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Integration of Internet of Things Technology in Digital-Based Residential Security Application

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***Abstract*— This study evaluates the usability of an IoT-based residential security application designed to improve guest registration and access control in housing environments. The system integrates multiple user roles, including administrators, residents, guests, and security officers, and utilizes QR Code verification to streamline entry procedures. Usability testing was conducted using the System Usability Scale (SUS) with 30 respondents. The results show an average SUS score of 74.83, indicating that the application falls within the "Good" usability category. Most users reported that the interface is intuitive, the functions are well integrated, and system navigation is easy to understand. Although minor improvements are still required—such as notification speed and icon clarity—the system is considered acceptable for public use. These findings demonstrate that IoT integration can enhance residential security operations while maintaining positive user experience.**

***Index Terms*— Internet of Things; residential security; QR Code verification; System Usability Scale; usability evaluation; user experience.**

I. INTRODUCTION

According to Law of the Republic of Indonesia Number 1 of 2011, housing is defined as a group of houses equipped with various environmental infrastructure and facilities [1]. One of the essential environmental facilities in a housing area is a security system. The conventional security system commonly found in housing complexes involves placing guard posts along with security personnel to ensure that access in and out of the area remains controlled. Various standard operating procedures are implemented to maintain security within a housing area, where each housing complex may have different procedures, but all share the same goal—ensuring the safety of the residential environment [2].

According to data from the National Criminal Information Center (PUSIKNAS), as of July 2024, theft remains the most frequently occurring type of crime [3]. Criminal acts are not only influenced by the personal factors of the perpetrators but are also strongly affected by environmental conditions [4]. Additionally, the high crime rate indicates that accessibility and the design of residential areas play a major role in determining the level of vulnerability to crime. Housing located near main roads and lacking adequate security systems is more likely to become a target for criminals. Therefore, crime prevention efforts must combine physical environmental planning (architecture and spatial design) with strengthened social control within the community [5].

The development of digital technology based on the Internet of Things (IoT) is increasingly widespread across various fields, including residential security systems. IoT enables physical devices such as cameras, motion sensors, and smart locks to connect to the internet and be controlled through mobile applications. This innovation allows real-time monitoring of home conditions, thereby enhancing residents' sense of security [6].

Although offering significant benefits, the implementation of IoT-based security applications is not without challenges. Some users still doubt the usefulness of new technologies compared to conventional security systems, particularly regarding their effectiveness in preventing criminal acts [7]. Moreover, issues of privacy and data security have also become concerns, as the potential for information leakage can reduce user trust [8].

In the context of Human–Computer Interaction (HCI), user acceptance of an application is influenced by its ease of use and perceived usefulness. Applications considered difficult to use may reduce user interest and positive attitudes, even when the features offered are beneficial [9]. Therefore, user experience becomes one of the key factors determining the success of implementing IoT-based digital security systems.

In previous studies [6], the application of IoT has been utilized in residential security systems. However, those studies did not implement usability measurement based on the System Usability Scale (SUS) in evaluating the application of IoT. This gap serves as the basis for identifying the novelty of this study, as it introduces a usability evaluation using the SUS framework, which has not been addressed in prior research.

Based on the above explanation, this study formulates the research problems to be addressed: How high is the usability value of IoT-based residential security systems? And how can the usability of IoT-based residential security systems be measured?

II. THEORY

A. *Internet of Things*

The Internet of Things is a concept in which physical devices such as sensors, cameras, actuators, and various other electronic devices are able to connect and interact with each other through the internet [10].

In general, the architecture of an IoT ecosystem follows a hierarchical pattern consisting of three main layers:

1. Edge, This layer contains connected devices and sensors that directly interact to process data in real time and make quick decisions.
2. Fog, This layer serves as an intermediary between the edge and the cloud layers by managing and optimizing data traffic, as well as performing a significant portion of distributed data processing.
3. Cloud, This layer stores data and applies advanced data analytics to generate deeper insights.

Through this architecture, data from various devices and sensors is collected, processed, and integrated to create useful solutions, ensuring that IoT-based services can be effectively utilized by users [11].

