Utilization of the NodeMCU ESP8266 Electronic Bord to Support IoV-Based Projects in AEEE Studies

Henry Iskandar [1], S.Triono [2], Safri Gunawan[3] Hidir Efendi [4], Lisyanto[5], Dwiki Muda Yulanto[6]

{henryiskandar@unimed.ac.id[1], striono@unimed.ac.id[2], safri_gunawan@unimed.ac.id[3], hidirefendi@unimed.ac.id[4], lisyanto@unimed.ac.id[5], dwikimudayulanto@unimed.ac.id[6]}

Automotive Engineering Education Department, Faculty of Technical Engineering, Universitas Negeri Medan, Medan, Indonesia[1,3,5,6]
Mechanical Engineering Education Department, Faculty of Technical Engineering, Universitas Negeri Medan, Medan, Indonesia[2,4]

Abstract. This study aims to develop an outcome-based learning approach in Automotive Mechatronics skills by utilizing NodeMCU ESP8266 as a hardware platform. This approach involves a project-based learning model where students design and develop Comfort Safety Information and Technology (CSIT) for vehicles. This system integrates Internet of Vehicle (IoV) technology through the Back Door (open/close) System (BDS) in the form of a prototype. This study involved eight students who studied in groups to develop the system for 21 days. The results showed that this approach effectively improved students' skills in Automotive Mechatronics, especially in designing and developing IoV-based systems. This study also highlights the importance of considering the rapid technological advances in the automotive sector and the need for continuous curriculum updates to ensure that graduates are ready to work in the industry.

Keywords: Automotive Mechatronics, NodeMCU ESP8266, Internet of Vehicles (IoV), Comfort Safety Information and Technology (CSIT).

1 Introduction

The field of Automotive Mechatronics encompasses a multidisciplinary approach that combines mechanical, electronic, and software systems in vehicles [1]. Classes in learning Automotive Mechatronics must integrate knowledge and competencies across fields, including automotive-specific mechanics, electronics, communications, and advanced controls [2]. However, in practice, the mismatch between what is taught in class and the skills needed in the workplace is a significant factor [3].

The pace of technological progress significantly influences this gap, resulting in a delay in integrating new technologies into the higher education curriculum and a skills gap between graduates and industry requirements [3]. To develop student creativity, an Automotive

ICIESC 2024, September 17, Medan, Indonesia

DOI 10.4108/eai.17-9-2024.2352849

Mechatronics system based on students' ideas, such as mechanical design, electronic circuit design, and microcomputer programming [4], is necessary. However, students must also consider the knowledge of software engineering, especially the design and testing process [5].

Implementing outcomes in learning is transforming new Automotive Mechatronics technology into the UNIMED Automotive Engineering Education curriculum; this effort requires several additional supporting media, including the NodeMCU electronic board used as an electronic control on the car [6]. The NodeMCU microcontroller board is a medium that assists students in learning because it is considered low-cost, easy to use, and also used by industry [7].

The NodeMCU microcontroller also facilitates integration between hardware and software as an Internet of Things (IoT) solution [8]. This technology is essential in designing driver comfort to reduce passenger anxiety related to comfort in autonomous vehicle scenarios [9]. The process involves parallel vehicle system management connected to Internet of Vehicles (IoV) information management to improve driver safety, reliability, and efficiency [10].

Research efforts to encourage technological transformation in Automotive Engineering Education are carried out. One such effort is to utilize the Node MCU ESP8266 hardware board device as a microcontroller media to facilitate the design of Comfort Safety Information and Technology (CSIT) projects based on IoV. This implementation aims to improve students' skills in Automotive Mechatronics through a project-based learning model.

2 Literature Review

2.1 Automotive Mechatronics

As a technological transformation, Mechatronics is needed in many sectors, such as agriculture, health care, security, and transportation[11]. In transportation in motor vehicles, the Automotive Mechatronics system continues to change; the integration of mechanical, electrical, and software components in modern vehicles requires education to prepare students with a multidisciplinary approach, including mechanical, electronic, and software engineering because this can introduce the concept of Industry 4.0, this change in the process is accompanied by the development and skills possessed by lecturers [1][2][12].

While focusing on improving automotive mechatronics skills is essential, it is also important to consider potential challenges, such as the need for continuous curriculum updates to keep pace with rapid technological advances in the automotive sector [1].

