

Design of a Greenhouse System for Vegetable Plants Based on the Internet of Things

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Abstract—This research aims to overcome the problem of lack of efficiency in Green House management in North Sulawesi. Where management is still done manually. The main problem in this research is the high cost of procuring a control system and farmers' lack of understanding regarding the Internet of Things (IoT). To solve this problem, an IoT based Green House control system was developed which integrates various sensors to monitor and control temperature, humidity and light intensity automatically. This system uses an ESP32 microcontroller and the Blynk application to facilitate remote monitoring. Trial results shows that this system is able to maintain optimal environmental conditions for plant growth, increase productivity, and reduce the risk of damage due to climate change. By implementing this system, it is hoped that farmers in North Sulawesi can optimize the use of resources and increase the quality and quantity of harvests make an important contribution to development of sustainable agriculture in the tropic.

Keywords— Green house, Internet of things, Blynk, ESP32

I. INTRODUCTION

Along with the increasing global food demand and increasingly limited agricultural land, Internet of Things (IoT) based agricultural technology has been rapidly developing as a solution to improve production efficiency. Greenhouse management is one approach that is widely used to create a more controllable and productive agricultural environment. However, most greenhouse systems still apply traditional methods that require manual intervention in regulating temperature, humidity, and watering plants. This leads to inefficient use of resources and increases operational costs.

Although previous research has developed various IoT systems for greenhouse monitoring, most of them are still limited in the scope of functions and controlled parameters. For example, some studies only focus on temperature and humidity monitoring without any irrigation automation system or CO₂ control [1,3]. In addition, many systems still use less user-friendly platform-based monitoring methods such as MQTT or Node-RED, which can make it difficult for farmers to implement [3,4].

This research presents a new innovation in IoT based greenhouse control systems that are not only able to monitor temperature and humidity, but also integrate CO₂ monitoring and sensor-based automatic irrigation. In addition, the use of the Blynk application in this research provides advantages in terms of ease of access and operation for farmers, compared to more complex systems that have been developed previously. Thus, this research offers a more holistic and innovative approach in improving agricultural productivity through the application of smart technology

Farmers are a group of agricultural people who work in the agricultural sector to meet their own living needs and for buying and selling in the market [5]. Meanwhile, according to the KBBI, farmers are defined as people whose livelihood is based on farming in paddy fields, fields or gardens [6]. Agriculture is one of the main sectors in meeting people's food needs, especially in agricultural countries like Indonesia. As the global population increases and food needs increase, this sector is faced with a variety of complex challenges. Some of these are increasingly extreme climate change, limited productive agricultural land, and the need for more efficient resource management. This situation demands technological innovation to increase agricultural productivity without sacrificing environmental sustainability.

In facing these problems, Internet of Things (IoT) technology has emerged as an innovative solution that offers a modern approach to agricultural management. One effective application of IoT technology is in the Green House management system. *Green House* is an ideal choice for creating a controlled environment that supports optimal plant growth. However, manual Green House management is still a major obstacle because it requires a lot of energy, time and operational costs. With IoT technology, various important parameters such as temperature, humidity and lighting can be monitored and controlled automatically, even remotely using a mobile device. [1].

IoT-based Control Systems also enable automation in agricultural processes. By using an integrated relay and water pump, the system can automatically regulate plant watering based on data received from soil moisture sensors. This not only saves time but also reduces excess water use as water is the most important resource in agriculture [4]

IoT provides great opportunities for farmers to optimize the use of modern technology in the cultivation process. Through internet connectivity, environmental data can be processed in real-time, providing accurate information needed to maintain ideal plant conditions [7]. In addition, supporting technology such as the Blynk application makes it easier to implement microcontroller-based control. With this platform, farmers can manage and monitor Green House conditions more flexibly and efficiently via smartphone or internet-based devices [8]. This solution is very important, especially in facing the challenges of unpredictable weather changes and environmental fluctuations that can affect crop yields.

IoT systems enable big data collection and deeper analysis. Data collected from various sensors can be analyzed to provide insight into plant growth patterns and their specific needs. This can help farmers make better, data-based decisions [2], [3], [9] IoT-based Greenhouse systems use cloud platforms such as AWS IoT, Blynk or Google Cloud for storage and analysis of big data (Big Data). Integration of artificial intelligence (AI) or machine learning analysis allows prediction of optimal conditions and automatic regulation based on plant growth patterns [10]. In this research, researchers used the Blynk system.