Sensor technology in IoT serves as the fundamental foundation for IoT development. With sensors, devices are able to detect and measure their surroundings. The key stages in IoT data and control flow include data collection, data processing, and the resulting processed output, which ultimately impacts the real world.

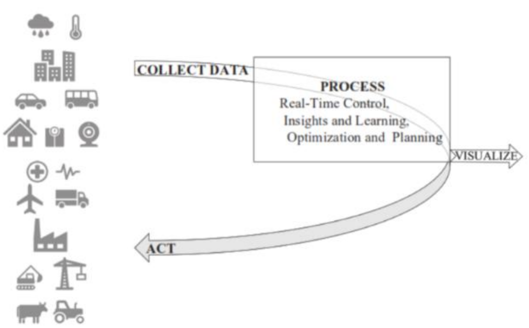

Fig 1. Functional flow in IoT system [11]

B. *Qr Code*

A QR Code is an abbreviation for *Quick Response Code* [12]. A QR Code is a type of two-dimensional (2D) barcode, which distinguishes it from traditional one-dimensional barcodes: instead of straight lines, a QR Code consists of a square pattern filled with numerous small black-and-white modules. It was first created in 1994 by Denso Wave, previously part of the Toyota Group, to assist in tracking components in manufacturing [13]. Since then, the QR Code has become an international standard—widely adopted for various modern applications [14].

QR Codes work by storing data through encoding information into a pattern of black-and-white modules (squares) arranged in a grid/matrix. When scanned with a smartphone camera or QR scanner, the device interprets the pattern into digital information (such as URLs, text, contacts, etc.) [15]. The three large squares located at three corners of the QR Code are position markers (also called *finder patterns*). These markers help the device determine the code's orientation so it can be read from various angles [16].

Fig 2. Qr Code

QR Codes can store various types of data: numeric, alphanumeric, binary/byte data, and even more complex characters such as Kanji [17]. QR Codes also incorporate an error correction mechanism, allowing them to remain readable even if part of the code is scratched, damaged, or obstructed—making them resistant to physical wear or imperfect printing [18].

C. *System Usability Scale*

The System Usability Scale (SUS) is a standardized instrument widely used to measure the usability level of a system, application, or device, and it has remained the most popular method over the past five years due to its simplicity, reliability, and validity [19]. Numerous studies have shown that SUS provides consistent evaluative performance across various contexts, including digital interfaces [20], interactive environments [21], and cross-device evaluations involving IoT technologies [22].

SUS consists of ten items rated on a 1–5 Likert scale, and the score is calculated using the standard formula: (1) for odd-numbered items: contribution score = response value − 1; (2) for even-numbered items: contribution score = 5 − response value. All contribution scores are then summed and multiplied by

2.5 to produce a final value ranging from 0 to 100. The interpretation of SUS scores has been refined through contemporary approaches, including grading scales (A–F), adjective ratings, and acceptability ranges [19].

In general, a score of ≥ 80.3 is categorized as Excellent (Grade A) and indicates a very high level of usability; scores between 68–80.3 fall into the Good (Grade B) category and are generally considered to reflect good usability; scores within 65–68 are classified as OK / Marginal High (Grade C); scores from 50–65 are categorized as Marginal / Poor (Grade D); while scores < 50 fall into the Not Acceptable (Grade F) category. These interpretations allow researchers to determine whether a system meets usability standards and to compare a system's performance with industry and research benchmarks.

Thus, SUS remains a relevant and empirically robust tool for evaluating usability in IoT systems as well as other digital technologies [23].

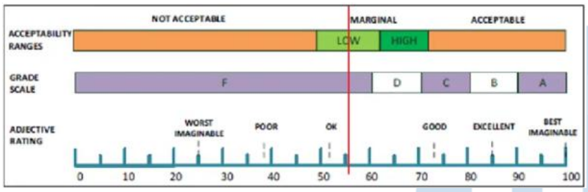

Fig 3. Acceptance rate SUS [19]

III. METHOD

A. Research Design

Studies using the System Usability Scale (SUS) generally employ a descriptive quantitative approach, as SUS produces numerical scores that objectively represent the usability level of a system [24]. This research aims to evaluate the usability level of a technology-based system/product, where data are collected once after users have interacted with the system.

