 330Ω and 2.2 kΩ resistors are used. The value of variable resistor used is 5kΩ. The capacitor of 100 uF is used. Here Op-Amp 741 is used as comparator. A LED is used as an indicator of output voltage of the Op-Amp. The model of transistor in the sensor circuit is C828. Here LDR is used to sense the presence of LASER.

C. *Calculation from transmitter and sensor circuit:*

When there is no vehicle between LASER and LDR, LASER light directly falls on LDR and the resistance of LDR is approximately 300Ω.So, the positive input of Op-Amp = 5.64 Volt The negative input of Op-Amp is set to 3.5 volt with the help of variable resistor.As the Op-Amp here is working as comparator and positive input is higher than negative input, the output voltage is approximately 5.4 volt. Approximately 3.3 volt drops across the resistor R1 (330Ω), and a current 10 mA flows to the base of the transistor, which turns-on the transistor. So the output current discharges through A, B, C to ground and we do not get any output voltage.When there is vehicle between LASER and LDR, the LASER light doesn't fall on LDR and this time the resistance of the LDR is approximately 7.3 KΩ.So, the positive input of Op-Amp = 2.35 Volt And the negative input remains fixed to 3.5 volt.As the Op-Amp here is used as comparator and the positive input is lower than negative input, the output of Op-Amp is approximately zero. So no current flows to the base of the transistor and the transistor remains OFF. At this moment we get a output voltage from the sensor circuit, which is the input of microcontroller.

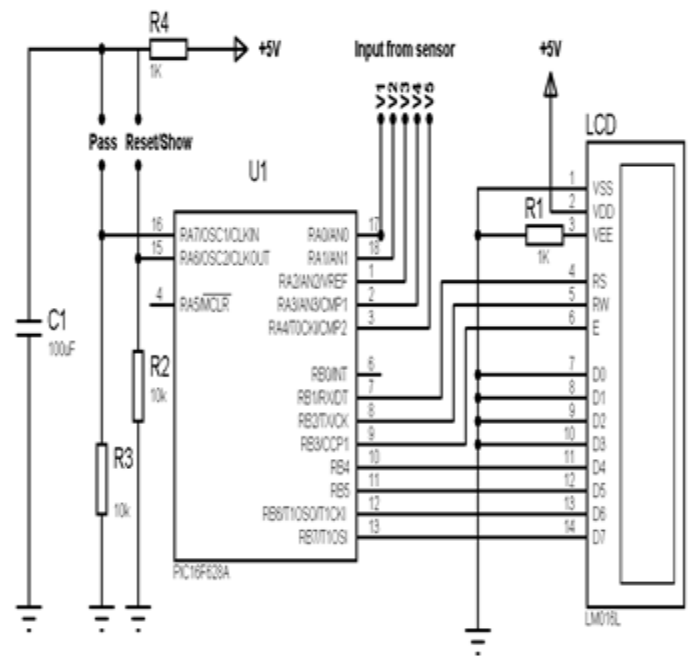**D.** *Microcontroller and LCD Pin Connection Diagram:*

Fig.4: Microcontroller and LCD Pin Connection Diagram.

The micro-controller used in this system is PIC 16F628A. Input from sensor circuit is fed to the 17, 18, 1, 2, 3 pin of the micro-controller. PASS switch is connected to the pin no 16 of the micro-controller and RESET/SHOW is connected to the pin no 15 of the micro-controller. The LCD display used is a 2X16 line display. RS, RW and E pin is connected to the pin number of 7,

8, and 9 of the micro-controller serially. In LCD pin, D_0, D_1, D_2, D_3, V_{SS}, V_{EE} are connected to the ground. Pin D_4, D_5, D_6 and D_7 of the LCD display are serially connected with the pin no 10, 11, 12 and 13 of the microcontroller respectively.

