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IoT based real time road traffic monitoring and tracking system for hilly regions

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Abstract*: Nowadays, the occurrence of road accidents (typically two-wheeler) in hilly terrains is increasing at an alarming rate. Apart from the bad driving skills, the reason for accidents being terrain-based issues like the number of blind turns, elevated U-turns, poor lighting (absence of street lighting) and lack of supportive gear. Though the road conditions are conducive and modernized due to fast urbanization, population growth and development of various living spaces and reachability of transportation facilities for farthest corners, the serious issues of human loss due to accidents still happening has captured the attention of modern researchers and are coming up with technical solutions that can reduce or avoid the accident occurrences in these terrains. Hence, a system is required, which should be capable of addressing such situations. The paper proposes an IOT based accident prevention unit (APU), as a solution for the stated problem. The recommended APU is deployed and tested on the parameters like the number of accidents, helmet defaulters and average response time in hilly terrains of northern India. Over the period of two years, it is observed that the suggested unit in the paper has successfully assisted in reducing the accidents and reduction in helmet defaulters significantly.

Index Terms*: Raspberry Pi, PIR Movement Sensor, Accident Prevention Unit (APU).

I. INTRODUCTION

Lack of road safety awareness among drivers has become a major concern due to the rise in the number of road accidents. This happens especially in the hilly terrain, majorly due to over speeding, lack of safety measures and un-availability of strict monitoring mechanism to penalize the offenders. Due to high road accident rates in India, in 2015 it was decided to sign the Brasilia declaration ("Brasilia Declaration on Road Safety", 2019) with an intent to reduce road accidents and fatalities by half till 2020. However, the decline in the number of accidents is not substantial as per the recent statistics. The decrease in the number of accidents was found to be only 3.27% when the figures for the years 2016 and 2017 were compared. Additionally, fatalities dropped to only 1.9%. This data clearly indicates the lack of road safety measures being undertaken by the administration as well as the citizens. Further, it was found that the first quarter of the year 2018 observed a rise in fatalities by 1.68%. In the last decade, the average annual road death crashes is about 1.3 lakhs per year. This figure surpasses the population of many Indian cities like Roorkee, Darjeeling, Gangtok, etc. Hence, to emphasize we can say that India wipes out a whole city in a year due to the rising toll of road accidents ("India way behind 2020 target, road accidents still kill over a lakh a year | India News - Times of India", 2019).

The contribution of this paper is to solve the problem of increased number of accidents that take place frequently on the hilly terrain. This paper aims to save the lives of those who might die in road accidents. To mitigate such tragedies an APU system is setup. APU consists of Raspberry Pi which is a card-sized board available at an affordable cost. Multiple sensors are integrated on to the card that are used for detecting traffic load on the roads and identify the traffic violators, providing alerts on over-speeding and instant approaching vehicle from the other side of the sharp turns. To process the data, Microsoft Cognitive Services are utilized. The command and control center is setup at a specified location for the continuous monitoring of the proposed system. Resultantly, a valuable and life-saving system has emerged. The validation of proposed system is analyzed on the basis of parameters like frequency of accidents, average response time and number of helmet defaulters.

II. MOTIVATION

In hilly terrains, there exists steep cuts, uneven and elevated roads making the drive much more unsafe for drivers giving rise to accidents or even killing themselves and also innocent by-passers, if not they follow the safety speed limit and roadside warnings. This has become a major concern for law enforcement agencies to monitor offenders and tackle the road mishaps in these regions.

A. Literature Review

In India, studies on road accidents in the recent past concluded that many of the casualties in the road accidents are caused in the age group of 18-35 years, considered to be the youth of the country. The most concerning and frequent mistakes causing these accidents are majorly due to high-speed driving, riding without a helmet, driving under the influence of alcohol etc. Moreover lack of stringent monitoring and punishing the offenders by administration has made the road users lenient when it comes to ensuring their own safety.

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As the need of the hour, many companies proposed various models to enhance road security. But still, they are lagging in providing solutions to the problems like cost-efficient accident prevention systems. For this, various articles are reviewed and surveyed for better understanding of the problem [1] [2].

