

A DESIGN FOR PREVENTION OF VIOLATION OF DISABLED PARKING SPACES: DDPS (DETERRENT DISABLED PARKING SYSTEM)

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DOI: <http://dx.doi.org/10.31796/ogummf.594213>

Keywords	Abstract
<i>Smart parking, Disabled people park, RFID, Parking occupancy.</i>	<i>Limited public awareness and insufficient parking spaces result in the conscious or unconscious occupation of disabled parking by other drivers. According to the law on traffic penalties, violation of disabled parking is punishable by a penalty and driving reputation points. However, it is only possible to control and implement this law under ideal conditions. This study describes in detail the Deterrent Disabled Parking System (DDPS), a distinctive design, planned in order to control disabled parking and to allow the implementation of penal sanctions in case of violation and the algorithm for the system is presented. The design is modeled with Arduino UNO, ultrasonic distance sensor, Radio Frequency Identification (RFID), LCD screen and various connection elements. The performance of the system is tested with three different scenarios with a 76% measurement accuracy. The results are discussed and ways of improvement are indicated.</i>

ENGELLİ BİREYLERE AYRILMIŞ PARK YERİ İŞGALLERİNİN ÖNLENMESİNE YÖNELİK BİR TASARIM: CEPS (CAYDIRICI ENGELLİ PARK SİSTEMİ)

Anahtar Kelimeler	Öz		
<i>Akıllı park, Engelli park, RFID, Park işgali</i>	<i>Toplumsal farkındalığın yetersizliği ve araç park yerlerinin sınırlı sayıda olması durumları engelli kullanıcılara ayrılmış park alanlarının diğer kullanıcılar tarafından kasten veya herhangi bir kasıt olmaksızın işgal edilmesine yol açmaktadır. Trafik cezaları kanununda engelli park yerlerinin istismarına yönelik para cezası ve sürücü itibar puanının düşürülmesi gibi cezalar bulunmaktadır. Ancak bu denetimin sağlanması ve cezai işlemlerin uygulanması yalnızca ideal koşullarda mümkün olmaktadır. Bu çalışmada engelli park yerlerinin denetiminin yapılmasına ve işgal durumlarında cezai yaptırımın uygulanabilmesine yönelik özgün bir tasarım olan Caydırıcı Engelli Park Sistemi (CEPS) detaylı bir şekilde anlatılmış, sistem için geliştirilen algoritma sunulmuştur. Tasarım Arduino UNO, ultrasonik mesafe sensörü, RFID, LCD ekran ve çeşitli ara elemanlar kullanılarak modellenmiştir. Tasarımın performansı 3 farklı senaryoda test edilerek %76 ölçüm doğruluğu gözlemlenmiştir. Sonuçlar incelenerek, sistem performansı için gerekli iyileştirmeler vurgulanmıştır.</i>		
Araştırma Makalesi	Research Article		
Başvuru Tarihi	: 19.07.2019	Submission Date	: 19.07.2019
Kabul Tarihi	: 24.10.2019	Accepted Date	: 24.10.2019

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1. Introduction

Intelligent Transportation Systems (ITS), which is a sustainable transportation structure that uses advanced technology informatics, communication, electrical and electronic systems, has been developing rapidly and continues to make our life easier with the solutions it presents to our problems (Nuzzolo & Comi, 2016; Satunin & Babkin, 2014). The applications within the scope of ITS operate in diverse areas such as electronic audits, ensuring safety on the roads with vehicle to vehicle interactions, examination of weather conditions on the road and informing drivers instantly, ensuring load, fleet and clearance control, traffic and intersection management, park management and control and so on (Dullaert et al., 2009; Y. Lin, Wang, & Ma, 2017). Although ITS includes all the solutions for all modes of transport, it is possible to discuss the tendency of these solutions to road transport, especially considering the increase in the number of vehicles in traffic in recent years.

In addition to the increase in vehicle numbers, parking space problems increase day by day. Researchers in many countries around the world are focusing on producing solutions under the headings of smart cities and intelligent parking systems. Intelligent parking systems offer significant benefits such as reduced parking time, reduced environmental pollution, reduced fuel costs and reduced traffic congestion (Caicedo, Blazquez, & Miranda, 2012; T. Lin, Rivano, & Le Mouel, 2017).

