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Road Crime Control and Reporting System for Public Service Vehicles in Developing Countries: A Case of Kenya

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Abstract In this paper, we introduce an Automated Decision Support System (DSS) that can help reduce road accidents in developing countries. The system incorporates a number of networked sensors that collect information related to road usage crimes that includes images and send the information to a central server for processing via a GPS tracking device. The type of sensors employed are weight sensors on the vehicles suspension to detect overloaded vehicles, a speed sensor to detect over speeding vehicles a sensor on the seatbelts to identify which seatbelts are not in use, alcohol detecting sensors for drunk drivers, and a camera to capture the people in the vehicle so that an identity can be put on defaulters. The Servers send analyzed data to different institutions that include, the Traffic headquarters, Kenya's National Transport Safety Authority (NTSA), the judicially and the owners of the vehicles. Vehicle owners can also access more detailed information using a web browser. Sensors will collect information from the vehicles, forward this to an on-board data analyzer that will upload to the nearest access point (normally to be placed at authority stations).

Keywords: *Sensors (DDE, DP) and Sensor Network, GPS vehicle tracking device, Access points, SMS, Bluetooth, DSS, OLAP, General packet radio service (GPRS), ORF monitors, Global System for Mobile communication (GSM)*

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1. Introduction

Road Safety is a serious problem all over the world, its severity is more pronounced in the developing countries, especially in Africa. According to World Health Organization (WHO) report [1], each year, over 1.2 million people are killed and 50 million injured on roads around the world. This report concluded that Road traffic crashes are predictable and therefore preventable. In order to combat the problem, though, there needs to be close coordination and collaboration, using a holistic and integrated approach, across many sectors and many disciplines. According to SafetyNet [2], Without new and effective action, deaths in low to middle-income countries are forecast to rise steeply**.** Dr. Maunder of Transport Research Laboratory [3] mentioned that almost 70 per cent of accidents occur in the developing or emerging world. The Author furthers stated that, Whilst there is a general decline in the number of fatalities in industrialized countries the opposite is true elsewhere. If account is taken of levels of motorization by expressing accident statistics as the rate per registered vehicle, then less developed countries (LDCs) have rates at least 10 to 20 times higher than the best industrialized countries. This shows that the techniques used in developed countries have either not been suitable for developing countries or they are not implementable due maybe to costs, infrastructure or other unknown reason. Some solutions that have been deployed in developed countries like, Increasing road safety with automated driver assistance systems in the Safer Journey [4] may not work in developing world since this is used on the upper end cars whose costs are beyond the developing countries. More over the roads in developed world can accommodate such systems, unlike in developing countries.

According to Safer Journeys [8], four safe system principals are: People make mistakes, People are vulnerable, We need to share responsibility, We need to strengthen all parts of the system.

Although the understanding may apply differently, the same are applicable in developing world.

Looking at the first principal, When a passenger fails to buckle the seat belt, the mistake can lead to fatal injuries. Drivers also overlook overloading which I a serious mistake that can lead to accidents. For the second principal, Vulnerability of people needs to be kept as low as possible and that's why measures need to be taken to ensure less severity of accidents on people. As for the third principal, Responsibility need to be shared by both the passengers, vehicle manufacturers, vehicle driver, vehicle owners and law enforcers. All parts need to be strengthen (fourth principal) in terms of making vehicles that can control mistakes, report defaulters and allow sharing of responsibilities in case accidents happen.

The major causes of road accidents in developing countries are: Over speeding, Overloading, Poor road conditions, drunkardness/intoxication, and driving of unroadworthy vehicles. According to Akongbota [9], about 30% of accidents on the roads in Ghana are caused by of speeding. The author also indicated that driving while intoxicated can cause fatal road accidents. Alcohol and drugs can affect ones driving skills. It causes general impairment of the brain and the function of nervous system. Drivers who drive tired or exhausted are mostly sleepy, agitated and aggressive on the roads. Fatigue can affect their clear thinking if they encounter a glitch on the roads and this can lead to accident. Abdul-Rahaman Haadi [10] also analyzed the accident cases in the Ghana and made the following observations: i) Some 70% of crashes occur on flat and straight roads. ii) Speeding is a major cause of crashes, accounting for over 50% of reported crashes. iii) Buses and mini-buses cause 35% of fatal crashes while cars are responsible for 32%. iv) Road users between 16-45 years are the most vulnerable group and account for 58% of total road crash fatalities from 2002-2006.