2.2 Internet of Vehicle (IoV)

Internet of Vehicles (IoV) is a sub-technology of the Internet of Things (IoT) in intelligent transportation systems, such as vehicle-to-vehicle, vehicle-to-road, vehicle-to-person, and vehicle-to-equipment communication [13]. IoV combines various technologies such as Vehicle-to-Everything (V2X), Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Pedestrian (V2P), Vehicle-to-Network (V2N) communication [14][15]. IoV technology in the learning environment for sustainability needs to be experimented on regarding the professional competence of students in automotive mechatronics [16]. The goal is to create a learning environment rich in intelligent technology knowledge for students, which is very important but sustainable considering the rapid technological progress in the automotive sector [3].

2.3 Comfort Safety Information and Technology (CSIT)

Integration of Comfort Safety Information and Technology (CSIT) with IoV, one of which is Vehicle to Network (V2N), which is a system of intelligent transportation; this system provides passenger safety and comfort in autonomous vehicle applications [17][18]. This innovation utilizes sensors and other intelligent electronic device components, providing monitoring facilities and the welfare of drivers and passengers [19]. It is concluded that integrating future automotive technology will be very important if it encourages user satisfaction to facilitate several user elements [20].

2.4 Project Based Learning (PBL)

Project-based Learning (PBL) is a practical pedagogical approach to improving technical skills by providing students with hands-on experience in real-world projects [21]. Increasing students' psychomotor skills allows them to form a way of thinking and to experiment in preparing for innovative and entrepreneurial roles in the automotive sector [22][23]. The implementation of improving students' skills in Automotive Mechatronics professional competencies is carried out in a group learning environment, the process through providing field assignments and projects in the laboratory; the planned product is the concept of CSIT application in autonomous vehicles [24][25].

3 Research Design

Internet of Vehicle (IoV) technology on Comfort Safety Information and Technology (CSIT) in vehicles as a prototype product developed by eight students in the Automotive Engineering Education Study Program as a final project for the Automotive Electrical and Electronics Engineering (AEEE) course. Teaching Automotive Mechatronics skills on the IoV Back Door (open/close) System (BDS) prototype in Multipurpose Vehicles (MPV) to students is the goal and learning achievement of the Automotive Electrical and Electronics Engineering (AEEE) course according to the needs of graduates, in this case, the description of the competencies to be achieved refers to the Decree of the Minister of Manpower Number 167 of 2019 SKKNI for Automotive Engineering, Subsector of the Automotive Engineering Field. The instructional approach is used to achieve the learning objectives of making the Back Door (open/close) System (BDS). The results of the theoretical study analysis determined that the prototype creation method was iterative design through the stages of (1) Field Observation, (2) Hardware Selection, (3) Software Selection, (4) BDS System Development, and (5) Product Function Testing.

4 Discussion

4.1 Field Observation

Data collection is obtained from field observation result sheets that are analyzed to provide more comprehensive information, such as data on the development of technology that has been applied to Multipurpose Vehicle (MPV) vehicles. The results of field observation data acquisition are on the development of the Back Door (open/close) System (BDS); at this stage, the data expansion is as follows:

a The results of the CSIT BDS technology analysis were carried out on MPV vehicles, Toyota Innova Reborn cars, production year 2020. The findings of the CSIT technology observation on the Toyota Innova Reborn MPV vehicle show that the rear door is operated mechanically, so it can be concluded that it is not equipped with BDS technology.

Fig. 1. Documentation Photos During Observation

b Report on the results of field observation and draft layout drawings of initial product prototypes for mechanical systems using CAD software.

