MODIFICATION DESIGN OF A BUILDING AUTOMATION SYSTEM TO IMPROVE ENERGY EFFICIENCY AT SYAMSUDIN NOOR AIRPORT TERMINAL

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ABSTRACT
This study addresses the optimization of the lighting control system within the Building Automation System (BAS) at Syamsudin Noor International Aiport Terminal, which served 3,069,435 passengers in 2024. The current Building Automation System relies on schedule-based control, causing lights to remain active in areas with minimum activity post-operational hours, particularly in three key terminal zones: check-in, waiting room, and baggage claim. This condition results in electrical energy inefficiency, leading to financial losses for the airport management. The main problem examined is the non-adaptive nature of the existing BAS, which does not respond in real-time to human presence, thus requiring modification of the BAS. The research stages include identification of terminal electricity consumption, financial loss identification, design of BAS modification, and projection of energy efficiency post-implementation. The objectives of the study are to identify losses resulting from the operation of the existing BAS, to design a modified BAS for lighting control, and to project the energy efficiency achieved. The method employed is Level I Research & Development up to the design validation stage. The results indicate that modifying BAS using microwave radar occupancy sensors can significantly reduce energy inefficiency. This proposed modification is expected to support the eco-airport iniciative and reduce operational costs. The study concludes that the BAS modification design utilizing microwave sensors represents an effective solution for energy efficiency in Syamsudin Noor International Airport Terminal, which experiences variable passenger traffic.
***Kata Kunci**: BAS, Efficiency, Energy, Lighting, Sensor, Terminal.*

INTRODUCTION

Transportation is one of key pillars in supporting public mobility and economic growth, particularly in province of South Kalimantan, Indonesia. Among various types, air transportation plays a crucial role as domestic and international link, as airport being the core facility to ensure smooth operations.

One of the main facility in airport, the terminal building, becomes the center of passenger service at Syamsudin Noor International Airport in Banjarbaru, which was serving 3,069,435 passengers in 2024, according to Badan Pusat Statistik of Banjarbaru. To support the operational and services activity, a lighting system which meets safety and comfort standard is required, in accordance with the Regulation of the Minister of Transportation of the Republic of Indonesia No. 178 of 2015 concerning Airport User Service Standards.

The current lighting system at Syamsudin Noor International Airport terminal relies entirely on Light Emitting Diode (LED), which has replaced conventional lighting for improving energy [1] efficiency [2][3][4]. Furthermore, the terminal building has implemented a Building Automation System (BAS) to automatically control loads [5]. These steps align with PT. Angkasa Pura Indonesia’s commitment to eco-airport initiative and environmental preservation, as well as reducing carbon emissions.

The disadvantage of the current lighting system lies in the suboptimal operation of the BAS. Observations indicate that lights remain on in the arrival and departure terminals after operating hours, particularly in unused areas. This is due to the BAS relying solely on static time schedule, making it incapable of adapting to real-time conditions, such as presence and the absence of passengers. This condition causes energy waste [6][7][8], despite the efficiency of LED lights, with the potential of significant financial losses due to this overconsumption.

The need for adaptive lighting control is crucial to address this disadvantage [6]. Studies show that automation utilizes smart sensors could improve energy efficiency by 30-50% compared to manual systems [9]. Passive Infrared (PIR) and Ultrasonic Occupancy Sensors (US) are the most common sensor used for lighting control, but both have limited accuracy and susceptible to placement limitations [10]. To address these limitations, other technologies sucs as hybrid PIR and US, video, CO2 [11], and radar have been developed [10][11][12]. Radar occupancy sensors have emerged as a dominant technology due to their reliability and features. They have also proven effective in detecting building occupancy [13].

This study aims to measure the extent of energy savings achieved by adding microwave radar sensor to the BAS. This research is expected to be the first step in optimizing the terminal lighting system, supporting the eco-airport vision, and providing a tangible contribution to airport management in reducing operational costs while improving passenger comfort at Syamsudin Noor International Airport.

RESEARCH METHODS

This research employed the Research and Development (R&D) method level 1 [19], limited to the design validation stage due to time and resource constraints. Data collection was conducted at Syamsudin Noor International Airport Terminal in December 2025 through field observations of occupancy patterns in check-in, waiting room, and baggage claim areas during post-operational hours; power measurements (voltage and current) on lighting sub-panels using multimeter and clamp meter; analysis of single-line diagrams and BAS schedules; interviews with Airport Equipment Technician and Airport Operation Center Head.