B. Population and Sample

The population in this study consists of prospective users of the IoT-based residential security application in urban housing environments. The sampling technique used slovin with the following criteria:

- Owning an Android or iOS smartphone.
- Having used or had prior experience with technologies.
- Residing in a housing/residential area.

The sample size was determined using Slovin's formula with a margin of error of 10%. Based on a population of 43 respondents, a total of 30 samples were obtained and considered sufficient to represent the population for user evaluation purposes.

$$n = \frac{N}{1 + Ne^2}$$

$$n = \frac{43}{1 + 43(0{,}1)^2}$$

$$n = 30$$

The total sample consists of 30 respondents drawn from residents across five housing complexes located in Bogor City.

C. Research Instrument

The research instrument used is the SUS questionnaire, which consists of 10 statements with responses measured using a 1–5 Likert scale, where:

1 = Strongly Disagree

2 = Disagree

3 = Neutral

4 = Agree

5 = Strongly Agree

The statements are arranged alternately as positive and negative items to maintain validity. The SUS items are as follows:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

It should be noted that the odd-numbered items (1, 3, 5, 7, 9) are positive statements, while the even-numbered items (2, 4, 6, 8, 10) are negative statements.

SUS Scoring Procedure:

- Positive items = (Response value − 1)
- Negative items = (5 − Response value)
- Total SUS Score = (Sum of contributions) × 2.5

The final SUS score ranges from 0 to 100, with the following interpretation:

- > 80.3 = Excellent
- 68 – 80.3 = Good / Acceptable
- 50 – 68 = Marginal
- < 50 = Not Acceptable

IV. RESULT AND DISCUSSION

A. Result

1) System Analysis

Before the system was developed and the IoT components were designed, a system analysis was carried out. The researcher analyzed what kind of system was needed and how the system would be used. The results of the system analysis included the system scenarios and a use case diagram.

Table 1. Actor and Role in System

Actor Name	Role in the System
Super Admin	An actor responsible for validating RT Head accounts.
RT Head	An actor who functions as the system administrator.
Security Officer	An actor responsible for validating guest presence/arrival.
Resident	An actor who serves as the primary business actor, registering guests who plan to visit.
Guest	An actor who receives the QrCode provided by the resident.

System Scenario

The system is used by actors, and each actor has their own role within the system.

Super Admin

The Super Admin logs into the system using registered credentials. The primary responsibility of the Super Admin is to register RT Head accounts by entering required information such as National ID Number, full name, phone number, home address, term of office, and the official appointment letter issued by the authorized authority. Upon completing system operations, the Super Admin may log out.

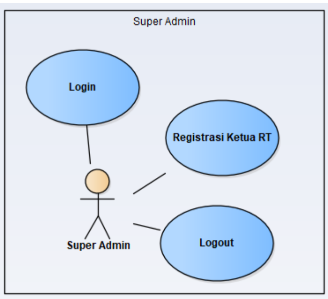

Fig 4. Usecase Diagram Super Admin

RT Head

The RT Head accesses the system using a registered username and password. The RT Head is responsible for managing resident data, including the Head of Family's National ID Number, name, home address, phone number, number of occupants, list of occupants, and resident status (local resident or newcomer).

The system notifies the RT Head when residents submit information regarding planned guest visits or their temporary absence from home. The RT Head validates guest visit requests, particularly when the guest intends to stay for more than 24 hours. Additionally, the RT Head can view the list of residents, security officers, and guest visit records within a specified period. The RT Head may log out after completing required tasks.

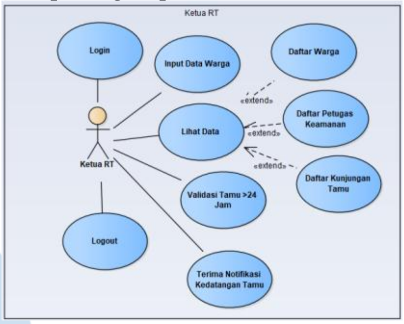

Fig 5. Usecase Diagram RT Head

Security Officer

The Security Officer logs into the system using registered credentials. The officer performs verification by scanning the QrCode presented by guests who have been registered by residents. The system also provides notifications of planned guest visits immediately after residents submit the data. The Security Officer is able to view the list of planned guest visits for the current day. The officer may log out after completing system-related duties.