The advantages of implementing IoT in a greenhouse include increasing resource efficiency, reducing labor costs and increasing plant productivity. However, the challenges faced include the need for network infrastructure, quite expensive initial costs, and limited technological knowledge among farmers [11]. The solution includes the use of Low-Power-Area Network (LPWAN) networks such as LoRa and NB-IoT, as well as the development of IoT devices that are cheaper and easier for farmers to use [12].

In the North Sulawesi region, the majority of farmers still rely on traditional methods which are less efficient in utilizing resources. Especially in urban areas, in recent years, the agricultural sector in many urban areas has faced a number of serious problems that affect the productivity and sustainability of agricultural businesses. One of the main problems is extreme hot weather due to the urban heat island phenomenon, where temperatures in urban areas are much higher than in rural areas. This increasing temperature is caused by high human activity, air pollution, and the large number of buildings and vehicles that absorb and emit heat. This excessive hot weather affects plants, disrupts their growth, and can even cause plant death if temperatures are not controlled.

Apart from that, limited agricultural land in urban areas is an equally big challenge. With rapid urbanization, much agricultural land is being converted into land for residential, commercial or other infrastructure [13]. As a result, the space available for agriculture is increasingly narrowing, while the need for food continues to increase. On the other hand, soil quality in urban areas is also often contaminated by pollution and contamination from industrial waste, vehicles and other human activities. This problem is exacerbated by limited water for efficient irrigation [14]. Urban water sources are often degraded or limited, hampering farmers' ability to manage their crops well. However,

amidst these challenges, greenhouses offer a very potential solution. Greenhouses can create a more controlled environment and are ideal for farming even in hot weather and limited land in urban areas. By using transparent materials that allow sunlight to pass through, greenhouses can regulate the temperature and humidity inside, protecting plants from temperature extremes and providing the humidity necessary for optimal growth.

Greenhouses also allow farming in confined spaces, such as on the roof of a building or an abandoned vacant lot. With a vertical or multi-story design, greenhouses can optimize the use of space in urban areas, allowing farmers to produce agricultural products even though available land is limited [15], [16]. Efficient irrigation systems, such as drip irrigation, are used in greenhouses to ensure more economical and controlled water use, thereby reducing waste of water resources. Apart from that, greenhouses also help minimize the impact of air pollution and soil contamination. Plants grown in a greenhouse are protected from external pollution, and the quality of the soil is maintained. This makes the resulting plants healthier and of better quality. Overall, the application of greenhouses in urban areas not only provides a solution to the problem of hot weather and limited land, but also creates an agricultural system that is more efficient, sustainable and resilient to climate change. With this approach, urban agriculture can develop and support better food security in the future.

Thus, this research focuses on developing an IoT-based Green House control system which is expected to increase productivity and quality of agricultural products in tropical areas. Apart from providing practical solutions, this research also aims to educate farmers about the use of advanced technology in daily agricultural activities. Thus, it is hoped that the use of IoT technology can support sustainable agriculture that is environmentally friendly and highly competitive. This research not only offers solutions for controlling the Green House environment, but also helps farmers optimize the use of resources such as water, electricity and labor. The implementation of this system is expected to increase agricultural productivity, reduce operational costs, and answer global challenges in maintaining food security amidst dynamic climate change.

II. METHODS

A. Definition of Methods

This type of research on the Design of Internet of Things (IoT)-based Green House Control System Prototype to develop or validate a certain existing product or model or create a new product that is more effective and innovative. The method used in this research is the research and development (R&D) method. The research and development method is a research method used to produce certain products, and test the effectiveness of these products [17]. The research model applied in this research is the ADDIE model. The ADDIE model is a model used for system development which consists of 5 main things, namely analysis, design, development, implementation, and evaluation. The following are the stages in this research

a. Analysis

This stage is the initial stage carried out by researchers to find out customer / customer complaints in controlling the environment in the Green House. From the problems that have been identified and literature studies conducted, researchers are interested in developing an innovation that can Green House by using the Internet of Things (IoT) control system as a remote control. The following is an illustration of the research needs analysis of the problems that need to be carried out, which can be described in Figure 1 below.