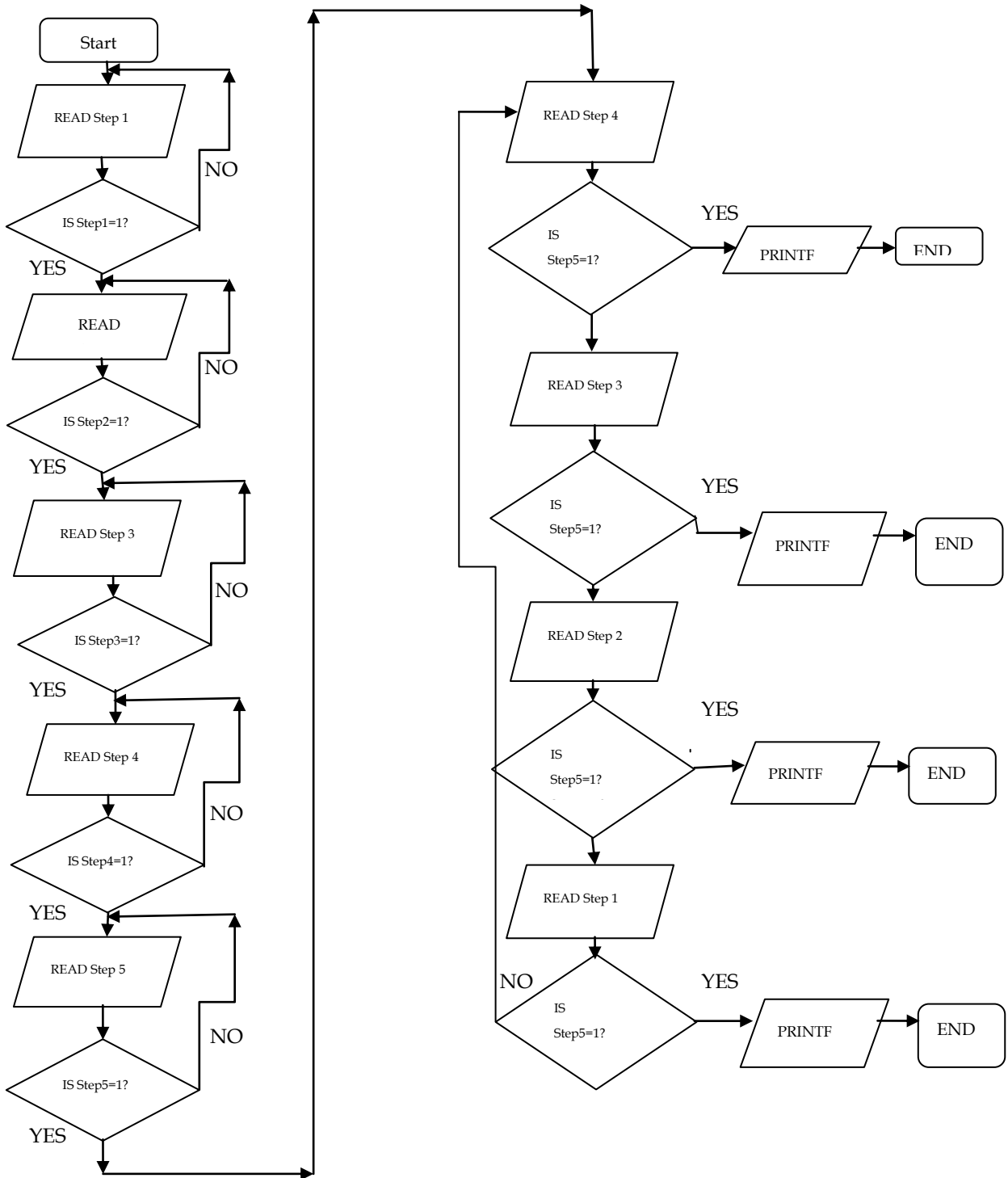### E. *Microcontroller and LCD Pin Connection Diagram:*

Fig.5: Flow chart of the micro-controller programming.

4 CONSTRUCTIONAL DETAILS

To accomplish this system transistor C828 is used. LASER is used here as transmitter. The terms LASER originated as an acronym for Light Amplification by Stimulated Emission of Light [13]. An Op-Amp 741 used here as voltage comparator. The model of micro-controller used in this system is is PIC 16F628A. A photo-resistor is used in the system to sense the presence of the vehicle depending on the LASER light available on it. A light emitting diode used in this system as indicator. A light emitting diode (LED) in essence is a P-N junction solid-state semiconductor diode that emits light when a current is applied through the device [14]. In this system, as a display, 2X16 line liquid crystal display (LCD Display) is used. Liquid crystals are first developed in 1888 [15]. Battery is used to supply power in the circuit of the system. Resistors are used in the system to make voltage divider and to limit current. A capacitor is a passive two terminal electrical component used to store energy. In this system capacitors are used to stable the voltage in different parts of the circuit [16].