In recent years, there are many studies based on smart parking systems (Amato et al., 2017; Lan & Shih, 2014). Kianpisheh, Mustafa, Limtrairut, and Keikhosrokiani (2012), in their study, presented a smart parking system to help people to find available parking slots quickly by using distance sensors for identifying empty slots, specific LED for informing the users. Huang, Chang, and Tsai (2017) took an approach to provide users with real-time information about the parking spaces using a mobile app, Arduino and Wi-Fi. Chaudhary, Bansal, and Valarmathi (2017) developed a system which enables authorized drivers to be allowed to enter parking slot by using Arduino, RFID reader and IR Sensor. Kanteti, Srikar, and Ramesh (2017) suggested an intelligent smart parking algorithm that works on hybrid technology of parking systems which involves sensors for detecting number plate of the vehicle, Raspberry Pi, Arduino, an ultrasonic sensor for detecting the vehicle and speed sensor for measuring the speed of the vehicle. Mohandes, Deriche, Abuelma'atti, and Tasadduq (2018), used RFID reader, ultrasonic distance sensors, LCD, GSM shield for messaging, RF transmitter to detect vacant parking spaces in a university campus and to inform the users. Nandyal, Sultana, and Anjum (2017) in their study introduced an Internet of Things (IoT) based smart parking system which checks the available parking lot

with sensors and informs the users with LEDs.

The increase in vehicle numbers also directly leads to the occupation of parking spots of disabled people. Without smart solutions, victimization of those cannot be eliminated due to the difficulty of inspection of this violation. Intelligent systems to inspect the occupation of disabled parking spots have been a topic for recent studies.

Cope and Allred (1991) made observations for nearly 1 year in a supermarket in a mall in order to prevent the illegal occupation of four parking spaces allocated to people with disabilities and recorded the three different methods they developed. These methods are respectively in the form of a vertical sign, message sign, and message distributor. In the light of the data they obtained, they state that putting the vertical sign decreases illegal parking by 51.3%, message sign by 37, 3 %, and addition of message distributor by %24,5 on top of this decrease. Lambrinos and Dosis (2013), in their study called DisAssist, made use of sensors, smartphones and mobile networks to instantly inform disabled people about parking availability, according to the principles of IoT. In his study, Disabled Parking Permit (DPP) system, Arai (2013) uses multiple methods such as infrared cameras, RFID, Electronic Toll Collection (ETC), and Global Positioning System (GPS) in a single design which emphasizes an economic and effective solution for the inspection of disabled parking spots. Yahaya and Zain (2014) intended to create a positive attitude towards the rights of people with disabilities based on the principles of multimedia learning and persuasion technology. Miniaoui, Sukic, and Dogru (2016) conducted a study called "Safe Parking Spots for Physically Challenged-SPSPC" in which the driver is informed instantly via mobile services according to the status of sticky banderol on the vehicle parked.

Yousaf, Duraijah, and Gobee (2006) use RFID and image processing technologies to facilitate the access of people with disabilities to reserved parking spots and their study intends to allow or prevent parking according to the detection of the tag placed on the vehicle by a camera. In their study, Gining, Fauzi, Hadi, Razak, and Jamaluddin (2018) design a system using IoT technology in order to observe the disabled parking violation and establish a social consciousness in this regard. The system using a microprocessor, motion sensor, alarm, and signal lamp aims to alert instantly the drivers violating disabled parking and communicate it to the environment. With the Disabled Person Plate or Placard-DPPP application developed for the people with disabilities, the Department of Motor Vehicles -DMV ensures the rightful usage of the disabled parking spots via the cards that may be obtained by presenting application form, disability report and citizenship certificate (Yardımcı & Akyıldız, 2005). Another

application for the protection of the parking rights of disabled drivers in public and private areas, especially in shopping malls, is the commercial Freepark Smart Park application. The application is based on control by the interaction of a mobile phone and specially designed parking barrier (Akbaş & Akdoğan, 2001). After detailed literature research, it has been seen that the literature mainly focuses on smart parking, however, it lacks deterrence for those who aim to park into the disabled parking spots.

In this study, a novel design called Deterrent Disabled Parking Systems (DDPS) is presented. The main objective of the paper is to model the design and to test them with simple elements. By using Arduino UNO, distance sensor, information screen and RFID (Radio Frequency Identification), the system is modeled. The performance of the system is tested with three different scenarios and the results are discussed.

