

Design and Construction of Car Seat Model for Child Safety

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Received: 24/02/2023

Accepted: 06/04/2023

Abstract

Every year, many young children get hurt, injured or died in different ways of car accidents. The last numbers show that about 17% of children have accidentally and intentionally died in cars, and more than 28% of them have forgotten alone in cars facing the risk of being died. So that we can help to prevent this from happening by using the child safety car alert system, which is an integrated device that sends an alert if a child is in danger in the car. The system of this research is developed using the Arduino board, which incorporates the integration between sensors and the GSM module that enable parents to get notified if their kid is in danger. It mainly consists of a car seat and surveillance system, the principle of work depends on measuring the temperature and oxygen level inside the car through some specific sensors inside the system programmed at a certain level. The system is activated when the load weight sensor detects a child in the seat; the system sends an alarm as a phone call to the parents when there is a change in temperature or oxygen level to prevent any potential danger to the child. If the parents do not answer the phone call, the system will send a message to the parents.

Keywords: Child Safety Seat, design methodology, GSM, Arduino Microcontroller.

1. Introduction

In Iraq, vehicle-related deaths for children fewer than 12 years' age keep occurring and the cases are in increasing trend [1-5]. Despite of various inventions to enhance the vehicle safety system and awareness campaign to prevent those incidents from occurring, the deaths caused by the non-moving vehicle keep increasing. When the car engine is turned-off with closed window, the temperature in the car will increase rapidly and children might suffer heat stroke.

A child's body overheats more easily than an adult's. Most of the incidents occurred due to the negligence of the parents. Parents or drivers, in certain situations, may leave the car without taking the children. It might also have occurred when the father or mother change his or her duty to send their children to nursery. This scenario can happen since their children taking sleep or nap, and they might not realize the presence of their children in the vehicle especially for the bigger vehicle such as multi-purpose vehicle which has more than two rows of seats.

Unlike vehicle's in United States or European countries which is requiring parents to put their children in the specified child's seat before driving as a safety matter. Those rules are not abided by most of the Iraqi vehicle's drivers. It seems that the requirement to use child's seat is applied merely on the children with age below 2 years old. However, children with age ranging from 2 to 6 years old are free to move around and inside the vehicle's cabin. Thus, they will be sitting, laying or napping somewhere in the vehicle's cabin. For example, it will be very hard for the multi-purpose vehicles' owner to locate his or her child if the child is lie down at the back seat or at the floor between the second and last row of the seat. It is a human nature to forget something and to think driving alone. As a result, he or she will park and leave the vehicle while his or her child is left behind or still inside the vehicle. Various techniques and inventions had been introduced but yet to provide the solid solution. Most of the techniques and inventions were patented especially in United States and Europe [2].

In United States and Europe, the child detection systems were developed especially for baby or infant seat and integrated with car alarm system. Here, the car security system will generate an audio alarm once the car is turned-off and the children are detected still in the car baby seat. Among the various child detectors were introduced by researchers are Passive Infrared Red (PIR) motion sensor, RFID, RF safety pad, capacitive sensor, microwave sensor, pressure transducer, temperature detector and image detector [6-9]. However, all the inventions are still yet to provide the effective and comprehensive warning and feedback systems to trigger parent for the unattended child in the vehicle. Some of the inventions have drawbacks. For example, for the child seat, there were synchronization issues between child-seat-sensing device and notification device. Meanwhile, PIR required motion from the children and will not effective for the children in sleep condition. Another invention was the use of pressure transducer on the child seat to detect the changing of air pressure due to the opening and closure closing of the vehicle door.

Here, the device was integrated with the vehicle alarm system to produce alarm once the pressure transducer activated. Meanwhile, for image detection technique, it requires wide angle camera and of course, a lot of cameras are required for bigger vehicle such as multi-purpose vehicle or sport utility vehicle. Another method is the use of visual signal at the car dashboard to enable driver to have a view behind the driver seat. However, this method might not practicable for bigger vehicle such as multipurpose vehicle. In term of communication systems, it cannot be denied that the wireless communication is a practical and an effective medium to enable human to communicate with electronics device. Among them are IEEE 802.4.15, the network Global System for Mobile Communications (GSM), Global Positioning System (GPS) and Radio Frequency Identification system (RFID) were used extensively especially in vehicle safety technology. In current vehicle technology, most of the modern vehicle already equipped with wireless anti-theft security system whereas the child detection system is installed on the vehicle baby seat and strictly applied for vehicle in US and European countries [9].

