SEMARAK ILMU PUBLISHING

Journal of Advanced Research in Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.com.my/journals/index.php/applied_sciences_eng_tech/index
ISSN: 2462-1943

Natural Daylighting Assessment on Theoretical Innovative Housing Window in Malaysia

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ABSTRACT

Installation of a bolted window grille in residential building has become a common practice in Malaysia with the aim to improve security aspect, especially against burglary. This feature however resulted in several problems: reducing opportunity to view surrounding outside, affecting building aesthetic, and blocking emergency exit. A theoretical innovative window was proposed to address the issues. The purpose of the research is to assess the performance of the innovation towards natural daylighting. Discussions were conducted with JBPM and local authority to understand legal perspectives of the innovation. Window to Floor Ratio (WFR), Window to Wall Ratio (WWR), and Average Daylighting Factor (ADF) were investigated through *Sefaira* building simulation. 3 guidelines were referred in this research: MB206 – Approval Form to Construct a Small-scale Building (MB), UBBL 1984, and Malaysian Standard MS 2680: 2017. 7 models were constructed to identify the performance of the innovation in every possible form and operation. Overall, there are several operations of the innovation were failed to sustainably perform. With a small alteration involving materials and dimensions, the innovation can successfully allow natural daylighting to take place.

Keywords:

Innovation; Window; Security; Residential; Natural daylighting; Simulation; Sustainability; Performance; Malaysia

1. Introduction

In Malaysia, it has become a norm and tradition, especially for the landed house dwellers to install a bolted window grille in their properties. The feature is undisputedly reliable against burglary, and based on a survey conducted, 85% of the respondents agree that the installation of the grille is necessary for security purposes [1]. It was also supported from a report by Goh and Ahmad which mentioned that house safety is the most important factor determining the quality of a residential building [2]. This research is a continuity from a recent paper: 'Addressing Security and Architecture through Proposing Innovative Idea on Landed Housing Windows' by Mohd Rodzi, Osman, Mohd Siraj. According to the paper, conventional window grille possesses

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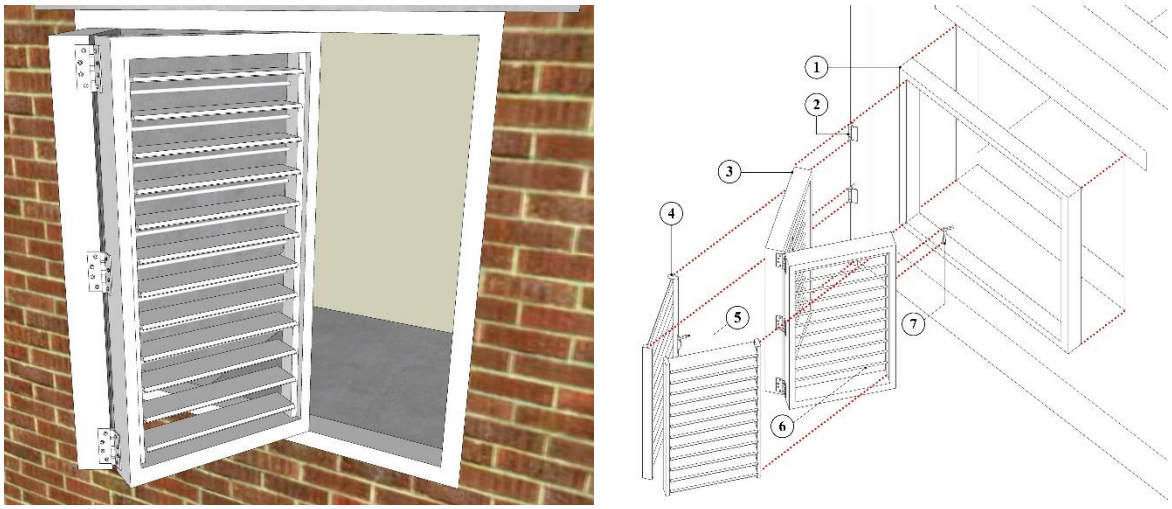
https://doi.org/10.37934/araset.57.2.220233

drawbacks: reducing opportunity to view surrounding outside, affecting building aesthetic, and issue on the emergency exit. The paper also has discussed an innovative idea on landed housing window that tackles the issues mentioned above, as well as increasing security aspect of a house against burglary. A prominent example can be seen in 2017 where bolted window grills in Pusat Tahfiz Darul Quran Ittifaqiyah had blocked the emergency exit of the students inside during fire outbreak [3]. Figure 1 below shows the design suggested.



