Feasibility Study of Smart House Design with ESP32 and Telegram in a Simple House

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Abstract. The development of internet of things (IoT) technology currently provides convenience for humans both in industrial activities, offices, and agricultural households, as well as in other fields. As is known today, the density of people's activities and the high level of congestion have caused electrical equipment to often be forgotten turned off and left unattended. This can result in wasteful use of electrical energy, additional costs for electricity bills, and the possibility of a fire disaster. So that IoT technology is very appropriate to be the solution. The use of IoT in the control and supervision of electrical equipment is known as a smart home system (SHS). The SHS module itself is already available in the market, but not many people can afford it because the price is quite expensive. Therefore, it is necessary to develop an SHS module with a lower cost but with functions and performance that support the control and supervision of electrical equipment so that the public can ensure that their electrical equipment does not operate unnecessarily. This study proposes a low-cost SHS configuration so that more people can use it. The proposed SHS module uses ESP32 and the Telegram bot. The results of testing with the black boss method are known that this module is very feasible based on the function and performance of the telegram bot as a user interface (UI). Price comparisons have also been made and it is known that the production cost of the SHS module with ESP32 and Telegram bots is Rp. 355,000. If sold for an additional 50% profit, the proposed SHS module is Rp 98,000.00 cheaper than the smart bulb and smart plug combinations on the market for 5 lamps and 5 controlled sockets. The results of this test provide an opportunity for more people to be able to use the SHS facility in monitoring and control their electrical equipment.

Keywords: Smart home system, ESP32, Telegram bot, electrical equipment, control and monitoring

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1 Introduction

The use of electrical equipment currently has the opportunity to become easier and more efficient in the Industrial Revolution Era (RI) 4.0. The era of RI 4.0 was marked by intelligent control and the internet of things (IoT). So, new technology appears in the use of electrical equipment which is then known as a smart home system or smart home. Smart home systems are known to have an important role in efforts to provide a good quality of life for users [1]. However, it should be noted that in building a smart home system, the implementation of IoT is needed [2,3]. So, it can be said that IoT is the most important part of building the system. IoT technology has actually been around since 1980 when beverage machines are connected to the internet to simplify the inventory reporting process on each machine [4]. Along with the advancement of internet technology, the definition of IoT is mentioned as an environment or ecosystem where the equipment in the ecosystem can communicate with each other without any interaction with humans using the internet network [5]. In addition to IoT, it is necessary to add smart control or smart control so that the desired smart home system can be formed [6].

Designing and building a smart home system with IoT and smart control can now be done using an electronics development board (EDB) or electronic development board [7]. Given that there are still many obstacles faced by users, especially the cost constraint to be able to enjoy this smart home system, researchers and developers are still trying to research to obtain a smart home model with various functions but low cost [8]. Some of the popular EDBs used include ESP8266, ESP32, Arduino Yun, Wemos, and so on. One EDB that is currently popular for use in smart home development is ESP32. In this article, we will show the architecture of IoT, smart home configuration, benefits, and feasibility of EDB ESP32 for building smart home systems.

This research is motivated by the problems found in the community where dense activities often cause abandoned houses with electrical equipment that is still operating. Electrical equipment that operates without supervision can increase electricity bills which will burden the user's economy [9]. In addition, electrical equipment that operates without supervision can also pose a fire risk, especially if using equipment that does not comply with established standards [10]. IoT technology allows solutions to monitor and control electrical equipment by users even though they have left the house from anywhere and anytime using the internet network. These systems are known as smart home systems (SHS) and there are many ready-to-use products to purchase and use. However, the price is still relatively expensive, making it difficult for the lower middle class to enjoy these facilities [11]. Therefore, this study tries to develop SHS with EDB ESP32 to provide the benefits of monitoring and controlling electrical equipment at a lower cost. This article will present the proposed SHS which is designed and developed to then calculate the feasibility of this system to be used in terms of benefits and prices for the middle to lower economic community.