Guravaiah, Thivyavignesh and Velusamy [3] presented a device that can detect any movement and notification can be sent to the monitoring center. In smart homes, sensors will get activated during your absence or based on your instruction. The security system can be programmed to detect movement by means of inbuilt camera of Rasberry pi.

Barua and his team [4] proposed an outline, which observed the driver's state by utilizing numerous sensors and searched for triggers that can cause mishappenings. At that point, when certain abnormal patterns were identified, the framework notify the driver and alarm him about the situation. On the other-hand if the driver do not react within a stipulated time, the framework will turn on a distress call outside the vehicle to warn adjacent drivers and sent an instant message to the driver's closest relative about the situation. Thus, giving most extreme likelihood in maintaining a strategic distance from street mishaps and expanding a crucial window for preventive measures to be taken.

Huang and Wang with their team [5] exhibited an independent accident prevention framework which was made out of two separate outline units: transmitter unit and receiver unit. Just before the vehicle was in the transmitter zone, the vehicle speed was controlled by getting the flag from the RF transmitter. For this, RF transmitter was kept at a couple of meters before the zone.

Nguyen, Loan, Mao and Huh [6] described the security framework which included liquor sensor, eye sensor and smoke sensor. Mishap recognition framework included GPS and GSM in mobile phones. When crash happens, piezoelectric sensor would recognize the flag and transmit information to ATmega328P microcontroller. At that point, the GPS accessible in the PDA would begin to communicate with the satellite and get the longitude and latitude values. As a result, the place of mishap would be sent to the registered telephone numbers of relatives or rescue vehicle authorities. In case of accidents, immediate help or assistance can be critical as emergency services are stationed far away from the accident zone. After sunset, the area becomes absolutely dark making things even worse. There is no automated system and scarce government/private helpline that can assist traffic in these hilly regions.

India loses 3% of its GDP in terms of human loss through accidents which is its valuable human resource. Most of these are preventable and it's high time that India takes necessary action to maintain road safety and put a curb on the rising death toll.

III. Proposed System Model

The present research proposes an accident prevention unit (APU) consisting of Raspberry Pi micro-controller along with the number of sensors to reduce the problem of road mishappenings. Raspberry Pi is a card sized single-board computer that was developed in 2012 by the Raspberry Pi Foundation [7]. It works with standard keyboard, mouse and monitor. The cable can be plugged in the Raspberry Pi board directly for the display purpose.

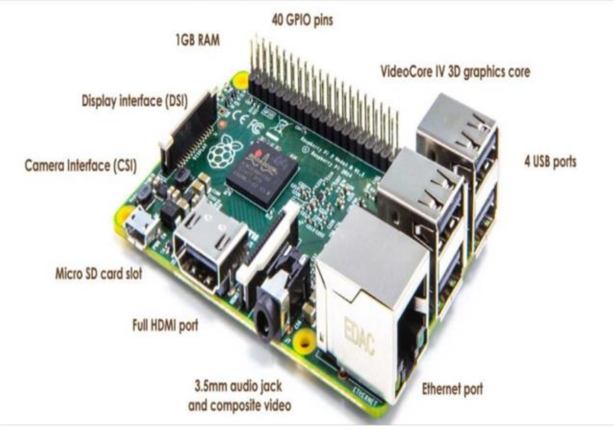

Fig. 1 Structure of Raspberry Pi 3 [8]

All Raspberry Pi models have a Broadcom system on a chip, which includes an ARM-compatible Central Processing Unit (CPU) and an on-chip Graphics Processing Unit (GPU, a Video Core IV). The performance that Raspberry pi provides in the real world is approximately equal to 0.041 GFLOPS, provided we are operating it at 700 mhz [9]. The range of RAM available with board varies from 256 MB to 1 GB. The operating system is stored on Secure Digital (SD) cards & program memory can be SDHC or MicroSDHC. Raspberry Pi board has four USB slots. Fig. 1 shows the structure of Raspberry Pi 3. High-resolution videos and photographs can be collected using the camera connected to the Raspberry Pi board [10] [11]. Common protocols such as I2C are supported by the number of General purpose input-output (GPIO) pins.