With the ordinarily poor road conditions in developing countries, high rate of road mishaps and road congestion, there lies a great vacuum in communication between the daily road users and the National Transport and Safety Authorities especially in developing countries. Acording to Boniface Ekechukwu [11], the inability for fast, efficient and accurate decision making through provision of adequate traffic situation information to road users (motorist and cyclists alike) has led to loss of lives. The national Road Authority (NRSA) is not rendering a 24hours/7days satisfactory service, while the road is in constant use and traffic situation at late hours are not properly coordinated. The unavailability of a functional Database is an obstacle to an effective communication.

Michael Ian Pinard [12] in his paper on Overload Control Practices in Eastern and Southern Africa, discusses in detail the challenges and problems caused by vehicle over loading in parts of Africa. The Author mainly discusses control of overloading on the roads.

Dr Matunda in her paper, A Nation Asleep at the Wheel , [16] discusses the inability by authorities to control road accident in developing world.

In Kenya, a number of solutions have been introduced by the Kenya Government. This includes, use of speed Governors on PSV vehicles which always meet the challenges of being tampered with by the owners, Introduction of rules like what was referred to as “Michuki Rules“ among other measures. These are rules that ensured soberness on the road in terms of adhering to the laid out traffic rules. All these have succeeded for a short time but been challenged by failure of follow-up by government agencies. Partrick Asingo and Winnie Mitullah in their paper [13], implementing road safety measures in Kenya, discuss this problem with focus on policies introduced by the government. They discuss how the legal notice emphasize reduced speeds through use of speed governors, passenger safety through compulsory use of safety belts, and reduced passenger capacity for more comfort in all PSV vehicles. This Paper concluded that The measures being implemented do not seem to have correctly diagnosed the root cause of road crashes in Kenya. While it is increasingly becoming evident that human behavior and attitude significantly do not contribute to road carnage, the past road safety measures, nor do the prescriptions of the Legal Notice No. 161 of October 2003 [13] adequately address the behavior and attitude of road users and regulators.

The International road assessment program iRAP [14] stated that, “More than 85 per cent of road traffic deaths and serious injuries occur in developing countries. Road deaths in high-income countries are expected to fall between 2000 and 2020, but they are likely to increase by more than 80 per cent in the rest of the world.” There is therefore a call to look into ways of bringing this down in a “developing country's way”.

2. Proposed System

The system discussed in this paper proposes use of cheap sensors mounted in vehicles to monitor what happens in the vehicles. It presents a way of monitoring the passengers and drivers remotely. It introduces a way of integrating an active authority in the vehicle that will always ensure that there is evidence for any incriminating activities that take place in a public service vehicle that can lead to an accident.

This system will help monitor all the people who get into the vehicle by using a surveillance camera, identify those who do not use seatbelts by using seatbelt sensors and switches, and detect overloading and over speeding using an assortment of cheap but accurate devises.

By availing necessary information to a central system, the system will not only let the law enforcers and vehicle owners know what is going on in the vehicles but will also allow other developers to create applications draw from this data to make traveling safer and easier. It will be a system for the entire society, a system for integrity and reality.

The proposed system requires installation of sensors into public service vehicles and use the information gathered by these sensors to warn the driver of any traffic rule breaches. It will be up to the drive to act on this initial information, failure to which will lead to uploading of the offence details for processing by the central server.

The data gathered will include the total weight of the loaded vehicle against the recommended weight, the number of seated people together with the status of their seatbelts also against the recommended vehicle seating capacity, the current driver's status (drunk, intoxicated or sober) and the current speed. This is the basic information that the system will leverage. However, the system also intends to collect data for future use or for use by third parties .If a crime takes place in the vehicle, videos and voice will be captured.. The additional information collected that includes brief video footages of the passengers entering the vehicle together with sound recording when needed, the driver, GPS location and frequent photos of the people seated in the vehicle data will be collected and maintained at a remote location . This information can help in the development of other applications or during security investigations.