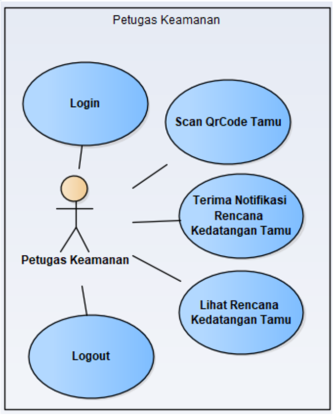

Fig 6. Usecase Diagram Security Officer

Resident

Residents access the system using registered accounts. They can submit planned guest visit information, including guest name, the resident being visited, number of guests, type of vehicle, and duration of the visit. The system automatically generates a QrCode based on the submitted data, which residents can share with guests through messaging applications such as WhatsApp. The QrCode is temporary and remains valid according to the visit duration. Residents may also provide information regarding travel plans or indicate unavailability for receiving guests. This allows security personnel to inform unexpected visitors about the resident's absence or unavailability. Residents can view records of guest visits within a given time range and may log out after completing their actions.

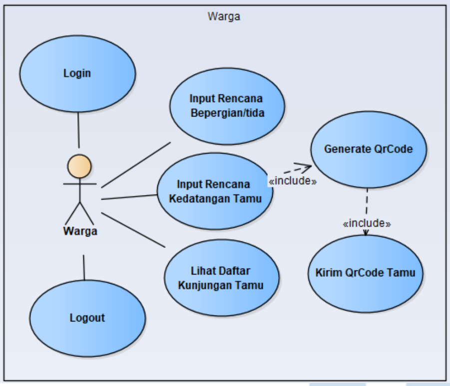

Fig 7. Usecase Diagram Resident

Guest

Guests receive a QrCode from the resident who has registered a planned visit. Upon arrival, guests present the QrCode to the Security Officer for verification.

2) *System Design*

Fig 8. Guest Registration Form

This form is used by residents to register guests who plan to visit their homes. Residents input detailed information based on the required fields.

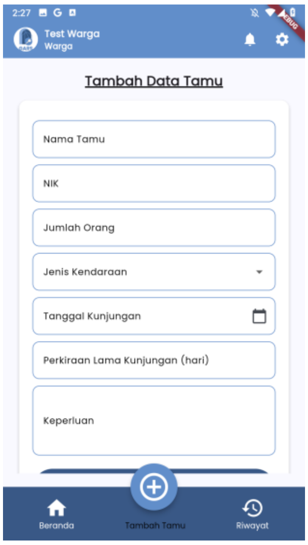

Fig 9. Guest Data Form Fields

This form is filled out by residents to register the guests who will be visiting.

Fig 10. QR Code Form

This is the QR code generated from the guest data entered. Residents will share this QR code with the guests who plan to visit.

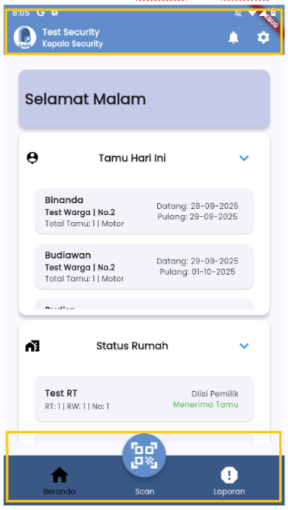

Fig 11. Security Officer Form

This form contains the main feature: QR code scanning. Security officers will scan the QR code shown by the guest.

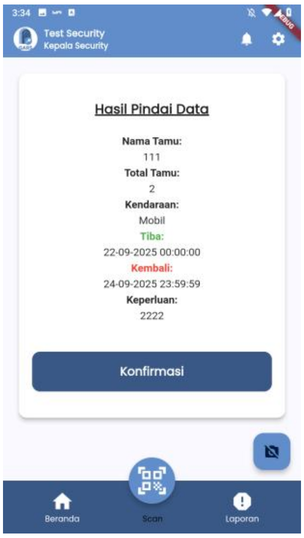

Fig 12. QR Code Scan Result Form

After the guest's QR code is scanned by the security officer, the detailed contents of the QR code will appear, including the name, date and time of visit, and the vehicle used.

