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GPS-BASED CAMEL-VEHICLE ACCIDENTS AVOIDANCE SYSTEM: DESIGNING, DEPLOYING AND TESTING

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Abstract. *Animal-Vehicle Collisions (AVC) phenomenon is a worldwide problem. In United States, Canada and Europe the AVC have been shown to be a considerable problem on the road. In Saudi Arabia, hundreds of Camel-Vehicle collisions are reported every year. They are causing numerous deaths and loss of property running into millions of Saudi Riyals. Ministry of Transport of the Kingdom spends billions of Saudi Riyals to treat this problem by building fences along the highways. Fences are costly to install, difficult to maintain, and they isolate the camel habitat. This paper investigates the design and the implementation of a deployable and intelligent Camel-Vehicle Accident Avoidance System (CVAAS) using global positioning system (GPS) technology. The use of GPS sensors in this kind of application is a novel idea. The main aim of the CVAAS is to save lives of humans and as well as camels in such accidents and save billions of Saudi Riyal through this research. The CVAAS's team developed high-level diagrams and detailed steps needed to accomplish the proposed system. To study the effectiveness of the CVAAS, the team implements and deploys the system into a selected test area. Finally, this paper provides a set of recommendations for deploying the CVAAS in large scale. In conclusion, it is expected that the CVAAS will be recognized as a world leader in using GPS technology for avoiding animal-vehicle collisions.*
Keywords: Camels-vehicle accidents, Review, Designing, Deploying and testing animal-vehicle avoidance systems, GPS technology, GSM

1. **Introduction.** Worldwide the animal-vehicle collisions (*AVC*) were seriously occurred. In the United States, Canada, Europe, Australia and the Middle East the *AVC* usually involve deer, moose, kangaroos and camels. The total number of reported *AVC* in United States (US) is about 300,000 per years [1]. Langley et al. [7] examined risk factors involved with fatal *AVC*s in the US from 1995 to 2004 and found that 89.5% occurred on rural roads, 64.8% in darkness, 85.4% on straight sections of road, 91.1% occurred in dry weather conditions, and 28% of the victims were motorcyclists. D. Zhou estimated there are over 35,000 deer-vehicle collisions yearly in the US, which results in about 200 deaths and close to 4,000 property damages of $1,000 or more [20]. *Food and Agriculture Organization* (FAO) reported that the total number of camels globally is said to be 20 million [8]. In Saudi Arabia, more than half a million camels move freely [2]. In 2004, the *FAO* estimated that around *Riyadh* and *Qaseem* area camel concentration per square km has been reported to be 0.4 and 0.6 respectively. M. Al-Hamzi reported that the density of camels along the highways in western areas in Saudi Arabia is 12 Camels/Kilometer [3]. Arabian camels having one hump, also known as dromedaries, is the traditional animal of

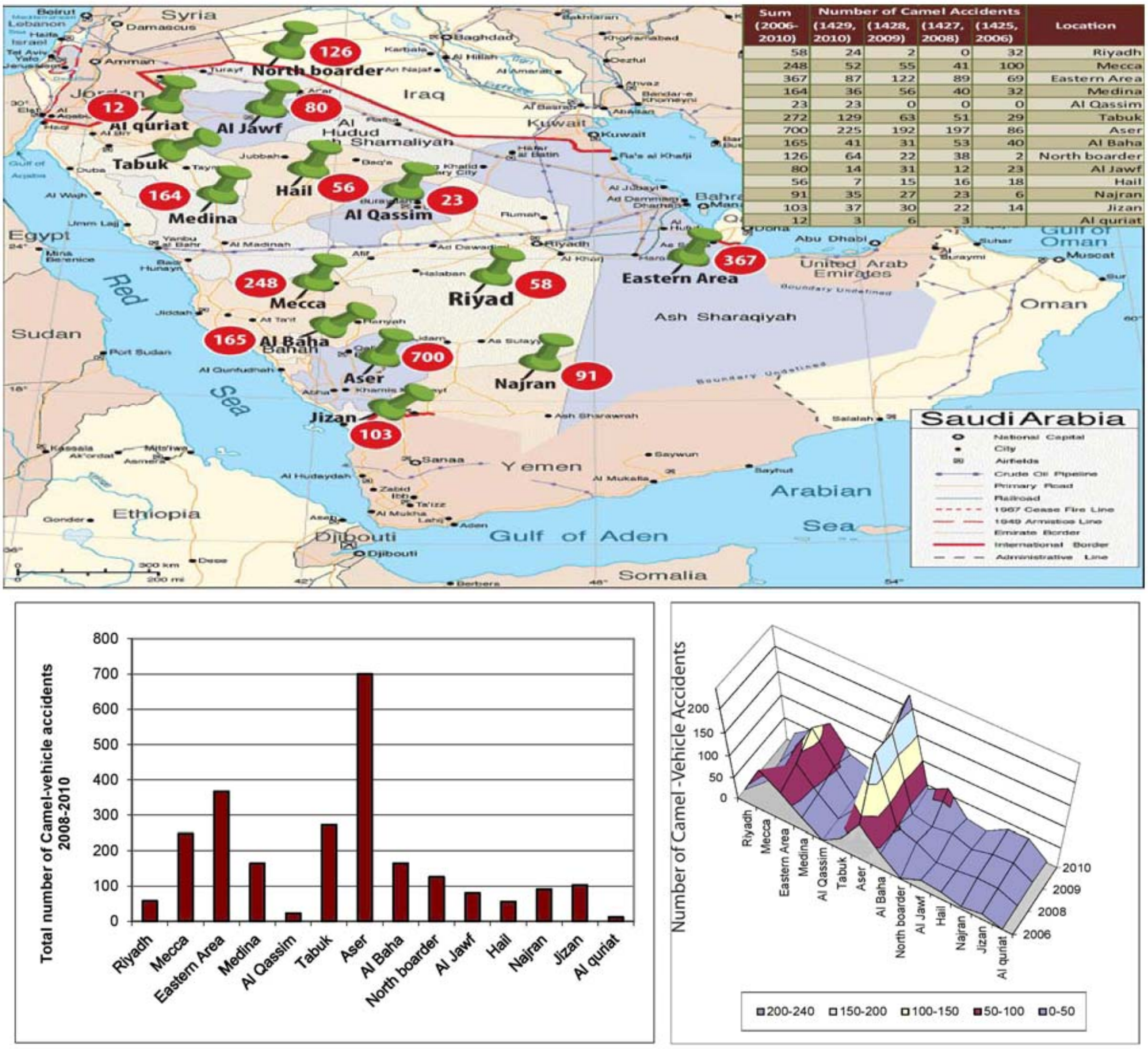
the desert. They can be over 2.1 meters tall at the hump and weigh up to 726 kilograms [5]. Camels are very hard to detect by vehicle drivers especially in the night time and results in severe accidents if a collision occurred. Al-Ghamdi and AlGadhi reported that in Saudi Arabia more than 200 camel-vehicle collisions (*CVC*) occurred in 2004 [2]. Figure 1 shows the statistics of the number of *CVC* in Saudi Arabia in 2006-2010. It shows that *Aser* is the area suffering from the highest *CVC* (700) followed by the Eastern area (367). According to Al-Ghamdi and AlGadhi [2] study, the most frequently involved animal in *AVC*s is camel; it is estimated that 97% of all reported *AVC*s were camel related. More than 90% of these accidents occur at night, between dusk and dawn [6]. These accidents cause a lot of damage to the environment, economy and social life such as significant economic loss, human injuries and/or fatalities, loss of valuable wildlife, and damage to properties. Crucial Cervical and dorsal spinal injuries, especially fractured discs, head and chest injuries, are the most commonly reported injuries, and the fertility rate is four times higher than for other causes of traffic accidents [4]. Table 1 shows an official statistics of accidents including *CVC* in a selected region in Saudi Arabia called *Al-Ahsa* 2007-2009. Every year, these accidents cause numerous deaths and loss of property running into millions of Saudi Riyals.