By ensuring that public service vehicles operate according to the law, the system will help reduce road accidents. In addition to this, data collected from the system can be used for billing defaulters with fines thus

punishing drivers automatically, and can help reduce congestion in courts and help keep the nation moving parallel to the 2030 vision of a working nation. In addition to this, by collecting and availing information to other developers, this can open avenues for helping passengers know their preferred vehicles. For instance, the information gathered can be used to develop application that lets a passenger at the bus stop know where their favorite buses are and whether it is full thus making travel convenient for passengers.

Corruption on African roads have also greatly contributed to road carnage increase. Law enforcers usually get compromised by public service vehicles operators. Implementing the proposed system will ensure that the law enforcers don't get compromised as the information is forwarded to the headquarters. Again people entrusted with the task of enforcing traffic rules are highly outnumbered by the number of crimes and cannot be omnipresent to monitor all these defaults happening in the hundreds of thousands of vehicles we have on the road.

The proposed system will ensure that the careless drivers pay for their mistakes and that no one goes unpunished. By combining this power with the ability to limit the continuing of events that would lead to defaulting of traffic laws, we will have our roads safe again courtesy of artificial protection and actual human protection that will come automatically when everyone knows that the system is always watching and ready to report defaulters.

3. Methods

The Idea developed in this paper is based on the principles of Decision Support System DSS. Distributed Systems, Intelligent Systems and Sensor Networks. The term DSS works under the same principal with On Line Analytical Processing (OLAP). DSS is an old term that now applies collectively to a number of 'new' systems such as OLAP, EIS, ESS, expert systems and more [5,6,7].

This project involved first analyzing the main causes of accidents on the roads in developing countries. The second part involved identifying how these cases come up and how they can be avoided. The next step was to design a system that considers all the analyzed causes and represent them in the system. This led to the identifying the modules that would be required to represent the causes and connect them together in a system.

The next step was to develop a prototype of the proposed system and decide the types of interfaces that would be required by the system.

It was then important to consider the infrastructure that would be required to relay information between the different modules and how to transfer the information for analysis, given the available infrastructure.

Equipment for collecting information was identified and means for transferring this information was also defined. Necessary Information was to be collected using appropriate sensors and the sensors were networked so as to pass information collectively. Functions of the sensors that were to be used were defined before identification of the particular sensor.

Five types of sensors were identified. These were: weight sensors for detecting the weight of the vehicle, seat occupancy sensors for detecting occupation of the seat and a seat belt engaged sensor that works with the seat occupancy sensor to determine if the passage has tied the seat belt, alcohol levels detector to determine if the driver is under the influence of alcohol, speed detectors to determine the maximum speed of the vehicle and cameras to identify the passengers on board.

The next question was to identify the types of information to be collected by the sensors, detectors and cameras. Weight sensors were to collect weight and compare with prescribed weight by vehicle manufacturers. Speed detectors were to identify the speed of the vehicle and compare with the speed prescribed by the road safety authority (in case of Kenya, this is 80 kmph). Seat occupancy sensors were to identify seat occupancy and compare with the condition of the safety belt switch to notify the driver the seats that are occupied and seat belts not engaged. The cameras were just to identify the passengers in case of queries of who used the vehicle, at what time in case of theft, accident, carjacking of any other undesired activity in the vehicle. These would work with other motion detectors to activate sending of such images to law enforcers in case of violence in the vehicle. An additional switch can be added to the drivers console to activate transmission of the images in case the motion detectors don't capture such activities.

From there, the next question was how to transfer the collected data for certain action and for further analysis. Some data collected was first to be conveyed to the driver for action while some go straight away for action by preferred agencies. For example, information on the seats occupancy and status of the seat belts is first given to the driver so that he/she can take the necessary action. The weight on the vehicle is also given to the driver so that he/she ensures that the prescribed weight is not exceeded. Identification of individuals is sent straight to a remote server for secure custody. Exceeding of speed of the vehicle is also sent to the driver in form of a beep sound so that it is not exceeded. Although there has been equipment installed on vehicles to either cut the fuel supply so as to reduce the speed, additional sending of information to law enforcers will be done of the speed exceeds for a defined duration of time without reduction.

Information from weight sensors can be sent using Bluetooth technology or wires to the vehicles console and later forwarded to remote servers via access points. This can be done using Bluetooth, GPRS or SMS systems.