2 Literatur Review

2.1 Smart Home System

A smart home system is defined as an effort to integrate computer innovation, programming, and connection of household appliances on the internet network to provide convenience for users [12]. The economic potential of smart home systems mentioned in an article in 2016 reached USD 24.10 billion and is expected to reach USD 53.45 billion by 2022 [13]. Seeing this economic potential, it is only natural that research on smart home systems is becoming popular today. The economic potential is caused by the advantages that this system offers to users. Various advantages that can be enjoyed by users include energy saving, cost-saving, safety, and time-saving as shown in Figure 1. a. In addition to the advantages offered, the use of this smart home system attracts users' interest because it is reliable, credible, user-controlled, and can be adapted to needs as shown in Figure 1. b [14].

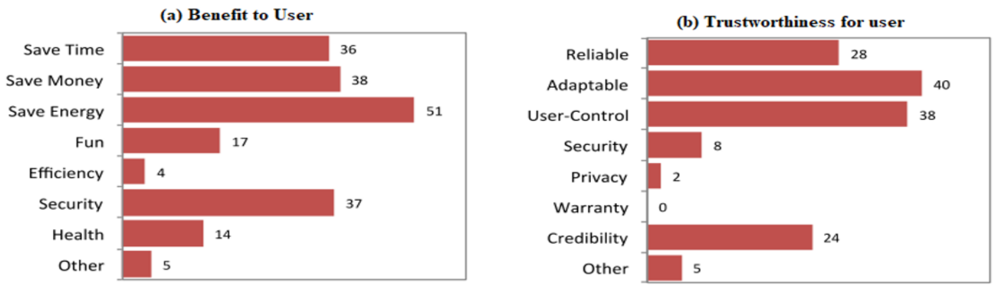

Fig. 1. Benefits and attractiveness of smart home system for users [14].

Under the advantages offered by the smart home system, the use of the system by users is generally to regulate energy use, control household appliances, control heating devices, improve home comfort and security, simplify housework, and monitor personal health to detect problematic household appliances. The goal is of course to make life at home more comfortable [14].

2.2 Internet of Things (IoT)

The Internet of things (IoT) is one of the technological concepts that can make a smart home system a reality. IoT is known to allow objects with objects to be able to exchange data with each other over the internet. The data can then be processed to obtain useful information for user needs or as a basis for taking action. The architecture of the IoT consists of 3 layers, namely the physical layer, the transport layer, and the application layer. The physical layer generally consists of sensors and actuators that are implemented on the equipment to be controlled and controlled. The transport layer consists of a network for sending data and a server. While the application layer is the application as a user interface that allows users to obtain information and perform the necessary actions on the equipment. The architecture of this IoT can be seen in Figure 2 [15].

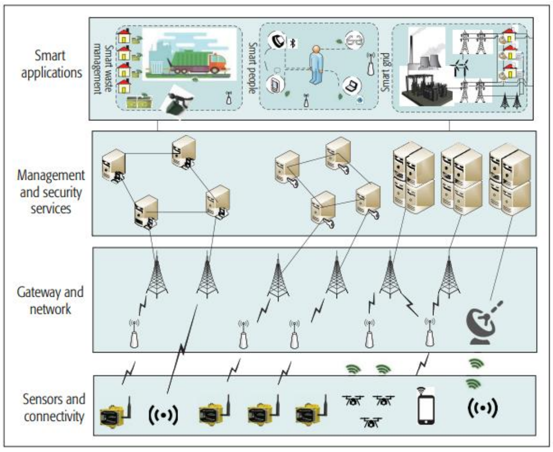

Fig. 2. Common IoT architecture with 3 layers [13].

This 3-layer of IoT architecture is said to still have various shortcomings, including data security factors [15]. The development of the IoT architecture then continues to grow from 3, 4, and 7 layers. In addition to the 7 layers, there are also cloud-based architectures and fog layers as can be seen in Figure 3. It should be noted that the more layers of the IoT architecture that are chosen to build a system, the higher the complexity of the work [15]. Therefore, IoT designers and developers must be able to choose an IoT architecture that is suitable for its implementation, including building a smart home system.