Figure 1. Needs analysis based on problems in the greenhouse

Based on figure 1 above, it shows a researcher interacting with customers to collect complaints related to environmental control. Various IoT sensors monitor temperature, humidity and soil moisture, while computer screens display real-time data analysis so that any changes can be immediately detected. In this way, of course, the results of reading data from the computer will be visible to the operator or user so they can intervene or adjust quickly and efficiently.

b. Design

Research Instruments The tools and materials used in this study can be seen in table 1. below. Table 1. Tools and Materials for Prototype Control System Design Green House Based on the Internet of Things (IoT) As an Energy and Time Saving Measure

Table 1. Software and hardware requirements analysis

Number	Tools And Materials	Function
1.	NodeMCU ESP32 8266	As a Microcontroller
2.	Motor servo	Roof drive
3.	Dht 11	Temperature and humidity sensors
4.	Relay	Switch
5.	Waterpump	Water pump
6.	Power suplay	Power source
7.	WiFi	IoT connector
8.	Smartphone	Use of blynk App
9.	Water Pipe	Flow Water

c. Development

Setting aplikasi Blynk such as download the Blynk app via Playstore on Android. Open the Blynk Application. Set up templates in the Blynk application according to control needs. Creating tokens that will be input into the arduino IDE program. Connecting the Blynk application with the internet. Following is what Blynk looks like in the image below.

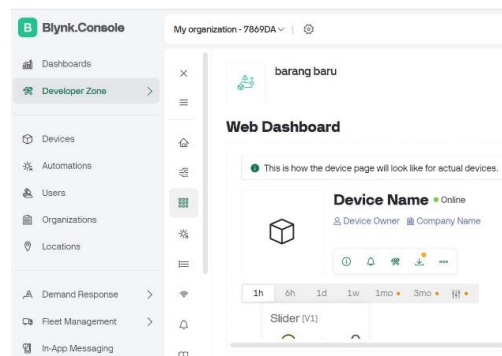


Figure 2. Blynk app view

Based on the figure 2 above, blynk application shows the interface of Blynk Console, an IoT-based platform that allows users to manage and monitor connected devices online. In the Web Dashboard display, there is information about devices that are online, including controls and real-time data that users can access. The left part of the screen displays navigation menus such as Devices, Automations, Users, Organizations, and others, which makes it easier to set up devices and use them in IoT systems. This dashboard can be used to monitor device performance, control its functions, and manage integration with other systems efficiently. Then to program on Arduino IDE includes open the Arduino IDE application on a PC/Laptop. Enter the program in Arduino IDE. Enter the Wi-Fi ssid and password that the board will use to connect to the internet. Enter the data / token code that has been set in the Blynk application in the topic, username, password section. Verify sketch. If there are no errors, continue by selecting the “upload” option to perform coding to the NodeMCU. A control system is a system designed to regulate, control and supervise a process or device so that it operates according to the desired output conditions[18]

d. Implementation

This stage is done by testing the system that has been made whether it is as expected or there are failures in the system that has been made. System trials are carried out by opening and closing the roof which is moved by a servo motor and using a button that has been set in the Blynk application, if the opening and closing of the roof has been successful the next stage is to test the temperature and humidity sensors and automatic watering when the temperature reaches a certain point then the water pump will work automatically

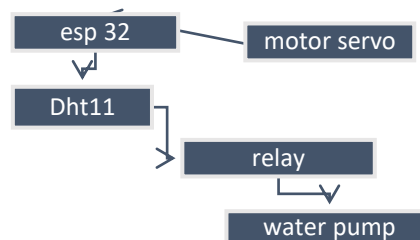


Figure 3. System diagram

This research involved an evaluation of the developed system to ensure that the designed tool functions properly in accordance with the set objectives. The evaluation was carried out in three stages, namely: circuit testing, software testing, and testing the electrical energy consumption used. Circuit Testing includes at this stage, testing of the circuit that has been built is carried out. The tool is considered successful if it can be controlled either through remote control. If the control system does not work, an evaluation is carried out to analyze the cause of failure in the tool that has been made. Software Testing includes software testing is done by writing code in the Arduino IDE, then verifying the code before uploading it to the device. The application will give an error mark (in red) if there is a problem in the code used. Testing the use of water discharge and electrical energy includes the device is considered as expected if it is able to provide efficiency in the use of water and energy. To measure the amount of energy consumed, a wattmeter is used which can show the amount of energy used. and to measure the amount of water used by analyzing the condensation process carried out automatically and manually. Energy savings are achieved thanks to the ease of operation of the appliance through automatic control. The following research diagram is shown below.

