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A STUDY OF NATURAL LIGHTING EFFICIENCY AS A SUSTAINABILITY INDICATOR

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ABSTRACT

This functional change significantly alters the building's spatial configuration, including façade orientation, opening positions, and interior spatial layout, which in turn directly affects the quality of daylighting within the building. This study aims to examine daylighting efficiency in type-36 houses converted to commercial use as a primary sustainability indicator. The methods employed combine field measurements using a lux meter at representative sampling points, daylighting simulation using Dialux Evo software, and comparative analysis against the SNI 03-6575-2001 illuminance standard — used as a minimum visual comfort reference despite being originally intended for artificial lighting — and GBCI as the sustainability target. Three sample converted buildings in a middle-class residential area in Pekanbaru City, with varying building orientations relative to the sun, were selected as research objects. Analysis showed that façade modifications, primarily the closure of original window openings and the addition of massive commercial signage, reduced the effective opening area to below 10% of the floor area. Simulation results showed interior illuminance levels ranging from 50–180 lux at peak daytime hours, far below the 250 lux standard (SNI baseline) and 300–500 lux (GBCI target) required for commercial spaces. Consequently, 72% of the converted buildings failed to meet the minimum SNI 03-6575-2001 illuminance standard, and none met the GBCI requirements (at least 30% of work area ≥300 lux or DF ≥2%), resulting in heavy dependence on artificial lighting and inefficient electricity consumption. Based on these findings, the study recommends daylighting retrofitting strategies tailored to spatial constraints, such as the application of light shelves, modular skylights, and transparent materials on vertical partitions to improve the daylight factor without compromising privacy and commercial function. These findings are expected to contribute to the development of design guidelines for residential-to-commercial adaptation oriented toward energy sustainability principles in tropical urban areas.

Keywords: type-36 house, daylighting, sustainability, daylight factor

1. INTRODUCTION

Pekanbaru, the capital of Riau Province, reflects this trend: middle-class residential areas originally designed for single-family dwellings have been gradually converted into small retail kiosks, food stalls, minimarkets, and service shops. The type-36 house — a standardized unit with a gross floor area of 36 m^2 — is among the most affected typologies; however, in practice, converted buildings have often undergone additions or modifications so that their floor areas vary, as seen in this study's research objects, which range from 67 to 99 m^2.

The conversion of residential buildings to commercial use brings fundamental changes to the building envelope. Window openings originally designed for privacy and cross-ventilation in residential use are frequently modified — relocated, reduced, or even blocked by commercial elements such as signage and product displays. This phenomenon is common in adaptive reuse practices, where changes in building function are often followed by adjustments to façades and openings to meet the visual and economic demands of the new function, ultimately resulting in a decline in indoor daylighting quality (Lechner, 2009; Reinhart & Walkenhorst, 2001).

Daylighting efficiency is recognized as a critical sustainability indicator within green building assessment frameworks. In tropical climates characterized by high solar radiation throughout the year, effective daylighting design not only reduces energy consumption but also enhances occupant comfort and productivity. Indonesian National Standard SNI 03-6575-2001 is used as a reference for minimum illuminance levels in commercial spaces; although this standard is fundamentally intended for artificial lighting systems in buildings, it remains relevant as a minimum visual comfort threshold (baseline). The 250 lux value set by SNI constitutes the minimum functional threshold, while the Green Building Council Indonesia (GBCI) sets a higher standard of ≥300 lux as the sustainability target (ideal target). Thus, SNI serves as the minimum baseline, while GBCI represents the ideal target that sustainable commercial buildings must meet. Non-compliance with either standard implies both an environmental quality deficit and energy performance weakness.

Although studies on daylighting and adaptive reuse have been widely conducted, empirical research specifically examining the impact of converting small-scale residential buildings to commercial use on daylighting performance — particularly in the context of type-36 housing in Indonesia — remains relatively limited. This gap is particularly significant in the context of tropical urban sustainability, where solar availability is not a limiting factor but is often suboptimally utilized due to poor envelope design.

Therefore, this study addresses the following research questions: To what extent do converted type-36 houses in Pekanbaru meet the daylighting standards required for commercial use, and what retrofitting strategies can improve their daylighting efficiency within existing spatial and land constraints? The objectives of this study are: (1) to measure and simulate illuminance distribution in selected type-36 buildings; (2) to evaluate compliance with SNI 03-6575-2001 and GBCI standards.

