Automated Toll Collection and Charging System using Radio Frequency Identification in Bangladesh

Md. Ibrahim Khalil
Dept. of Electrical and Electronic Engineering
University of Dhaka, Dhaka, Bangladesh
ibrahim.eee.du@gmail.com

Sazzad M.S. Imran
Dept. of Electrical and Electronic Engineering
University of Dhaka, Dhaka, Bangladesh
sazzadmsi@du.ac.bd

Abstract—*We proposed an automated system to collect toll at different toll plaza using RFID (radio frequency identification) suitable in Bangladesh and other developing countries. The advancement in technology has become more of a consistent presence in modern life. Automated Toll Collection System is an advanced technology for collecting toll in a faster and more efficient way. It is used to avoid traffic congestion near toll plaza and ultimately save fuel consumption. We have come up with a concept of RFID based ATCS using Arduino microcontroller. RFID cards contain unique identities provided to every vehicle by Vehicle Registration Office. Whenever a vehicle with its unique RFID card reaches the toll plaza, the RFID card reader attached on the toll plaza gate reads the card and transfers the unique ID to the microcontroller. Accordingly, the processor works and deducts a fixed amount of money from the prepaid card. The deducted amount will be sent as an SMS to the registered user mobile number which is synced with his/her prepaid account using GSM. If the card's ID has insufficient balance or for unregistered vehicles toll gate will be closed and will indicate to go through alternative way for manual toll collection. When sensor will sense the vehicle present on the manual toll collection way the main gate will be opened for the next vehicle. Users can recharge their RFID cards with any amount using standard digital card recharge system which is incorporated in our proposed ATCS.*

Keywords - Automated toll collection; radio frequency identification; microcontroller; traffic congestion.

I. INTRODUCTION

Now a day's traffic problem is a very rigorous problem in Bangladesh and other developing countries. In Bangladesh, consistently we need to confront congested driving conditions for several hours. Traffic jam is mainly due to reckless driving, rash of the vehicles in the road and lack of proper management. For the reduction of traffic problem and to increase connectivity government has made many bridges, flyovers and bypass roads. Certain amount of toll is charged when any vehicle passed these. Unfortunately, in Bangladesh, like other developing countries, the toll collection system is manual which takes more times to pass the vehicles creating long queue and traffic jam near toll plaza.

The Toll Collection System has changed drastically over the years; from being a single borderline, significant revenue has been generated from a small passage booth to the huge toll collection infrastructure; working of the traffic of a city or even a state also depends on that toll collection system. While most of the populace is travelling through various means it has turned into a need and an administrative strategy to control traffic.

Authors mentioned the benefits of Electronic Toll Collection System often abbreviated as ETC over the Manual Toll Collection System [1]-[6]. It stated that the former aides in controlling the traffic congestion amid different festivals. In addition, it is helpful for the administrators in controlling the incorporated centralized review system. Use of image processing tools for the toll collection was described in which the number plates on the vehicles can be processed and checked so as to match any existence in the database; from which the toll can be deducted thus giving it an upper hand from the manual toll collection [7]-[8]. The use of RFID for the toll collection was conceptualized in [9]-[11] thus making the whole system easy and feasible. The idea proposed in the papers had an edge over other electronic methods due to its flexible nature and easy implementation. Authors in [9] slightly change the existing system and proposed the use of passive RFID tags that can be used instead of active RFID tags that takes use of the car battery. Authors then introduced the use of a microcontroller ATMega328PU which is the centralized unit that controls the whole system to detect any

close range tags and hence requesting the database to deduct amount from the account connected to the ID [12]-[13].

Since conventional methods for collecting toll fees or roadways taxes are not very efficient and reliable so there was a need for a new advanced system that eliminates most of the drawbacks of the current system in use. This technology is not very familiar in most of the countries for it requires a highly efficient infrastructure and needs to be well maintained. In this paper, we presented an automated toll collection system using RFID technology which will not stop the vehicles to collect toll. Therefore, this system will help to reduce the traffic jam and fuel consumption. We incorporated the card charging system, and kept alternate path to collect toll from unregistered vehicles and from those cards with insufficient balance without disturbing the normal flow of traffic. The main objectives are to improve the performance of the toll collection system, ensure smooth traffic flow near toll gates, and convenient and quick service to the vehicle owners.