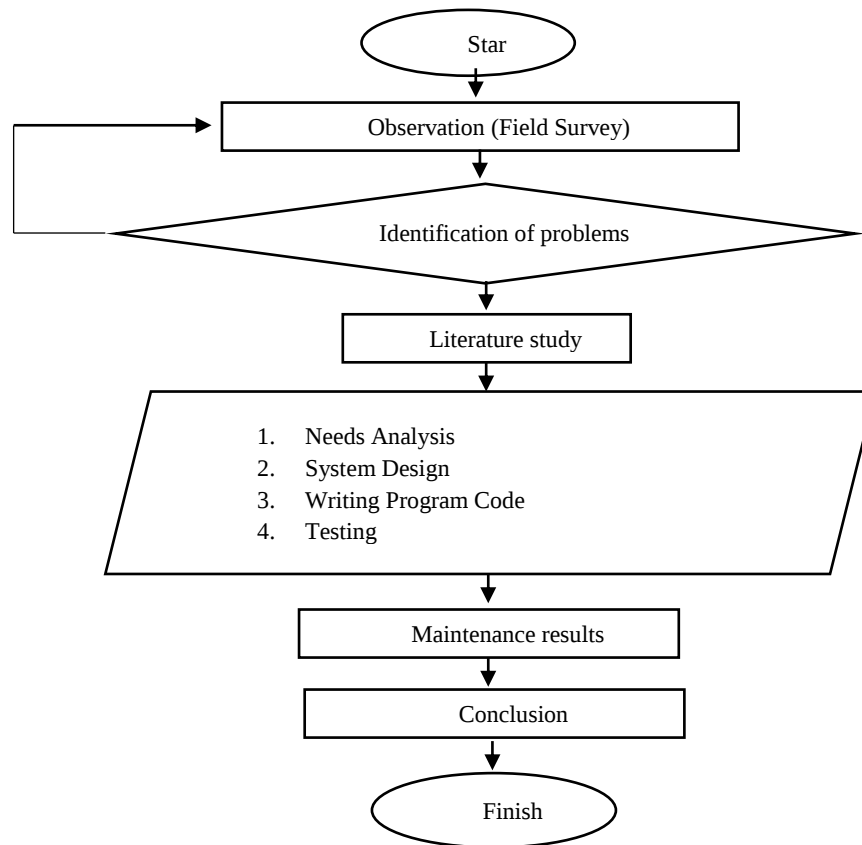


Figure 4. Flowchart Research

Based on figure 4 above, this figure is a research flowchart that describes the stages in a research or system development process, especially in the field of technology or software engineering. In the research flowchart it is divided into the Start stage which marks the start of the research or system development process. Observation: Field observations or surveys are carried out to understand real conditions and collect the necessary initial data. Then, Identification of Problems, where after the data is collected, the main problems to be resolved are identified so that research or development is more focused. Literature Study is carried out by examining various references or previous research to gain insights and solutions that can be applied. The development stage includes a needs analysis carried out to determine the specifications and features needed in the system. System design is carried out based on the results of the needs analysis. Writing Program Code is done as program code is written in accordance with the system design that has been created. Testing is carried out to ensure the system runs well and meets the expected specifications. Then, after the system has been developed and tested, the maintenance stage is carried out to ensure the system continues to function optimally. Finally, conclusions are made based on the results of system implementation and testing. Thus this flowchart shows a systematic approach in research and development, starting from problem identification to final evaluation to ensure the success of the system being developed.

III. RESULT AND DISCUSSION

A. Research Results

The research results indicate that the developed IoT-based greenhouse control system can operate automatically in managing environmental conditions. The integrated temperature sensor in the system can detect temperature changes and automatically

activate the irrigation mechanism when the temperature reaches a predetermined threshold. Additionally, this system is capable of controlling the movement of a servo motor to open and close the roof adaptively, allowing for more optimal ventilation regulation. Testing results show that the implementation of this system contributes to maintaining temperature and humidity stability within the greenhouse, thereby enhancing efficiency in plant cultivation.