(a) (b)

Fig. 1. The design of the innovative window. (a) View from the outside. (b) Components involved in the design

There was no glass included in the proposed design. Researchers believe the application of the material can increase the risk of burglary. This idea emerged from Abd. Malek *et al.,* where burglary can be prevented through 3 suggested methods, and one of them is understanding behaviour of a burglar [4]. It is extremely crucial to limit visibility towards valuable things inside of the house from the outside. Reducing this burglary ideation can be achieved through replacing glazing with opaque and solid materials.

The design has partially changed the façade of a building. This façade changes not just improving the aesthetic aspect, but an important factor determining daylighting, ventilation, thermal comfort, and total energy required to heat and cool the entire room [5]. The design is a foldable frame with adjustable louvres sub-frame, supported by cylindrical steel to increase the strength and minimize risk of burglary. It was suggested that occupants of a building prefer movable shading strategies which allow desirable solutions, both in minimizing energy demand and maximizing daylight utilization [6,7]. The energy consumption aspect was also considered as the third most important aspect among dwellers [2]. The aim of the research is to discuss the sustainability performance of the innovative window through lens of natural daylighting acceptance. This sustainability assessment is important to ensure the window is not just addressing security aspect, but able to serve its purpose and provide comfort to the inhabitants.

2. Methodology

To conduct this research, researchers have conducted a literature review to understand several aspects:

i. The importance of natural daylighting in residential building context.
ii. To understand perspective, behaviour, and *modus operandi* of a burglar.
iii. To understand norm and culture of a housing dweller, especially relating to doors, windows, and grille installation.
iv. To understand legal aspect and standard set by authorities on security and natural daylighting.
v. The conceptual understanding of the innovative housing window in relation to natural daylighting permission.

Other than that, meetings with authorities, such as Jabatan Bomba dan Penyelamat Malaysia (JBPM) and Bahagian Senibina & Inspektorat Bangunan, Perbadanan Putrajaya (PPJ) representing local authorities were held to understand the perspectives of legal aspect in the innovative housing window. Discussion was conducted with JBPM because they are responsible body in giving approval to building plan in regard of safety and firefighting strategy. The discussion was conducted specifically with PPJ due to higher focus and demand from the authority compared to other local authorities regarding aesthetic, passive design strategies, and percentage of compliance to the natural daylighting and natural ventilation.

For the sustainability assessment, performance of the window is perceived through the lens of natural daylighting. The natural daylighting of the innovative window is assessed through window to floor ratio (WFR), window to wall ratio (WWR), and Average Daylighting Factor (ADF). Mixed method analysis is conducted through simulation where MB206 – Approval Form to Construct a Small-scale Building (MB), Uniform Building by Law 1984 (UBBL 1984) and Malaysian Standard MS 2680: 2017 are referred to identify the performance level. Simulation software adopted in the research is *Sefaira* Building Simulation on a model generated in a Sketchup software. Figure below summarizes the methodology used throughout the research.