The access points then forward the information to servers for analysis and sending results to agencies for action. A lot of data will be assembled at the servers and a powerful server plus data base like oracle will be required for analysis and presenting summaries to agencies for action.

When law enforcing agencies receive the information, the information is then forwarded to enforcers near the location of the event as well as the judiciary for commencement of judicial procedures. Different crimes will be treated differently some of which will attract fines while some may require follow up by law enforcing agencies.

4. Systems Design and Implementation

The road safety system gives some of the most basic security features that will enable traffic police and courts

enforce traffic rules without spending much time on the roads and use the time in other activities. The system will be relevant to:

- Public Service Vehicle Owners
- Traffic Police
- The Judiciary
- Road Transport/Traffic Authorities
- The Public (PSV users)
- Developers.

Generally, the system will work in the following manner. The relevant sensors will be installed in the vehicle. When passengers get into the vehicle, the sensors will collect the appropriate information and send it to the driver. It will be up to the driver to ensure that all the occupants are belted in before driving off and that the vehicle is not overloaded.

The system will avail this information to the driver on a VDU that will be mounted on the dashboard. If for any reason the driver decides to ignore the warning, a beeping alarm will remind him or her of the mistake. In case the vehicle continues moving with the alarm still on, the system will forward a report of the rule broken and when it was broken. This information will be uploaded to any of the several Wi-Fi hotspots (access points) before uploading the data to the central server.

Since over speeding will only be handled as a countermeasure, the system will have an accelerometer that will work to identify when a certain speed limit is breached hence detect a faulty or tampered with speed governor.

After the information has been uploaded to the central server, the system will notify the owner of the vehicle of the happening via text and then liaise with a database for ticketing the defaulter and deducting points from the driver who committed to the crime. This will ease the congestion in courts and smoothen out the mode in which traffic law breaches are handled.

In addition to this, it will also ensure that drivers stay on the right side of the law since a law has to be enacted to ensure that drivers who's point score is below a given value cannot be allowed on our roads. High ranked drivers should also be given an incentive to reward their good behaviors.