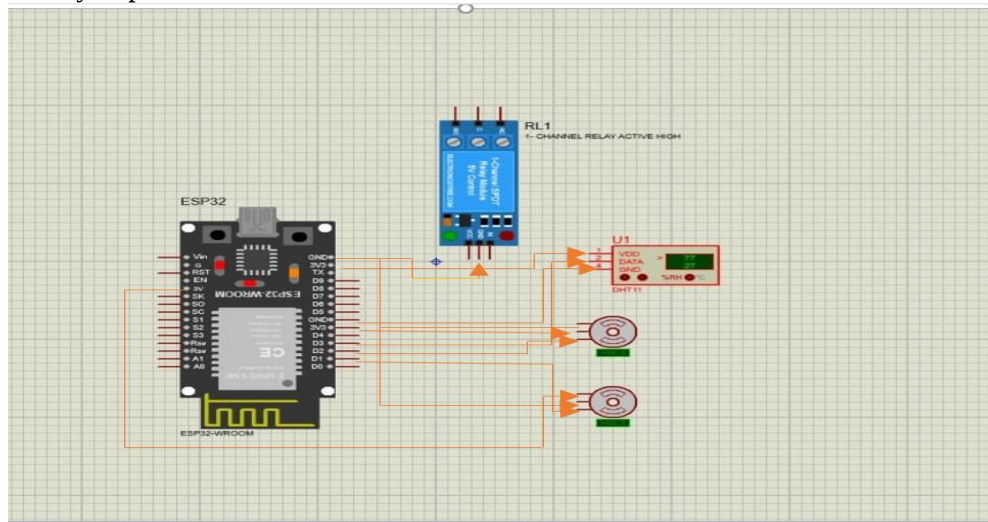


Figure 5. Prototype design

Based on the figure 5 above, green House control prototype system based on the Internet of Things (IoT). Temperature and humidity control trials were carried out using artificial heaters only to ensure that the dht 11 sensor was functioning properly. Remote control trials were conducted using android through the Blynk application. Data from sensors is processed by a microcontroller and delivered to the IoT platform via a wireless communication module. Users can access information via web-based applications or Blynk IoT applications, which allows monitoring and tracking of tool progress[19]



Figure 6. Temperature and humidity control

Based on the figure 6 above, showing temperature measurements using the DHT11 sensor, the display on Blynk can be seen that the minimum to maximum temperature range starts from 22°C to 31.5°C. The program standard specified in the

active temperature setting is 27⁰C. The measurement results obtained for room temperature in green houses show an average temperature of 27⁰C. This shows that when the plant space in the green house starts to get hot, the electric servo motor will automatically open the pump valve so that the water flow will spray the room. This study shows that the IoT-based smart farming system is able to monitor and control temperature, humidity, and light intensity in the greenhouse effectively. [20]. The results of this study strongly emphasize the importance of controlling environmental parameters to support plant growth. However, the study focused more on a specific plant (lettuce), while researchers were more general and covered a variety of vegetables. Likewise, to find that the application of IoT technology can effectively control temperature, air humidity, and light intensity, and the Arduino program built can function well in testing. Meanwhile, the IoT system is controlled via a cellphone with the Android operating system, which allows users to control and control the device in real-time. With a special application, users can access sensor data, set environmental parameters, and receive notifications or warnings regarding detected conditions. This makes the IoT system more practical and efficient in supporting automation and remote management[21]. These findings lead to the use of IoT technology to monitor and control environmental factors [22]. However, researchers are adding new dimensions by integrating more sensors and features into the control system, such as monitoring CO₂ levels. From the comparison, it can be seen that Kaengke's research has similarities in technological approaches with other studies, but offers advantages in broader integration and monitoring of environmental parameters. This shows the potential to increase agricultural productivity by utilizing IoT technology more comprehensively.

Tabel 2. System Testing with Black Box Testing Method

Tools tested	Testing	Test Type	Final Result
Motor Servo	Receiving Control Signal	Black Box	Works
DHT 11	Temperature sensor	Black Box	Works
Waterpump	Water Flow	Black Box	Works
Esp32	Connected WIFI	Black Box	Works
Relay	Switch Contacts	Black Box	Works

Based on table 2 above, testing the green house tool system after installation is carried out testing or testing the tool. The results prove that the tool can work each component properly. Internet of Things (IoT) system device testing is the process of evaluating the performance, functionality, security, interoperability and reliability of IoT devices under certain conditions. This testing aims to ensure that IoT devices can work according to specifications, interact with the environment and provide results; that are accurate and safe[23]. By carrying out this test, IoT devices are expected to be able to work according to predetermined specifications, interact effectively with their environment, and provide accurate and safe results for users.