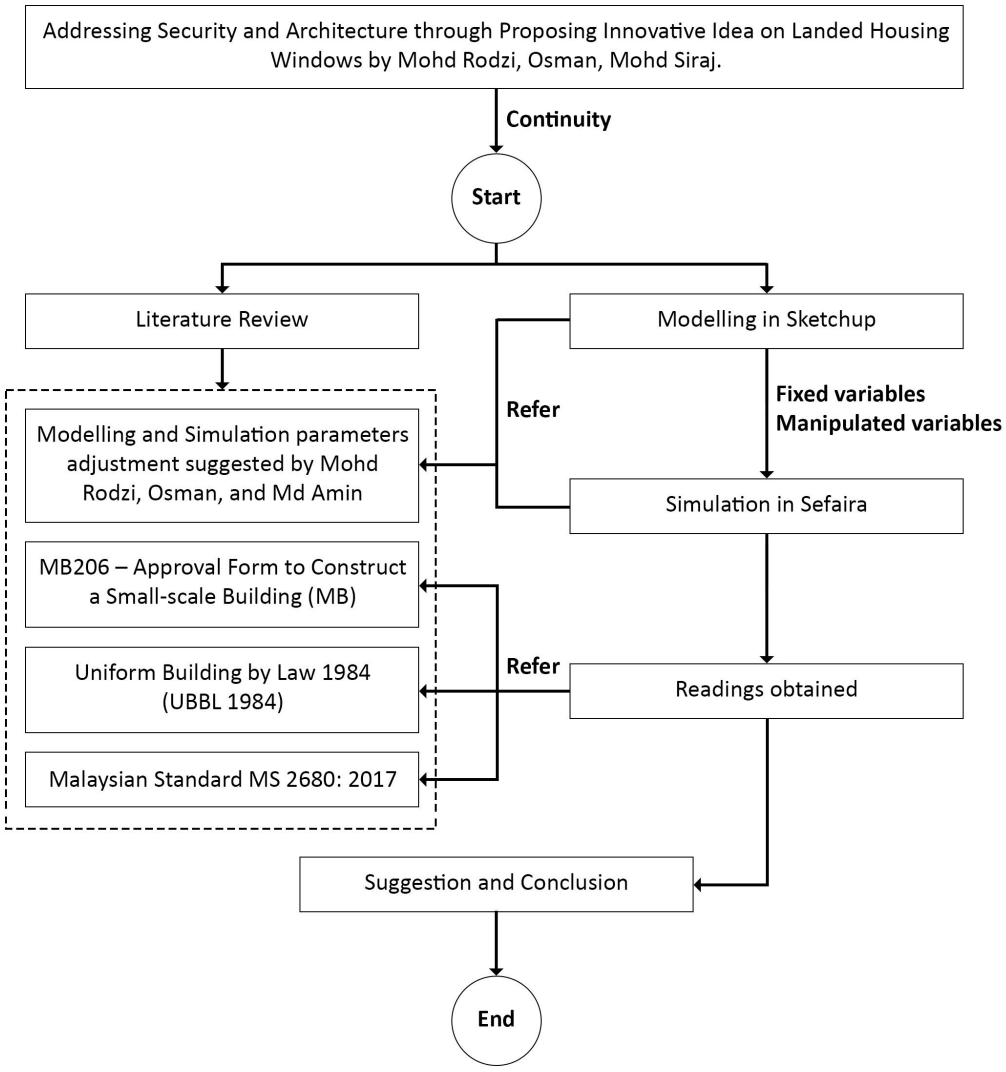


Fig. 2. Methodology conducted throughout the research

3. Literature Review

During the post-pandemic era, people are spending more hours in a house and some of the works that used to be done in the office can be executed in the house. In fact, it has become a norm where the house is already regarded as a home-office place. Thus, ensuring an adequate natural daylighting in a residential building have become an essential topic. Based on Mardaljevic, daylight illumination inside of a building is important to promote human health and well-being [8]. Windows and doors were regarded as means of penetration of the natural daylighting and natural ventilation, thus, making these features are extremely important. However, the features also become an opportunity for burglary. Residential dwellers are required to install grille on windows and doors to enhance security aspect without compromising natural daylighting and natural ventilation [2]. According to Jing *et al.,* the researchers have outlined four basic principles in improving the security level of a residential area and one of them is target hardening. The application of walls and fences, burglary-proofed doors and windows are important to ensure they are invulnerable to the burglary [9]. It was reported that landed house possesses 15% more likely to be burglarized than high-rise building, due to higher number of doors and windows [10]. Even though there are lot of strategies suggested by Abd Malek *et al.,* such as empowering Rukun

Tetangga, increasing the numbers of streetlamp, etc. [4], single approach seems inadequate. As suggested by experts, combination of various approaches, both community level and individual level are required to effectively prevent burglary [10].