5 SYSTEM IMPLEMENTATION AND RESULT ANALYSIS

5.1 Identification and toll charging from vehicle

After implementation of this project, different types of vehicles have passed through the toll plaza and the project runs successfully. It showed the category of different types of vehicles and total toll to be charged from it. The vehicles that have entered the toll plaza are listed in the categories below which were shown in the LCD display after the vehicle passed the toll plaza.

Category A (length approximately 6 feet 7 inches): CNG, Baby-taxi.

Category B (length approximately 8 feet 1 inch): Car, Microbus, Zeep.

Category C (length approximately 13 feet 4 inches): Minibus, Pick-up.

Category D (length approximately 17 feet 5 inches): Large bus, large truck.

For example, the figure and details of implementation for a single vehicle (CNG) from category A is shown below.

Category "A" Vehicle:

Figure 3.1 (a): Category "A" vehicle entering to the vehicle monitoring system.

Figure 3.1 (b): Vehicle entering between 1st set of transmitter and receiver and step 1 is shown in the display.

Figure 3.1 (c): Vehicle entering between 2nd set of transmit - ter and receiver and step 2 is shown in the display.

Figure 3.1 (d): Vehicle entering between 3rd set of transmitter and receiver and step 3 is shown in the display.

Figure 3.1 (e): Vehicle entering between 4th set of transmitter and receiver and step 4 is shown in the display.

At first, CNG (Category "A" vehicle) has passed through the vehicle monitoring system which is shown in figure 3.1(a). During passing the vehicle monitoring system, when CNG cut the LASER between 1st set of transmitter and sensor (Category D), then step 1 is shown in the LCD display, which is shown in figure 3.1 (b). Then the CNG cut the LASER between 2nd set of transmitter and sensor (Category C), then step 1 & step 2 is shown in the LCD display, which is shown in figure 3.1 (c). After that, the CNG cut the LASER between 3rd set of transmitter and sensor (Category B), then step 1, step 2 & step 3 is shown in the LCD display, which is shown in figure 3.1 (d). Then the CNG cut the LASER between 4th set of transmitter and sensor (Category A), then step 1, step 2, step 3 & step 4 is shown in the LCD display, which is shown in figure 3.1 (e). Finally, when CNG cut the LASER between 5th set of transmitter and sensor, then the last point of CNG was between 4th set of transmitter and sensor and the category of vehicle and the toll to be charged from it is shown in the LCD display, which is shown in figure 3.1 (f).

5.2 . Calculation of total number of vehicles and total toll under each category:

Figure 3.2 (a): Total number of vehicles and total toll collected under category A is shown in the display.

Figure 3.2 (b): Total number of vehicles and total toll collected under category B is shown in the display.

Figure 3.2 (c): Total number of vehicles and total toll collected under category C is shown in the display.

Figure 3.2 (d): Total number of vehicles and total toll collected under category D is shown in the display.

After passing different types of vehicles through the vehicle monitoring system, the total number of vehicles and toll under category A, category B, category C, category D are shown in the display serially in figure 3.2(a), figure 3.2(b), figure 3.2(c), figure 3.2(d).

6 APPLICATIONS

The system can be implemented to a road or bridge to collect toll. It is necessary to revenue generation to repay the long-term debt issued to finance and the building and maintenance of the toll facility and to collect money to accumulate finance to expand future capacity.

7. LIMITATIONS:

The length of the vehicle in this system is measured from front wheel to back wheel. This is because if it is measured by means of its body length; the LASER may not be cut by the body of all types of vehicles as the body of all types of vehicle is not solid (e.g. CNG). So, the setup is required to be as low as possible to the ground to at least cut the tyre of all the vehicles. Again there are only four categories. This may lead to count excess or less toll from a vehicle. To solve this problem, more categories can be introduced in the future work.

8.CONCLUSION

Manual system of toll collection is more time consuming and inefficient. Automatic toll collection system reduces the manual assistance and delivers secure and time efficient solution for the busy roads. Vehicle monitoring system for toll collection on the basis of the length of vehicle is cost effective and efficient. It can be easily implemented on highways and bridges.

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