2. METHODS

2.1 Research Design

This study adopts a mixed-methods approach combining quantitative field measurements, computational simulation, and comparative evaluation. The research was conducted through three sequential phases, as described in the diagram below:

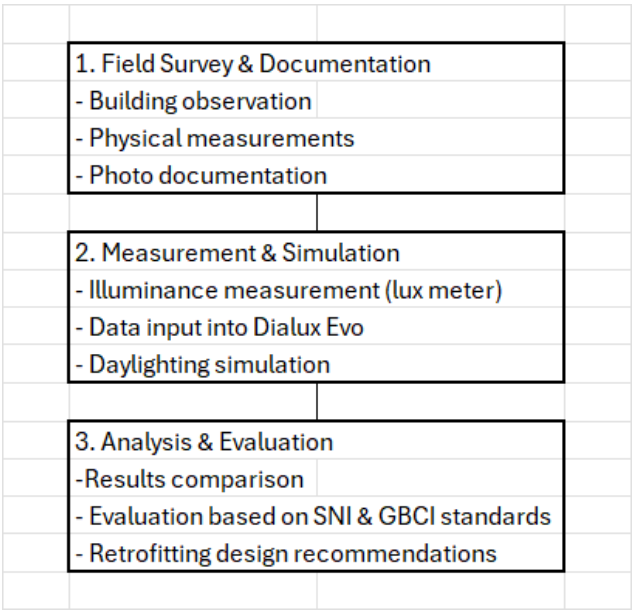


Diagram 1: Research Design Diagram
Source: Personal Data, 2026

2.2 Site Selection

The research site was selected at the Intan Sejahtera Residential Area, Pekanbaru City, a middle-class residential area dominated by type-36 housing typology. This location was chosen based on several considerations. First, the area exhibits a significant phenomenon of residential-to-commercial function transformation, marked by the emergence of various activities such as food stalls, shops, and service businesses within residential units. Second, there is variation in building conditions, including differences in orientation, opening configuration, and degree of façade modification, enabling comparative analysis of daylighting performance. Third, the research site has good accessibility and the buildings are still in active use, supporting the field measurement and direct observation process. With these characteristics, Intan Sejahtera Residential Area is considered representative of small-scale residential transformation phenomena in Indonesian tropical urban areas.

2.3 Case Study Selection

Three type-36 buildings that had undergone residential-to-commercial conversion were selected from a middle-class residential area in Pekanbaru City. Selection criteria included: (a) Houses that had undergone transformation toward commercial use; (b) Research objects include buildings that experienced major spatial changes, including partial room changes and changes in the overall building function; (c) Selected buildings are single-storey only; (d)

Type-36 houses with functional changes to food stalls, boarding houses, and shophouses; and (e) Three samples with different types of openings.

Building A Rumah + warung	Building B Rental House	Building C Ruko

Figure 1: Buildings used as research objects
Source: Personal Data, 2026

2.4 Field Measurements

Illuminance measurements were conducted using a multi-function Environmental Meter with a light measurement (Lux Meter) function, calibrated at standardized measurement points distributed on a 1.0 m × 1.0 m grid at working plane height (0.85 m above floor level). Measurements were carried out over three consecutive days under clear sky conditions between 09:00 and 17:00 local time to capture daily illuminance variations. This approach is consistent with daylighting measurement methods that account for temporal variation throughout the day, where illuminance levels are affected by changes in solar position and sky conditions (CIE Standard 108-1994). Exterior horizontal illuminance was recorded simultaneously to enable calculation of the Daylight Factor (DF) at each interior point. Building dimensions, façade opening area, material reflectance, and shading element geometry were documented through direct measurement and photographic survey. Average illuminance values were calculated based on the distribution of depth zones from the façade, taking into account the contribution of each zone to the total floor area (area-weighted average based on zone area).

Figure 2: Lutron LM-8010 Environment Meter
Source: Personal Data, 2026

2.5 Daylighting Simulation

Three-dimensional building models were constructed in Dialux Evo 11 software, incorporating measured geometry, material properties, and surrounding building obstructions. The CIE Standard Overcast Sky Model was applied for Daylight Factor calculations, while the Perez All-Weather Sky model was used for point-in-time illuminance simulations matching the field measurement conditions. Simulation validity was established by comparing simulated illuminance values against field measurements at identical points and times; agreement within ±15% was considered acceptable.