B. Discussion Research

Table 2. Research comparison table

Aspects	The result of this research	Previous Research
Technology Used	ESP32 and Blynk-based IoT for greenhouse control	Some studies use Node-RED, MQTT [1], or Arduino-based systems without Blynk [6, 7].
Controlled Parameters	Temperature, humidity, light, automatic irrigation, and CO ₂ monitoring	Most of the previous studies only monitored temperature and humidity [7, 8].
System Advantages	More comprehensive system with additional sensor-based CO ₂ monitoring and automatic irrigation	Some studies only use monitoring systems without irrigation automation [9].

Practical Implementation	Focus on ease of use by local farmers, using the Blynk app for remote monitoring	Some other studies rely on more complex programming systems such as Python or MQTT [3, 6].
Effectiveness and Efficiency	Increase productivity with automatic settings that are more responsive to the environment	Other studies have shown the benefits of IoT in improving efficiency, but without more extensive CO ₂ monitoring features [10, 12].

Based on table 2 above, it is better to use internet of things based green house system technology using control using ESP32 and Blynk demanding using Arduino and Blynk. Likewise, the parameters for controlling temperature, light and CO₂ levels in green houses have advantages in observing the conditions of lettuce plants in green houses. In practice, programming makes it easier to use the Blynk application compared to the Python application because it is not yet compatible with Arduino or ESP32 equipment connectors. Finally, in terms of efficiency, of course the system works automatically, controlled via the Blynk application, while other efficiencies are not through internet of things monitoring (ESP32 and Blynk). It can be concluded Comparison Conclusion Integrate CO₂ monitoring, which has rarely been done in previous studies. Using Blynk, which is more user-friendly than MQTT-based systems or Node-RED. It has sensor-based automatic irrigation, which improves water use efficiency. This study shows that the IoT-based smart farming system is able to monitor and control temperature, humidity, and light intensity in the greenhouse effectively[20].

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From the comparison, it can be seen that Kaengke's research has similarities in technological approaches with other studies, but offers advantages in broader integration and monitoring of environmental parameters. This shows the potential to increase agricultural productivity by utilizing IoT technology more comprehensively. It is more adaptive to a wide range of crops, whereas many other studies only focus on one crop. Shortcomings or development opportunities. an explore the use of AI or Machine Learning for optimal condition prediction. Device usage IoT makes it easy to collect data in real-time and sending it to a cloud platform for further analysis. Thus, testing the reliability of the system on a larger scale to ensure its effectiveness in various greenhouse conditions could be an alternative solution to utilizing farming technology using the internet of things.

IV. CONCLUSION

The conclusion should describe this research has successfully developed an Internet of Things (IoT)-based Green House control system that has proven effective in improving agricultural efficiency and productivity, especially in vegetable growing in North Sulawesi. By utilizing IoT technology, this system can real-time monitor and control various important environmental parameters such as temperature, humidity, and light, which are crucial for plant growth. The use of an automatic control system integrated with IoT allows remote monitoring, so that farmers can control the condition of the Green House without having to be physically present at the location. With the ability to automatically set and adjust environmental parameters, the system not only speeds up

the plant maintenance process but also reduces reliance on manual labor. In addition, energy and other resource savings can also be achieved through more precise and efficient control. In the long run, the application of this technology is expected to have a positive impact on agricultural yields in North Sulawesi, improve food security, and encourage the sustainability of environmentally friendly agriculture. Overall, the application of IoT in this Green House control system not only provides convenience for farmers in managing crops, but also opens up new opportunities for the development of more advanced and integrated agricultural technology. This research is a significant first step in encouraging the adoption of IoT technology in the agricultural sector, which has great potential to improve the quality and quantity of agricultural production in the future. With the rapid development of technology, it is hoped that this kind of system can be implemented more widely in various regions, not only in North Sulawesi, but also throughout Indonesia.

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