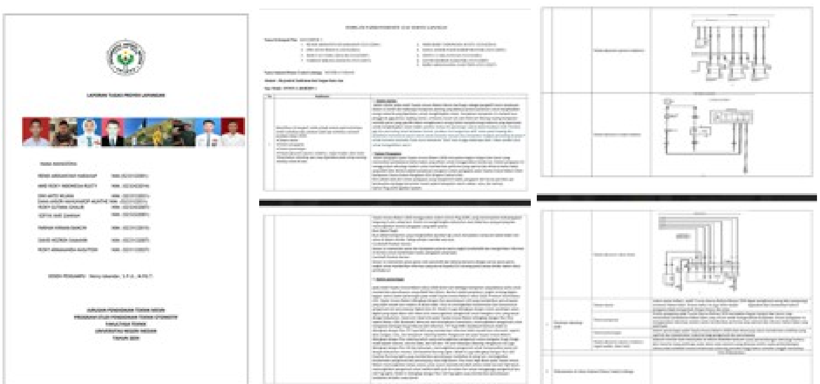


Fig. 2. Field Observation Results Report

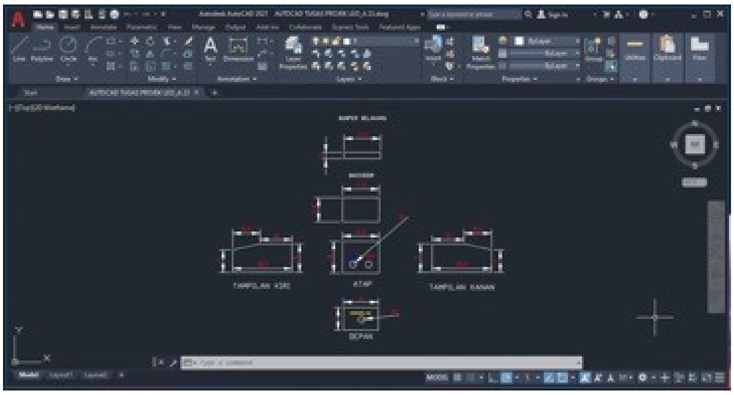


Fig. 3. Draft Layout of Mechanical Design with CAD Software

4.2 Hardware Selection

The selection of the Internet of Vehicles (IoV) as the basis for determining hardware through the identification of integration between vehicles and the Internet, which allows vehicles to communicate with each other and the surrounding infrastructure [14]. This technology allows various technologies, including sensors and wireless communication protocols, to allow vehicles to communicate with each other and the infrastructure [15][19]. This communication will enable it to be applied to various intelligent applications, including CSIT on the Back Door (open/close) System (BDS). IoV technology on BDS allows designing a cost-effective system by considering its hardware. The following requirements consider: (1) a microcontroller that can communicate wirelessly, (2) an IoT network so that the microcontroller can communicate (WIFI router), (3) actuators are used to move or control mechanical devices.

The microcontroller capability is required to have a minimum data storage memory of 4 MB, the system performance speed is needed to be at least 80 MHz, has general purpose input/output that is not too much according to what is required, the microcontroller at least supports WiFi 2.4 GHz, supports programming languages used such as C ++ and Python, allows the use of Arduino libraries and frameworks to create programs. The description of the theoretical study above can determine the microcontroller device according to the needs, namely the NodeMCU ESP8266 [6] [7].

Next, ensure wireless communication with the WiFi router that has been appropriately configured so that it can be connected with the microcontroller to the WiFi router using a WiFi connection [8]. Ensure that the IP address configuration on the microcontroller can communicate with the WiFi router or in another way using the Dynamic Host Configuration Protocol (DHCP) is obtained automatically [7].

The selection of the actuator type as a BDS prototype configuration ensures optimal performance and efficiency, in this case, the control of mechanical devices through consideration of the kind of movement, torque, speed and accuracy, size and weight, power, and efficiency [6]. The results of the analysis the type of actuator according by the needs of the mechanical device; the movement is rotation as the optimal one, then the appropriate actuator is a DC motor or stepper motor [26].

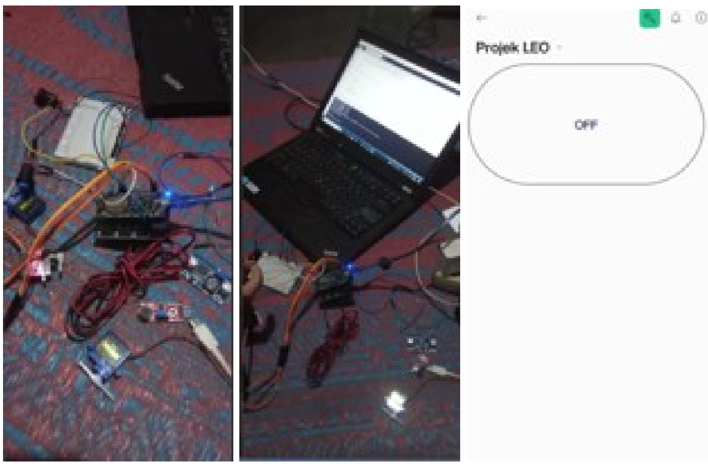
4.3 Software Selection

The selection of software applications as an operating system, its function is as an electronic control controller through the input/output device process by considering the operating systems that are frequently used by most people, namely Windows, macOS, Android, and iOS [27].