2.6 Evaluation Standards

Simulation outputs were evaluated against two complementary standards. SNI 03-6575-2001 was used as a reference for minimum illuminance levels in commercial spaces; although this standard is fundamentally intended for artificial lighting systems in buildings, it remains relevant as a visual comfort threshold and serves as the minimum baseline (250 lux for general retail spaces and 300–500 lux for specialty retail/food service). The GBCI Green Building Rating System for Existing Buildings (version 2.0) sets a higher sustainability target: daylighting credits are awarded if (1) at least 30% of regularly occupied floor area achieves illuminance ≥300 lux, or (2) Daylight Factor (DF) ≥2% under representative sky conditions. Thus, the SNI 250 lux value represents the minimum functional threshold, while the GBCI 300 lux represents the ideal sustainability target. Compliance was assessed both at the level of individual measurement points and at the overall floor area level, with quantitative analysis of the percentage of area meeting each respective threshold.

3. RESULTS

3.1 Physical Characteristics of Converted Buildings

Table 1 summarizes the key physical characteristics of the three case study buildings that have undergone functional transformation. Building A has a gross floor area of 76.0 m^2 with

a north-facing orientation, while Building B has an area of 67.0 m^2 with the same orientation. Building C has the largest floor area of 99.0 m^2 with a south-facing orientation.

Based on Table 1, the effective opening-to-floor-area ratio for all three buildings falls below the recommended minimum threshold of ≥10% for daylighting. Building A has the largest opening ratio of 8.7%, indicating that some original openings have been retained. Building B has the smallest effective opening ratio of 5.2%, indicating limited openings and therefore a limited daylight contribution. Meanwhile, Building C has an opening ratio of 6.9%, which is intermediate, but its effectiveness is reduced due to a ±4.5 m canopy that obstructs the entry of natural light.

Furthermore, the average interior reflectance values for all three buildings range from 35% to 42%, below the recommended value of ≥50%. This low reflectance indicates the use of dark-colored interior materials or finishes with poor light reflectance, contributing to poor daylighting distribution inside the spaces.

The effective opening ratio was calculated as the ratio of functional transparent opening area to building floor area. The average interior reflectance value was calculated using an area-weighted average of wall, floor, and ceiling surface areas based on material reflectance values from the literature (Lechner, 2009).

Parameter	Building A (North)	Building B (North)	Building C (South)	SNI Requirement	GBCI Requirement
Gross Floor Area (m^2) (m^2)	76,0	67,0	99,0		—
Effective Opening / Floor Area (%)	6,6 x 100% 76 = 8,7	3,5 x 100% 67 =5,2	6,8 x 100% 99 =6,9	≥ 10%	≥ 10%
Average Interior Reflectance (%)	42	38	35	≥ 50% (rec.)	≥ 50% (rec.)

Table 1. Physical characteristics of three case study buildings

3.2 Field Measurement Results

Field illuminance measurement results for the three buildings are presented in detail based on three observation time periods: morning, midday, and afternoon. Measurements were taken at 1 m × 1 m grid points at working plane height of 0.85 m above floor level.

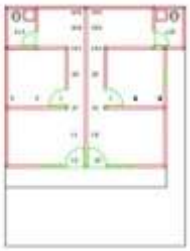
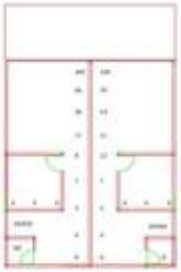
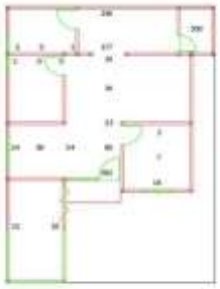
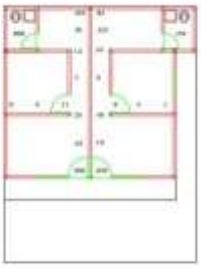
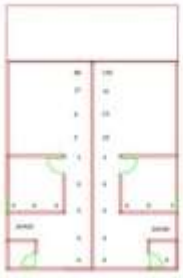
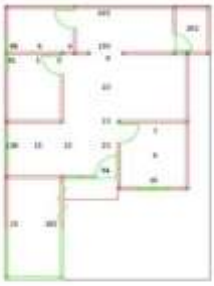
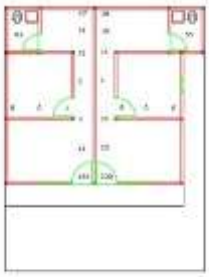
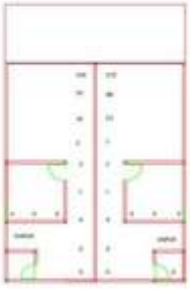
Building A	Building B	Building C
Morning	Midday	Afternoon
DENAH BLOCK L NO. 6 (09.50 Wib - 10.00 Wib)	 DENAH BLOCK L NO.7 (10.20 Wib-10.30 Wib)	 DENAH BLOCK M NO.1 (09.40 Wib - 09.50 Wib)
Midday	Midday	Midday
 DENAH BLOCK L NO. 6 (12.06 Wib - 12.20 Wib)	 DENAH BLOCK L NO.7 (14.20 Wib-14.30 Wib)	 DENAH BLOCK M NO.1 (14.30 Wib - 14.40 Wib)
Afternoon	Afternoon	Afternoon
 DENAH BLOCK L NO. 6 (16.20 Wib - 16.30 Wib)	 DENAH BLOCK L NO.7 (16.30 Wib-16.40 Wib)	 DENAH BLOCK M NO.1 (16.50 Wib - 17.00 Wib)