A+ and B+ models of Raspberry Pi 1, B Model of Pi 2 and Pi 3, and GPIO J8 of Pi Zero have a 40 pinout. There are 26 pins in Models A and B, also they provide a feature of GPIO access to the ACT status LED using GPIO 16. While Models A+ and B+ provide this service using GPIO 47. Raspberry Pi B+ GPIO Header is shown in Fig. 2. Raspberry Pi 3 comes with inbuilt Wi-Fi and Bluetooth facilities.

A. System Design

The basic design of the proposed system consists of the Raspberry Pi along with sensors that can be utilized to provide an optimal solution for reducing the number of accidents that occur in hilly terrains. At every blind turn and accident-prone zone, APU will be installed on each side i.e. uphill side and downhill side of the road. Each APU consist of a Raspberry Pi 3 board, a camera, a wireless USB adapter, ultrasonic sensors, PIR movement sensor [12], 20 x 4 character LCD display, speaker and a buzzer board. All APU systems will be connected to the centralized command center through a communication network

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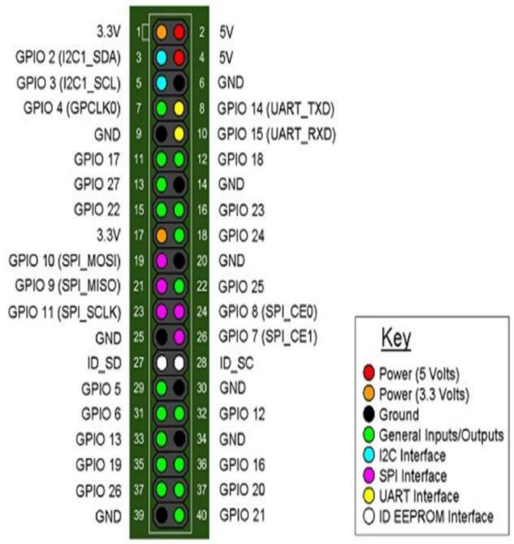

Fig. 2 Raspberry Pi 3 GPIO Header [8]

When a vehicle approaches the installed proposed APU, PIR sensor will capture the movement and generate a signal, indicating that vehicle is approaching from the opposite side and the camera attached to adjacent APU will take snapshot of the approaching vehicle. The speed of a vehicle is calculated using an ultrasonic sensor installed in the proposed APU. If the speed of the vehicle is greater than the threshold value then the buzzer is triggered on both sides, warning that the rash driver is approaching from the other end of the road thus alerting the opposite side-driver to prevent the accident.

Threshold value of the APU system is dependent on the region where the road is located and can be taken from the state road regulatory bodies.

The proposed APU installed in the region is provided with easy access to electricity and powered by the electricity supply of the same region. For backup, each APU has an Uninterrupted Power Supply (UPS) unit. Wifi routers and repeaters can be installed in the region with low network availability [13].

The data collected from the proposed APU installed on the route under test, is shared with command center setup at nearby specified location. The data gathered is then processed and the commuters who are violating the traffic rules are identified and penalized according to the state rules and regulations. To ensure easy access to data, cloud technology is used and all the data collected by the APU is streamed to the cloud [14].

Fig. 3 depicts workflow of the system. As vehicle approaches the APU 1, it will be detected using the PIR sensor and its speed will be calculated with the help of an ultrasonic sensor. If the vehicle is over-speeding then the sensor of APU 2 will activate the buzzer and the vehicle approaching APU 2 will be alerted.