On the individual level, foldable louvre frame window is suggested, not just a tool to increase security level, but to allow inhabitants to adjust the desirable daylighting to take place inside of the house. According to item (1) under by-law 39: natural daylighting and ventilation, every habitable room must be equipped with a window that provides not less than 10% and 5% of the floor plan area for natural daylighting and natural ventilation respectively (WFR) [11]. Based on Mohd Sahabuddin and Gonzalez-Longgo, a different approach was taken which is total opening areas to total external wall areas (WWR), where 15% – 25% is the value suggested [12].

4. Finding and Analysis

The innovation idea was initiated to promote security for the inhabitants from burglary, and at the same time provide opportunity for the dwellers to view surrounding outside, preserve the aesthetic of the house, and act as an exit point during emergency events. Thus, it is important to assess the performance of the innovation to ensure it can serve the purpose as a window.

Comparative study was conducted to compare the performance of the innovative window to a standard window and a window with bolted grill. These windows were used as a benchmark to identify the performance of the innovative window. There are seven models that were simulated where:

i. Model 1: Standard window
ii. Model 2: Standard window with a bolted grill
iii. Model 3: Innovative window – completely shut
iv. Model 4: Innovative window – completely opened
v. Model 5: Innovative window – partially opened
vi. Model 6: Innovative window – closed frame and completely opened louvres
vii. Model 7: Innovative window – closed frame and partially opened louvres.

These experiments were run to identify the performance of the innovative window in every possible form and operation. There are several factors that were maintained and adjusted to ensure the reading is consistent throughout the process. The dimensions of rooms accommodating the windows were maintained, which is 3.1 m x 3.1 m, reflecting to the standard room size in a residential building. The sill height and window size were also fixed throughout every model, referring to the standard size which is 0.9 m and 1.2 m x 1.2 m respectively. Building orientation plays a big factor in exposure and acceptance of the sunlight, solar radiation, and direct hit gain [13]. Thus, orientation of the models was maintained throughout the process, where the windows were modelled towards the North (0º towards the North).

In this section, there are three sub-sections included: legal requirements understanding from the discussions with the authorities, and natural daylighting assessment through window to floor ratio (WFR), window to wall ratio (WWR), and average daylighting factor (ADF).