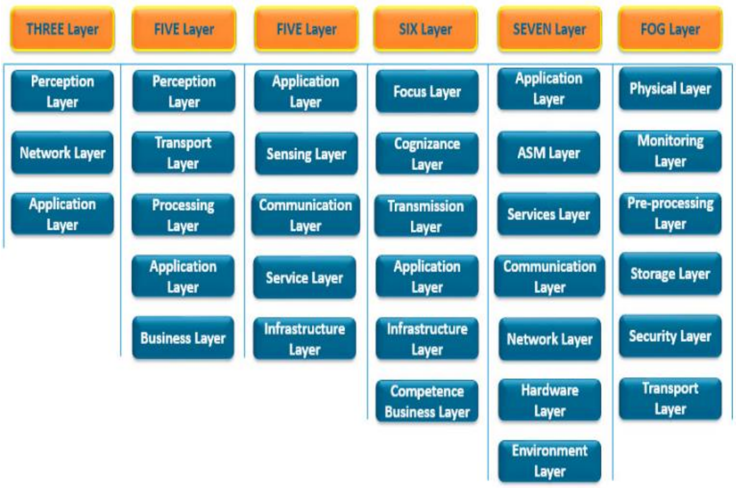

Fig. 3. Various IoT architectures [15].

2.3 ESP32 Module

ESP32 is an electronic development board (EDB) used to develop IoT. The use of EDB is increasingly popular because it includes a connection module so that it is possible to connect to the internet network directly. In addition, compared to its competitors who have the same specifications [15], the price of this module is cheaper and has high performance than the previous generation, namely ESP8266 [16] as shown in Figure 4.

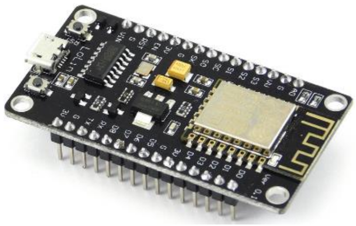

Fig. 4. ESP32 Module

The ESP32 has a general-purpose input/output (GPIO) pin or pin that is used to connect to sensors or actuators and 48-pin data display devices. Of the 48 pins, 15 of them function as an analog to digital converter (ADC), 2 UART pins for serial communication, 25 pulse width modulation (PWM) pins, 2 digital to analog converter (DAC) pins, 3 SPI pins, and 1 I2C pin. as a peripheral and 9 pins for capacitive sensors. The large number of GPIOs from this ESP32 will make it very possible to build an IoT system to be implemented as a smart home system that can monitor and control many pieces of equipment.

3 Method

This research was conducted by following the rules of the research and development (R&D) method This method has been widely used in prototype development studies, some of which can be seen in previous studies [18-20]. The research steps begin with (a) requirements analysis, (b) design, (c) code generation, (c) testing, and (e) maintenance. In general, these steps of this research are depicted as shown in Figure 5.

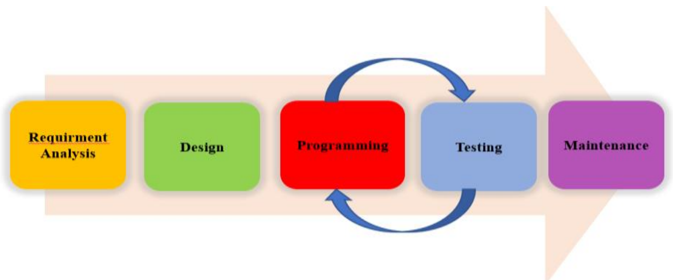

Fig. 5. R&D method.