The paper is organized as follows. Next two chapters describe the working principle and circuit design of automated toll collection system and associated card recharge system, respectively. After that we discuss the practical implementation and result analyses together with feasibility study of the proposed system. Finally, we conclude the paper with concluding remarks and mentioning the scope for future development of this proposed system.

II. AUTOMATED TOLL COLLECTION SYSTEM

ATCS (automated toll collection) is a system that allows payments of toll automatically with vehicles not having to stop at toll booths. Facility of reading RFID tags fitted on vehicles are available at the toll booth to automate the whole process of collecting toll. The system reads the card, deducts fixed amount of toll from the user's account and authenticates the vehicle to pass through the toll gate. The proposed circuit mainly consists of two ultrasonic sensor and RFID reader which takes input and sends the data to processing unit Arduino. The Arduino analyses the data and gives its response to motor and other components. The Arduino is programmed in such a way it automatically adjusts to give most accurate result possible. The block diagram of our proposed ATCS used in toll plaza are given in fig. 1.

When a vehicle will come close to the toll plaza ultrasonic sensor will detect it. Then RFID reader will check whether any registered card is present. If the card is available, reader will read the card and at the same time Arduino will check the balance. If the balance is sufficient, fixed amount of money will be deducted and an SMS confirming the reduction will be sent to the registered mobile number and the vehicle will pass the tool plaza. In case there is no registered card available or if the balance is insufficient, gate will be closed and Arduino will indicate to go manual toll collection way. When ultrasonic sensor will sense the vehicle gate will be opened. How the automated toll collection system works is given in the flow-chart in fig. 2.

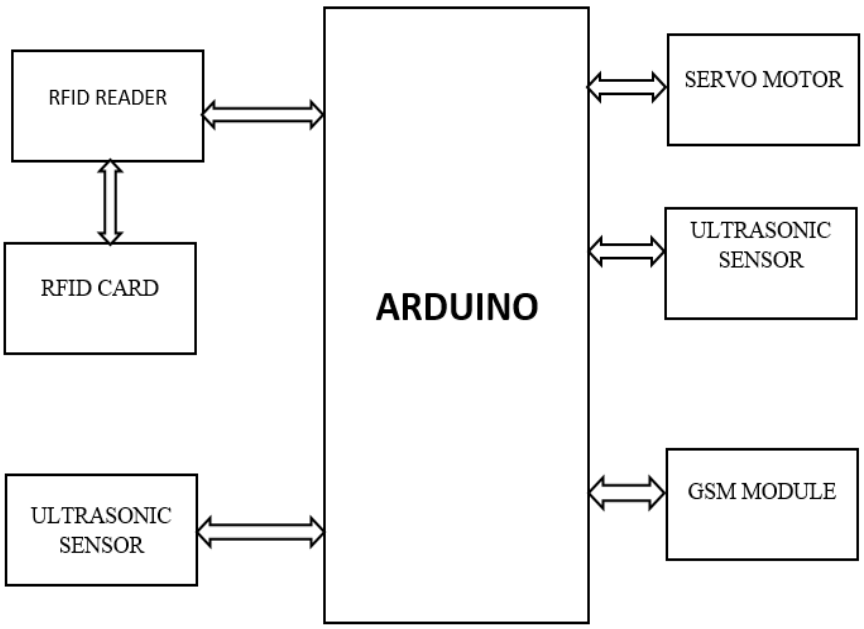

Figure 1: Block diagram of automated toll collection system in Toll Plaza.