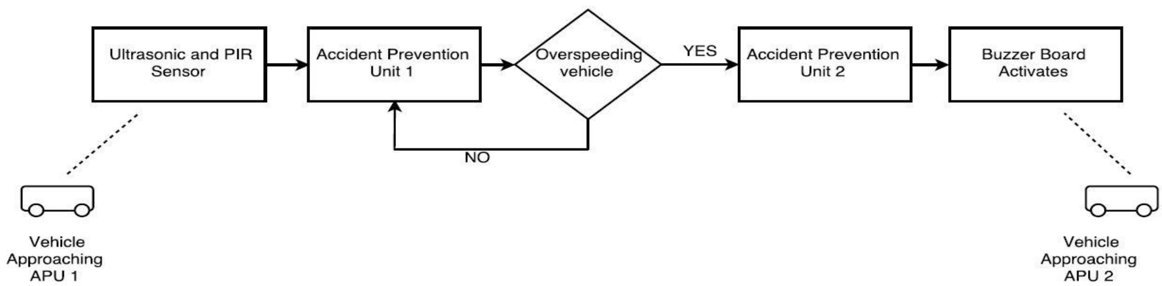

Fig. 3 Workflow of the System

Internet of Things (IoT) is a “concept of communications between multiple devices equipped with sensors and actuators for the purpose of convenience and economic benefits over Internet” [15]. The control room is connected to all APUs with the help of IoT devices. The main function of the control room is to monitor proper working of the system and give suitable responses. Control room can do live monitoring of a particular route in case of heavy traffic. It has administrative rights to control, communicate, maintain and manage the APUs. Up-gradation of APUs can be done as and when required.

IV. Implementation and Result Analysis

For the proposed system, hardware requirements are Raspberry Pi Model 3 B+, Ultrasonic sensor, PIR movement sensor, 20 x 4 character LCD display, Speaker, Buzzer board and software requirements are Python and Raspbian. The proposed APUs are installed on the 8.6 kilometers route from ``Nanda ki chowki'' to ``Bidholi village'' and the control room is setup at the Bidholi village of Dehradun city of India. The proposed Accident Prevention Unit which is capable of monitoring the vehicles and generating information to make the route under test safe to drive, should be verified and validated. The effectiveness of the proposed approach is quantitatively analyzed on the basis of performance metrics i.e. Frequency of Accidents, Average Response Time and Helmet defaulters.

A. Frequency of Accidents

Frequency of accidents is a performance metric that represents the count of accidents that occur in a month [16]. For the proposed method to be effective, the number of accidents should be minimized.

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Table 1 shows a tabular representation of the Number of Accidents w.r.t. Months before installation of APU in the year 2017 and after installation of APU in the year 2018. The proposed device reduced the number of accidents effectively in the whole year as shown in Fig. 4. For instance, in 2018 during the month of January, February, March, April, May and June, the percentage of accidents are reduced by 50%, 60%, 57%, 50%, 33% and 75% respectively as compared to 2017. While in 2018 during the month of July, September, October, November, and December, the percentage of accidents reduced by 27%, 85%, 70%, 40% and 60% respectively in contrast to 2017. The APU reduced the number of accidents close to none in the months of June and December and efficiency of 80% in the month of September of 2018 as compared to 2017. The number of accidents have consistently reduced over the edges of the year and marginal increase in the middle of the year. This could be attributed to the heavy rain downpour season in the month of July.

Table I Tabular Representation of Number of Accidents w.r.t Months

Month	Number of Accidents before installation of proposed APU in the year 2017	Number of Accidents after installation of proposed APU in the year 2018
Jan	04	02
Feb	10	04
Mar	07	03
Apr	10	05
May	06	04
Jun	08	02
Jul	11	08
Aug	04	05
Sep	27	04
Oct	10	03
Nov	20	05
Dec	05	02

This quantitative and graphical analysis proved that the proposed APU is highly effective in attaining the objective of reducing the number of accidents. There is randomness in the number of accidents as the count of commuters varies monthly i.e in the month of September and November the number of commuters is high due to university presence in the road, attributing to its academic activity.