This study aims to develop a smart home system for monitoring and controlling electrical equipment, namely lights and electrical equipment connected to a socket. The goal is that with a lower cost, this proposed system can still provide the function of monitoring and controlling electrical equipment from anywhere and anytime using a smartphone using internet services. Research is initiated by first conducting a survey and analyzing the problem and the need to design a solution. The solution that has been determined is then designed in the form of a prototype which is then continued with programming so that the prototype can work according to needs, namely being able to provide services to monitor and control electrical equipment. Furthermore, the prototype that has been programmed is tested to ensure the conformity of performance with the design. Finally, a cost evaluation will be carried out to see that the system can be reached by the community economically.

3.1 Smart Home System (SHS) Design

In this article, a smart home system configuration with ESP32 is proposed and refers to a 3 layer IoT architecture. The proposed configuration adopts a 3-layer IoT architecture to get a smart home system with functions that suit user needs but at a relatively low cost because of its low complexity. The proposed system configuration in question is shown in Figure 6.

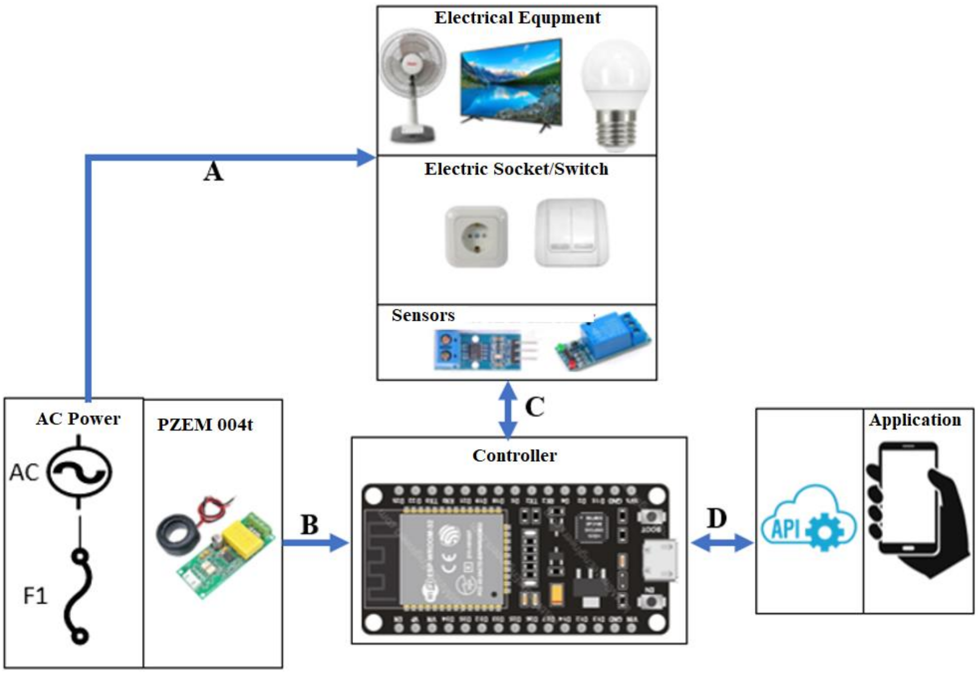

Fig. 6. Proposed smart home system configuration with ESP32.

The proposed system is divided into 4 working systems as follows;

a) This section consists of a source of electrical energy and a current sensor. The power source equipped with safety supplies the electrical energy needs of the equipment that is in operation.

b) The current sensor type PZM-004T measures the amount of electric current that comes out of the power source and then forwards it to the process and control unit, namely ESP32. The data received is then processed to produce the amount of energy used by electrical equipment.

c) The ACS712 type current sensor is used to detect the current flowing in the load it is monitoring and sends the data to the ESP32. This data is then used to ensure that the electrical equipment is operating or not. The ESP32 can send commands to the relay to turn on or off the power source to the load according to program instructions or user commands through the application.

d) ESP32 sends the data received from the sensor unit to the REST API or server to then be forwarded to the smartphone so that users can see the condition of electrical equipment in real-time. The user can then send commands to the ESP32 to control the relay to disconnect or connect the power source to the equipment.