In those countries, there is a law to put the young child or infant in the child seat when driving the vehicle. In Asian countries, especially in Iraq, the law is not fully followed and merely the expensive vehicle has the accessories for anti-theft only. Thus, it a must for every vehicle regardless the type of the vehicle, to be equipped with the wireless child detection system since the system is proven by researchers to enable human to communicate with the vehicle regardless the location of the vehicle unless the location cannot be reached by the GSM.

Therefore, this research will introduce a comprehensive child detection system which Enhancement of the previous researches by combining both temperature and oxygen level detection systems. The proposed system is constructed to achieve the followings following objectives:

1. To design a warning system
2. To detect the presence of children in unattended vehicle using a combination of pressure, oxygen level, and temperature detection techniques.
3. Besides, the system is created to provide the intelligent feedback system by sending a phone call to notify the parents.

2. Literature Review

This part illustrates several studies published by researchers related to car safety seat based on different systems. In 2005 study by “Guard and Gallagher,” recommend educating parents on keeping cars locked when unattended and on the unique susceptibility children have to extreme heat, as well as the rapid increase of vehicle internal temperature [10]. The national highway traffic safety Administration released an article to parents/guardians in May of 2015 reminding them of the dangers of heat stroke and providing the following tips to prevent such an accident from occurring. Therefore, never leave a child unattended in a vehicle. [11].

1. Make a habit of looking in the vehicle forward to back before locking the car.
2. Ask the child care provider to call if the child does not show up as expected.

3. Do things that serve as a reminder that the child is in the car.
4. Teach children that a vehicle is not a play area.

2.1 Car Seat Sensors System

The safe Sensor is currently one of the only car seats manufactured including a safety system to prevent child vehicular heatstroke. The safe Sensor plays a series of chimes or tones when the car stops at its destination [12]. The safe Sensor serves to remind the parent or guardian that the child is buckled into the car by preventing a situation where the parent may unintentionally leave the child in the car seat. The system does not offer Bluetooth or wireless cell phone connectivity and serves only as an initial reminder that the child is in the car. In the event the child is still left in the car, there is no additional notification system in place.

2.2 Other Systems

In a year 2012 a study eighteen different child safety products were analyzed to determine effectiveness in preventing/notifying parents or guardians that a child was at risk for child vehicular heatstroke. Seven of the products utilized a force or pressure sensing, three utilized child restraint fastening, five had no sensing capability, and the remainder had vehicle interface [13]. None of the products tested were a full car seat package. Some of these products included the baby be safe that is attached to your key chain to serve as a visual reminder and the forget me not car seat system that measure pressure in the car seat and sends an alarm to a

2 key chain if pressure is sensed and the key chain moves 10 or 20 feet away from the vehicle [13].

2.3 Types of Car Seats

This chart Table (2): is a quick guide on where to start your search. It's important to continue your research to learn about each seat you use.

Chart Table (2)

Types of Car Seats		
Age-group	Type of Seat	General Guidelines
Infants and toddlers	<input type="checkbox"/> Rear-facing-only <input type="checkbox"/> Rear-facing-convertible	<p>All infants and toddlers should ride in a rear-facing seat until they reach the highest weight or height allowed by their car safety seat manufacturer. Most convertible seats have limits that will allow children to ride rear facing for 2 years or more.</p>
Toddlers and preschoolers	<input type="checkbox"/> Forward-facing convertible <input type="checkbox"/> Forward-facing with Harness	<p>Children who have outgrown the rear-facing weight or height limit for their convertible seat should use a forward-facing seat with a harness for as long as possible, up to the highest weight or height allowed by their car safety seat manufacturer. Many seats can accommodate children up to 65 pounds or more.</p>
School-aged children	<input type="checkbox"/> Booster	<p>All children whose weight or height exceeds the forward-facing limit for their car until the vehicle seat belt safety seat should use a belt-positioning booster seat properly, typically when they have reached 4 feet 9 inches in height and are 8 to 12 years of age. All children younger than 13 years should ride in the back seat.</p>
Older children	<input type="checkbox"/> Seat belts	<p>When children are old enough and large enough to fit the vehicle seat belt to them correctly, they should always use lap and shoulder seat belts for the best protection. All children younger than 13 years should ride in the back seat.</p>