The system will have the modules described in Figure 1

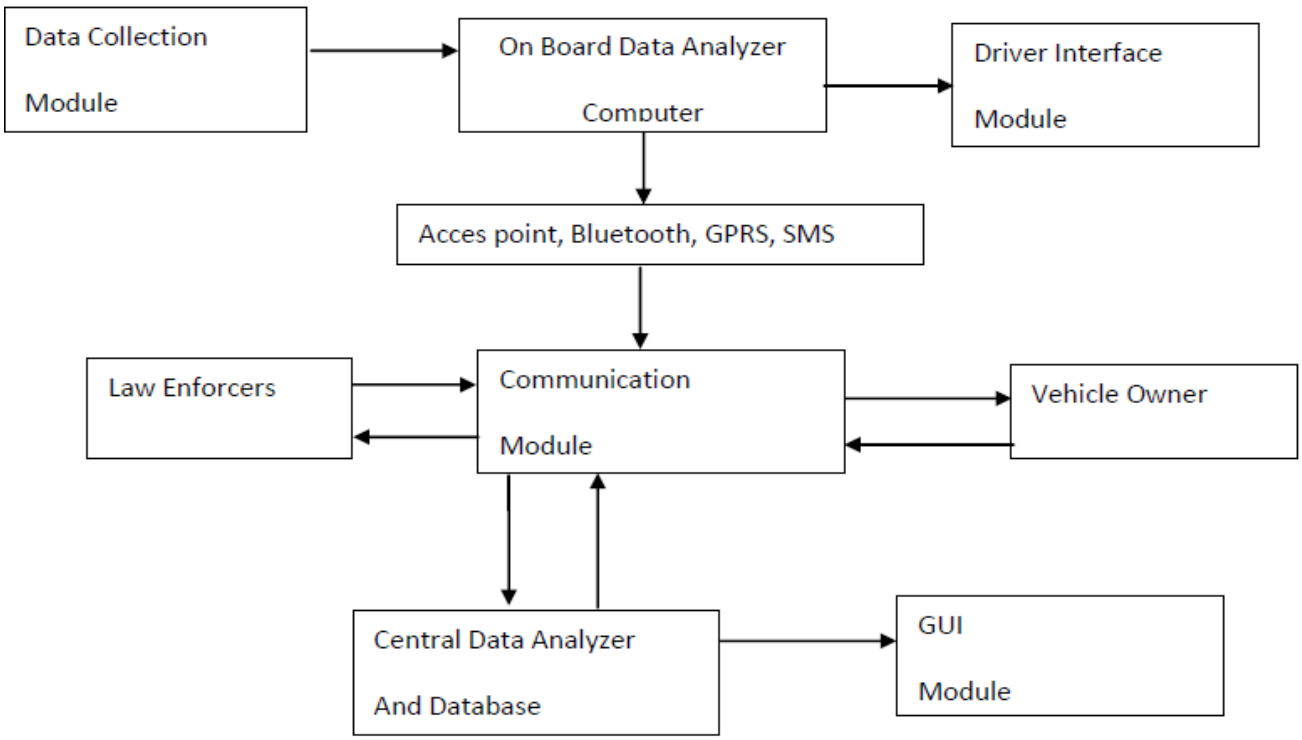

Figure 1. System diagram for communicating modules if the proposed system

To actuate this project it is important that the system should use components that are readily and cheaply available. There are multitude of possibilities to exploit but only those conforming to the above stated points will be considered.

The operation of the system can be divided into the following steps:

1. Collecting the data from the vehicle using sensors, detectors and cameras

This is the core part of the system. The needed sensors will be a speed sensor, weight sensors on seats that should be in synchrony with seat belts in specific seats, strategically mounted cameras and a GPS system.

The speed sensor will be for the purpose of detecting over speeding. Even though the system must work hand in hand with a speed governor, this speed sensor will be a perfect way of detecting tampered speed governors since it can tell you when the vehicle goes past the needed speed.

Weight sensors on seats will be used to detect over loading. Since overloading is all about weight and people have different body weights, there will be a weight range past which a drive would be warned of per seat overloading. The weight per seat will also be mixed with seatbelt sensors. If there is a weight that can qualify as a human beings weight and that specific seatbelt is not connected, the driver will be warned of the happening. There will also be an overall weight sensor on the chassis to help detect vehicle overloading or extra weight due to standing passengers.

The cameras will help identify each and every person in the vehicle by recording entrances and exits and taking photos of the seated and standing passengers at a regular interval.

2. Preliminary evaluation of the collected data and presenting the necessary parts to the driver. This will be done by a computer system based on the vehicle. It will display necessary information like a faulty speed governor, overloading and unfastened seatbelts to the driver so that he or she can take necessary action.

3. Uploading the collected information to a central server via strategically located access points

The system that warns the driver of any short comings will also be responsible of uploading collected data to access points. This could be done once the vehicle comes in range with Wi-Fi network that picks the information and pass to the server or using GPRS once it senses a network that it is set to automatically connect to.

Alternatively, the system can use mobile carrier provided internet connectivity or direct satellite connections to upload the information at regular intervals. This will do away with the need to install Wi-Fi hotspots at the bus stops and cater for remote areas that cannot support this requirement. This will also ensure that the vehicle can be actively tracked for more advanced system functionality.

4. Analyzing the uploaded information and reacting appropriately

This part of the system will run on the server side and will be in charge of notifying the authorities and vehicles owners of any defaults or rule breakages. It will also be in charge of billing the vehicle owner in case there is the need and notifying him or her via text and if possible give room for some remote pay transaction.

The billing process will have to be handled via mobile money transfer like MPESA or credit card and confirmation for a payment will be made once money is deposited to the account that each vehicle owner will have activated for his or her vehicle.