More efforts need to be done to reduce the number of *AVC*s. Most researches have attempted to cope with the *AVC*, but neither unique solutions nor efficient results have been found. Ministry of Transport of the Saudi Arabia spends billions of Saudi Riyals to deal with this problem by building fences along the highways. Fences are costly to install, difficult to maintain, and they isolate the camel habitat. In addition, the Saudi Arabia's government attempted to reduce vehicle collisions with camels by installing standardized warning signs. Al-Ghamdi and AlGadhi [2] concluded that using warning signs along the highways is not effective and recommended to warn drivers about the potential for camel-crossings. To address this problem this paper discusses the design of a deployable and intelligent *Camel-Vehicle Accident Avoidance System* (*CVAAS*). Multidisciplinary professionals have joined hands to develop an accident avoidance system using modern tools such as *GPS* sensors. The use of *GPS* technology in this kind of application is a *novel idea*. The *CVAAS* aims to save lives of humans and as well as camels in such accidents and save billions of Saudi Riyal through this research.

The *CVAAS* is an animal-based system which primarily includes three units as follows: an Animal Based Unit (*ABU*), Animal Detection System (*ADS*) and Warning Unit (*WU*). The *ABU* includes programmable GPS receiver to identify camel position and Global System for Mobile Communications (*GSM*) receiver/transmitter to transfer the camel position to the *ADS*. The *ADS* is a web-server application that identifies the presence of a camel on or near the highway and then forwards a warning SMS message to the *WU*. The SMS message will activate the warning system to warn the vehicle drivers to slow down in order to avoid collision with the camel. Figure 2 illustrates such a scenario. More details have been furnished in Section 3.

Table 1. Official statistics: vehicle-camel accidents from Al-Ahsa Traffic department from 2007-2009

	Number of Traffic Accidents	Number of Death	Fatality rate	Number of Camel-Vehicle Accidents	Number of Death	Fatality rate
2007	23339	281	0.012 %	29	20	68%
2008	24216	349	0.014 %	24	18	75%
2009	29480	355	0.012 %	38	27	71%



Sum (2006-2010)	Number of Camel Accidents (1429, 2010)	(1428, 2009)	(1427, 2008)	(1425, 2006)	Location
58	24	2	0	32	Riyadh
248	52	55	41	100	Mecca
367	87	122	89	69	Eastern Area
164	36	56	40	32	Medina
23	23	0	0	0	Al Qassim
272	129	63	51	29	Tabuk
700	225	192	197	86	Aser
165	41	31	53	40	Al Baha
126	64	22	38	2	North boarder
80	14	31	12	23	Al Jawf
56	7	15	16	18	Hail
91	35	27	23	6	Najran
103	37	30	22	14	Jizan
12	3	6	3		Al quriat

FIGURE 1. Statistic of camel-vehicle accidents in Saud Arabia 2006-2010

The remainder of this paper is organized as follows. Section 2 illustrates and classifies the current animal-vehicle collision avoidance technologies. Section 3 briefly discusses and presents the design of the *CVAAS*, the proposed novel system. The deployment and testing of the *CVAAS* have been presented in Section 4. Section 5 concludes the results of the *CVAAS* and provides significant recommendations.

2. **Classification and Evaluation of the AVC Avoidance Technologies.** Animal-Vehicle Collisions avoidance system is a system which detects the presence of an animal on or nearby a road/highway and activates a warning system to alert the drivers. Detection of the large animal on or nearby road/highway is a critical aspect for the implementation of such systems. There are many animal detection systems that are used around the world. The animal detection systems are preferred over fences since they improve human safety while not confining animal movement or separating animal habitat areas. The animal detection systems alert the drivers of an animal on or near the road. The effectiveness of these systems relies on the driver response. In this paper, the team has summarized the pros and cons of animal detection systems versus fences or other animal crossing