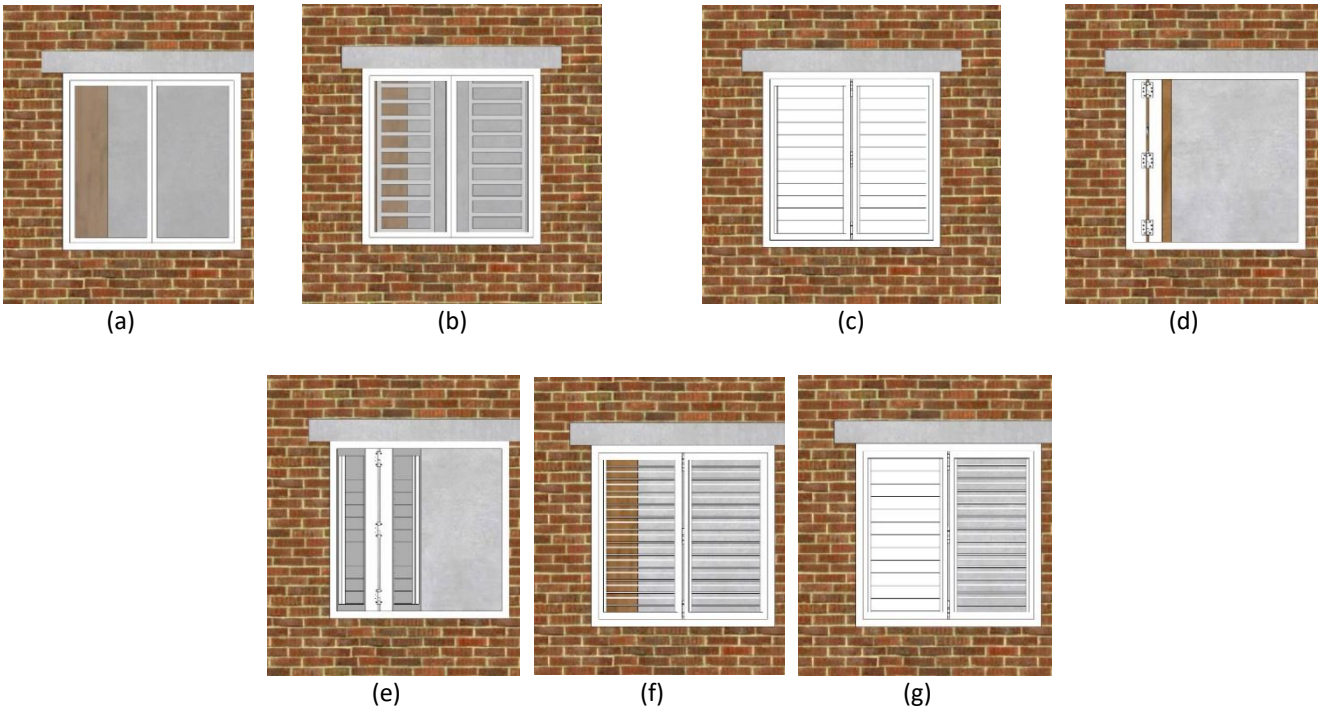


Fig. 3. Perspective images of the model. (a) Model 1 (M1). (b) Model 2 (M2). (c) Model 3 (M3). (d) Model 4 (M4). (e) Model 5 (M5). (f) Model 6 (M6). (g) Model 7 (M7)

Table 1
The experimented models with the respective operations

Model	Name	Operation
Model 1 (M1)	Standard Window	Nil
Model 2 (M2)	Standard Window with Bolted Grill	Nil
Model 3 (M3)	Innovative Window – Completely Shut	The frames and the louvres of the innovative window are completely shut
Model 4 (M4)	Innovative Window – Completely Opened	The frames of the innovative window are completely opened.
Model 5 (M5)	Innovative Window – Partially Opened	The frames of the innovative window are partially opened.
Model 6 (M6)	Innovative Window – Closed Frame and Completely Opened Louvres	The frames are completely shut and the louvres on both frames are opened.
Model 7 (M7)	Innovative Window – Closed Frame and Partially Opened Louvres	The frames are completely shut and the louvres on one frame are opened.

The innovation was designed with typical dimensions, which are 1.2 m x 1.2 m, which are equivalent to 1.44 m². However, the design possesses multiple modes of operation and hence, providing a spectrum reading of opening area for natural daylighting and ventilation that can take place in a room.

In this research, the louvres were adjusted with 90º opening. This value was reflected in a case study by Sern *et al.,* where the angle performed the highest Daylight Factor (DF) and Average Daylight Factor (ADF) on a row 1 – 4 [14]. The comparison was made only from VB1 to VB4 to demonstrate the operation limit of the innovative window louvres. The figure and equation below show the method taken for calculating the innovative window opening.

(a) (b)

Fig. 4. Perspectives of the innovative window design idea. (a) Section view indicating 'y' as the height of the opening. (b) Elevation view indicating 'z' as the width of the opening

$$A = (y \times 12) \times z \quad (1)$$

From the equation, *y* and *z* is the vertical and horizontal opening respectively. 12 is the numbers of vertical opening and this value could be varies depending on the height of the window. In this research, the single closed windowpane with opened louvres can results in 0.58 m² opening.