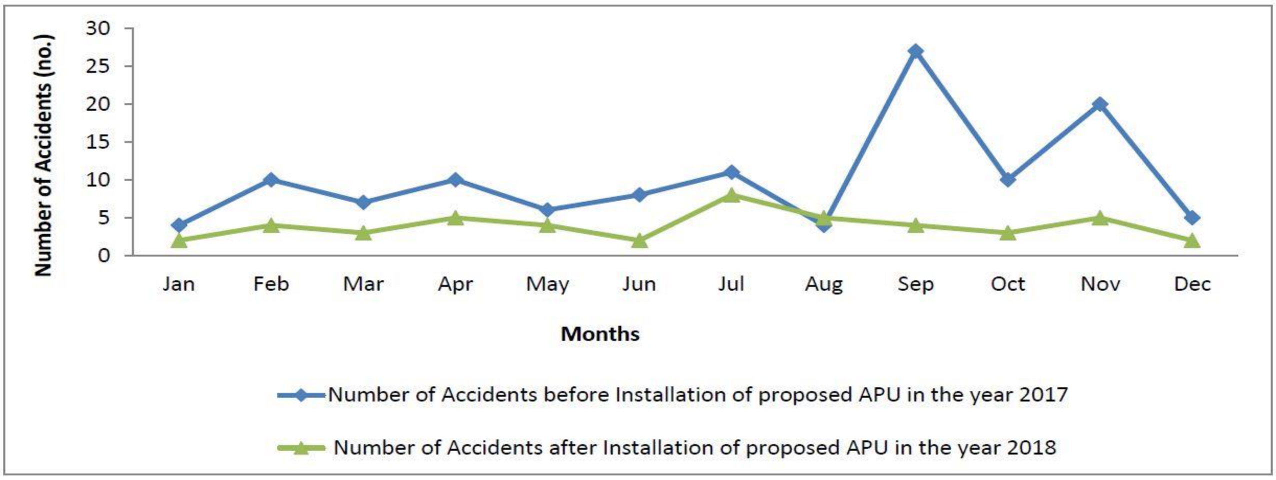

Fig. 4 Graphical Representation of Number of Accidents (no.) w.r.t Months (m)

Average Response Time and Helmet defaulters.

B. Average Response Time

Response time represents the time taken by the state road safety authorities to reach for aid to an accident that took place on the route under test. Response time is calculated from equation 1. it is defined that the emergency response unit is present at the same location of the command center from where the distance is measured as 0 to 8Kms. APUs are setup at every 2km and alert buzzer systems are at the road bends/curves.

$$\Psi = \rho - \lambda \quad (1)$$

Where, Ψ = Response Time, ρ = Time instance at which authorities reach the accident place and λ = Time instance at which accident take place. The average response time can be calculated using equation 2:

$$\tau = (\Sigma\Psi)/\eta \quad (2)$$

Where, τ = Average response time, Ψ = Response time and η = Number of accidents in a month.

Table 2 indicates the tabular representation of average response time w.r.t months before APU setup in the year of 2017 and after APU setup in the year 2018.

For the proposed method to be effective, the average response time should be minimum.

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Fig. 5 indicates Average Response Time (min) w.r.t Months (m) before APU setup in the year 2017 and after APU setup in the year of 2018. This has been proved from the quantitative analysis that the proposed unit reduced average response time adequately in the entire year. For instance, response time has nearly shown an improvement with an average increase in efficiency per kilometer by 33% ie., there is a reduced time of almost 6-8 min for the varying distances of 0-8 kms. If a prediction straight line is drawn then it can be claimed that as the distance increases response time efficiency increases in correspondence with the non-APU setup conditions.

Table II Tabular Representation of Average Response Time (minutes) w.r.t Months

Months	0-2 km Before APU in 2017	0-2 km After APU in 2018	2-4 km before APU in 2017	2-4 km After APU in 2018	4-6 km Before APU in 2017	4-6 km After APU in 2018	6-8 km Before APU in 2017	6-8 km After APU in 2018
Jan	0	0	0	0	0	0	0	0
Feb	0	0	12.4	10.8	19.24	16.12	0	0
Mar	8.54	7.11	0	0	17.1	15.34	0	0
Apr	9.12	8.3	13.5	11.4	0	0	24.12	20.34
May	0	0	14.45	12.3	18.54	17.48	0	0
Jun	9.58	8.15	0	0	0	0	23.27	21.35
Jul	0	0	14.54	11.34	17.44	16.11	22.18	20.33
Aug	0	0	14.23	12.33	0	0	0	0
Sep	9.48	7.12	15	11.8	19.48	17.38	24.56	20.12
Oct	0	0	0	0	16.11	15.31	24.52	23.33
Nov	9.58	7.42	13.35	11.45	16.45	19.43	23.22	21.5
Dec	8.34	7.45	0	0	0	0	0	0