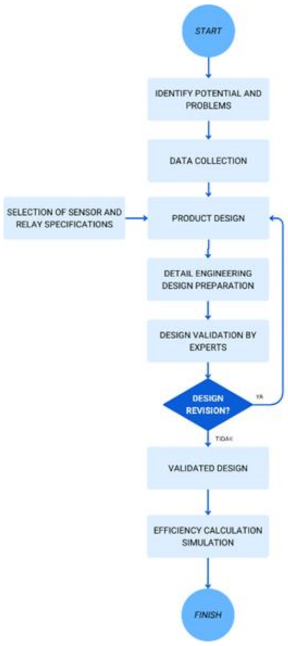

Fig. 1. Research Flow

RESULTS AND DISCUSSION

This section presents the findings from data collection, design development, testing, validation, simulation, and efficiency projection of the proposed BAS modification.

A. Existing Lighting System and Energy Consumption

The terminal receives electricity from PT. PLN (Persero) under the B-3/TM tariff category with a contracted power of 5,540 kVA. Field measurements on the lighting sub-panels (PL-PEN 1A1, 1A1E. 2A3, 2B3, 1B1, and 2B2) during December 2025 showed an average daily terminal electricty consumption of 10,487 kWh/day or 437kWh/hour.

Table 1. Terminal Electrical Energy Consumption Value

DATE	DISTRIBUTION PANEL		
	FIRST-KWH READING	LAST-KWH READING	KWH CONSUMED
15/12/2025	2.693.250	2.703.210	9.960
16/12/2025	2.703.210	2.714.230	11.020
17/12/2025	2.714.230	2.724.210	9.980
18/12/2025	2.724.210	2.733.680	9.470
19/12/2025	2.733.680	2.744.390	10.710
20/12/2025	2.744.390	2.755.100	10.710
21/12/2025	2.755.100	2.766.660	11.560
MEAN			**10.487**

This kWh value could be converted into rupiah value by considering the tariff category (Rp. 1,553.67/kWh during peak-load hours 18:00-23:00 WITA and Rp. 1,035.78/kWh during outside peak-load hours) using the following equation [20]:

a) *Peak-Load Hour (18.00-23.00)*

$$PLH\ Cost = PLH\ Tariff \times Energy\ (kWh) \times Duration$$
$$PLH\ Cost = Rp.1{,}553.67 \times 437\ kWh \times 5\ hours$$
$$PLH\ Cost = Rp.3{,}394{,}768.95/Day$$

b) *Outside Peak-Load Hour (23.00-18.00)*

$$Outside\ PLH\ Cost = Outside\ PLH\ Tariff \times Energy\ (kWh) \times Duration$$
$$Outside\ PLH\ Cost = Rp.1{,}035.78 \times 437\ kWh \times 19\ hours$$
$$Outside\ PLH\ Cost = Rp.8{,}600{,}081.34/Day$$

c) *Total Cost/Day*

$$Total\ Cost = PLH\ Cost + Outside\ PLH\ Cost$$
$$Total\ Cost = Rp.3{,}394{,}768.95 + Rp.8{,}600{,}081.34$$
$$Total\ Cost = Rp.11{,}994{,}850{,}3/Day$$

It can be estimated that the overall electricity consumption of the Syamsudin Noor International Airport terminal building is Rp. 11,994,850.3/day or estimated Rp. 4,318,146,108/year.

Power measurement on the relevant sub-panels providing electricity power for lighting system (PL-PEN 1A1, 1A1E, 2A3, 2B3, 1B1, and 2B2) yielded the following lighting loads for three critical areas: check-in area 33.14 kW, waiting room 24.04 kW, baggage claim 28.61 kW.

Table 2. Schedule and Grouping of Terminal Lighting System

NO	LIGHTING GROUP	AREA	SCHEDULE
PL-PEN 1A1 (EAST CHECK-IN AREA)			
1	Q7, Q8, Q9, Q10, Q13, Q14, Q16	EAST CHECK-IN	**ON**: 3.50 - 6.30 **ON**: 18.00 - 21.36
PL-PEN 1A1E (MAIN CHECK-IN)			
1	Q4, Q5, Q6, Q8	WEST CHECK-IN	**ON**: 3.50 - 6.30 **ON**: 18.00 - 21.32