The configuration of the proposed smart home system is equipped with an interface of a feature offered by the messaging application, namely the Telegram bot. This application has been widely used for various purposes of monitoring and controlling several previous studies [21-24]. The use of Telegram is also based on cost-cutting considerations where this service does not require additional costs like other applications [25]. The use of the Telegram application also provides data security in the form of an application programming interface (API) key where only users with an API key can monitor and control electrical equipment at home.

3.2 Electrical and Connectivity Design

As previously explained, the development of SHS in this study aims to provide benefits for users to be able to monitor and control their electrical equipment remotely using the internet network. **Fig. 7** shows how the electrical system and connectivity of the SHS design in this study correspond to the proposed design.

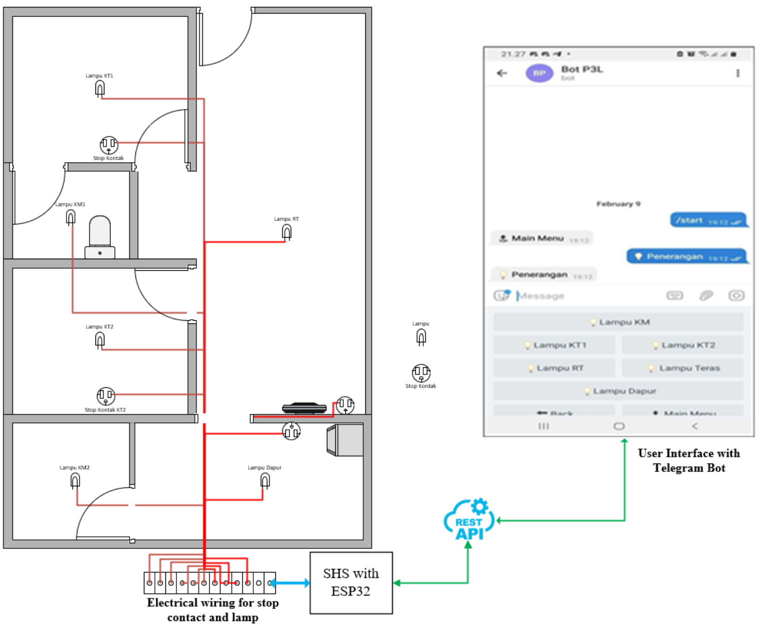

Fig. 7. Proposed SHS electrical wiring and connectivity.

Fig.7 shows that the installation connected to the SHS device built with the ESP32 is only a light load and a socket. The socket needs to be monitored to see electrical equipment that operates based on the current contained in the socket. The received data is then forwarded to the user's telegram to show the current state of the equipment at home. The user can otherwise give orders via telegram to be sent to the ESP32 via the internet to control whether electrical equipment needs to be turned on or off.

3.3 SHS Module Workflow

ESP32 programming for the SHS prototype in this study was carried out by utilizing a software known as the Arduino integrated development environment (IDE). Programming is done using C/C++ language. The working principle of the designed SHS is shown in Figure 8 with the core function of allowing users to monitor and control electrical equipment via the internet.