When analyzed by considering the data points at every 2 kms, average response time of 14.2 min, 19.09 min, 22.59 min and 28.51 min were observed with a distance splits of 0-2 kms, 2-4 kms, 4-6 kms, 6-8 kms in 2017. After APU setup in 2018, average response times were 7.46 min, 11.31 min, 16.54 min and 20.55 min respectively. These observations have finally demonstrated that the proposed APU is profoundly effective in accomplishing the goal of minimizing the response time.

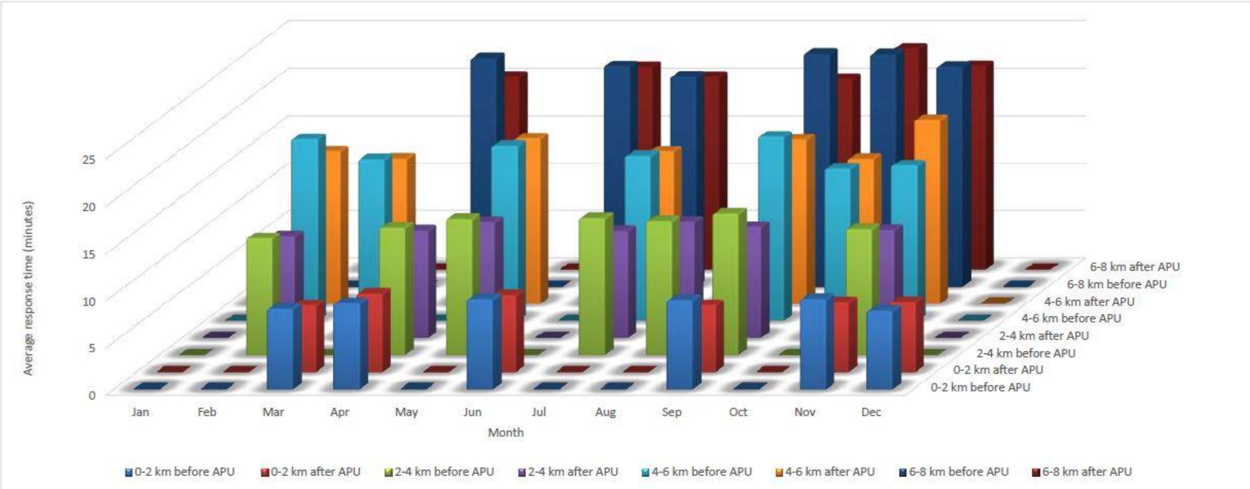

Fig. 5 Graphical Representation of Average Response Time (min) w.r.t Months (m)

C. Helmet Defaulters

Helmet defaulters refer to the count of the commuters who are not wearing the head protector equipment (Helmet) while driving on the route under test. The main strategy is to inculcate helmet awareness among the commuters for a safe road driving. Table 3 demonstrates the tabular representation of the number of helmet defaulters w.r.t. months before installation of the proposed APU in the year 2017 and after setting-up of the proposed APU in the year 2018.