2	Q7, Q9, Q10, Q11	WEST COUNTER CHECK-IN	**ON**: 3.50 - 6.30 **ON**: 18.00 - 21.32
3	Q12, Q16	EAST COUNTER CHECK-IN	**ON**: 3.50 - 6.30 **ON**: 18.00 - 21.32
PL-PEN 2A3 (EAST WAITING ROOM)			
1	Q1, Q5, Q6, Q7, Q8, Q9, Q10, Q11, Q12	GATE 9 & 10	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
2	Q2, Q13, Q14, Q15, Q16, Q17, Q18	GATE 6, 7, & 8	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
3	Q3, Q4, Q20, Q21, Q22, Q23, Q24	MID WAITING ROOM	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
PL-PEN 2B3 (WEST WAITING ROOM)			
1	Q4, Q5, Q6, Q9, Q10, Q13, Q14, Q15, Q16	GATE 1 & 2	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
2	Q11, Q12,Q17, Q18, Q19, Q20	GATE 3, 4, & 5	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
3	Q3, Q7, Q8, Q21, Q22, Q23	MID WAITING ROOM	**ON**: 3.45 - 6.45 **ON**: 17.30 - 20.00
PL-PEN 1B1 (INTERNATIONAL BAGGAGE CLAIM)			
1	Q14, Q15, Q16,	INTERNATIONAL BAGGAGE CLAIM	**ON**: 17.30 - 19.00
PL-PEN 2B2 (DOMESTIC BAGGAGE CLAIM)			
1	Q1, Q9, Q10	WEST AREA	**ON**: 18.00 - 22.00
2	Q6	MID AREA	**ON**: 18.00 - 22.00
3	Q7, Q8	EAST AREA	**ON**: 18.00 - 22.00

The lighting system contributes significantly to the total load. Detailed power calculations based on measured voltage, current, operating hours according to the existing BAS schedule, and the applicable tariff could be calculated using the following formula:

$$Power = Pr + Ps + Pt$$

$$Power = (Vr \times Ir \times cos\varphi \times \sqrt{3}) + (Vs \times Is \times cos\varphi \times \sqrt{3}) + (Vt \times It \times cos\varphi \times \sqrt{3})$$

Example for PL-PEN 1A1:

a) Power Calculation

$$Power = (409{,}4 \times 2{,}67 \times 0{,}9 \times \sqrt{3}) + (412{,}8 \times 1{,}44 \times 0{,}9 \times \sqrt{3}) + (411{,}6 \times 3{,}68 \times 0{,}9 \times \sqrt{3})$$

$$Power = 4.99\ kW$$

b) Peak-Load Hours

$$PLH\ Cost = PLH\ Tariff \times Power\ (kW) \times Duration\ (hours)$$

$$PLH\ Cost = Rp.1{,}553.67 \times 4{,}99\ kW \times 3{,}6\ hours$$

$$PLH\ Cost = Rp.27{,}919.99/Day$$

c) Outside Peak-Load Hours

$$Outside\ PLH\ Cost = Outside\ PLH\ Tariff \times Power\ (kW) \times Duration\ (hours)$$

$$Outside\ PLH\ Cost = Rp.1{,}035.78 \times 4{,}99\ kW \times 2{,}67\ hours$$

$$Outside\ PLH\ Cost = Rp.13{,}787.65/Day$$

d) Total Cost

$$Total\ Cost = PLH\ Cost + Outside\ PLH\ Cost$$

$$Total\ Cost = Rp.27{,}919.99 + Rp.13{,}787.65$$

$$Total\ Cost = Rp.41{,}707.64/Day$$

Similar calculations were performed for other responsible sub-panel, resulting an annual lighting cost of Rp. 214,767,917. This accounts for approximately 4,97% of the total terminal electricity cost.

Observations conducted over seven days (15-21 December 2025) post-operational hours revealed substantial over-lighting (which lights remained on when areas were empty) in three critical zones: check-in, waiting room, and baggage claim. The average over-lighting durations per day were: check-in area (35 minutes 26 seconds), waiting room (22 minutes 17 seconds), baggage claim area (1 hour 12 minutes 51 seconds).

Energy waste per day for each area was calculated using formula:

$$Energy\ (kWh) = Power\ (kW) \times Over\ Lighting\ Duration\ (hours)$$

Example for Check-In Area:

a) *Energy Calculation*

$$Energy\ (kWh) = 33.14\ kW \times 0.583\ hours$$
$$Energy\ (kWh) = 19.33\ kWh/Day$$

b) *Cost*

$$Cost = Energy\ (kWh) \times PLH\ Tariff$$
$$Cost = 19.33\ kWh \times Rp.1{,}553.67$$
$$Cost = Rp.30{,}035.03/Day$$

Similar calculations were performed for the waiting room (8.81kWh/day) and baggage claim (34.8kWh/day). These unnecessary lighting periods resulted in annual energy waste of 22,658.4 kWh, equivalent to a financial loss of Rp. 35,212,158. (16.4% of the total lighting cost).