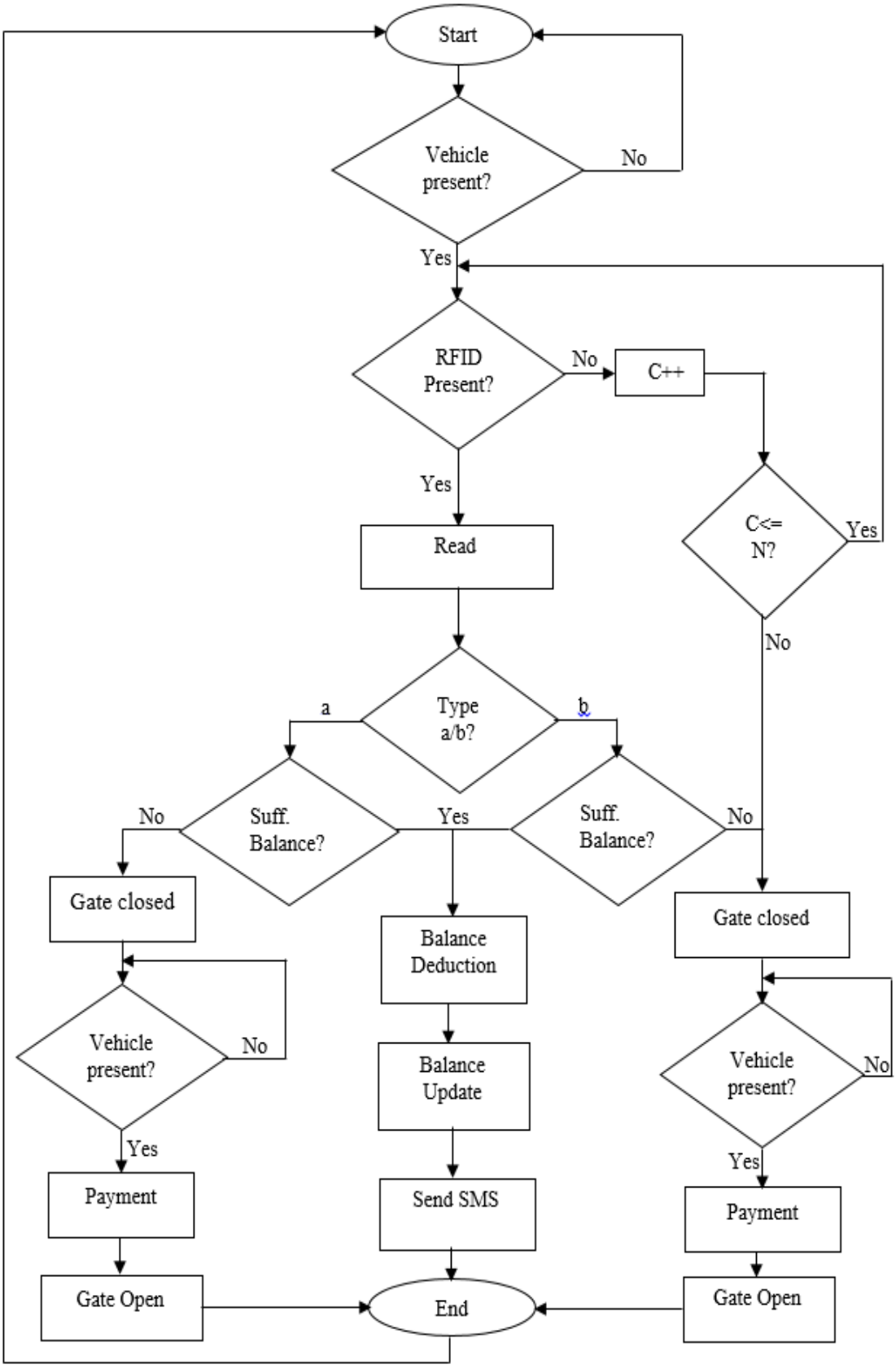

Figure 2: Flow-chart of how automated toll collection system works.

III. RECHARGE BOOTH

When balance of the RFID card is low it needs to be recharged. Recharge can be done in ways either sweeping card or entering tag ID. How a card can be recharged is given in the flow-chart in fig. 3.

Every vehicle has a unique tag ID. When balance of any card is insufficient we need to recharge it. When we want to recharge we will be asked to choose the options. If we select the option 1 we have to sweep the card, otherwise we have to enter the tag ID; then we have to enter the recharge amount and PIN code. If tag ID and PIN code are matched recharge will be successful and the system immediately send an SMS to the registered mobile number showing the current balance. Otherwise, we will be asked to cancel or continue again.