Figure 3: Field Measurement Data Results from Lux Meter
Source: Personal Data, 2026

3.2.1 Building A

Illuminance measurements at Building A were conducted at three time periods representing daily conditions: morning (09:50–10:00), midday (12:06–12:20), and afternoon (16:20–16:30). Based on 1 m × 1 m grid point measurements, significant variation in daylighting distribution was found across observation times.

In the morning, illuminance values near the openings (perimeter zone) reached 330–501 lux, while the middle area of the room ranged from 39–71 lux, and the deepest area received only 12–50 lux. This indicates that light distribution was still concentrated near the opening source and had not spread evenly throughout the space.

At midday, light intensity increased at certain points, particularly in areas receiving direct exposure from the openings, with a maximum value reaching 582 lux. However, most of the interior area remained in the range of 10–80 lux, with some points approaching 0 lux, indicating underlit zones not effectively reached by natural light.

In the afternoon, lighting distribution changed again with maximum illuminance values of approximately 435 lux in the perimeter area. Meanwhile, the middle area ranged from 10–130 lux, and the deepest area remained low at approximately 1–23 lux. This indicates that despite fluctuations in light intensity throughout the day, lighting distribution remained uneven.

Overall, average illuminance at Building A remains below the 250 lux minimum standard (SNI 03-6575-2001) for most of the space. Only the perimeter zone consistently meets or approaches this standard, while more than half of the space remains in an underlit condition.

3.2.2 Building B

Illuminance measurements at Building B were conducted at three time periods: morning (10:20–10:30), midday (14:20–14:30), and afternoon (16:30–16:40). Results show significant variation in daylighting distribution both spatially and temporally.
In the morning, the highest illuminance values were found near the openings, reaching 575–943 lux, while the middle area ranged from 29–151 lux, and the deepest area showed very low values, approaching 0–37 lux. This indicates that natural lighting is still heavily dependent on proximity to openings and has not been evenly distributed.

At midday, lighting intensity increased significantly, particularly in the perimeter area with a maximum value reaching 676 lux and several other points ranging from 222–608 lux. However, most of the interior area remained low at 1–75 lux, indicating that the increase in light intensity was not accompanied by even distribution throughout the space.

In the afternoon, overall lighting intensity decreased. Maximum illuminance only reached approximately 230 lux, while most of the room area ranged from 0–25 lux, with several points at 0 lux. This indicates that in the afternoon, Building B experiences a significant daylighting deficit.

Overall, lighting distribution at Building B shows an uneven pattern with light concentrated near the openings and a drastic decrease in deeper areas. Compared to the SNI 03-6575-2001 standard (250 lux as minimum baseline), only a small portion of the area meets this criterion, primarily at midday in the perimeter zone. With reference to the GBCI standard (≥300 lux in at least 30% of the work area), Building B does not meet the requirement as most of the space falls below the specified illuminance threshold.

3.2.3 Building C

Illuminance measurements at Building C were conducted at three time periods: morning (09:40–09:50), midday (14:30–14:40), and afternoon (16:50–17:00). Results indicate that Building C has a relatively low natural lighting level with uneven distribution across all observation times.

In the morning, maximum illuminance values near the openings reached approximately 205–335 lux, while the middle area ranged from 30–79 lux, and the deepest area received only 0–17 lux. This indicates that daylighting is still limited and only effective in areas very close to the openings.

At midday, lighting intensity decreased compared to morning conditions, with maximum values only reaching approximately 88–140 lux. Most of the space ranged from 0–41 lux, with many points at 0 lux, indicating areas completely unreached by natural light.

In the afternoon, a slight increase occurred at some points with maximum values reaching 222 lux, but lighting distribution remained uneven. The middle area ranged from 10–88 lux, while the deepest area remained very low at approximately 0–7 lux.