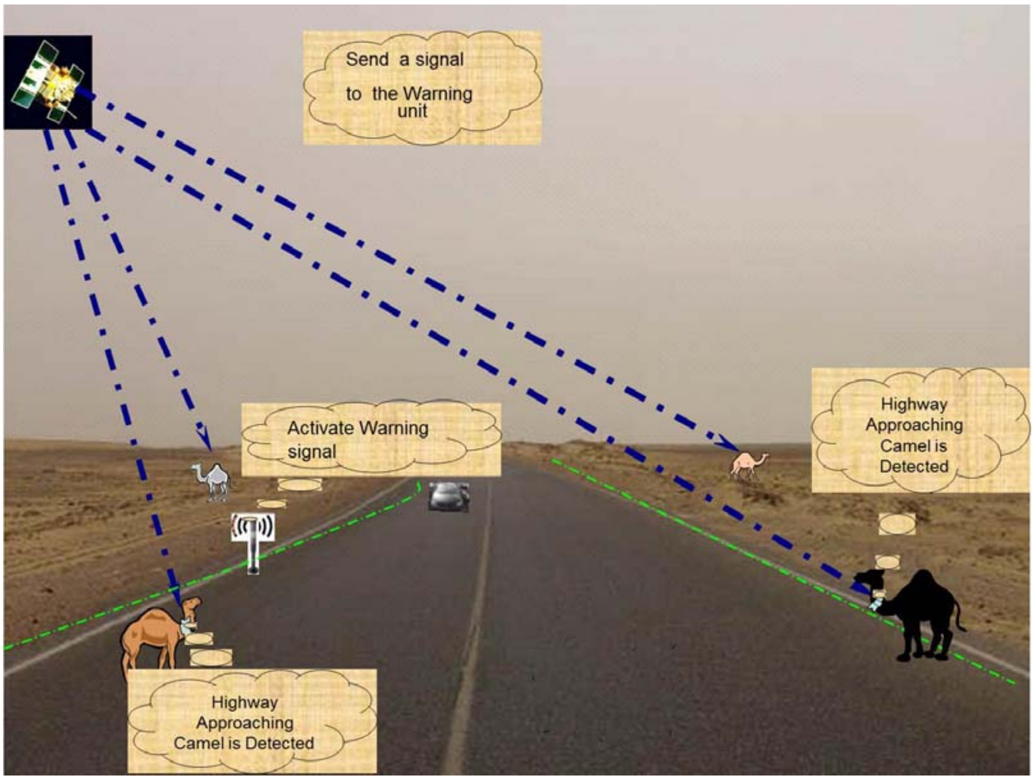


Figure 2. *CVAAS* typical scenario

structures (i.e., underpasses or overpasses).
Pros

- Animal detection systems have the potential to provide wildlife with safe crossing opportunities anywhere along the mitigated roadway, but wildlife crossing structures are usually limited in number, and they are rarely wider than about 50 meter.
- Animal detection systems are less restrictive to wildlife movement than fencing or crossing structures. They allow animals to continue to use their existing paths to the road or to change them over time.
- Animal detection systems can be installed without major road construction or traffic control for long periods.
- Animal detection systems are likely to be less expensive than wildlife crossing structures, especially once they are mass produced.

Cons

- Animal detection systems allow the movement of animals on to the highway which will not eliminate completely the chance of *AVC*.
- Animal detection system effectiveness depends on driver response which is dependent on many factors listed later.
- Fences and other structures have greater longevity and lower maintenance and monitoring costs.

Animal detection systems detect large animals as they approach the road and then warning signs are activated alerting the drivers. The drivers notice the activated warning sign and reduce the vehicle speed or are more cautious. The decrease in vehicle speed depends on many factors such as [10]:

- The type of warning signal and signs.

- Whether the warning signs are accompanied with advisory or mandatory speed limit reductions.
- Road and weather conditions.
- Whether the drivers actually see an animal.
- Whether the driver is a local resident.
- Perhaps the road length of the zone with the animal detection system and the road length that the warning signs apply to (the more location specific the better).
- Perhaps also cultural differences that may cause drivers to respond differently to warning signals in different regions.

Worldwide numerous technologies have been used in attempts to reduce *AVC*. This section presents a brief review of the methods widely used to reduce *AVC* on most of the world's highways. This paper classifies the techniques used in the past to mitigate *AVC* into three categories *animal-based*, *roadway-based* and *vehicle-based* technologies. The first category, *roadway-based* technology developed for and dedicated to the highways. It includes roadway fencing, underpasses, overpasses, roadway reflectors, warning signs, infra-red, microwave RF, etc. Roadway-based detection systems, however, are designed to inform all drivers, regardless of what equipment their vehicle may or may not have. The second category, *animal-based* includes the technologies that were installed in animals to alleviate the *AVC*. The third category, *vehicle-based* includes the technologies that are equipped into vehicles to reduce the *AVC*.

2.1. **Animal-based technologies.** The animal based technologies to avoid *AVC* used different types of collars fasten with the animal to trigger a warning system such as blinking signals. The collars are classified as reflective collars and radio collars. In 2006 the ministry of environment in British Columbia, Canada put collars with reflective tape on a number of animals to increase their visibility to drivers. In Saudi Arabia, a major company *Aramco* distributed around 3000 reflective collars to the camels' owners in Al-Ahsa. These collars are not efficient to reduce the *AVC* because vehicles must be close enough to ensure that the collars are visible which defeats the whole purpose of avoiding accidents. Moreover, the reflective materials of the collars will disappear over time. Multiple of projects utilized radio collars since 1999 up to now.

In 1999 about 10 percent of the elk herd was radio collared [11]. Receivers placed along the road scan for the frequencies of the individual radio collars 24 hours per day. When the radio-collared individuals come within about 400m of the road, the receivers that pick up the signal activate the flashing beacons that are linked to that receiver. ***WSDOT*** is one of hundreds of agencies that have been trying for years to find effective and affordable ways to reduce Wildlife collisions. It put radio collars on elk near *Port Townsend* that trigger flashing beacons telling drivers there are animals on the road ahead. It found out that when a collared elk settles down for the night near a receiver, the beacon flashes all night [12]. The system seems to work well. Maintenance was limited to replacing the battery pack of a receiver and some minor repairs to a receiver.

In the other hand, GPS collar is a valuable tool for documenting the movements of large, wide-ranging animal kinds. It provides abundant amounts of continuous movement data amid even extreme environmental conditions. Recently, GPS collar has been instrumental in monitoring large mammals use of highways and wildlife underpasses in Arizona [13-15]. Using data gathered from GPS collar, the authors of [13] were able to identify spatial patterns in bighorn sheep movement relative to a key section of US 93. Based on GPS collar data, the authors were able to make informed recommendations regarding placement of wildlife-engineered crossing structures on US 93. To the best of our knowledge, most of the systems that used GPS collars to monitor large animal movements for the sake of recommending the placements

of wildlife-engineered crossing structures on highways.

2.2. **Road-based technologies.** The road-based technologies include the methods to either prevent or detect the animal to avoid collisions. A variety of methods have been attempted to reduce or prevent *AVC* [15]. There are several road-based technologies have been researched to attempt to dissuade the animals from approaching the road. Although this is a good idea, it has been proven to be a challenge. Some of these technologies include roadside reflectors [21], animal reflectors [22], removal of roadside vegetation [23]) and electronic mats [24]. Other methods include active and passive roadway signs, modified speed limits, fences and designated crossing areas [16], underpasses and overpasses [25], chemical and biological repellents and roadside lighting. A study was done by Sullivan to investigate the relationship between roadway lighting and vehicle collisions with animals [17]. It concluded that the highest proportion of fatal accidents with animals occurred on roads, which had high speed limits and poor lighting. The reduction of even a few miles per hour at a relatively high speed substantially decreases fatalities in collisions between vehicles and animals [18]. A reduction in vehicle speed can be achieved by reducing the posted speed limit and changes in road design. However, substantially reducing the speed limit in an area often results in additional collisions between cars, since they will be moving at different speeds due to variable compliance with the new speed limit. AlGhamdi and AlGadhi concluded that road signs as road-based technology did not result in a reduction of vehicle speed [2]. While in *Saudi Arabia* where camels are a problem does not have extensive vegetation, there are frequently other obstacles, which impair the driver's vision. These obstacles could be large road signs which extend to the ground, abandoned vehicles, or any other item, which obstructs vision.

In addition to being difficult to implement these methods, most proved ineffective. Instead of attempting to dissuade the animals, it may be more effective to detect the animal and alert the drivers. There are a few roadside technologies that are being developed including flashing signs that are triggered to alert the driver when an animal is detected in the vicinity. In 2009, the state of *Nevada* used solar powered sensors to detect and record animal movement patterns near roadways. Moreover, these sensors were used to detect large animals near a roadway and trigger the activation of warning lights to alert drivers [19]. With an estimated fifty nine thousands kilometers of lane roadway in the *Saudi Arabia* [26], installing the road-based technologies adequately would require the development of infrastructure. It is more feasible to develop a less expensive system and install them on the vehicles themselves. However, it will add extra cost to the owners of the vehicles.