The results of selecting the most appropriate software to meet the operating needs of hardware, in this process through a comparison of several software options according to the technical calculations of use [28][29], the stages of software selection include (1) determining the technical specifications needed that can communicate long distances equipped with intuitive interface devices for users and compatible with vehicle systems, (2) exploring available hardware that is predominantly used, namely Windows and Android operating systems, but must be open source considering cost efficiency, (3) comparing several software applications according to hardware needs. The analysis results are determined for the Android operating system using the Blynk application, while additional options outside the software use Google Cloud Speech-to-Text.

4.4 BDS System Development

After the specifications for the hardware and software devices were determined, the next step was to create the Back Door (open/close) System (BDS) by 8 (eight) students. This process was carried out outside face-to-face class hours for 40 assignments by the lecturer for 21 days. The method of creating the Back Door (open/close) System (BDS) product can be seen in Figure 4 and the video link below.

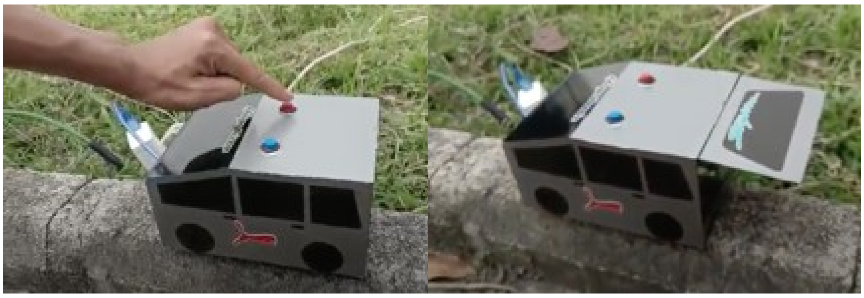


Video Link: https://drive.google.com/file/d/1IIK_bu9-hP1tug822YPy69JEO5YWsbm9/view?usp=sharing

Fig. 4. Back Door (open/close) System (BDS) Creation Process

4.5 Product Function Test

At this stage, it is essential to do so because in the product manufacturing process, especially in the results you want to see, it is the connectivity between hardware and software. This action mainly intends to ensure that the developed product meets quality standards and is as expected. The results of the function test show that the prototype product is functioning well, but there are weaknesses in the internet connectivity network because the hardware device only supports 2.4 GHz WiFi; for the following action, consider a microcontroller that supports WiFi more than 2.4 GHz because of the unstable connection problem. The results of the product function test can be seen in Figure 5 and the video link below.



Video Link: https://drive.google.com/file/d/1RZBPRSTQbGuHrywxmPyH9JOGsbtBQraP/view?usp=sharing

Fig. 5. Back Door (open/close) System (BDS) Function Test

5 Conclusion

The main objective of this study is to see how the outcome-based learning mechanism by utilizing the NodeMCU ESP8266 media board as a hardware device to improve Automotive Mechatronics skills applied to group project assignments for 21 days (40 hours) to create a prototype product of the IoV Back Door (open/close) System (BDS) in vehicles. The estimated completion time and estimated cost usage are shown in Table 1.

Table 1. Time and Cost Estimates

	Estimated Implementation Time (hours)	Estimated Costs
Field Observation	4	IDR 30,000
Hardware Selection	5	Free
Software Selection	2	Open Source
BDS System Development Materials	9	IDR 120,000
Product Manufacturing and Functional Testing	20	Free
Total Estimate	40	IDR 150,000

The process of selecting hardware component materials is complicated by the need to wait days for materials to be purchased online, which makes ship. The follow-up to the BDS system produced is quite long and will be developed for direct application in actual vehicles.

Acknowledgments

The author would like to thank the Institute for Research and Community Service, Universitas Negeri Medan, for financial support through the Universitas Negeri Medan PNBP fund with contact number 0093/UN33.8/PPKM/PD/2024. Moreover, the author also thanks the support from the Dean of the Faculty of Engineering, Universitas Negeri Medan, and five students for their participation and contribution to this project.