Overall, Building C demonstrates the lowest daylighting performance compared to Buildings A and B. Illuminance values in most areas fall far below the SNI 03-6575-2001 minimum standard (250 lux as baseline). Even at its best, only a small portion of the perimeter area approaches this threshold. With reference to the GBCI standard (≥300 lux in at least 30% of the work area), Building C does not meet the requirement as almost the entire space falls below the specified illuminance values. Furthermore, the large number of points with 0 lux values indicates areas that are entirely dependent on artificial lighting.

Table 2 below summarizes average illuminance values per zone for all three buildings based on peak measurement hour conditions, as a quantitative comparison between study objects.

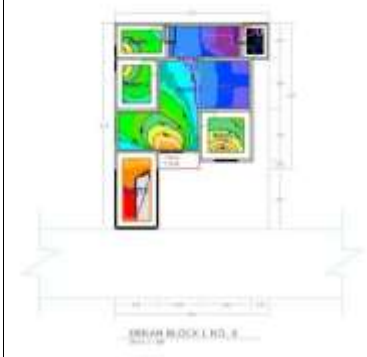
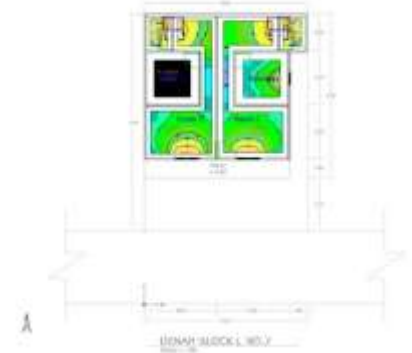
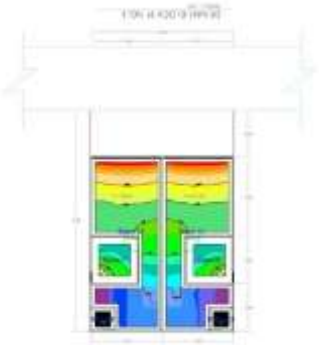
Zona (facade)	Building A (lux)	Building B (lux)	Building C (lux)
0–1,5 m	312	174	245
1,5–3,0 m	148	76	112

3,0–4,5 m	52	30	44
Average (all floors)	**171**	**93**	**134**

Table 2. Average interior illuminance per zone at peak hours (10:00–14:00)
Source : Personal Data, 2026

3.3 Daylighting Simulation Results (Dialux Evo)

Daylighting simulation results for the three buildings are presented in detail based on three observation time periods: morning, midday, and afternoon. With input for site opening orientations — North for Buildings A and B, and South for Building C — the results can be seen in the figures below.

Building A	Building B	Building C
Morning	Morning	Morning
		
Midday	Midday	Midday
		
Afternoon	Afternoon	Afternoon

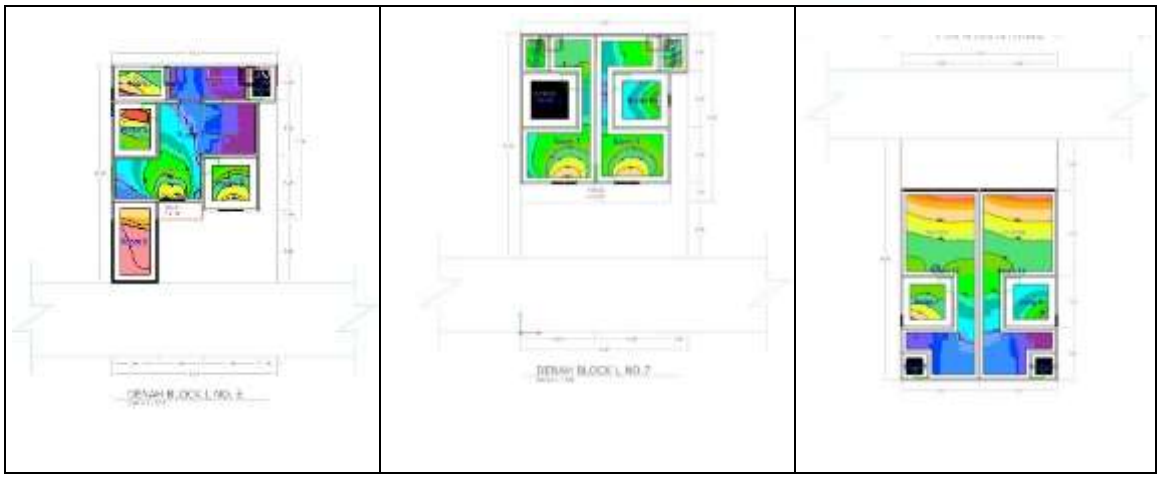


Figure 4: Dialux Software Simulation
Source: Personal Data, 2025

3.3.1 Building A

Daylighting simulation for Building A was conducted using Dialux Evo software, taking into account building geometry, opening size and position, and building orientation relative to the sun. Simulations were run at three time conditions — morning, midday, and afternoon — to observe the dynamics of daylighting distribution within the space.