3) IoT Architect

Fig 13. ESP32 Dev Kit

ESP32 Dev Kit is a development board designed to simplify the use of the ESP32 microcontroller (System on a Chip/SoC) developed by Espressif Systems. This board typically includes all the essential components (such as a voltage regulator, USB-to-UART chip, and pin headers) so you can directly program and test the ESP32 chip without needing to build a complex supporting circuit.

The **ESP32 chip** itself is the core of this kit and is known for its main features:

- **Integrated Wi-Fi and Bluetooth:** This is the key feature that makes it a top choice for IoT projects. ESP32 supports Wi-Fi (802.11 b/g/n) and Bluetooth (Classic and Low Energy/BLE).
- **Powerful Processor:** Most variants have a Tensilica Xtensa Dual-Core 32-bit LX6 processor with speeds up to 240 MHz, offering better performance compared to its predecessor, the ESP8266.
- **Low Power Consumption:** Designed for low-power applications with various sleep modes to conserve battery life.

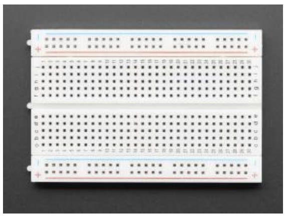

Fig 14. Breadboard

Breadboard is a board used for assembling and testing electronic circuits temporarily without requiring any soldering.

The name "breadboard" originates from early inventors who used wooden bread-cutting boards to attach nails and connect electronic components. Modern breadboards are made of plastic and contain small holes with internal conductive metal clips or rails that serve as connectors.

Its main functions are:

- **Rapid Prototyping:** Allows users to quickly assemble, test, modify, and disassemble electronic circuits.
- **Non-Destructive:** Components can be inserted and removed repeatedly without damage.
- **Learning Tool:** Ideal for beginners and educational purposes because it helps users understand circuit paths, voltage, and component connections.

Fig 15. Ultrasonic Sensor HC-SR04

HC-SR04 is a widely used, low-cost ultrasonic distance sensor. It works based on sonar principles by using ultrasonic waves (sound waves above 20 kHz) to determine the distance of an object. It is commonly used in various microcontroller projects (such as Arduino or ESP32).

The working principle of the HC-SR04 is based on measuring the travel time of sound waves:

- **Trigger:** The microcontroller sends a HIGH pulse for at least 10 microseconds to the sensor's Trig pin.
- **Wave Transmission:** After receiving the trigger signal, the module emits eight ultrasonic pulses at 40 kHz through the transmitter.
- **Echo Reflection:** The ultrasonic waves travel through the air at the speed of sound (343 m/s or 0.0343 cm/microsecond) and reflect off any solid object in front of it.

- **Reception:** The reflected wave (echo) is received by the sensor's receiver.
- **Time Measurement:** The Echo pin stays HIGH from the moment the wave is sent until the reflected wave is received. The microcontroller measures the duration of this HIGH pulse, which represents the total travel time.

Fig 16. Direct Current Motor

DC Motor (Direct Current Motor) is an electric machine that converts direct current (DC) electrical energy into mechanical energy in the form of rotational motion.

DC motors are widely used in many applications such as toys, household appliances (blenders, car wipers), robotics systems, and industrial machines that require speed and torque control.

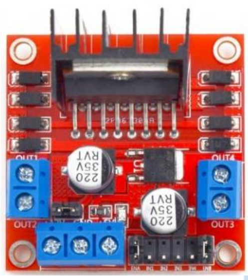

Fig 17. L298N Motor Driver

L298N Motor Driver is an electronic module based on the L298N Dual H-Bridge Integrated Circuit (IC). Its main functions include:

- **Controlling Motor Direction:** Converts low-voltage logic signals (e.g., from Arduino) into sufficiently large power signals to reverse motor voltage polarity, enabling forward or reverse rotation.
- **Controlling Motor Speed:** Allows DC motor speed control using PWM (Pulse Width Modulation).
- **Current Amplification:** Microcontrollers can only output very small current (around 20 mA). The L298N acts as a bridge, enabling motors requiring higher current (up to 2A per channel) to be powered by an external supply without damaging the microcontroller.