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Table III Tabular Representation of Helmet Defaulters w.r.t Months

Month	Number of Helmet Defaulters before installation of proposed APU in year 2017	Number of Helmet Defaulters after installation of proposed APU in year 2018
Jan	157	120
Feb	297	162
Mar	351	150
Apr	325	136
May	398	165
Jun	107	90
Jul	93	90
Aug	341	65
Sep	322	117
Oct	275	97
Nov	284	86
Dec	117	32

Fig. 6 demonstrates the Number of Helmet Defaulters w.r.t Months before the installation of proposed APU in the year 2017 and after APU setup in the year 2018. This has been proved from the quantitative and graphical analysis, that the proposed mechanism expanded the helmet wearing habit among commuters in the months come by. In the months of Feb, Mar, Apr, May, Aug, and Sep there is a huge reduction in the number of helmet defaulters. Marginally there is reduction in the months of Jan, Jun, July and Dec but still its accountable decrease. June and July could be discussed as a special time region of season which can e attributed to the ineffective data capturing by the APU. As these months are marred by heavy rainfall. Cumulative interesting observation is that the scale percentage is in the order of 20% in the Jan and steadily rises to 80% and overall helmet defaulter reduced to 57%.

This quantitative and graphical examination demonstrated that the proposed APU is exceedingly successful in achieving the goal of making the riders to wear the head protector.

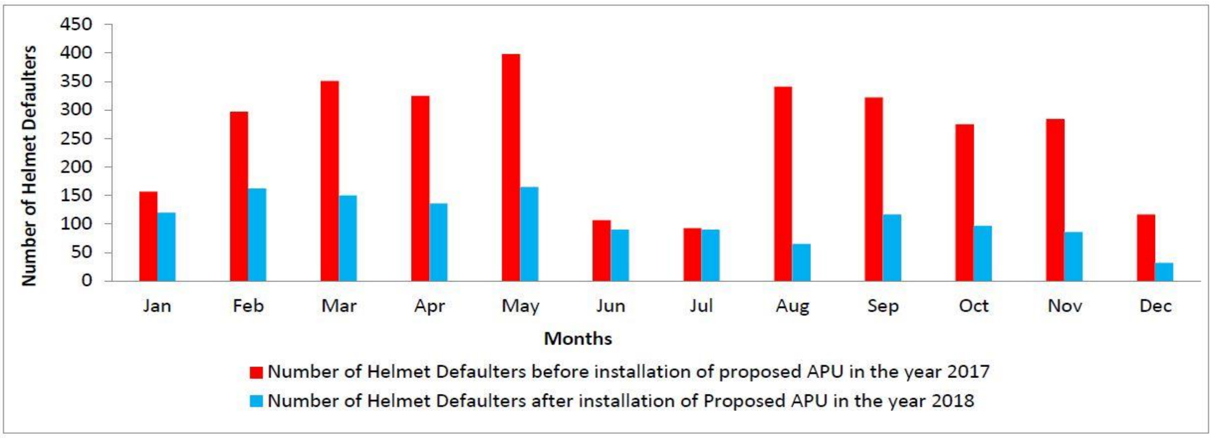

Fig. 6 Graphical Representation of Number of Helmet Defaulters (person) w.r.t Months (m)

D. Discussion

The paper proposed improvement over traditional way of preventing road accidents by deploying an IOT based Accident Prevention Unit (APU). The result was concluded on the parameters such as the Frequency of Accidents, Helmet Defaulters and Average Response Time on route from "Nanda Ki Chowki" to Bidholi village, Dehradun, India. In the period of two years, second year is monitored with APU and compared with first year's non-APU setup. It is concluded that it has effectively helped in minimizing the road mishappenings.

V. CONCLUSION

The problem of road accidents in hilly terrains is addressed in this research paper. There is an urgent need for such a road safety monitoring, alerting system to prevent, preserve human loss from accidents. Raspberry Pi is an effective gadget used for solving this problem because of its compact size and low power consumption. An APU is proposed in this research paper which proves itself to be quantitatively effective in reducing the Frequency of Accidents, Average Response Time and Helmet Defaulters. This paper foresees great future possibilities. It can be used with more advanced IoT devices and emerging technologies. Moreover, the data extracted from the proposed APU will be utilized by the prediction model to predict the frequency of traffic increase, congestion, traffic violations, rate of accidents in the years ahead, also traffic early warning and vehicle thefts notifications can be some of the innovative features which can be built into the system.

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Some of these features are aligned with the advancements with the image capturing and image processing technologies with HD cameras and machine learning mechanisms which will make the system intelligent and formidable in all weather conditions and difficult terrain.

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