2. Material and method

2.1. Implementation

The operation of the system starts with the entrance of the vehicle to the parking spot and the distance sensor identifying the presence of the vehicle. The system welcomes the driver with an informative screen and asks the driver to scan the disability card previously acquired due to the disability situation to the RFID sensor. For this action, the driver has 5 minutes. Three different scenarios come into play at this point. In the first scenario in which the driver has a valid disability card, the RFID sensor verifies the card scanned and communicates with the informative screen that the driver is allowed to park (Figure 1).



Figure 1. Valid Parking Demonstration

In the second scenario in which the driver has an expired disability card or scans another card, the information screen warns the driver to scan a valid card or to leave the parking spot. After this message, the

system allows the driver another 5 minutes to complete the request. If the vehicle does not leave the parking spot or no valid card is scanned in 5 minute period allowed, the system blocks the vehicle by means of a spike barrier and prevents it from leaving the parking spot (Figure 2). In the case of not scanning any card to the RFID scanner until the end of the first 5 minutes which is the third scenario, the system gives another 5 minutes like the second scenario and waits for the valid card or leaving the parking spot.



(a) Invalid Parking



(b) Spike Barriers

Figure 2. Invalid Parking and Spike Barriers Demonstrations

Not scanning valid card will lead to activation of the spike barriers after which, the vehicle may leave the parking spot only if the parking attendant releases the spike

barrier after the driver informs him/her about the situation and receive the fine receipt. These three

scenarios are visualized at the flowchart of DDPS given in Figure 3.

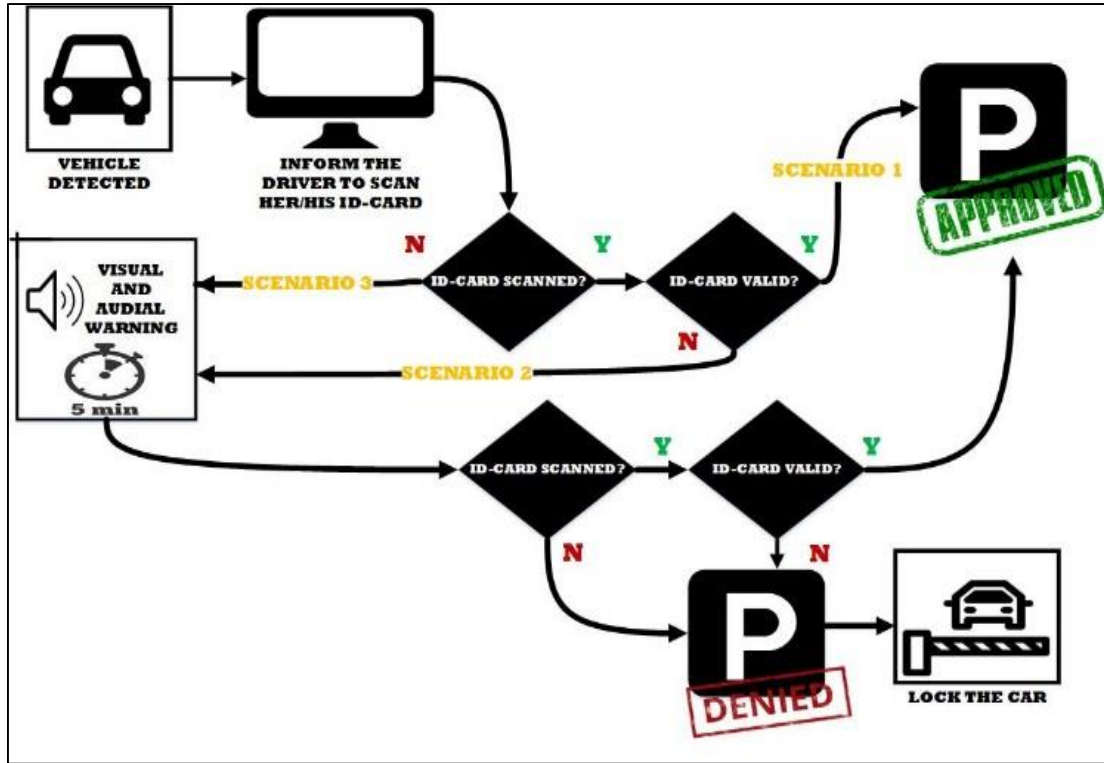
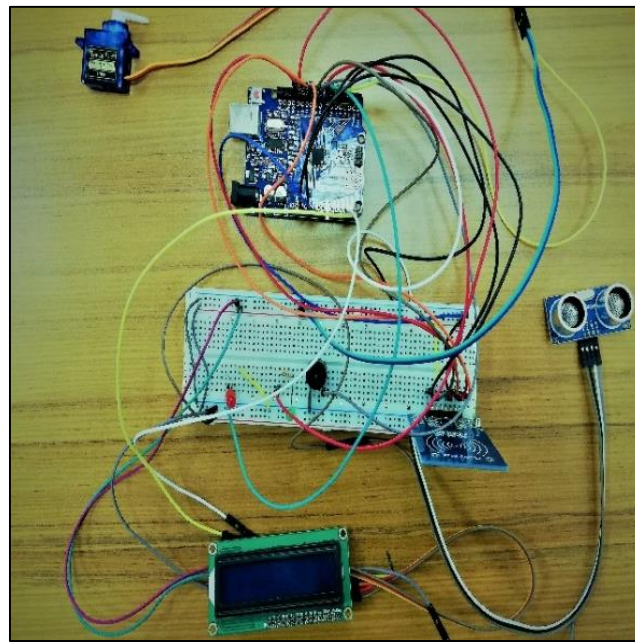