Fig 2. Over-Lighting in 3 Critical Areas of Terminal

Table 3. Estimate of Energy and Cost Efficiency

ENERGY AND COST INEFFICIENCY		
PERIOD	**ENERGY (kWh)**	**COST (Rp.)**
DAY	62,94	97.811,55
WEEK	440,58	684.680,85
MONTH	1888,2	2.934.346,50
SEMESTER	11329,2	17.606.079,00
YEAR	22658,4	35.212.158,00

B. Proposed Modification Design

The modification transforms the current open-loop (schedule-based) control into a closed-loop system [21][22] by integrating microwave radar occupancy sensors (DRM-01-24V specification: detection range up to 12m, installation height 6m, operating voltage 180-240VAC).

A total of 27 sensors were planned after expert validation (revised from the initial 23 sensors based on recommendations from Airport Equipment Engineer and Airport

Equipment Department Head of Syamsudin Noor International Airport. Sensors were zoned per lighting group to maintain partial manual/BAS override as fail-safe mechanism.

Integration was designed using spare channels in the existing panels and additional relays (OMRON MY2-GS-R) without requiring major changes to the BAS software. A 10-minutes delay was set after the last detected movement to prevent premature shut-off and ensure passenger comfort.

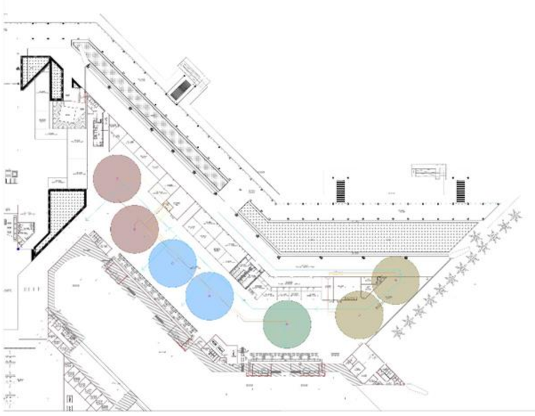

Fig 3. Revised Layout of Microwave Sensor Installation in The Check-In Area

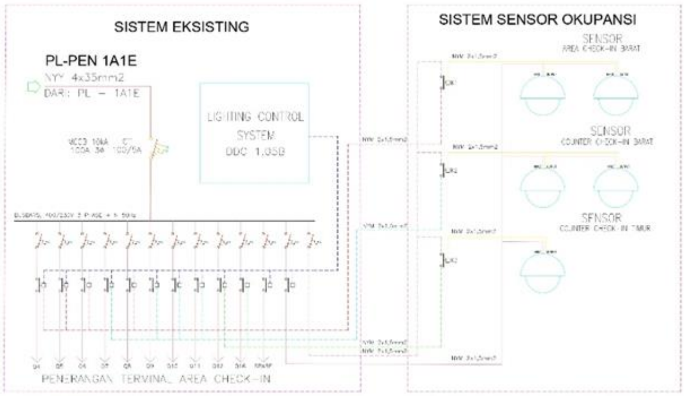

Fig 4. Revised Single-Line Diagram of The Proposed Lighting Control for PL-PEN 1A1E Panel (example)

Table 4. Final Sensor Configuration

PANEL NAME	SENSOR AMOUN T	SENSOR HEIGHT (m)	DELAY (minutes)
PL-PEN 1A1	2	6	10
PL-PEN1A1E	5	6	10
PL-PEN 2A3	7	6	10
PL-PEN 2B3	7	6	10
PL-PEN 1B1	1	6	10
PL-PEN 2B2	5	6	10

C. Sensor Testing and Expert Validation

On-site testing of the microwave radar sensor showed consistent detection performance. The sesnsor achieved 100% detection accuracy for human movement (macro & micro) up to 12 meters in line-of-sight conditions. Detection remained reliable even with minor obstacles.

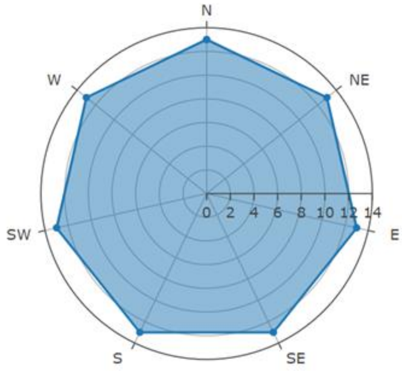

Fig 5. Microwave Sensor Detection Radius

Table 5. Sensor Testing Results at Various Distances

NUMBER OF TESTS	DISTANCE (m)	*LINE OF SIGHT*	DETECTED?	RESULT
1	0	No	Yes	Consitent Response
2	2	No	Yes	Consitent Response
3	2	Yes	Yes	Consitent Response
4	4	No	Yes	Consitent Response
5	4	Yes	Yes	Consitent Response
6	8	No	No	Inconsistent Response
7	8	Yes	Yes	Consitent Response
8	10	No	No	Inconsistent Response
9	10	Yes	Yes	Consitent Response
10	12	No	No	Inconsistent Response
11	12	Yes	Yes	Consitent Response
12	>12	No	No	Out-of Range
13	>12	Yes	No	Out-of Range