Fig 18. Limit Switch

Limit Switch is a type of mechanical sensor used to detect the presence, position, or movement boundary of an object or machine.

Simply put, a limit switch is an electrical switch activated (opened or closed) by physical contact when a moving object reaches its predetermined limit.

Working Principle:

- **Actuator Contact:** When a moving object contacts the actuator (lever, roller, or push button) of the limit switch.
- **Contact Change:** The actuator pushes the internal microswitch mechanism.
- **Electrical Signal:** This changes the electrical contact state:
  - ✓ **NO (Normally Open):** Becomes closed, allowing current to flow.
  - ✓ **NC (Normally Closed):** Becomes open, cutting off the current.

Fig 19. Jumper Wires

Jumper Wires are short conductive cables used to connect two points in an electronic circuit. They allow connections without soldering, making them ideal for assembly, testing, and prototyping.

Fig. 20 QR Code Scanner

QR Code Scanner is a hardware or software tool designed to read and decode information stored in a QR Code (Quick Response Code).

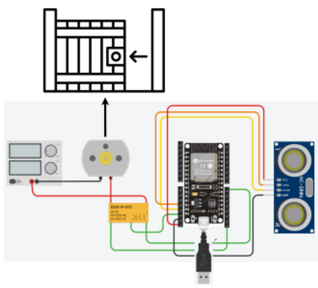

Fig 21. IoT Prototype Architect

Figure 21 explains that the IoT system operates alongside the existing system that has been developed. The system is initiated by residents, who register planned guest visits to their homes. This data is then generated in the form of a QR code. The IoT system becomes active when the QR code is scanned by a QR code reader. The sensor system, consisting of an ESP32 microcontroller and an L298N motor driver, detects the QR code and activates the gate drive motor (DC motor) to open the gate. When the gate opens, its movement stops upon reaching the limit switch. Another sensor, namely the ultrasonic sensor HC-SR04, ensures that the gate will automatically close after an object identified as a vehicle passes through the sensor, which then triggers the gate to close again.

B. Discussion

The following is the recap of the SUS questionnaire that was distributed to 30 respondents. The respondents were given questions based on the standard SUS question set.

Table 2. Recap of the SUS questionnaire

	q1	q2	q3	q4	q5	q6	q7	q8	q9	q1
r1	4	4	3	3	4	3	4	4	3	4
r2	4	5	3	4	3	5	3	5	3	4
r3	3	5	3	5	5	4	3	3	5	4
r4	5	4	4	4	4	5	4	3	5	5
r5	5	4	3	4	4	3	5	4	4	5
…	…	…	…	…	…	…	…	…	…	…
r28	3	4	4	4	5	3	4	3	5	4
r29	3	3	5	5	3	5	4	4	3	3
r30	4	5	5	4	4	4	5	3	3	5

1) Usability Measurement Results Using the System Usability Scale (SUS)

Usability testing on the IoT-based residential security system application was conducted using the System Usability Scale (SUS) involving 30 respondents. The SUS instrument consists of 10 statements rated on a 1–5 Likert scale. The score calculation follows the standard procedure: odd-numbered statements are calculated as score – 1, while even-numbered statements are calculated as 5 – score, and the total result is then multiplied by 2.5 to produce a final score ranging from 0–100. Based on the calculations from 30 respondents, individual SUS scores ranged from 65 to 92.5. The average SUS score reached 74.83, with a median of 75, a minimum score of 65, a maximum score of 92.5, and a standard deviation of 8.12. With an average score of 74.83, the application falls into the “Good” category according to SUS interpretation standards.

This value indicates that, in general, the application meets user expectations in terms of ease of use, clarity of functions, and interaction efficiency. An average score above the threshold of 68 signifies that the application has an acceptable level of usability and is suitable for use by the general public.

2) Distribution and User Perception Patterns

The score distribution shows that most respondents gave ratings in the range of 70–85, indicating a consistent perception that the application is easy to operate and supports users’ needs in monitoring home security. Only a few respondents provided scores close to the lower threshold (65–68), although these values still fall within the acceptable category.