2.4 Car Seat Installation Information: Seat Belts and LATCH

Car safety seat as shown in Figure (1) may be installed with either the vehicle's seat belt or its LATCH (lower anchors and tethers for children) system. LATCH is an attachment system for car safety seats. Lower anchors can be used instead of the seat belt to install the seat, and many parents find them easier to use in some cars. The top tether should always be used with a forward-facing seat, whether you use a seat belt or lower anchors to secure it. The seat belt and LATCH systems are equally safe, so caregivers should use one or the other whichever works best for them, their car safety seat, and their vehicle. In general, parents should only use one of the two options, unless the car safety seat and vehicle manufacturers can be used both systems at the same time. use one of the two options, unless the car safety seat and vehicle manufacturers can be used both systems at the same time.

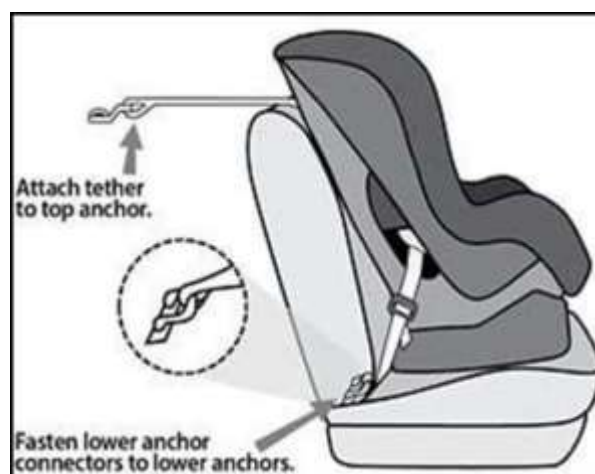


Figure (1): Car safety seat

Vehicles with the LATCH system have lower anchors located in the back seat, where the seat cushions meet. Tether anchors are located behind the seat, either on the panel behind the seat or on the back of the seat, ceiling, or floor (in most minivans, SUVs, hatchbacks, and pickup trucks). All forward-facing car safety seats have tethers or tether connectors that fasten to these anchors. Nearly all passenger vehicles and all car safety seats made on or after September 1, 2002, are equipped to use LATCH. See vehicle owner's manual for highest weight of child allowed to use top tether. All lower anchors are rated for a maximum weight of 65 pounds (total weight includes car safety seat and child). Parents should check the car safety seat manufacturer's recommendations for maximum weight a child can be to use lower anchors. New car safety seats have the maximum weight printed on their label.

2.5 Seat belts

If you install a car safety seat by using your vehicle's seat belt, you must make sure the seat belt locks to hold the seat tightly. In most new cars, you can lock the seat belt by pulling it all the way out and

then allowing it to retract to keep the seat belt tight around the car safety seat. In addition, many car safety seats have built-in lock-offs so you can lock the belt without having to lock the seat belt separately as well. Refer to the vehicle owner's manual for details about how your seat belt locks.

2.6 Middle of the back seat

The safest place to ride for all children younger than 13 years is the back seat. If possible, it may be best for the child to ride in the middle of the back seat. However, it is sometimes difficult to install a car safety seat tightly in the middle if the vehicle seat is narrow or uneven. Also, many vehicles do not have lower anchors for the middle seating position. It is safest to put the car safety seat in a position where you can install it tightly with either the lower anchor system or the seat belt, in some cases, this position may be on either side of the back seat rather than in the middle. A child passenger safety technician (CPST or CPS technician) can help you decide which place is best to install your child's car safety seat in your vehicle.

2.7 Advantages of Child's Safety Seats

2.7.1 Protection for the baby

Babies and infants do not have enough resistance to bear vibrations or sudden stops when driving the car and the child may become dizzy due to the instability in the seat properly and therefore children's car seats are important to protect the baby.

2.7.2 The car seat keeps the baby installed

The movement of the child naturally and often after the age of three months, the child begins to recognize things more accurately and try to pick them up and play with them, so the children's car seats can install the baby for a long time. Many children have suffered significant damage due to their instability in the car seats many accidents may occur due to the mother's distraction from the child's movement while driving.

3. Proposed System Design

The components were added to a child safety seat are Arduino Uno microcontroller, Battery, load cell 20kg, load cell amplifier HX711, GSM SIM900, DHT11 temperature and humidity sensor, gas sensor and the microphone sound sensor. These components are designed and implemented to protect children from the risk of death inside the vehicle [14,15].