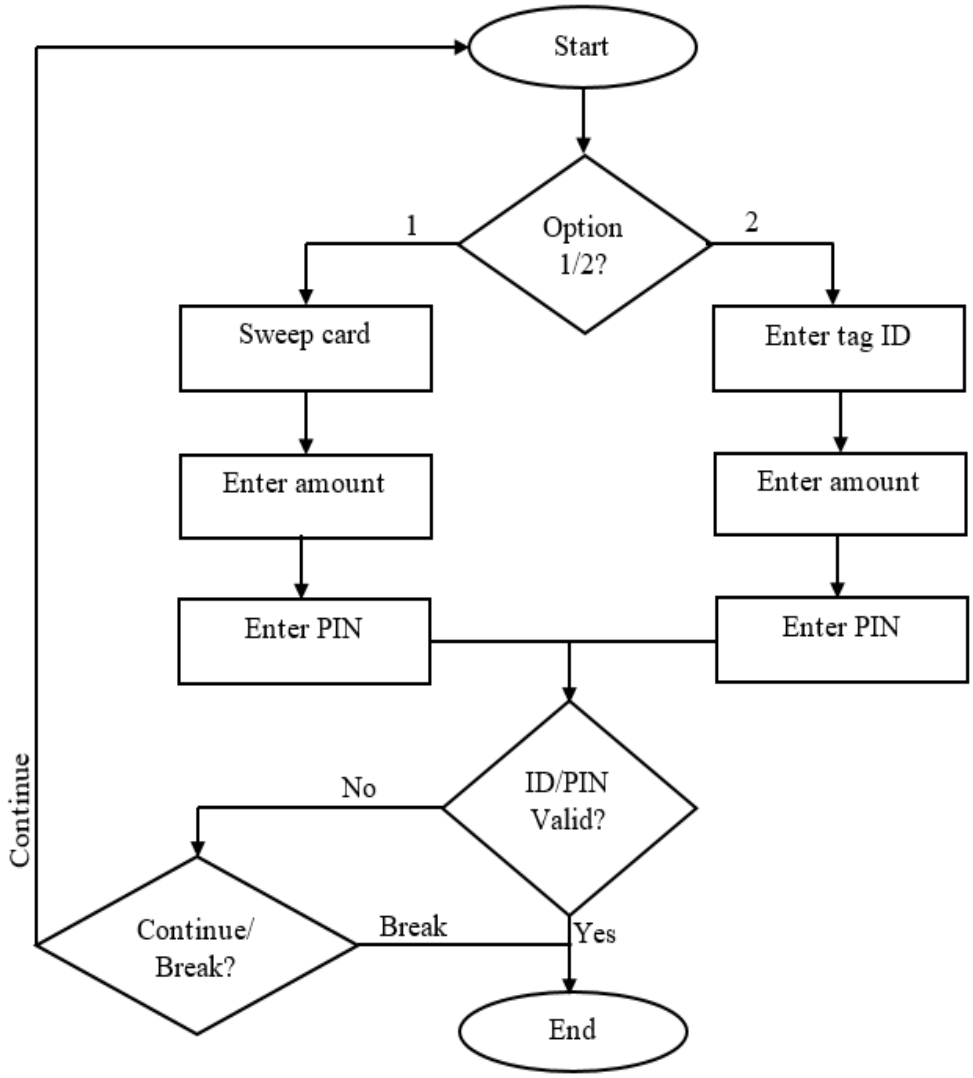

Figure 3: Flow-chart of how an RFID card can be recharged.

IV. RESULTS DISCUSSION

Whether the system works properly or not, we checked all the separate appliances for several times to run altogether. After connecting all the parts as circuit design, we upload the programming code in the Arduino with IDE. The coding and debugging was done on the Arduino 1.6.8-1.6.9v of the software of the same name. Instead of going to a single program that is debugged all the time, we framed out various different codes that gave outputs based on their work and interfacing of the Arduino board with different components.

We consider some of the following cases and found the system works perfectly- when no vehicle is present, when vehicle present with RFID card and sufficient balance, when vehicle present with RFID card and insufficient balance, when vehicle present with RFID but not registered and when vehicle present without RFID card are shown in fig. 4 to fig. 6. We also checked the recharging system with card sweeping, recharging with card sweeping but not registered or invalid PIN, recharging with tag ID and recharging with tag ID but not registered or invalid PIN. Corresponding results of the above cases are shown in the fig. 7 to fig. 10.

Date	Time	Tag_ID	Privious_B	Toll_Aount	Current_B	Manula_C
11/28/2018	11:31:13 AM	033FE4D5	114	TK.20	94	0

(a)

Dear user, you toll bill is TK.20. your current balance is tk.94.

(b)

Figure 4: Successful payment of toll if RFID card and PIN code are matched. Account is updated and SMS is sent to vehicle owner's mobile number.

Date	Time	Tag_ID	Privious_B	Toll_Aount	Current_B	Manula_C
11/28/2018	11:25:10 AM	033FE4D5	14	N/A	14	1020

Figure 5: Unsuccessful payment of toll; RFID card and PIN code are matched, but current balance is insufficient. Vehicle is redirected to alternate gate to pass after payment of toll charge manually.