The maximum score of 92.5 indicates that there is a group of users who find the application highly intuitive, with clear navigation flow and fast system responses. This may suggest that the application design is already highly optimized for certain user profiles.

3) SUS Category Interpretation

The maximum score of 92.5 indicates that there is a group of users who find the application highly intuitive, with clear navigation flow and fast system responses. This may suggest that the application design is already highly optimized for certain user profiles.

- 68–80.3 = Good / Acceptable
- 80.3 = Excellent

Thus, the application is categorized as Good, meaning that it:

- Can be used easily by the general public without requiring special training.
- Provides interactions that are easy to understand, resulting in a relatively low cognitive load for users.
- Demonstrates good user satisfaction, particularly in navigation, interface clarity, and the effectiveness of the application's core functions.

The “Good” category also implies that the application is sufficiently competitive compared to similar applications in terms of usability and only requires minor improvements to reach the “Excellent” level.

4) Qualitative Analysis Based on Rating Patterns

Although the overall score falls within the “Good” category, respondent rating patterns reveal several important points:

- Ease of use during first-time interaction is rated highly by most users, indicating that the application interface is quite intuitive.
- IoT function integration performs well, with few users experiencing confusion during the device pairing or monitoring process.

- Visual consistency also received positive responses, suggesting that the interface design is comfortable and facilitates navigation.
- Some respondents indicated the need for minor improvements in notification speed and the clarity of certain icons, although these issues did not significantly affect the overall score.

V. CONCLUSION

The SUS score in the Good category implies that the application has successfully achieved an acceptable level of usability and can serve as a solid foundation for further development. However, to reach the Excellent category, several areas can be improved, including:

1. Optimizing response time in updating IoT sensor status.
2. Refining icon designs to make them more understandable for general users.
3. Simplifying several menus that are considered less frequently used.

Improvements in these aspects have the potential to increase the SUS score in the future and enhance the overall quality of the user experience.

This study demonstrates that the implementation of IoT-based security systems can be further expanded into a more comprehensive security framework. Beyond access control, the proposed system has the potential to be developed into an integrated residential security system by incorporating additional features, such as a panic button function that can be activated by residents and directly connected to security personnel. Furthermore, future development may include integration with existing infrastructure, such as residential CCTV systems, to enhance real-time monitoring, incident logging, and overall situational awareness.

REFERENCES

[1] Pemerintah Republik Indonesia, *Undang-undang Republik Indonesia Nomor 1 Tahun 2011 Tentang Perumahan dan Kawasan Permukiman* . Indonesia: https://bphn.go.id/data/documents/11uu001.pdf, 2011.

[2] R. Prabowo and M. R. Lubis, “Tinjauan Hukum Pidana terhadap Kebijakan Keamanan di Perumahan Berdasarkan Peraturan Perumahan,” *JBH: Jurnal Begawan Hukum*, vol. 3, no. 2, pp. 1–10, Sep. 2025, doi: https://doi.org/10.62951/jbh.v3i2.133.

[3] A. D. Ayuningtyas, “Pencurian Jadi Kejahatan Paling Masif di Indonesia,” *GoodStats*, Jakarta, 2024.

[4] K. Rinaldi, D. Prayoga, and H. Mianita, “Enviromental Criminology : Penerapan Defensible Space Sebagai Alternatif Pencegahan Kejahatan,” *Jurnal Hukum Pidana dan Kriminologi*, vol. 3, no. 1, pp. 14–29, Apr. 2022, doi: 10.51370/jhpk.v3i1.66.

[5] Z. Hidayati and M. Noviana, “KORELASI AKSES PERUMAHAN DAN KRIMINALITAS DI PERUMAHAN KOTA SAMARINDA,” *Jurnal Kreatif : Desain Produk Industri dan Arsitektur*, vol. 1, no. 1, p. 10, Oct. 2020, doi: 10.46964/jkdpia.v1i1.113.

[6] G. Vardakis, G. Hatzivasilis, E. Koutsaki, and N. Papadakis, “Review of Smart-Home Security Using the Internet of Things,” *Electronics (Basel)*, vol. 13, no. 16, p. 3343, Aug. 2024, doi: 10.3390/electronics13163343.