2.3. **Vehicle-based technologies.** The vehicle-based technologies also include the methods to either prevent or detect the animal to *AVC*. They are classified into two categories vehicle-based deterrence technologies and vehicle-based detection technologies. The first category vehicle-based deterrence technologies include deer whistles [27,28], and TH – High Intensity Discharge lighting systems [29]. However, neither the audible nor visible methods of deterrence proved effective in any studies. In this paper, we have not found any scientific studies related to camel hearing sensitiveness and effectiveness of air whistle to reduce camel vehicle collision. However, our proposed *CVAAS* would not face acoustic related problems encountered by these warning whistles. The second category of vehicle-based detection technology possibly is the best method of *AVC* avoidance can be found in on-vehicle detection technologies. Several forms of these technologies are already in existence, including forward-collision sensors [30], ultrasonic sensors [31], and thermal cameras [32], [33] that give the driver a thermal image of the road ahead. These detection technologies can improve the driver's awareness of the road in front of the vehicle. The displayed image looks like a black and white photographic negative [34]. Hot objects appear white and cool objects appear black. The system is designed to be used outside urban areas because too much surrounding light may flood the display. These technologies also have limitation in bad weather. Some drivers have noted that objects are difficult to see and appear fuzzy due to the field of view that is too limited to be useful. Others have complained of headaches after only one hour of use. Some drivers have been bothered by sun reflection on the projection screen during the day. There was also risk that drivers may only look through the display. General Motors (GM) research and development division and several universities are working on a system using data gathered from an array of vehicle sensors and cameras that would project images directly onto the entire surface of the windshield [35].

2.4. **Discussion.** The previous subsections show diverse types of systems that have been installed around the world to reduce the *AVC*. Many of the systems encountered technical problems and maintenance issues. More importantly they experienced *false positives* and *false negatives*. The false positive occurs when the warning system is activated even if there is no animal. Whereas, false negative occurs when there is animal but the warning system is not activated. False positives may cause drivers to eventually ignore activated signs [36] and false negatives present drivers with a hazardous situation. Drivers' responses, through reducing vehicle speed or increased alertness, determines how effective animal detection systems really are. It is of immense importance that any system designed to reduce or avoid *AVC* should ensure minimal number of false positives and false negative. *CVAAS* aims to address these false detection problems by using the novel idea of using *GIS* along with *GPS* which gives accurate positioning of an animal. Previously the *GIS* incorporated with *GPS* technologies were used to monitor and collect data for the migration and movements of the animals [37,38]. An integrated system of *GIS* and *GPS* sensors is a novel idea in designing a system for avoiding domestic animal and vehicle collisions. Next section presents the design of the *CVAAS*.

3. **Design of the CVAAS.** The design of the *CVAAS* consists of three sub-systems: *Animal-Based Unit* (*ABU*), *Animal Detection System* (*ADS*) and *Warning System* (*WS*) as shown in Figure 3. There are three alternatives to connect them, i.e., *Wi-Fi*, Dedicated short-range communications (*DSRC*), and General packet radio service (*GPRS*). The main aim of the *ABU* subsystem is to detect the camel's position and transmit it to the *ADS*. The *ADS* detects whether any camel is inside or outside the dangerous zones. It transmits warning messages to the *WS*. Finally, the main task of the *WS* is to warn the driver. The *ABU* is attached to the animal and consists of General Packet Radio System (*GPS)* receiver, Wireless and/or GSM transmitters, and an interface as shown in Figure 4. This paper implements the *ADS* as centralized *ADS* system. The centralized *ADS* system relies on web servers connected to *ABU* with *GPRS* technology and it sends *SMS* alarm to *WU*.

3.1. **Animal-based unit.** The Animal-based unit (*ABU*) consists of three main components: *GPS module*, *interface* and *transmitter* as shown in Figure 4. *GPS module* captures key data such as animal's position, velocity, acceleration, heading. The transmitter forwards that key data to the *ADS.* The *ABU*'s interface grants the ability to update the system parameters of both *GPS* receivers and transmitter such as the frequency of key data transmission, positioning times based on animal behavior (e.g., more frequent during activity, less frequent when relaxing, packet payload size and message life time).

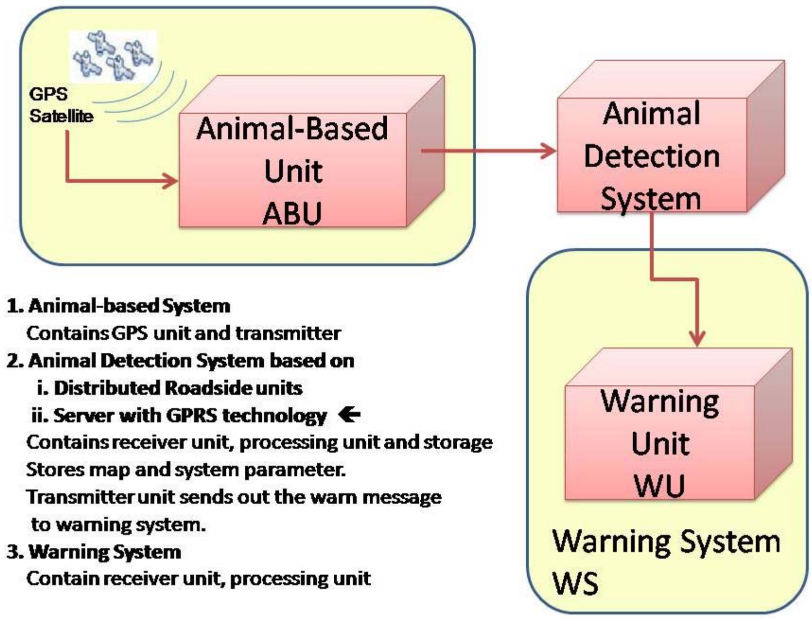


FIGURE 3. *CVAAS* block diagram

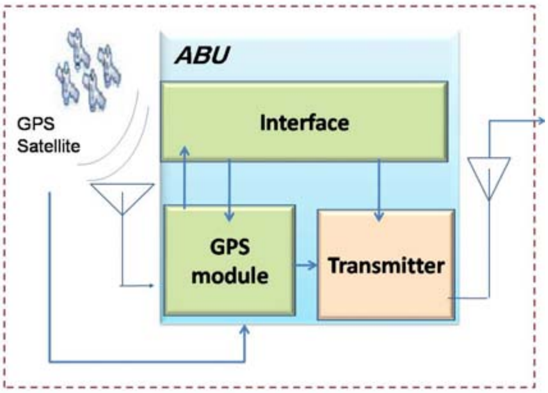


FIGURE 4. Animal-based unit

3.2. **Animal detection system.** The animal detection system (*ADS*) operates to detect whether any animal is inside or outside the dangerous zones. It consists of four components *receiver, transmitter, communication unit, processing unit* and *storage*. The receiver gets the key data from *ABU*'s transmitter. The communication unit forwards the received key data to the processing unit. The processing unit executes a thread that runs the *ADS_activate()* procedure. As soon as, the *ADS_activate()* procedure receives the key data that matches with the description of the dangerous zones, it takes the decision to send an appropriate activate*warning message* to the *WS*. The *activate message* includes the classification of dangerous zones. The centralized animal detection system is implemented based on *ADS* web servers. The *ADS* server is also called *CVAAS* server. Each *ADS* server consists of the same four components as shown in Figure 5. The receiver and transmitter operate based on the *TCP/IP* Internet protocol. The tools used to implement the centralized *ADS* web servers are *SQL 2008*, *ASP.NET 2008*, *C#* and *Java script*. The Active Server Pages (*ASP*) dynamically generates web pages based on *HTML* and *XML*. The *Microsoft C#* has been used to support codes behind scripting language and to handle