Date	Time	Tag_ID	Privious_B	Toll_Aount	Current_B	Manula_C
12/1/2018	1:57:15 PM	9352432E	Not Reg.	Not Reg.	Not Reg.	1030

Figure 6: Unregistered vehicle is redirected to alternate gate to pass after payment of toll charge manually.

```
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
#<======>#<=====>##Recharge Booth##<======>#<=====>#
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
Please choose Your optin.
1. Card.
2. Tag ID.
Enter your card:UID tag :434C26D5
Enter the amount:
50
Enter the PIN:
50TK. recharge successful.your corrent belance is 60TK
```

Figure 7: Recharging with card sweeping. If RFID card and PIN code are matched recharge is successful. Account is updated and SMS is sent to vehicle owner's mobile number.

```
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
#<======>#<=====>##Recharge Booth##<======>#<=====>#
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
Please choose Your optin.
1. Card.
2. Tag ID.
Enter your card:UID tag :E33420D5
Enter the amount:
50
Enter the PIN:
Invalid PIN/ Tag ID is not Registered.

Do you want to Continue or Break?
 please select the option.
 1.Continue
 2.Break
```

Figure 8: Recharging with invalid card sweeping/PIN. If RFID card and PIN code are not matched recharge is unsuccessful. We are asked to continue or break.

```
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
#<======>#<=====>##Recharge Booth##<======>#<=====>#
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
Please choose Your optin.
1. Card.
2. Tag ID.
Enter your Tag ID:
9352432E
Enter the amount:
60
Enter the PIN:
TK. recharge successful.your corrent belance is 62TK
```

Figure 9: Recharging with tag ID. If card ID and PIN code are matched recharge is successful. Account is updated and SMS is sent to vehicle owner's mobile number.

```
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
#<======>#<=====>##Recharge Booth##<======>#<=====>#
#<======>#<=====>#<=====>##<======>#<=====>#<=====>#
Please choose Your optin.
1. Card.
2. Tag ID.
Enter your Tag ID:
9352432E
Enter the amount:
100
Enter the PIN:
Invalid tag ID/PIN.

Do you want to Continue or Break?
 please select the option.
 1.Continue
 2.Break
```

Figure 10: Recharging with invalid tag ID/PIN. If card ID and PIN code are not matched recharge is unsuccessful. We are asked to continue or break.

V. FEASIBILITY STUDY

TABLE I. FUEL CONSUMPTION

Item	Mayor Mohammad Hanif Flyover (ATC System)	Mayor Mohammad Hanif Flyover (Manual System)
Total number of vehicles per day	15719	15719
Percent vehicles estimate to use ETC system	100%	100%
Payment time (second)	5	105
Total reduce time when using Toll Collection system (Seconds)	27	0
Distance between before and after tollbooth ramp (km)	0.37	0.37
Vehicle average speed during deceleration/acceleration (km/h)	40	10
Tollbooth approach or leave time (Second)	15	99.9
Reduced time due to elimination of deceleration/acceleration (Seconds)	84.9	0
Average waiting time in queue (Second)	180	960
Fuel consumption in one second stop (liter)	0.00033	0.00033
Total waiting time in a queue a day (Hours)	785.95	4191.73
Total reduced time per day (Hours)	3405.78	0
Fuel consumption per day (liter)	933.7	4979.78
Fuel cost per liter	65	65
Average fuel consumption per day for a vehicle (liter)	0.06	0.32
Total fuel consumption per year for a vehicle (liter)	21.68	116.8
Total cost per year for fuel consumption (TK)	22152032.5	118145280.5
Total Fuel Saves per year (TK)	95993248	0

TABLE II. COST SAVINGS ANALYSIS

Item	Mayor Mohammad Hanif Flyover (ATC System)	Mayor Mohammad Hanif Flyover (Manual System)
Number of staff in toll collection system	12	80
Constant average cost including ticket issuing as per day	0	2000
Average salary per employee TK)	18000	17000
Total Annual Cost (TK)	2592000	16320000
Annual Cost Savings	137228000	0

In this study, we selected semi-automated system at Mayor Mohammad Hanif Flyover in Dhaka, Bangladesh where computerized gate control system with manual toll transaction has been used. Toll collectors kindly supplied us the secondary data on the traffic flow. Time of delay, required speeding up and slowing down of different vehicles, and transaction time were observed through a primary survey. Automated system for toll collection was found out in terms of saving in money, fuel and time.