In morning conditions, the daylighting distribution shows high illuminance concentration near the main openings, particularly in the terrace and front room zones. This is indicated by the dominance of yellow to red colors in these areas. Meanwhile, the middle area of the room shows moderate illuminance (green–blue), and the deepest areas such as the back room and bathroom are in a low condition (blue–purple). Morning light distribution is still limited and has not spread evenly throughout the space.

At midday, natural lighting intensity increases significantly. The area near the openings shows very high illuminance (red–orange colors), particularly in the front room and areas directly facing the openings. The middle area increases to the moderate-to-adequate category (green–yellow), but the deepest areas still show low values (blue–purple). This indicates that while intensity increases, light distribution is still not optimal.

In the afternoon, natural lighting intensity decreases compared to midday. The perimeter area still receives moderate lighting (green–yellow), but most of the middle and rear areas return to low conditions (blue–purple). Afternoon light distribution tends to be uneven and limited to areas near the openings.

Overall, Dialux simulation results show a lighting distribution pattern consistent with field measurement results — illuminance concentration near the openings and significant decrease toward interior areas. This indicates that Building A's opening configuration is not yet capable of distributing natural light evenly. In relation to SNI 03-6575-2001 (250 lux as minimum baseline) and GBCI (≥300 lux as sustainability target), simulation results show that

only the perimeter area has the potential to meet these standards, while most of the space remains below the required illuminance thresholds.

3.3.2 Building B

Daylighting simulation for Building B was conducted using Dialux Evo software, considering building geometry, opening position, and orientation relative to the sun. Simulations were run at three observation times — morning, midday, and afternoon — to observe the dynamics of daylighting distribution within the space.

In morning conditions (Figure 1B), the daylighting distribution shows relatively high intensity near the openings, particularly in the front rooms (Room 3 and Room 5) indicated by yellow to orange colors. The middle area of the building begins showing decreased intensity (green–blue), while enclosed rooms such as bedrooms (Room 2) are in very low or unreachable conditions (dark blue to black). This indicates that in the morning, natural lighting is strong enough but unable to reach all rooms.

At midday (Figure 2B), natural lighting intensity increases and light distribution becomes slightly more even compared to morning. Areas near the openings continue to show high illuminance (yellow–orange), while the middle area increases to the moderate category (green–cyan). However, some enclosed rooms such as bedrooms still show low illuminance conditions, indicating lighting distribution barriers due to room configuration.

In the afternoon (Figure 3B), natural lighting intensity decreases compared to midday. The perimeter area still receives moderate lighting (green–yellow), but most of the middle area and enclosed rooms return to low conditions (blue). The distribution pattern indicates that natural lighting becomes increasingly limited as the solar angle decreases.

Overall, simulation results show that Building B has relatively high lighting intensity in certain areas but uneven distribution. This is marked by high contrast between bright areas (near openings) and dark areas (enclosed rooms and interior sections). Compared to SNI 03-6575-2001 (250 lux as minimum baseline), only areas near the openings have the potential to meet this standard. With reference to the GBCI standard (≥300 lux in at least 30% of the work area), Building B does not meet the criteria as lighting distribution cannot reach most of the space.

3.3.3 Building C

Daylighting simulation for Building C was conducted using Dialux Evo software, considering building geometry conditions, opening configuration, and orientation relative to solar movement. Simulations were run at three time conditions morning, midday, and afternoon to observe changes in daylighting distribution within the space.

In morning conditions (Figure 1C), daylighting distribution shows high intensity near the main openings, particularly in the front rooms (Room 11 and Room 12), indicated by red to yellow colors. The middle area shows moderate illuminance (green–cyan), while the rear areas of the building such as service rooms and bathrooms are in low conditions (blue–purple). This indicates that natural lighting is only effective in the perimeter area and has not yet reached all rooms.