3.1 Arduino Uno Microcontroller

A microcontroller is a computer on chip that is programmed to perform all control, sequence, monitoring and display functions. Because of its low cost, this microcontroller is a natural choice for researchers [16,17]. Arduino is one of the open-source computing platforms (OSEPP) in microcontrollers and used in projects to design and use the microcontroller development boards [18,19]. These microcontroller boards come with a variety of development board packages (Schmidt, 2011). Arduino is an open-source electronics platform based on easy to use hardware and software. Arduino are able to read inputs light on a sensor, a finger on a button, or a twitter message and turn it into an output - activating a motor, turning on an LED. That Arduino microcontroller is simple and has accessible user experience. Arduino boards are completely open-source,

empowering users to build them independently and eventually adapt them to their particular needs. Those Arduino need large portions sorts similar to UNO, MEGA and various others, here Arduino UNO is applied as shown in Figure (2).



Figure (2): Arduino Uno microcontroller

Arduino Uno microcontroller board is based on the Atmega 328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. The Arduino programming language is C/C++. Arduino Uno board requires just 5V supply. When you reconnect the battery, the last program you set away will run. This assembles you interface the board to the host PC to make your program, after uploading the program in Arduino board you never again need the PC to run the program

The Load cell amplifier HX711 modules allow you to easily read load cells to measure weight. By connecting the amplifier to your microcontroller such as an Arduino you will be able to read the changes in the resistance of the load cell, and with some calibration you'll be able to get very accurate weight

measurements. This can be handy for creating your own industrial scale, process control or simple presence detection. The HX711 as shown in Figure (3) uses a two-wire interface (Clock and Data) for communication. Any microcontroller's GPIO pins should work, and numerous libraries have been written, making it easy to read data from the HX711. Check the hookup guide below for more information. Applicable to electronic scale, price computer scale, electronic platform scale, digital scale, parcel post scale, electronic balance and all varieties of commercial scales using single load cell.

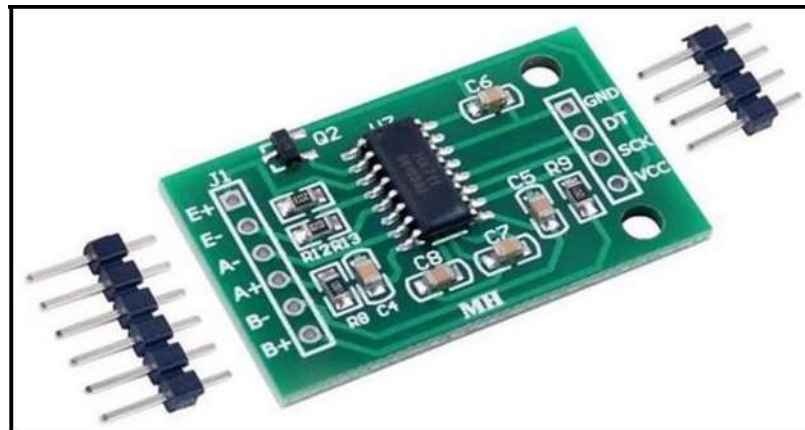


Figure (3): Load cell amplifier HX711

(GSM) SIM900 addresses Global System for Mobile Communications is shown in Figure (4). It is a specially designed model that accepts the Subscriber Identity Module (SIM) Card and operates like a mobile phone. The coverage area of each cell varies according to the execution environment. SIM900A GSM Module

5 is the smallest and cheapest module for GPRS/GSM communication. It is common with Arduino and microcontroller in most of embedded application. The module offers GPRS/GSM technology for communication with the uses of a mobile SIM card. It uses a 900MHz and 1800MHz frequency band and allows users to receive/send mobile calls, SMS text message, connecting to internet through GPRS and TCP/IP. The keypad and display interface allows the developers to make the customize application with it. Furthermore, it also has modes, command mode and data mode. In every country the GPRS/GSM operates with different protocols/frequencies. Command mode helps the developers to change the default setting according to their requirements.



Figure (4) GSM SIM900

DHT11 temperature and humidity Sensor is shown in Figure (5), it a combination of the features of a temperature sensor and humidity sensor with a calibrated digital signal output. By using the exclusive digital signal acquisition technique and temperature - humidity sensing technology, it ensures high reliability and excellent long term stability. This sensor includes a resistive-type humidity measurement component and an NTC temperature measurement component, and connects to a high performance 8-bit microcontroller, offering excellent quality, fast response, anti-interference ability and cost effectiveness.