References

[1] M. Hirz. : Automotive Mechatronics Training Programme - An Inclusive Education Series for Car Manufacturer and Supplier Industry. pp. 341–351. (2020) doi: 10.1007/978-3-030-56441-4_25.
[2] G. Marzano, A. Martinovs, and S. Usca. : Autonomous Vehicles and Mechatronics Education. pp. 302–310. (2020) doi: 10.1007/978-3-030-39688-6_38.
[3] L. F. Manta, D. Cojocaru, M. M. Abagiu, A. Mariniuc, and A. Dragomir.: Developing a New Course 'Mechatronics in Automotive' in Collaboration with Companies with Experience in the Field. in *2023 32nd Annual Conference of the European Association for Education in Electrical and Information Engineering (EAEEIE)*. IEEE. pp. 1–6. (2023) doi: 10.23919/EAEEIE55804.2023.10181533.
[4] Y. Takahashi, T. Hayashi, Y. Takemura, K. Hara, and S. Yamaguchi.: Mechatronics Education via Project Based Learning and Involvement in Small Electric Vehicle Competition - pico-EV Eco Challenge. in *2019 19th International Conference on Control, Automation and Systems (ICCAS)*. IEEE. pp. 839–844. (2019) doi: 10.23919/ICCAS47443.2019.8971741.
[5] J. Zabavnik, A. Riel, M. Marguč, and M. Rodič.: Knowledge and skills requirements for the. pp. 373–379. (2019).
[6] R. Balaji V, S. Sanjay, N. Sakthishree G, and T. Sushruthan.: Implementation of a Pre-Crash Detection System using Node MCU. in *2023 5th International Conference on Smart Systems and Inventive Technology (ICSSIT)*. IEEE. pp. 84–87. (2023) doi: 10.1109/ICSSIT55814.2023.10061016.
[7] Y. Lin, J. Conners, and S. Livengood.: Assessing the use of open source microcontroller board for teaching engine sensing and communication in automotive laboratory. in *2017 IEEE Frontiers in Education Conference (FIE)*. IEEE. pp. 1–5. (2017) doi: 10.1109/FIE.2017.8190738.
[8] L. M. Baicu, M. Andrei, and B. Dumitrascu.: Automotive Vibration Analysis Using ESP8266 Microcontroller. in *2023 8th International Symposium on Electrical and Electronics Engineering (ISEEE)*. IEEE. pp. 54–58. (2023) doi: 10.1109/ISEEE58596.2023.10310354.
[9] T. Sawabe *et al.*: Warning Notification of Potential Collisions for Comfort Intelligence on Autonomous Vehicles. in *Intelligent Transport Systems for Everyone's Mobility*. Singapore: Springer Singapore. pp. 279–295. (2019) doi: 10.1007/978-981-13-7434-0_16.
[10] S. Han, Y. Bai, T. Zhang, Y. Chen, and C. Tellambura.: Parallel Management of IoV Information Enabled by Blockchain and Decentralized Autonomous Organizations. *IEEE Trans. Intell. Veh.* vol. 9. no. 4, pp. 4759–4768. (2024) doi: 10.1109/TIV.2024.3368510.
[11] G. Marzano, A. Martinovs, and S. Ušča.: MECHATRONICS EDUCATION: NEEDS AND CHALLENGES. *Environ. Technol. Resour. Proc. Int. Sci. Pract. Conf.*, vol. 2, p. 214, Jun. (2019) doi: 10.17770/etr2019vol2.4199.
[12] S. Stankovski, G. Ostojic, X. Zhang, I. Baranovski, S. Tegeltija, and S. Horvat.: Mechatronics, Identification Tehnology, Industry 4.0 and Education. in *2019 18th International Symposium*