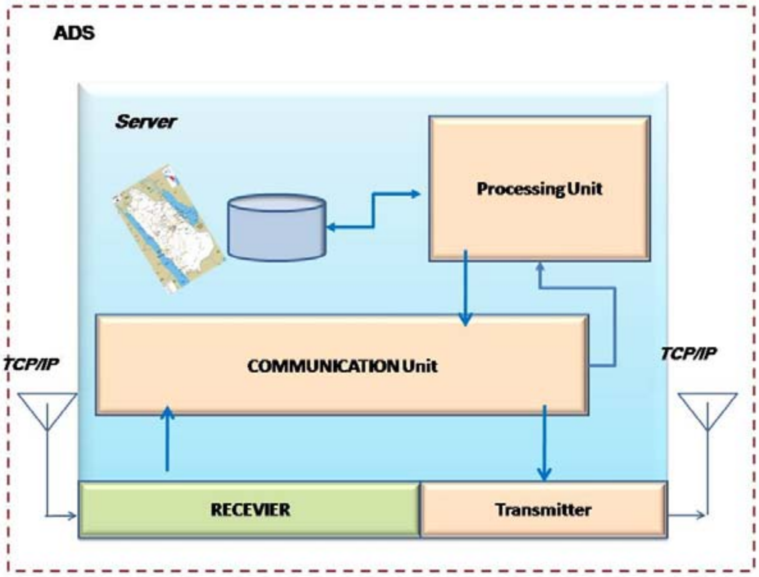


FIGURE 5. Centralized *ADS*

all database instructions and commands as well as handle all the server functionalities and responsibilities. Java script has been used to add interactivity to *HTML* pages without invoking the server. Each *ADS* server has the following duties and responsibilities:

(1) Store the highway maps of the *Saudi Arabia* and the *ABU*'s data.
(2) Enable the administrators to add/edit/delete maps, *ABU*'s data, and dangerous zones.
(3) Process all the received messages from the *ABU* units and match them with dangerous zone. As soon the *ADS* server detects any of the camel in the dangerous zone it sends *SMS* alarm message to the *WU* that is exist in the same dangerous zone.
(4) Track the camel movement and search on the camels trips.
(5) Create various reports about camels, camel's movements, speed, warnings, dangerous zone, etc.

3.3. **Warning system.** Various studies have been conducted to determine the effectiveness of intelligent alerting systems for warning drivers of impending collisions. Studies include examining effectiveness of such warning systems on different age groups [39], as well as on comparing the effectiveness of alarm warnings presented through different modalities: visual [35], sound [40], and the multi-staged alerts [41]. Further research has also been conducted on drivers' performance in distinguishing between sound alarms like auditory icons and beeps [42], as well as the effectiveness of visual warnings like warnings signs [35]. Those studies have comprehensively studied a number of critical issues in the introduction of intelligent predictive alarms into the driving domain. The presentation of different alerts could affect drivers' performance, as well as the interactions among the various other alerts, and distractions combine to affect situational awareness of drivers. Recently, an alternative approach known as cooperative driving has appeared based on vehicle-to-infrastructure ($V2I$) or vehicle-to-vehicle ($V2V$) communication [43-45]. This new approach of collaborative driving lies in the fact that the infrastructure or the vehicle can communicate its information (e.g., location) to surrounding vehicles or nearby infrastructure. In this case, the warning system is intended by incorporating the information communicated from the surrounding vehicles into the warning process. The concept of holographic images which contain visual information (warnings or signs) for installation as optical barriers in highways can also be used in the warning system. As the drivers approach the danger area the holographic signs would inform them, visually, to stop or to drive carefully [46,47].

One of the objectives of the proposed system *CVAAS* is the provision of a method and system for warning drivers of the presence of camels near highways. The designed *CVAAS* provides a warning system to notify drivers about the presence of camels along the highway, such that the drivers can slow down and drive cautiously to avoid an accident with the camels. The system includes *ADS* which activates warning system (*WS*) when a camel enters the danger zone. The WS be implemented using flashing light.

Flashing light warning system

The warning system is implemented using flashing lights. After receiving and analyzing the collected data from *ABU's* transmitter, the communication unit of *ABU* forwards the received data to the *ADS*. If the received data match the description of the danger zones, the *ADS* takes decision to send an activation message to at least two closest *WS* via *SMS* as shown in Figure 6. Then, *WS*, on receiving activation message, activates the flashing light.