5. Alternative Solutions

There are alternative solutions to reducing the road carnage by managing how public service vehicles are used on the roads. Nonetheless, none of these approaches have proved as effective as the proposed system. They include:

a. Speed Cameras

The installation of speed cameras at different places on our roads could help capture defaulters. However, this will only cover one aspect of the problem and is of no use against overloading, unfastened seatbelts and more important drivers will mark the location of the cameras and over speed whenever they are confident that they are out of range.

b. Public Safety Messages

This is an approach where the passengers are expected to send a text to some central number whenever traffic rules are defaulted. While this could be a viable option if the citizens are willing, the implementation could be slightly expensive. There is need to cater for the message sending cost and some incentive to motivate the masses. In addition to this, gathering evidence for claims send in in such a manner would be next to impossible.

c. Use of Speed governors

Once again, the main problem with this solution is in the fact that it will only monitor over speeding [15]. In addition to this, drivers can always deactivate the systems or tamper with them in other ways hence rendering them useless. The proposed system will have ways of going around this to ensure that drivers adhere to speed limits and that other rules of the road are obeyed.

6. Results and Discussions

After the interconnection of the sensors in the vehicle, the driver should be able to see the number of seats occupied and the number of seatbelts fastened. If a seatbelt is not fastened, he or she should know which occupied seats have passengers without fastened seatbelts. A beeping alarm that increases in volume each minute a seatbelt warning goes unnoticed should be implemented. A typical display unit for this information would like the display in Figure 2.

<table>
<tr><td>Current speed = 70 kmph</td><td>Speed Limit = 80 kmph</td></tr>
<tr><td>Seated passengers 10 Total seats = 14

Unfastened Belts

Seat 2 | Seat 7 | Seat 4 | Seat 12

Total Weight Loaded = 800 kg

Maximum Load Capacity = 1000kg</td><td>Last System Audit: 20-3-2014

Next System Audit: 20-6-2015</td></tr>
<tr><td colspan="2">ALERTS</td></tr>
</table>

Figure 2. Typical display for the driver before data sent to the server

On the server side, there will be the capability of viewing all the names and details of drivers. This will be fetched from a data base of drivers that will be related to any other road offences they have done. All the information will be used to determine how much longer the driver can stay on the road before the license is revoked.

The things that can be evaluated in this system to vet how well it performs lies in its power to enforce law and order onto the road passively and actively.

The proposed system will enforce order passively by holding the drivers responsible since they are the ones who will be answerable if the vehicle is reported to move with the core test factors in disorder.

Since defaulters will be booked and ticketed later if the mistakes are solely theirs, it will be guaranteed that members of public travelling in that same PSV vehicles and are innocent will not suffer or pay for the mistakes of the driver.

The system will ensure that drivers and their assistants are more careful with what they do. This will help reduce road accidents and the fast wearing down of public service vehicles that has caused so many road accidents to date.

Since the vehicle details will be uploaded to the server, all the information need to ticket an offender, will always be hard evidence in case of court cases and ticketing will ease court cases and eliminate corruption on the road.

When choosing the types of sensors and other devices, is important to consider some parameters like sensitivity of the sensors, seize of cameras and microphones, seat sensors, and other specifications of devices.

For the sensors that will be used to detect the weight of the vehicle and people seating on the seats to combine weight and seatbelt status. Any sensor that can register weight above a specific threshold would be good enough to do this job. Sensors for vehicle weight will be mounted on the vehicle suspension system. Typical sensors available in the market like the ODE-08 air system pressure sensor [19] designed for vehicles using air suspension, or DP-01 axle load sensor designed for vehicles using spring suspension.

For identification of vehicles location, a vehicle tracking system like ORF monitor can be used [20]. This is a universal vehicle tracking software which is not tied to any particular type of tracking devices.

Conventional seat weight sensors are usually a combination of both a sensor and a dedicated Electronic Control Unit (ECU). When someone seats on the seat, the pressure sensor signals the occupant's weight to the ECU which then outputs it for use. The system will tap into the outputs of the ECU to get the weight per seat for the necessary comparisons.

For cameras and microphones, standard small seize CCTV that are used in homes can be employed. The seize need to be small for secrecy and convenience of use.

7. Conclusions

Paper has highlighted the need for a system that will help reduce road carnage especially involving PSV vehicles. The system developed will be suitable for developing countries that cannot afford the technology adopted by the first world. When used effectively, the system is expected to drastically reduce road accidents that are mostly caused by laxity of drivers and passengers, ineffective law enforcers and in some cases human error. Although actual implementation on the vehicles has not been done, simulation of the system has been done using java and the outcome was promising. The next level of research will be using parameters from manufacturers of specific devices and incorporation of all safety and security of the devises and the software being used.

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