INFOTEH-JAHORINA (INFOTEH). IEEE. pp. 1–4. (Mar. 2019) doi: 10.1109/INFOTEH.2019.8717775.
[13] M. Wang and S. Wang.: Communication Technology and Application in Internet of Vehicles. in *2021 IEEE 4th International Conference on Information Systems and Computer Aided Education (ICISCAE)*. IEEE. pp. 234–237. (2021) doi: 10.1109/ICISCAE52414.2021.9590660.
[14] S. Hira and S. Hira.: Smart energy management using vehicle-to-vehicle and vehicle-to-everything. in *Artificial Intelligence-Empowered Modern Electric Vehicles in Smart Grid Systems*. Elsevier. pp. 253–290. (2024) doi: 10.1016/B978-0-443-23814-7.00010-9.
[15] M. A. Rehman, M. Numan, H. Tahir, U. Rahman, M. W. Khan, and M. Z. Iftikhar.: A comprehensive overview of vehicle to everything (V2X) technology for sustainable EV adoption. *J. Energy Storage*. vol. 74. p. 109304. (2023) doi: 10.1016/j.est.2023.109304.
[16] K. Liu, P. Dai, V. C. S. Lee, J. K.-Y. Ng, and S. H. Son.: Background of IoV," in *Toward Connected, Cooperative and Intelligent IoV*. Singapore: Springer Nature Singapore. pp. 3–11. (2024) doi: 10.1007/978-981-99-9647-6_1.
[17] O. N. Mbanzabugabo, C. Kabiri, K. Jayavel, and L. Sibomana.: Performance Analysis of Vehicle to Infrastructure Network. in *2023 6th International Conference on Advanced Communication Technologies and Networking (CommNet)*. IEEE. pp. 1–6. (2023) doi: 10.1109/CommNet60167.2023.10365288.
[18] R. Thummalapenta.: V2V Network for Autonomous Vehicles. *J. Student Res.*, vol. 12, no. 1. (2023) doi: 10.47611/jsrhs.v12i1.3839.
[19] M. Subramaniyam *et al.*: Recent developments on driver's health monitoring and comfort enhancement through IoT. *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 402, p. 012064, Sep. (2018) doi: 10.1088/1757-899X/402/1/012064.
[20] T. Sawabe, M. Kanbara, and N. Hagita.: Comfort Intelligence for Autonomous Vehicles. in *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*. IEEE. pp. 350–353. (2018) doi: 10.1109/ISMAR-Adjunct.2018.00102.
[21] C. Renato Vázquez, D. Cárdenas-Fuentes, and A. Guajardo-Cuéllar.: Project-Based Learning on Automotive Engineering: Building an Electrical Vehicle. in *2024 IEEE Global Engineering Education Conference (EDUCON)*. IEEE. pp. 01–05. (2024) doi: 10.1109/EDUCON60312.2024.10578726.
[22] A. V. Bobrovskii, M. M. Bazhutina, D. A. Gorokhova, and E. D. Chizhatkina.: The project-based learning model of training engineers: exploring opportunities for building an individual learning trajectory from the students' and instructors' perspectives. *Perspect. Sci. Educ.* vol. 69. no. 3. pp. 179–191. (2024) doi: 10.32744/pse.2024.3.11.
[23] C. Rajendra Prasad, P. Bojja, S. Kollem, and P. Ramchandar Rao.: Implementation of Experiential and Project-Based Learning in Mechatronics Course. pp. 607–619. (2023) doi: 10.1007/978-981-19-1906-0_50.
[24] F. Guc, J. Viola, and Y. Chen.: Digital Twins Enabled Remote Laboratory Learning Experience for Mechatronics Education. in *2021 IEEE 1st International Conference on Digital Twins and Parallel Intelligence (DTPI)*. IEEE. pp. 242–245. (2021) doi: 10.1109/DTPI52967.2021.9540196.
[25] M. Törngren, A. Qamar, M. Biehl, F. Loiret, and J. El-Khoury.: Integrating viewpoints in the development of mechatronic products. *Mechatronics* vol. 24. no. 7. pp. 745–762. (2014) doi: 10.1016/j.mechatronics.2013.11.013..
[26] T. Singh, M. De Mauri, W. Decré, J. Swevers, and G. Pipeleers.: Feedback control of linear systems with optimal sensor and actuator selection.: *J. Vib. Control*. vol. 27. no. 11–12. pp. 1250–1264. (2021) doi: 10.1177/1077546320939836.

[27] L. Nikityuk and R. Tsaryov.: Optimization of the Process of Selecting of the IoT-Platform for the Specific Technical Solution IoT-Sphere. in *2018 International Scientific-Practical Conference Problems of Infocommunications. Science and Technology (PIC S&T)*. IEEE. pp. 401–405. (2018) doi: 10.1109/INFOCOMMST.2018.8632088.
[28] P. Buń, F. Górski, P. Zawadzki, R. Wichniarek, and A. Hamrol.: Selection of Optimal Software for Immersive Virtual Reality Application of City Bus Configurator. pp. 480–489. (2017) doi: 10.1007/978-3-319-56541-5_49.
[29] M. Z. Hasan, H. Al-Rizzo, and M. M. Allawi.: Selecting Embedded Feature Modeling with Software Product Line for Smart Home Applications. in *2022 8th International Conference on Contemporary Information Technology and Mathematics (ICCITM)*. IEEE. pp. 46–52. (2022) doi: 10.1109/ICCITM56309.2022.10031714.