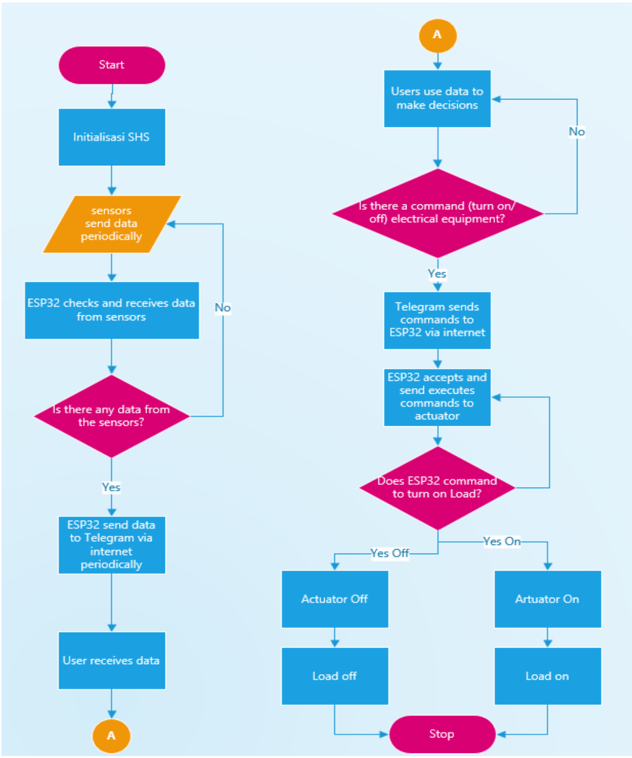

Fig. 8. SHS workflow with ESP32.

4 Result and Discussion

The product produced in this study is an SHS prototype developed with the EDB ESP32 module. The number of loads being monitored consists of 5 lights and 5 sockets. Details of the costs required to develop this system are shown in Table 1. The costs referred to are only for making the system and do not include electrical installations for lights and sockets. The total price is estimated at IDR 355,000.00.

Table 1. The total production cost of SHS with ESP32 (price accessed on 15 September 2022).

No	Material	Purchase Link	Unit Price (IDR)	Amount	Total (RP)
1	ESP32	shorturl.at/qyz36	69.000	1pcs	69.000
2	PZEM-004t	shorturl.at/jnVWZ	108.000	1pcs	108.000
3	6 Channel Relay	shorturl.at/ghlz0	40.000	1pcs	40.000
4	Current Sensor ACS721	shorturl.at/kxY69	19.000	5pcs	95.000
5	Jumper M-M 20 cm	shorturl.at/aBFGT	300	40pcs	12.000
6	Jumper F-F 20 cm	shorturl.at/jo048	300	40pcs	12.000
7	Single cable 0.5mm **B**	shorturl.at/FGJOZ	1.900	5m	9.500
8	Single cable 0.5mm **M**	shorturl.at/FGJOZ	1.900	5m	9.500
				Total	**355.000**

4.1 SHS Module Prototype

This research has completed the manufacture of a prototype SHS device and has been tested on a load to be monitored. The shape of the prototype that has been worked on is shown in Figure 9.

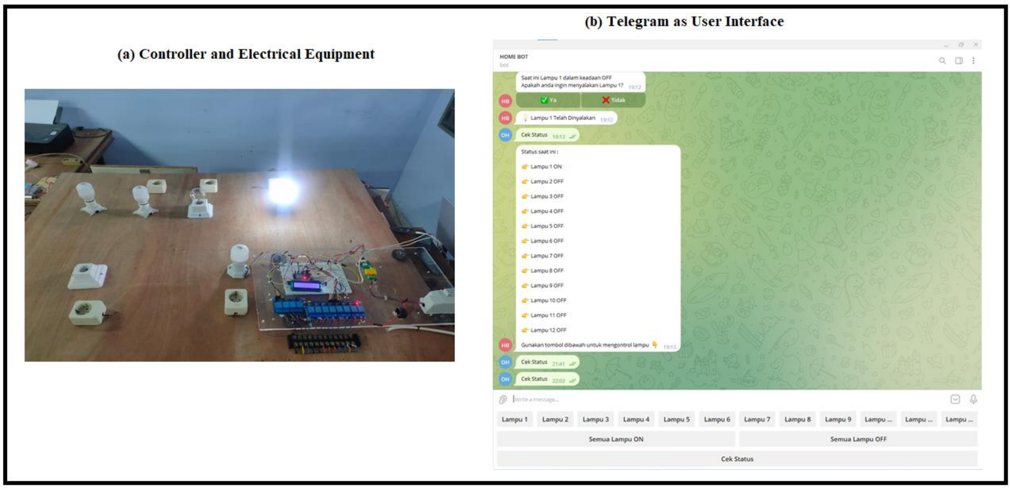

Fig. 9. SHS module prototype.