Each DHT11 element is strictly calibrated in the laboratory that is extremely accurate on humidity calibration. The calibration coefficients are stored as program in the OTP memory, which are used by the sensor's internal signal detecting process. The single-wire serial interface makes system integration quick and easy. Its small size, low power consumption and up to 20-meter signal transmission making it the best choice for various applications, including those most demanding ones.

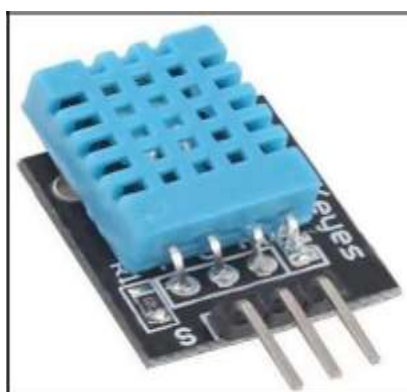


Figure (5) DHT11 temperature and humidity sensor

Gas sensor (also known as gas detector) is shown in Figure (6), it is electronic device that detect and identify different types of gasses. It is commonly used to detect toxic or explosive gasses and measure gas concentration. Gas sensor is employed in factories and manufacturing facilities to identify gas leaks, and to detect smoke and carbon monoxide in homes. It is commonly used in air quality control

equipment. It operates from 2.5V to 5.0V and can provide both digital and analog output. When the levels of these gases go beyond a threshold limit in the air, the digital pin goes high.



Figure (6) Gas Sensor

The microphone sound sensor is a small board that combines a microphone (50Hz-10kHz) and some processing circuitry to convert sound waves into electrical signals. This electrical signal is fed to on-board LM393 high precision comparator to digitize it and is made available at OUT pin. The module has a built-in potentiometer for sensitivity adjustment of the OUT signal. You can set a threshold by using a potentiometer, so that when the amplitude of the sound exceeds the threshold value, the module will output LOW otherwise HIGH. The microphone sound sensor is shown in Figure (7)

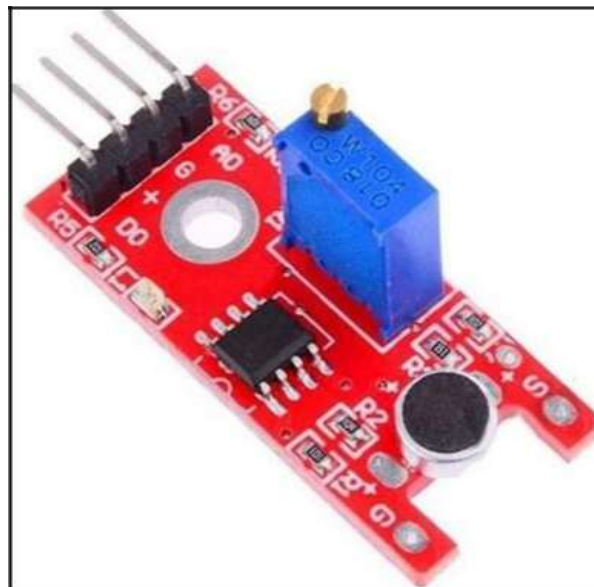


Figure (7): The microphone sound sensor

Overall project consists of Arduino Uno, battery, load cell temperature and humidity sensor, gas sensor, the microphone

20kg, amplifier HX711, GSM sim900, DHT11 soundsensor and car seat as shown in Figure (8)



Figure (8): Overall Project

Acknowledgements

We would like to express our deep appreciation and gratitude to Engineer Mustafa Safaa Mahdi, who gave us great support, encouragement and precious advice throughout the progress of this work. We would like to thank the staff of Medical Instrumentation Techniques Engineering department for their kind assistance.

Finally, we would like to thank all nice, helpful and lovely people who help us directly and indirectly to complete this work and being apologize to them for being unable to mention them by name.