Expert validation by two airport specialists confirmed the technical feasibility. Recommendations included the delay to 10 minutes and optimizing sensor placement to cover passenger and staff movement paths

D. Simulation of Energy Efficiency

Simulation was performed using actual seven-day occupancy data. With the proposed system, lighting in each zone turns off automatically 10 minutes after the last occupant (officer or passenger) leaves.

Table 6. Comparison of Over-Lighting Duration Before and After Modification

DATE	BEFORE MODIFICATION			AFTER MODIFICATION		
	CHECK -IN	WAITING ROOM	BAGGAGE CLAIM	CHECK-IN	WAITING ROOM	BAGGAGE CLAIM
15/12/2025	00:55:00	00:33:00	00:50:00	00:10:00	00:10:00	00:10:00
16/12/2025	00:31:00	00:12:00	00:45:00	00:10:00	00:10:00	00:10:00
17/12/2025	00:17:00	00:07:00	00:27:00	00:10:00	00:10:00	00:10:00
18/12/2025	00:21:00	00:12:00	02:09:00	00:10:00	00:10:00	00:10:00
19/12/2025	00:49:00	00:43:00	01:54:00	00:10:00	00:10:00	00:10:00
20/12/2025	01:00:00	00:46:00	01:16:00	00:10:00	00:10:00	00:10:00
21/12/2025	00:15:00	00:03:00	01:09:00	00:10:00	00:10:00	00:10:00

Table 7. Comparison of Daily Lighting Energy Cost Before and After Implementation

COST BEFORE IMPLEMENTATION	COST AFTER IMPLEMENTATION

PERIOD	COST (Rp.)	PERIODE	COST (Rp.)
DAY	97.811,55	DAY	22.214,87
WEEK	684.680,85	WEEK	155.504,09
MONTH	2.934.346,50	MONTH	666.446,10
SEMESTER	17.606.079,00	SEMESTER	3.998.676,60
YEAR	35.212.158,00	YEAR	7.997.353,20

The simulation demonstrates a reduction in unnecessary lighting energy cost from Rp. 97,811.55/day to Rp. 22,214.87/day, resulting in a 77.28% efficiency improvement for the over-lighting period. This translares to annual saving of Rp. 27,214,804.80 from the three observed areas alone.

E. Discussion

The significant 77.28% efficiency gain stems from eliminating most of the over-lighting waste caused by the static BAS schedule. Microwave radar sensors proved superior to PIR and ultrasonic sensors in this large, high-ceiling terminal environment because they could detect micro-movements, penetrate minor obstacles, and are less affected by temperature variations, consistent with findings by [16][17].

Compared to previous studies [14][15], the efficiency achieved here is higher due to the substantial baseline waste in the airport setting (average over-lighting >30 minutes). However, the overall annual terminal-wide saving will be lower (estimated 20-40%) because the research primarily targets post-operational hours.

However, there are still limitations of the study, such as the simulation based on December 2025 data only (one week period), seasonal variations in passenger traffic may affect actual savings and no real long-term implementation and monitoring yet (Research and Development Level 1 only up to design validation).

CONCLUSION

The modification of the Building Automation System using microwave radar sensors effectively addresses lighting energy inefficiency at Syamsudin Noor International Airport Terminal. Key findings are current annual lighting cost reaches Rp. 214.77 million, with Rp. 35.21 million wasted due to non-adaptive control of the BAS, the proposed design with 27 sensors reduces over-lighting duration significantly, achieving 77.28% efficiency in the affected period, implementation cost is estimated at Rp. 78.85 million with fast payback.

For future improvements, it is recommended to combine the microwave radar sensors with light-dependent resistors (LDR) to improve the optimize energy usage during daytime operations. Additionally, extending the sensor apllication to control HVAC systems could provide greater overall energy efficiency in the airport terminal [23]. Long-term research should focus on native integration of sensor outputs into the BAS software to enable predictive control algorithms using flight schedule data and machine learning techniques. Real implementation and continous monitoring are also suggested to validate the actual energy savings under varying seasonal passenger traffic conditions.

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