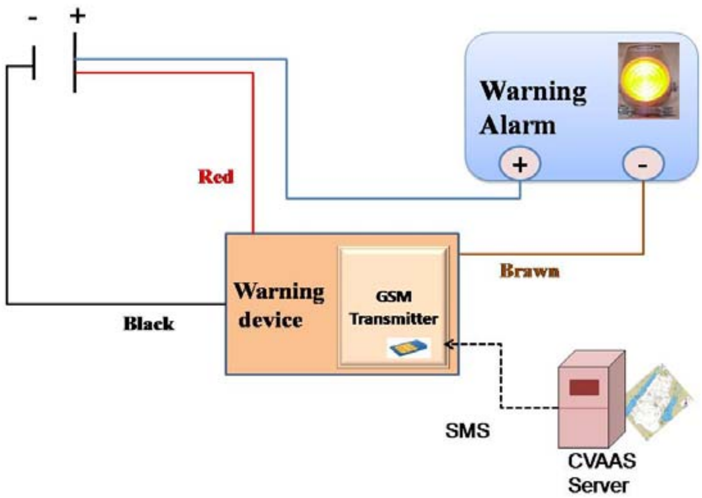


FIGURE 6. Circuit design for warning unit

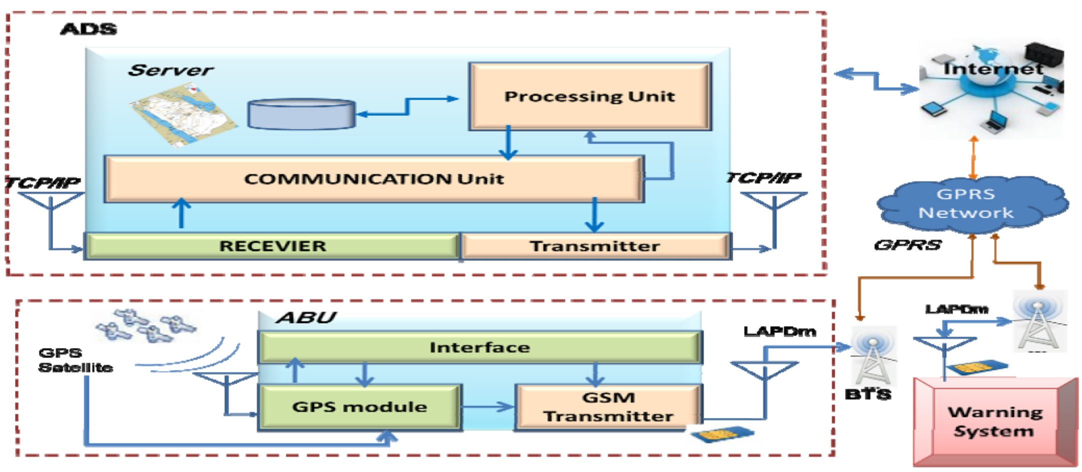


FIGURE 7. *CVAAS* with centralized *ADS* components and communication links

3.4. **Overall design of CVAAS.** Figure 7 shows the overall design of the *CVAAS* including the centralized *ADS* components and communication links. The *ABU's* transmitter sends the key data to the *ADS* server through Global System for Mobile communication *(GSM)* cellular networks based on the *LAPDm* data link layer protocol. The *LAPDm* is used as an interface between any mobile device as the *ABU* device and the Base Transceiver Station (*BTS*). The *BTS* forwards the key data received from the *ABU* to the General packet radio service (*GPRS*) network. In the *GPRS* network an IP-based protocol is defined and called *GPRS tunneling protocol*. Primarily it is the protocol which allows *ABU* to move from place to place while continuing to connect to the Internet. As a result, the key data sent from the *ABU* to the *ADS* server. Consequently, the processing unit at the *ADS* server checks the received key data from the *ABU* and identifies the location of the camel. If the camel enters one of the defined dangerous zone it sends an alarm as *SMS* message to the closest *WU* in order to warn the drivers. This *SMS* message sent out from the *ADS* server to the Internet through TCP/IP protocol and then it is forward to the *WU*.

4. Deployment and Testing of CVAAS.

4.1. **CVAAS deployment.** The *CVAAS* has been deployed for testing in the *Hofuf-Riyadh* road in *Saudi Arabia*. This testing area has been selected for several reasons as follows. Frequent camel-vehicle accidents take place in the *Hofuf-Riyadh* road. In addition, there is significant camel's concentration in the *Hofuf-Riyadh* road. Finally, it is easy access by the project's team. In fact we operate the *CVAAS* on the selected area from the *Hofuf-Riyadh* road as seen in Figure 8. In this test we deployed two main devices: *ABU* and *WU* devices. The *CVAAS*'s team designed the *ABU* as follows: fasten a programmable GPS sensor (*ATrack AT1*) [48] with a reflective collar as shown in Figure 9. It has a built-in *GPS* sensor and *GSM* antenna. It is attached with external long life battery and it has a slot for mobile subscriber identification module (*SIM*). The *AT1* device

FIGURE 8. Testing area with dangerous zones

FIGURE 9. *ABU* unit

came with some accessories such as power *I/O* cable, serial cable to connect with serial port of the computer, a high sensitivity *GSM* module with 65 channels and configuration program that enables users to configure the *AT1*. It can operate in $-30 \sim +70$°C (note: Temp. up to +85°C with extreme condition).

The *AT1* is a programmable *GPS* sensor that is attached to the *ABU*. It comes with software that enables the *CVAAS*'s team to configure it as follows. First, they attached the AT1 to a personal computer through serial port with following settings: 57600bps baud rate, 8 data bits, none parity, stop bits 1, with no flow control. Second, the team member ran the *AT1* configuration software as seen in Figure 10(a). In the system tab, the team put a unique ID and the pin code of the *SIM* for the *ABU*. In addition they put the *NMEA* [49] output as *GPRMC*. The *AT1* requires entering GPRS APN (Access Point Name), username and password if required by carrier, Host address and port, and packet type in order to establish a connection to the *CVAAS* server. So that, the communication tab enables the team members to set the GPRS as shown in Figure 10(b) and as follows: APN as *jawalnet.com.sa*, *CVAAS* server as *196.202.90.94*, port as 8070, packet type as *TCP*, etc. Moreover, the *AT1* could be re-programmed remotely by sending *SMS* messages to the *ABU* with the following format to define the APN.

```
AT$GPRS=<Enable>,<APN>,<Username>,<Password>,<Host Address>, <Host Port>,
<Socket Type>,<Retry>,<Timeout>,<Keep Alive>,<Report ACK>
```

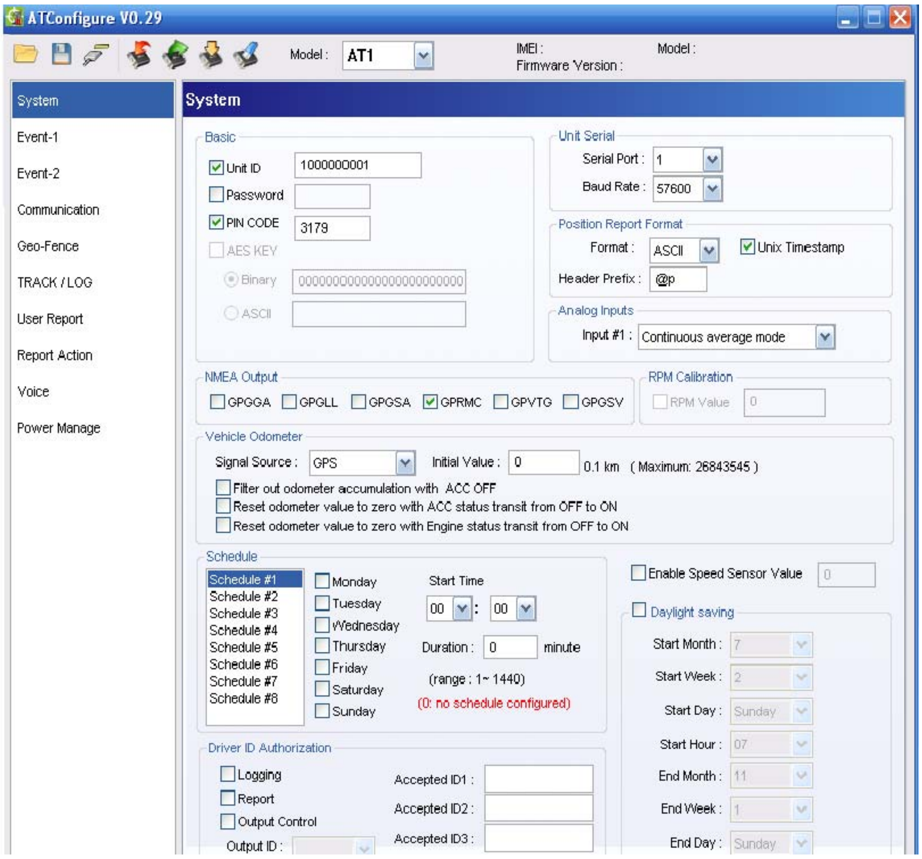
For example, consider the following parameters:

GPRS APN = *jawalnet.com.sa*
GPRS Username =
GPRS Password =
Host Address = *196.202.90.94*
Host Port = 8070
Packet Type = TCP

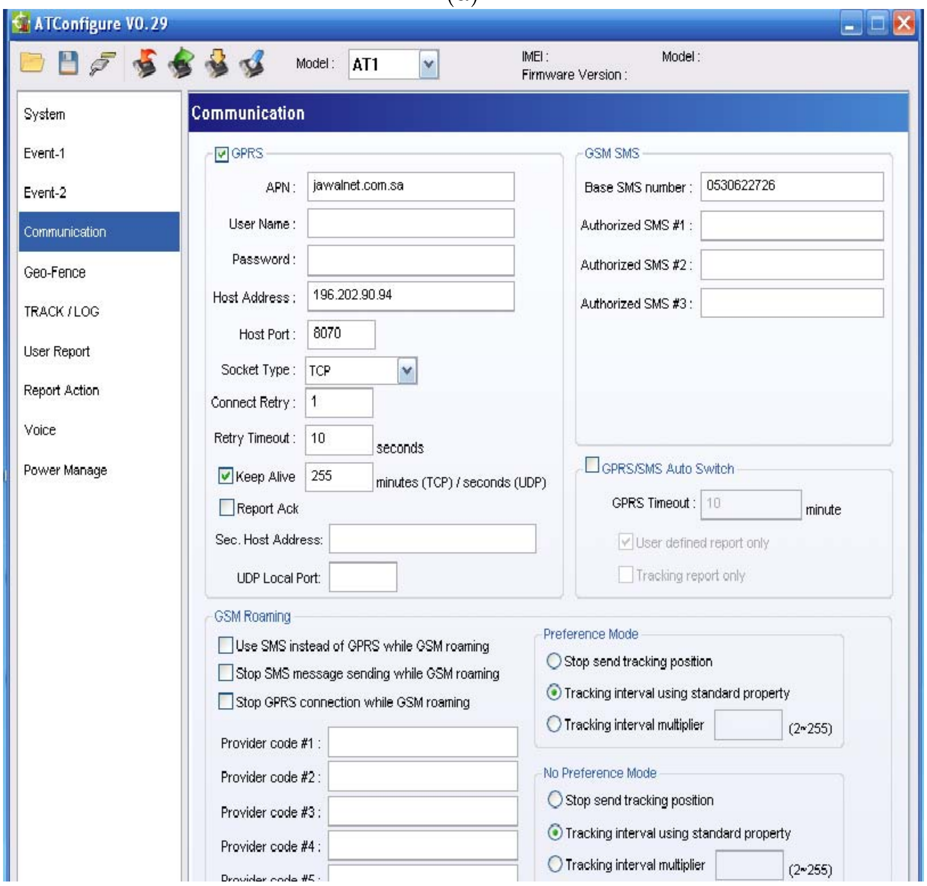
Then, the command will be:

```
AT$GPRS=1,"jawalnet.com.sa","","","196.202.90.94",8070,0,1,10,255,0
```

After programming the *ABU* devices, the *CVAAS*'s team hired an expert man to mount the *ABU* devices with camels as shown in Figure 11. It is noticed that mounting process is not a difficult task however with some camels it is a dangerous process that need an expert man to perform it. Moreover, we designed a WU as follows and seen in Figure 12. The *CVAAS*'s team designed the *WU* as a rectangle box with a red camel symbol. The team puts a warning lamp with a loud siren and a *GSM* warning device inside this



(a)



(b)

FIGURE 10. AT1 configuration software

Figure 11. Mounting *ABU* device with camels

Figure 12. Warning units

rectangle box. This *GSM* warning device activates/deactivates the warning lamp with siren as soon as it received SMS message from the server of the *CVAAS*. The *CVAAS*'s team fixes this rectangle box upon a vertical metal bar. Then, they positioned the *WU* in the lane of the highway at the right as shown in Figure 12. The *WU* is easy to install and maintain.

As shown in Figure 13(a), the *CVAAS* system includes several menus as follows: main menu (القائمة الرئيسية), map menu (الخريطة), dangerous zones menu (القطاعات الأرضية), menu for data of camels (بيانات الجمال), privileges menu (الصلاحيات), reports menu (التقارير), logout menu (الخروج تسجيل). The dangerous zone menu enables the user to create rectangles or polygons that are used as dangerous zone around the highways. Moreover, it enables the users to activate search for any camel or all camels that enters to specific dangerous zones. The data camels menu enables the user to add, edit, and delete camels. The privileges menu enables the admin of the *CVAAS* to create users with various privileges. It enables admin to assign *ABU*s/*WU*s to the nearest officers to monitor them. The *CVAAS* enables users to create several reports to track the camel movements and speed.

(a)

(b)

FIGURE 13. (a) *CVAAS* system, (b) *CVAAS* officers 3G tablets

For more reliable CVAAS, it is recommended to perform the following actions:

(1) Construct a *CVAAS* center that includes replica of the *CVAAS* servers,
(2) Hire employees to monitor the sections of the highway that have high camel-accident rate.
(3) Provide the traffic department's officers on the highway with 3G tablets as shown in Figure 13(b) that enable them to monitor the nearby area. Moreover, the tablets allow the officers to detect false positive/false negative and take the associated actions. Consequently, we can eliminate the false positive and negative of the *CVAAS*.

4.2. **Testing of CVAAS.** The project team members performed several testing scenarios to test the *CVAAS*. Dangerous zones were set as shown in Figure 8 in *Hofuf-Riyadh* Highway, *Saudi Arabia*. A camel would enter and leave the dangerous zones at varying speed. Whenever, the camel enters a dangerous zone, the sever sends *SMS* message to

FIGURE 14. Alarming message as soon as camel enter dangerous zone

the *WU* located in the same zone. In addition, a red camel icon appears in the dangerous zone and a message that includes the number of camels in this zone appears at the left of the current tab as seen in Figure 14. Consequently, the *WU* activates the light and sound alarms. As soon as, the camel leaves the dangerous zone, the server sends *SMS* message to the *WU* to deactivate the alarms. The team noticed that sometimes the camel physically is in the dangerous zone while for a few seconds the *CVAAS* system could not detect it. In other words, false negative had occurred. The major reasons of the false negative are the width of the dangerous zone, the camel speed, and delay in receiving SMS message. On the other hand, the team also rarely noticed that the camel physically left the dangerous zone (no camel in that zone) while the *WU* was still alarming. This is due to the required time to send *SMS* message from the server to the *WU*, in other words, the false positive had occurred. To study the false negative the team repeats the same scenario several times with different average camel speed and varying dangerous zone width.