References

- [1] S. Zulaikah, W. H. Rahmanda, and F. Triawan, "Foldable front child -seat design for scooter motorcycle: strength analysis under static and dynamic loading," *International Journal of Sustainable Transportation Technology*, vol. 3, no. 2, pp. 37–44, 2020.
- [2] L. Mazurkiewicz, P. Baranowski, H. R. Karimi et al., "Improved child -resistant system for better side impact protection," *International Journal of Advanced Manufacturing Technology*, vol. 97, no. 9-12, pp. 3925–3935, 2018.
- [3] M. Ptak, J. Wilhelm, M. Sawicki, and E. Rusinski, "Child safety on various bicycle -mounted seats during vehicle impact," *Transport*, vol. 34, no. 6, pp. 684 –691, 2019.
- [4] N. Khoiriyah, S. A. Alfatih, M. Munir, and F. Triawan, "Component design and strength analysis of coffin lowering machine for Covid -19 corpse: a problem-based learning," *Indonesian Journal of Multidisciplinary Research*, vol. 1, no. 1, pp. 137 –150, 2021.
- [5] Z. Xiaoyun, Z. Dongming, Y. Xiaobo, and H. Xinyi, "Improvement on design and manufacture of bus based on traffic accident prevention," *International Journal of Crash worthiness*, vol. 24, no. 5, pp. 523–532, 2019.
- [6] I. L. Cruz -Jaramillo, C. R. Torres -San Miguel, J. A. Leal Naranjo, and L. Martinezaez, "Numerical child restraint system analysis in 6 ye ars old infant during a dolly rollover pp. 404–412, 2021.

- [7] A. M. Madni and M. Sievers, "Model -based systems engineering: motivation, current status, and research opportunities," *Systems Engineering*, vol. 21, no. 3, pp. 172–190, 2018.
- [8] J. Skiera, C. Crosby, C. Bare, M. Paradiso, and G. Campbell, "Passenger vehicle dynamic response and characterization of side structure during low - to moderate-speed side impacts," *SAE Technical Paper Series*, vol. 1, pp. 2019 -01-0420–950, 2019.
- [9] T. E. Cordoba and S. C. Sanders -Smith, "A closer look: socio -structural influences on teacher - child interactions during project work," *Journal of Early Childhood Research*, vol. 16, no. 4, pp.407–420, 2018.
- [10] A. Eizad, F. Zahra, F. Zahra et al., "Study on development of portable incubator," *Korean Society of Manufacturing Process Engineers*, vol. 18, no. 9, pp. 1 –6, 2019.
- [11] J. Li and H. Tanaka, "Rapid customization system for 3D -printed splint using programmable modeling technique – a practical approach," *3D printing in medicine*, vol. 4, no. 1, pp. 5–21, 2018.
- [12] K. E. Jackson, "Advances in rotorcraft crashworthiness: trends leading to improved survivability 37th alexander a. nikolsky honorary lecture," *Journal of the American Helicopter Society*, vol. 63, no. 2, pp. 1 –25, 2018.
- [13] P. Liu, K. R. Kryski, H. J. Smith, M. F. Joannis, and E. P. Hayden, "Transactional relations between early child temperament, structured parenting, and child outcomes: a three-wave longitudinal study," *Development and Psychopathology*, vol. 32, no. 3, pp. 923 –933, 2020.
- [14] E. J. Ramirez, "How to (dis)solve the Gamer’s Dilemma," *Ethical theory & Moral Practice*, vol. 23, no. 1, pp. 141 –161, 2020.
- [15] C. Schumacher, J. Zehnder, and M. Bcher, "Set -in-stone," *ACM Transactions on Graphics*, vol. 37, no. 6, pp. 1 –13, 2018.
- [16] E. Szumska, D. Frej, and P. Grabski, "Analysis of the causes of vehicle accidents in Poland in 2009-2019," *LOGI - Scientific Journal on Transport and Logistics*, vol. 11, no. 2, pp. 76 –87, 2020.
- [17] K. Arkusz, T. Klekiel, G. Sławinski, and R. Bezdziński, "Influence of energy absorbers on Malgaigne fracture mechanism in lumbar -pelvic system under vertical impact load," *Computer Methods in Biomechanics and Biomedical Engineering*, vol. 22, no. 3, pp. 313–323, 2019.
- [18] R. Hajizadeh, Y. Faghihnia Torshizi, A. Alami, and S. E. Samaei, "Compliance of children’s play equipment in urban parks of gonabad with national safety standards (casestudy)," *Iran Occupational Health*, vol. 16, no. 3, pp. 13 –25, 2019.
- [19] S. O’Donovan, C. van den Huevel, M. Baldock, and R. W. Byard, "Factors involved in the assessment of paediatric traffic injuries and deaths," *Medicine, Science & the Law*, vol. 58, no. 4, pp. 210–215, 2019.