Figure 3. Flowchart of DDPS and Visualization of Three Scenarios

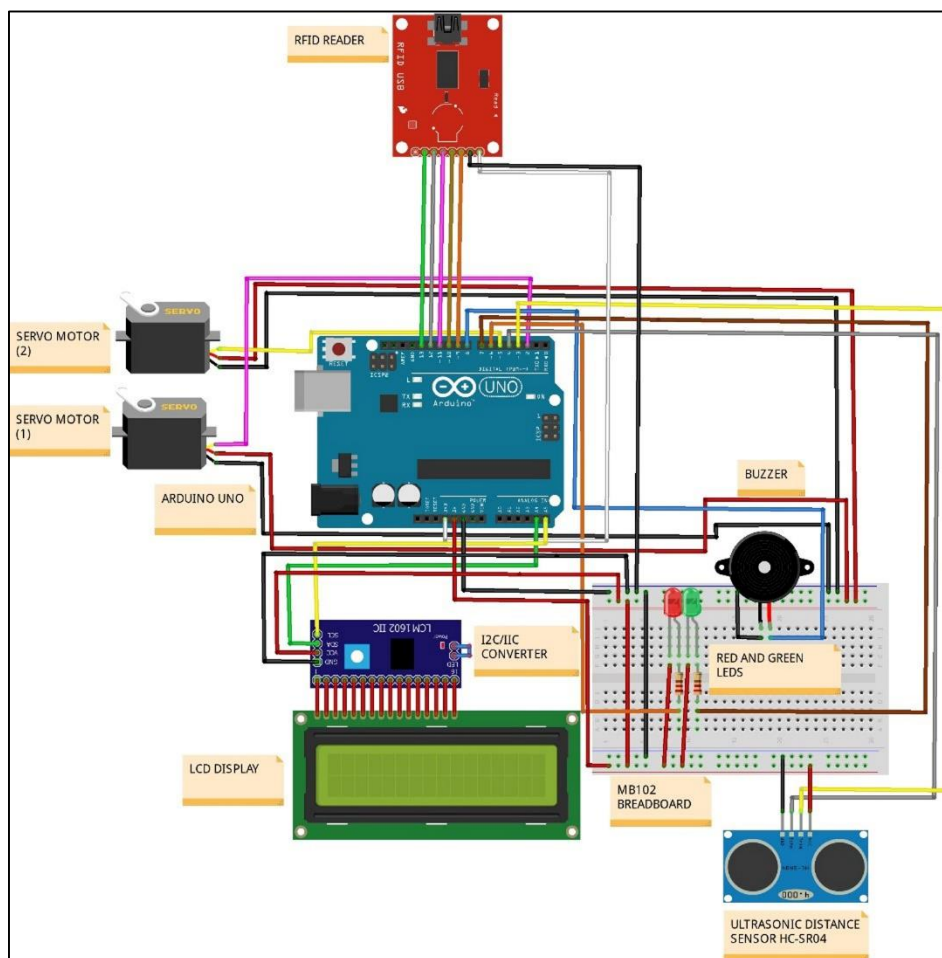
2.2. Materials

The microprocessor of the project is Arduino UNO which has enough connection pins which include 14 digital, 6 analog and 3,5V and 5V power pins. To detect the car entrance to the parking spot, the HC-SR04 ultrasonic distance sensor which can measure the distances between 2-400 centimeters with 3 millimeters error and has 4 pins. VCC, GND, TRIG and ECHO pins function as 5V power supply, ground, transmitting and receiving a pin for ultrasonic waves. The threshold value for this study is selected as 50 cm. For informing the user after the distance sensor is triggered, Liquid Crystal Display (LCD) TC1602B which supports 16x2 characters and two buzzers with CRE audio circuit. To decrease the number of pins used by LCD from 8 digital to 2 analogous, I2C/IIC LCD converter is used. RFID RC522 is used for the user to scan his/her RFID tag which stores and transmits data with the help of radio antenna inside. There are two types of RFID tags as active and passive. Active tags include battery inside and do not require a power supply from the RFID reader. To point out park

allowance or disallowance green and red light-emitting diodes (LED) are employed. The trap which will come into play in park disallowance is operated with two TowerPro SG90 servo motors which can produce up to the torque of 1.8 kg/cm.



(a) Implemented Circuit View.



(b) Schematic Circuit View.

Figure 4. Visualization of the Circuit

For the connection of the circuit MB102 type Breadboard, jumper wires, and various resistors. The schematic of the circuit is completed with Fritzing software. Fritzing also helped to overcome mistakes and misconnections. The schematic view and the completed full circuit are shown in Figure 4.

2.3. Programming the Arduino UNO

Arduino UNO is programmed after the completion of the connection of the components. During the programming, among Arduino UNO libraries, the ones matching the components used in the study at most are selected and installed. After the installation of the libraries, the pins to which the components are connected are defined.