Based on logs that were obtained from a national cellular carrier in India, *Pertos* [50] has reported that among the successfully delivered messages, 73.2% reach their destination in less than **10 seconds**, which justifies the conventional characterization of SMS as "near real-time". On the other hand, 17% of delivered messages need more than a minute, and a significant5% require more than an hour and a half [50].

During testing we noticed that the average delay of delivering *SMS* message ranged from 3.81 to 9.048 seconds that similar to *Pertos* report. The test results of the *CVAAS* are summarized in Figure 15(a) and Figure 15(b). In Figure 15(a) we plot false negative versus width of danger zone in two different time frames having different delay in delivering *SMS* message from *CVAAS* server to *WU*. The false negative shown here is average for

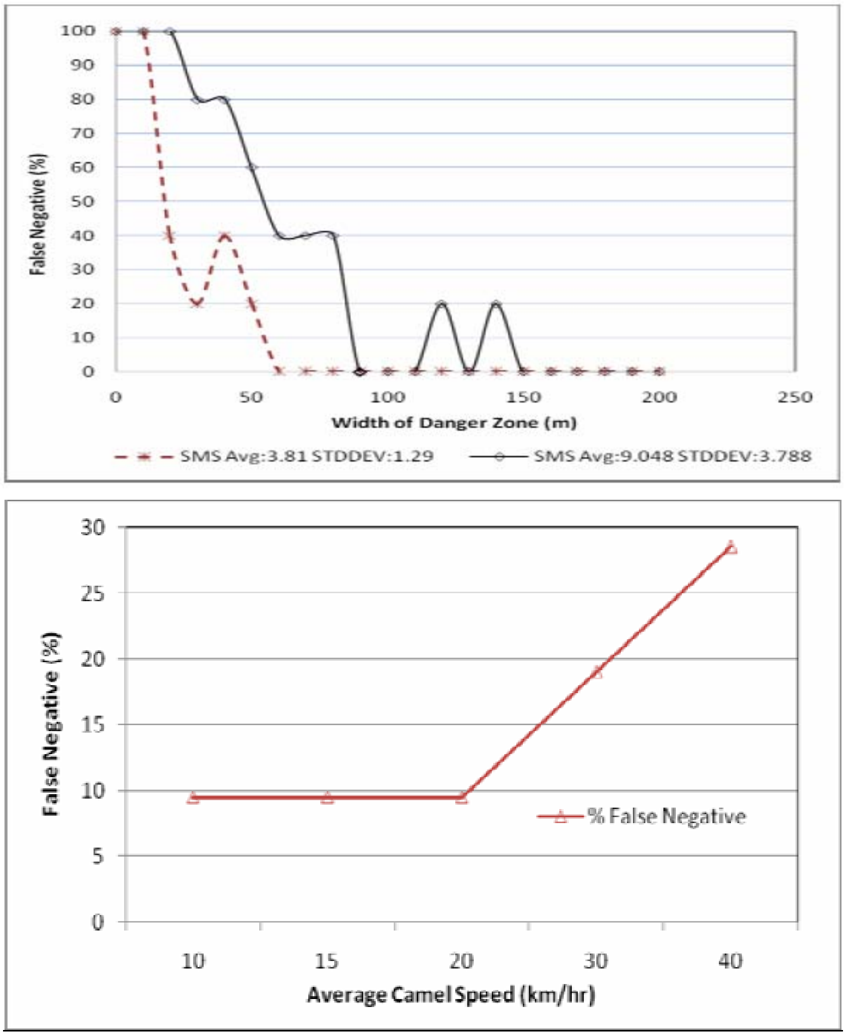


FIGURE 15. (a) False negative and width of danger zone, (b) false negative and average camel speed

various speeds (ranging from 10km/hr to 40 km/hr). We observed that false negative is decreases as width of danger zone is increased. However, if the *SMS* delay is higher than false negative is also higher. If the width of danger zone is reduced beyond 30m, it is very like to be false negative. It could be recommended that the width of danger zone to be 100m since the false negative remains below acceptable limit. In Figure 15(b) shows that false negative increases with increase of average camel speed. In this case the false negative is calculated for different widths of danger zones (20m to 200m) and average *SMS* delay was 3.81. It is noteworthy that false negative remains below 20%.

Consequently, these test results demonstrate that the proposed system *CVAAS* is a reliable system and working effectively. Based on the values of the false negatives, the *CVAAS* system meets the recommended acceptable limits for the reliability of animal detection systems [51].

5. **Conclusion and Recommendations.** Hundreds of Camel-Vehicle accidents are reported every year in the Kingdom of Saudi Arabia. They are causing numerous deaths and loss of property running into millions of Saudi Riyals. This project designed and implemented a deployable ***Camel-Vehicle Accident Avoidance System*** (*CVAAS*). It exploits two recent technologies *GPS* and *GPRS* to detect the camel position and then

to transmit that position to the *CVAAS* sever consequently. Subsequently, the *CVAVS* server checks the camel position and decides to warn the drivers through activating the warning system if the camel is in danger zone. The *CVAAS*'s team designed, deployed and tested the *CVAAS* system. Finally, they conclude from the results of testing the deployed *CVAAS* system that the values of the false negatives meet the recommended acceptable limits [51] for the reliability of animal detection systems.

However, for any such system to be effective in reducing camel-vehicle accident the behavior of the driver is critical. The driver needs to be very cautious when the warning signs are activated. Initiatives to increase driver awareness have to be taken. Further, we would like make following recommendations.

- In order to reduce the cost of deploying the *CVAAS* in large scale, we recommend conducting an intensive and official traffic database on camel-vehicle accidents at the *Saudi Arabia*'s highways. Then, we can use several analysis models such as given in [52] to identify the high accident sections in the highways. Therefore, instead of deploying the *CVAAS* into each kilometers and all the highways of the *Saudi Arabia*, it is sufficient to deploy it only on the sections that having high accidents rate.
- As Al-Amr [53] reported that more than 90% of the camel-vehicle accidents occur at night, between dusk and dawn. In order to reduce the operation cost of the *CVAAS*, it is suggested to fully operate the *CVAAS* system at the night especially between dusk and dawn while sub-operates it at the morning.
- The *Warning Unit* could be enhanced by utilizing a holographic camel image to warn drivers on the highway.
- Possibility of using solar-powered *ABU* and *WU* could be explored.
- In addition to roadside warning units, mobile communication service providers in the *Saudi Arabian Kingdom* such as *STC*, *Mobily* and *Zain* can provide such services that send *SMS* or *MMS* messages to warn drivers within the danger zone area where camels have been located.

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