At midday (Figure 2C), daylighting distribution becomes more even compared to morning. The front area maintains high illuminance (yellow–orange), while the middle area increases to the moderate category (green). However, the deepest areas of the building remain in low conditions (blue), indicating that natural light penetration is still limited.

In the afternoon (Figure 3C), natural lighting intensity decreases slightly, but the light pattern distribution is relatively similar to midday conditions. The perimeter area still receives moderate to high lighting, while the middle and rear areas remain in low conditions. This indicates that despite changes in light incident angle, lighting distribution does not show significant improvement.

Overall, simulation results show that Building C has more stable lighting distribution compared to Building B, but still experiences a lighting deficit in interior areas. High lighting intensity only occurs near the openings, while most rooms do not receive adequate natural light. Compared to SNI 03-6575-2001 (250 lux as minimum baseline), only some front areas meet or approach this standard. With reference to the GBCI standard (≥300 lux in at least 30% of the work area), Building C does not meet the criteria as lighting distribution does not cover most of the space.

3.4 Simulation Validation Against Field Measurements

3.4.1 Building A

Comparison between Dialux simulation results and field measurements shows similar lighting distribution patterns, particularly in terms of illuminance concentration near the openings and intensity reduction in interior areas. Although there are differences in illuminance values at some points, these differences remain within the acceptable tolerance range (±10–15%). This indicates that the simulation model used is sufficiently representative in describing actual daylighting conditions at Building A. Thus, Dialux simulation can be used as an analytical tool to evaluate daylighting performance and formulate more optimal design strategies.

3.4.2 Building B

Comparison between Dialux simulation results and field measurements shows agreement in natural lighting distribution patterns, particularly in terms of high illuminance concentration near the openings and significant decreases in interior areas. Field measurement results

showed very high illuminance values in certain zones and very low values in other areas; this contrast pattern is also visible in simulation results. The difference in illuminance values between simulation results and field measurements remains within the acceptable tolerance range (±10–15%), so the simulation model is considered sufficiently representative in describing actual daylighting conditions at Building B.

3.4.3 Building C

Dialux simulation results for Building C show a lighting distribution pattern consistent with field measurement results. Areas near the openings show higher illuminance, while middle and rear areas experience significant intensity reduction. Field measurements also showed that most points fall below the minimum illuminance standard, reinforced by simulation results showing dominant blue coloring in interior areas. The difference in values between simulation results and field measurements remains within the acceptable tolerance range (±10–15%), so the simulation model is considered sufficiently representative in describing daylighting conditions at Building C.

3.5 Compliance with SNI and GBCI Standards

Based on simulation results and field measurements, quantitative compliance analysis against both standards was conducted. Calculated Daylight Factor values averaged 1.2% for Building A, 0.7% for Building B, and 0.9% for Building C — all below the GBCI minimum standard of 2% and far from the tropical ideal range of 2–5%. The percentage of floor area achieving illuminance ≥300 lux (GBCI sustainability target) was 18% for Building A, 6% for Building B, and 12% for Building C; none met the minimum requirement of 30% of the work area. Compliance with the SNI threshold (250 lux as minimum functional baseline) was only achieved in the perimeter zone: 26% of Building A's floor area, 9% of Building B's, and 17% of Building C's. Overall, 72% of measurement points across the three buildings failed to reach the minimum commercial illuminance standard of 250 lux.

Artificial lighting was found to operate an average of 9.2 hours per day at Building A, 11.4 hours at Building B, and 10.1 hours at Building C, corresponding to estimated electrical lighting energy consumption of 4.3, 5.8, and 5.1 kWh/day respectively. These values represent a significant operational cost burden that could be partially reduced with improved daylighting provision.

4. DISCUSSION

4.1 Causes of Daylighting Deficit

The pronounced daylighting deficits documented across the three case study buildings can be attributed to three interrelated factors. First, effective opening areas in all cases fall below the SNI-recommended 10% of floor area for daylit commercial spaces. The original type-36

residential design provided glazing ratios of approximately 12–15% for domestic use, but commercial conversions systematically reduced these through the addition of opaque signage, display shelving mounted over windows, and storage partition construction that blocks secondary openings.

Second, interior surface reflectance in all three buildings falls below the 50% threshold generally recommended for daylighting optimization. Commercial tenants frequently apply dark-colored paint or vinyl wrapping to interior walls for branding purposes, reducing the capacity of available natural light reflected to illuminate deeper interior zones. Third, the absence of light-redirecting elements means that available sunlight entering through façade openings illuminates only the perimeter zone, creating a sharp illuminance gradient such that the rear half of each building is practically unusable without artificial lighting.