When connected to an Arduino power supply, the void setup function, which includes pin connections, inputs and outputs, and variables, is activated. This function works only once at the beginning, then it is replaced by a void loop function.

The void setup function works again if we disconnect and reconnect power and press the reset button on the board. The void loop function is activated once the Void setup function is activated.

The Loop function puts the Arduino in an infinite number of loops and allows the user to control the pins and perform certain commands (Noble, 2009). In the study, the loop started with the operation of the ultrasonic distance sensor. Ability to read from a distance less than 50 cm. is installed to the ultrasonic distance sensor as a condition. In this case, the LCD screen displays "Welcome, Please Scan Your Card" and the RFID reader is activated simultaneously. Some of the relevant codes are given below.

```
void loop(){
  long t, x;
  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
  t = pulseIn(echoPin, HIGH);
  x = (t/2)/ 29.1;
  if (x<10) {
    delay(5000);
    lcd.clear();
    lcd.noBacklight();
    //Variables for different
tags
    boolean userB_card = true;
    // User B - allowed user.
    // It can be defined for more users.
  }
```

If the RFID reader scans a defined tag, the system allows parking and the green LED lamp turns on and the LCD screen displays the welcome text "Parking allowed". Some of the codes for the system allowing to park are given below.

```
Serial.println();
if(userB_card){
  cardRead = 1;
  park_allowed();
  digitalWrite(LED_green,
HIGH);
  digitalWrite(LED_green,
LOW);
  Lock.write(90);
  a = false;
  delay(5000);
}
// this format can be modified for
other users.
```

If an undefined/invalid tag is scanned by the RFID reader, the system warns to scan a valid tag via buzzer and LCD informative screen during a pre-defined 5-minute waiting period. If no valid tag is scanned during this period, servo motors are activated and the spike barrier closes and the vehicle is blocked. Some of the relevant codes are given below.

```
}
else{
  if(a) {
    delay(300000);
    digitalWrite(LED_red, HIGH);
    delay(3000);
    park_not_allowed();
    delay(5000);
    Lock.write(0);
    digitalWrite(speaker_pin, HIGH);
    delay(100);
    digitalWrite(speaker_pin, LOW);
    delay(100);
    digitalWrite(speaker_pin, HIGH);}
}
```