VI. CONCLUSION

In this article, we present a simple and cost effective automated system for collecting toll using Arduino and RFID. We also incorporated card recharge system in our ATC. Feasibility study of the system in terms of fuel consumption and cost savings are also presented. Study shows that introduction of ATC system can be beneficial for Bangladesh and other developing countries and its people. The main benefits are savings time, low fuel consumption and smooth traffic flow. It has also the best benefit which is government will not lose any revenue from toll collection. More over the extra option of weight sensor will always help the bridge to avoid any kind of unwanted accidents like bridge collapse. The traffic free toll system will add a good impression to the people as well. GSM module will send massage to the phone, so the passenger will know how much he has paid for toll and no chance of charging extra money. Another objective is dealing with RFID tags and keeping all the vehicles under registration, so that no unregistered car can be used and do any unethical works.

Further, if we deploy RFID readers and speed calculators at small distances on the highways, penalty can be automatically imposed and deducted on vehicles exceeding speed limit through vehicle's RFID tag. This system can also be used to catch people violating rule of overloading their vehicles by adding weight calculators in the system.

ACKNOWLEDGMENT

We express our deep gratitude to the authority of Mayor Mohammad Hanif (Jatrabari-Gulistan) Flyover, Bangladesh for providing us our required data, and allowing us to conduct survey on service time and to find out other necessary information for various vehicles.

REFERENCES

[1] T.W. Kirchstetter, B.C. Singer and R.A. Harley, "Impact of California Reformulated Gasoline on Motor Vehicle Emissions: 1. Mass Emission Rates", Environ. Sci. Technol., vol. 33, pp. 318-328, 1999.
[2] H.M. Al-Deek, A.A. Mohamed and A.E. Radwan, "Operational Benefits of Electronic toll collection: Case Study", Journal of Transportation Research, vol. 123, no. 6, pp. 467-477, 1997.
[3] M. Burris and E. Hildebrand, "Using Microsimulation to Quantify the Impact of Electronic Toll Collection", ITE Journal, vol. 66, no. 7, pp. 21-24, 1996.
[4] D. Levinson, "A Model for Optimizing Electronic Toll Collection Systems", Transportation Research Part A: Policy and Practice, vol. 37, no. 4, pp. 293-314, (Department of Civil Engineering University of Minnesota, Minneapolis, MN 55455, United States), 2003.
[5] M. Sisson, "Air Quality Benefits of Electronic Toll Collection", Transportation Quarterly, vol. 49, no. 4, pp. 93-101, 1995.
[6] M.L. Zarrillo, A.E. Radwan, and H.M. Al-Deek, "Modeling Traffic Operations at Electronic Toll Collection and Traffic Management Systems", Computers & Industrial Engineering, vol. 33, issues 3-4, pp. 857-860, 1997.
[7] R. Zhengang and G. Yingbo, "Design of Electronic Toll Collection System in Expressway Based on RFID", Proceedings of the 2009 International Conference on Environmental Science and Information Application Technology, vol. 3, pp. 779-782, 2009.
[8] S.R. Soomro, M.A. Javed and F.A. Memon, "Vehicle Number Recognition System for Automatic Toll Tax Collection", Proceedings of the 2012 International Conference on Robotics and Artificial Intelligence (ICRAI), pp. 125-129, 2012.
[9] K. Kamarulazizi and W. Ismail, "Electronic Toll Collection System using Passive RFID Technology", Journal of Theoretical and Applied Information Technology, vol. 22, no. 2, pp. 70-76, 2010.
[10] G.K. Andurkar and V.R. Ramteke, "Smart Highway Electronic Toll Collection System", International Journal of Innovative Research in Computer and Communication Engineering, vol. 3, issue 5, pp. 4087-4094, 2015.
[11] P. Sharma and V. Sharma, "Electronic Toll Collection Technologies: A state of Art Review", International Journal of Advanced Research in Computer Science and Software Engineering, vol. 4, issue 7, pp. 621-625, 2014.
[12] L. Luis, "Principle of Arduino and Using it as a Tool for Study and Research", International Journal of Control, Automation Working, Communications and Systems, vol. 1, no. 2, pp. 21-29, 2016.
[13] A. Shajan, A. Jose and K. Tari, "Automatic Toll Collection System", International Journal of Emerging Trends in Science and Technology, vol. 2, issue 4, pp. 2242-2247, 2015.