The tests carried out on this SHS prototype are to see whether the system sends information according to its original condition and can respond to commands sent via telegram to turn on/off the lights/outlet by the user. The test results show that the system is able to send precise information such as load conditions and can execute commands as sent via telegram. The test is also carried out to see the response time of the system to see the length of the delay based on the internet speed of the provider. The results of this test are shown in Table 2.

Table 2. Testing the on/off command execution delay time via telegram based on internet operators.

No	Internet Operator/Wifi	Delay time (s) Morning	Delay time (s) Afternoon	Delay time (s) Evening
1	Telkomsel	5	4	5
2	Three	6	6	6
3	XL	7	6	7
4	Smartfren	6	5	6
5	Indihome	3	2	2
6	MyRepublic	2	1	1
7	Firstmedia	2	2	2
	Average	4.4	3.7	4.1

Based on **Table 2**, it is known that various internet providers available at the test location found that there were different delays in the morning, afternoon, and evening. The average delay time that occurs from all operators is 4.4s in the morning, 3.7s in the afternoon, and 4.1s in the afternoon. The highest delay occurs for 7s and the fastest is 1s. These three times are times when the user is likely not at home.

4.2 Telegram Performance as UI Testing

In addition to the internet connection that determines the delay time, testing is also carried out on the performance of the telegram bot which is used as a user interface (UI) for users to able to monitor and control electrical equipment. The test is carried out using the black box test method to see the function and performance of the telegram bot when used. Respondents who took the test were lecturers from Computer Engineering Education, totaling 4 people. The criteria assessed from this test are "Function" and "Performance" with the category "Feasibility Level" telegram bot as a user interface. The test results are shown in Table 3.

Table 3. Telegram bot function and performance testing as UI SHS.

Respondent	**Aspect**			
	Fuction		Peformance	
	%	Category	%	Category
Respondent 1	100	Very Feasible	100	Very Feasible
Respondent 2	100	Very Feasible	100	Very Feasible
Respondent 3	100	Very Feasible	100	Very Feasible
Respondent 4	100	Very Feasible	100	Very Feasible
Average	**100**	**Very Feasible**	**100**	**Very Feasible**

Based on Table 3, it is known that the Telegram bot is very suitable to be used as a UI on SHS which was developed using ESP32.

4.3 Comparison of costs

The feasibility test of the SHS module developed in this study was also carried out with cost parameters. The total cost required to manufacture SHS modules is shown in Table 1. Comparison of SHS devices available in the online market which are known to have lower prices than the prices in offline stores. It should be emphasized that this SHS module is equivalent to 10 controlled electrical appliances. Therefore, a comparison is also carried out by considering the number of loads, namely 10 loads. The price comparison is shown in Table 4.

Table 4. Comparison of SHS prices with smart home devices in the marketplace.

No	Modul SHS	Purchase Link	Unit Price (IDR)	Amount	Total (RP)
1	SHS ESP32 Prototype	***with 50 percent profit***		10pcs	532.000
2	Smart Bulb	shorturl.at/HOZ02	54.000	10pcs	540.000
3	Smart Plug	shorturl.at/lrtIK	72.000	10pcs	720.000
4	Smart bulb + plug	for the same function as the proposed SHS		5pcs	630.000
5	Smart				

Based on Table 4. SHS production costs are cheaper than smart home products that have been circulating in the marketplace of IDR 98,000.00 for 5 smart bulbs plus 5 smart plugs for the same function. So this SHS provides opportunities for more people to be able to use it.

5 Conclusion

Based on the problems raised in this study, the objectives and results of the research. This SHS device developed with ESP32 and Telegram modules is feasible to use based on function, performance, and price. This device has a function that can provide control to users to monitor and control their electrical equipment from anywhere and anytime. This capability can certainly support users to ensure that there is no wasted use of electrical energy and additional costs and prevent fires due to electrical equipment that is turned on without supervision. In addition, this device has a cheaper price than devices already circulating in the marketplace. Of course, this device has the opportunity to be enjoyed by more users.

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