Following the activation of the RFID reader, if no tag is scanned to RFID in 5 -minute period, the system displays on LCD "Inconvenient Parking, Drive Away" and the system waits for another 5 minutes with red led and buzzer are on. After this sequence, the spike barrier is activated. Some of the relevant codes are given.

```

}
else{
if(a) {
delay(300000);
digitalWrite(LED_red, HIGH);
delay(3000);
park_not_allowed();
delay(5000);
Lock.write(0);
digitalWrite(speaker_pin, HIGH);
delay(100);
digitalWrite(speaker_pin, LOW);
delay(100);
digitalWrite(speaker_pin, HIGH);
}
}

```

3. Results and Discussion

In this study, DDPS which offers a solution to the violation of disabled parking spots which has become a chronic problem despite the legislation with penal sanctions is developed. The model is tested by two different scenarios and the conclusions reached are summed up below.

- For the first scenario, after the triggering of the distance sensor, a valid RFID tag was scanned and the system sensed it as a valid tag and appropriate parking. Allowance was stated on the LCD and the green LED was turned on.
- Scanning of the invalid tag at any time of first 5 minutes, which is the second scenario, occurred as planned and the system gave warning via 5 minutes of red LED and buzzer during which "Please scan a valid card" phrase was displayed on LCD. In a still absence of

a valid tag, the spike barrier is triggered and the car is locked.

- In the case of the third scenario, scanning no tag in the given first 5 minutes, the system gives another 5 minutes with visual and audial warnings. In these 5 minutes, the system waits only for valid tag (Scanning invalid card does not refresh the time). At the end of that time trap mechanism was activated if no valid card was scanned. Thus the vehicle would be locked in the parking spots.

Furthermore, even after the activation of the trap if a valid tag was scanned, the system disabled the trap mechanism and allowed it to park. In this study, these scenarios are implemented 40 times for each in random order. For the first scenario, the system responded as expected 36 times out of 40. It is seen that 4 false readings of the RFID tag are due to hardware inadequacy or misuse so that the system responded like the second scenario and visual and audial warnings kicked in. Concerning the second scenario, 24 convenient results are obtained out of 40 trials. 11 of 16 total inconvenient trials, the system identified the false tag as a valid so system responded like the first scenario. In the remaining 5, RFID did not perceive the tag as valid or invalid and continued to demand a tag then after the first 5 minutes; the system gave another 5 minutes as the third scenario. In the third scenario experiments, 31 correct results are reached by all of 40 results. In 3 of them the system, in contrast to the desired state, allowed to park as in the first scenario. In the other 6 trials, the system locked the spike barriers after the first 5 minutes, i.e. did not give a total of ten minutes wait time as developed for this scenario. In total, 76% of trials gave the desired result. The confusion matrix regarding the experiments and three scenarios is given in Figure 5.