[7] L. Y. Rock, F. P. Tajudeen, and Y. W. Chung, “Usage and impact of the internet-of-things-based smart home technology: a quality-of-life perspective,” *Univers Access Inf Soc*, vol. 23, no. 1, pp. 345–364, 2024, doi: 10.1007/s10209-022-00937-0.

[8] J. M. Haney, S. M. Furman, and Y. Acar, “Research report : User Perceptions of Smart Home Privacy and Security,” Nov. 2020. doi: 10.6028/NIST.IR.8330.

[9] C. Zhou, Y. Qian, and J. Kaner, “A study on smart home use intention of elderly consumers based on technology acceptance models,” *PLoS One*, vol. 19, no. 3, p. e0300574, Mar. 2024, doi: 10.1371/journal.pone.0300574.

[10] Erwin *et al.*, *Pengantar & Penerapan Internet of Things Konsep dasar & Penerapan IoT di berbagai Sektor* . Jambi: PT. Sonpedia Publishing Indonesia, 2023.

[11] L. P. I. Kharisma *et al.*, *Internet of Things Pengenalan dan Penerapan Teknologi Internet of Things*. Jambi: PT. Sonpedia Publishing Indonesia, 2024.

[12] A. Francois, A. Danilova, D. Jagna, D. Caraig, and V. Petrov, “How Do QR Codes Work?,” Techslang . Accessed: Nov. 30, 2025. [Online]. Available: https://www.techslang.com/how-do-qr-codes-work/

[13] FORTINET, “What Is A QR Code?,” FORTINET. Accessed: Nov. 30, 2025. [Online]. Available: https://www.fortinet.com/resources/cyberglossary/what-is-a-qr-code?

[14] The QR STOCK Editorial Team, “What is a QR Code (2D Code)? A Complete Guide from its Official Name to Creation Methods,” QR STOCK. Accessed: Nov. 30, 2025. [Online]. Available: https://qr-stock.com/articles/knowledge/about-qrcode?

[15] ITU, “What is a Quick Response Code (QR Code)?,” ITU Online. Accessed: Nov. 30, 2025. [Online]. Available: https://www.ituonline.com/tech-definitions/what-is-a-quick-response-code-qr-code/

[16] Malwarebytes Team, “QR Codes: How they work and how to stay safe,” Malwarebytes . Accessed: Nov. 30, 2025. [Online]. Available: https://www.ituonline.com/tech-definitions/what-is-a-quick-response-code-qr-code/

[17] S. Roychoudhury, “What is a QR Code, how does it work, and are they safe?,” The QR Code Generator. Accessed: Nov. 30, 2025. [Online]. Available: https://www.the-qrcode-generator.com/whats-a-qr-code?

[18] C. Bustos, “How Do QR Codes Work—A Simple Guide,” QR.io. Accessed: Nov. 30, 2025. [Online]. Available: https://qr.io/blog/how-do-qr-codes-work/

[19] A. Bangor, P. Kortum, and J. Miller, “Determining what individual SUS scores mean: adding an adjective rating scale,” *J. Usability Studies*, vol. 4, no. 3, pp. 114–123, May 2009.

[20] Ahire, Ahmad, Bhatt, and Patel, “Evaluating the usability of emerging digital interfaces using the System Usability Scale (SUS),” *Int J Hum Comput Stud*, 2021.

[21] Rempel and Moffatt, “Applying the System Usability Scale to playful and interactive systems: A domain validity analysis,” *ACM Transactions on Computer–Human Interaction (TOCHI)*, vol. 29, no. 4, pp. 1–27, 2022.

[22] Yoon and Ji, “Psychometric evaluation of the System Usability Scale across device types,” *Int J Hum Comput Interact*, vol. 40, no. 2, pp. 150–165, 2024.

[23] Singh, Kumar, and Verma, "Usability assessment of mobile game applications using the System Usability Scale," *Mobile Information Systems*, 2024.

[24] J. Hair, G. T. M. Hult, C. Ringle, and M. Sarstedt, *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. 2022