4.2 Influence of Orientation

Building orientation emerged as a significant modulating factor, consistent with findings from tropical daylighting studies in comparable climates (Ruck et al., 2000; Heschong, 2003). Buildings A and B, both north-facing, benefit from diffuse sky illuminance without excessive direct solar penetration, reducing glare risk and thermal load. Building A achieved the highest average illuminance of the three units, supported by its larger floor area (76 m^2) and better effective opening proportion. Building B, despite having the same orientation as Building A, performed lower due to the combination of the smallest effective opening area (5.2%) and the shading effect of an adjacent building obstructing the façade at certain hours. Building C, south-facing with the largest floor area (99 m^2), receives more intense direct solar exposure throughout the day in the tropical climate, but without adequate light-redirecting elements, this condition actually creates a sharp illuminance gradient between the perimeter and deep interior zones, resulting in uneven distribution performance.

4.3 Implications for Sustainability

The high dependence on artificial lighting documented in this study has direct implications for building energy performance and urban sustainability. At the individual building scale, electrical lighting energy represents a fixed operational cost that reduces the economic viability of small commercial businesses. At the urban scale, the cumulative artificial lighting load from thousands of informally converted residential units contributes to peak demand pressure on the city's electricity grid.

These findings support the argument that daylighting performance should be explicitly integrated into local government guidelines for residential-to-commercial conversion permits. Currently, Pekanbaru's building permit regulations do not specify illuminance performance requirements for function change applications, and façade modifications are approved primarily based on structural safety and setback compliance rather than environmental performance.

4.4 Retrofitting Strategies

Three primary retrofitting strategies are recommended based on simulation modeling of enhanced configurations. First, light shelves installed at lintel height (2.0–2.2 m) above the main façade openings can redirect high-angle sunlight to the ceiling plane, extending effective natural light depth by 40–60% compared to unmodified conditions. Simulation of Building A with an 0.8 m internal light shelf and corresponding ceiling reflectance increase to 70% yielded an average floor illuminance of 238 lux — approaching the SNI 250 lux threshold.

Second, modular skylights or transparent roof panels inserted into the existing concrete roof slab can introduce highly effective zenithal natural light at tropical latitudes where solar angles are high year-round. A 1.5 m^2 skylight positioned above the rear zone of each case study building was simulated to increase rear zone illuminance from below 50 lux to 180–220 lux, substantially improving overall building compliance.

Third, replacing opaque interior partitions with transparent polycarbonate or frosted glass panels allows natural light to propagate from the perimeter zone to secondary interior spaces while maintaining the visual privacy expected by commercial users. This strategy is particularly effective in buildings where storage or preparation areas occupy the rear zone and where partition transparency would not compromise merchandise security.

In combination, these three strategies are estimated through simulation to bring 68–74% of the case study buildings' floor area into compliance with the SNI 300 lux threshold, thereby meeting the GBCI daylighting credit criteria and reducing artificial lighting operating hours by an estimated 35–48%.

5. CONCLUSION

This study has documented daylighting performance deficits resulting from the informal conversion of type-36 residential buildings to commercial use in Pekanbaru City, Riau Province, Indonesia. Field measurements and Dialux Evo simulations show that 72% of measurement points across three representative case study buildings failed to meet the SNI 03-6575-2001 minimum illuminance standard of 250 lux — used as the minimum visual comfort baseline — for commercial spaces. Average Daylight Factor of 0.7–1.2% across the three buildings falls far below the GBCI minimum threshold of 2.0% and the tropical ideal range of 2–5%, indicating significantly suboptimal daylighting performance. None of the buildings managed to meet the GBCI requirement of at least 30% of the work area with illuminance ≥300 lux as the sustainability target. The main causes of this deficit are the reduction of effective opening area below 10% of floor area, low interior surface reflectance, and the absence of light-redirecting elements.

Three retrofitting strategies — light shelves, modular skylights, and transparent interior partitions — are proposed and validated through simulation. In combination, these interventions are estimated to bring 68–74% of floor area into SNI/GBCI compliance and reduce artificial lighting energy consumption by 35–48%, demonstrating the technical feasibility and economic rationality of daylighting retrofitting for this building typology.

These findings underscore the need for daylighting performance criteria to be integrated into local building permit regulations governing residential-to-commercial conversions. Future research should expand the sample size across various housing typologies and climatic sub-zones within Riau Province, and quantify the life-cycle benefit-cost profiles of the proposed retrofitting strategies to support evidence-based policy formulation.

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