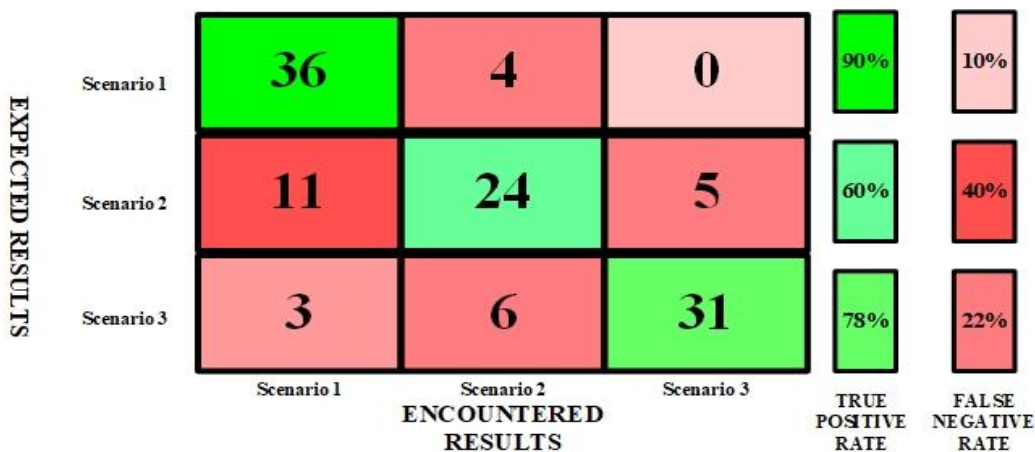


Figure 5. Confusion Matrix and System Accuracy in Three Scenarios

As can be seen in the confusion matrix, expected diagonality is observed. For the first scenario, the encountered results are distributed between scenario 1 and scenario 2 with 90% accuracy so that the results of this attempt are satisfactory. Among the 40 trials which are expected to belong to the second scenario, 24 trials are produced as true positive. The others distributed between scenarios 1 and 3. It is considered using better equipment can improve this deficiency. The last one gave better results when compared with the second scenario with a 78% true positive rate.

After many trials, it is thought that DDPS can contribute to the current literature and future studies as follows:

- It can be used to prevent the occupancy of parking spaces which are reserved for disabled people and to apply penal sanctions.
- It provides monitoring and protection of disabled parking spaces with higher disincentive elements than in the previous studies.
- Different colors of LED lights are used in DDPS so it allows easy detection of parking violations.

- Combined with a mobile application, it will allow easier control and charging.
- It can be connected with smart parking application thus; the driver can be directed to the other appropriate parking lots.
- The error rate of the results can be reduced when microprocessors with better computing power are used.

As seen in Table 1 which compares DDPS with other studies, having different features in issues such as outdoor usage, integrating with other applications, deterrence level, and cost-efficiency. These studies include a certain level of deterrence. In two studies Arai (2013) and Lambrinos and Dosis (2013), presented designs in which multiple of higher-cost components are used making studies suitable for outdoor usage whereas Gining et al. (2018), Chaudhary et al. (2017) and DDPS shine out with cost efficiency among related studies, due to the less expensive system components.

Table 1
Comparison Between DDPS and Related Studies

Related studies	Outdoor usage	Possible integration with other Intelligent Transportation Systems	Deterrence of the system	Cost-efficiency
Chaudary et al. (2017)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Lambrinos and Dosis (2013)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Yousaf et al. (2016)	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Gining et al. (2018)	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
Arai (2013)	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
Miniaoui et al. (2016)	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
DDPS	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>

4. Conclusions

In this paper, it was seen that the novel design, DDPS, produces successful results in the identification of disabled parking spot violations and starting the required procedure for the application of penal sanction. DDPS differs from previous studies in deterrence with the addition of spike barriers. The usage of spike barriers with the elements used in literature such as information screen, visual and audial warning systems is expected to decrease the violation of disabled parking spots.

One of the advantages of DDPS is the potential of easy implementation because the system has a simple structure. However, due to the possible efficiency drop of the electronic components (i.e. sensors, RFID device) in unfavorable weather conditions, it is suggested that it should be applied to current indoor parking lots in hospitals, shopping centers, airports, etc.

The system is very user-friendly since it includes the action of scanning an RFID card that is familiar with public transport, credit cards, door locks, etc. Whereas it is still abusable because the sensors can be triggered by many elements other than vehicles. Therefore the

system is designed as that the spike barriers are enabled after 10 minutes (5 minutes with only information screen plus 5 minutes with audial and visual warnings). Thus the element (bike, person, or animal) triggering the sensors would leave the spot in 10 minutes. In the first five minutes triggering the system will not enable the barriers and probably the element will leave the spot in this gap, or the other five minutes audial and visual warning will kick in, and the element would definitely leave the spot. At the instant of leaving the spot, the system will reset itself. The information screen will turn off or warnings will stop. Also, people can share the authorized RFID card among their acquaintances without a disability who are not supposed to use the disabled parking lot. As future work, it is planned to choose a suitable pilot area and apply the system and with the data after observation proficiency of DDPS at the inspection of violation of parking spots for disabled people. 76% measurement accuracy is related to the quality of the current equipment used in DDPS. Replacing the components with those of higher quality (i.e. more powerful computers than Arduino, sensors with higher precision) will drastically improve the performance of the system's measurement accuracy. Finally, future releases of DDPS will include the integration with ITS applications such as mobile applications to navigate the disabled users to the disabled parking spots which are controlled by DDPS and smart parking systems which are used to detect empty parking slots.

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