4.1 Legal Requirements

According to by-law 42: minimum area of rooms in residential building, there are three room types with designated minimum floor plan area [11]. The table below summarizes the relationship between the room area and the opening area required, based on a minimum 10% requirement for natural daylighting to take place.

Table 2
Relationship between minimum floor plan area and minimum window size required [11]

Room	Minimum floor plan area (sq.m)	Minimum window size required (sq.m)
1	11	1.1
2	9.3	0.93
3	6.5	0.65

Other than that, feedback from Jabatan Bomba dan Penyelamat Malaysia (JBPM) and local authority are also important to understand legal requirements of a window in a residential project. Meetings were held with officers from those two legal bodies and discussions were conducted to understand the applicable of the innovative window in a house.

4.1.1 Jabatan Bomba dan Penyelamat Malaysia (JPBM)

In general, there is no issue raised from the JBPM regarding the design of the innovative window. JBPM has issued guidelines for grille installation in residential houses. Even though the innovation is not a substitute to the existing window grille, the fundamentals remain the same.

According to the guidelines, residents are strongly advised not to install any permanent bolted grille because it will block exit points during emergency events such as fire outbreak. However, if the installation is required for 'security' purposes, the grille must be easily opened from the inside for 'safety' reasons [15]. The grille should be:

i. A keyless opening procedure. It can be easily opened from inside of the house during emergency events.
ii. Grille opening procedure can be done by all age groups.
iii. Affordable installation and maintenance costs.

Any innovation to substitute the conventional window and grille is allowed. However, the innovation needs to comply with the requirements set in the guidelines. The cost for the installation and maintenance of the innovation needs to be addressed to ensure it is affordable for the majority of residents.

4.1.2 Local authority

A discussion was conducted with the officers from Bahagian Senibina dan Inspektorat Bangunan, Jabatan Perancangan Bandar, Perbadanan Putrajaya (PPJ). According to Calculation Schedule Standards of 10% Natural Lighting & Ventilation, and 5% Unobstructed Air Path (UPA) For Residential / Commercial Buildings under MB206 – Approval Form to Construct a Small-scale Building (MB), it is mentioned clearly that there is no obstruction for the air flow and the air can circulate easily through cross-ventilation with the application of fixed-louvres window [16]. Here, casement windows are considered insufficient to allow natural ventilation, and should be replaced with either fixed-louvres or top hung windows. With the application of the adjustable louvres that promote natural daylighting and natural ventilation, as well as preserving the aesthetic value of a building, the innovation idea was considered 'desirable' to PPJ.

4.2 Natural Daylighting

The innovative design which made up from non-glazing materials offers an advantage to the dwellers from the risk of solar heat gain. It is an adjustable louvre that act as a shading device in a foldable frame. According to Kilic and Yener, shading device plays a significant role on the daylight availability alongside window wall ratio (WWR) and glazing type [17]. Furthermore, the presence of the shading device can effectively reduce the solar heat gain on the façade [18]. The natural daylighting of the innovative window is assessed through window to floor ratio (WFR), window to wall ratio (WWR), and Average Daylighting Factor (ADF).

4.2.1 Window to floor ratio (WFR)

It is suggested that a habitable room in a residential building requires 10% window size to the total floor plan area to allow natural daylighting to take place. Most of the authorities do not pay attention to the window type, except PPJ. Table 3 below shows the percentage of the opening area of the experimented models to the floor plan area.

Table 3
The relationship between opening area and floor plan area

Model	Opening Area (m^2)	Floor Plan Area (m^2)	Opening Area to Floor Plan Area (%)
M1	1.44	10.24	14.06
M2	1.44	10.24	14.06
M3	0	10.24	0
M4	1.44	10.24	14.06
M5	0.72	10.24	7.03
M6	1.16	10.24	11.33
M7	0.58	10.24	5.66

Based on the Table 3 above, it can be seen that every innovative window models (M3 – M7) possess a minimum WFR suggested in the UBBL 1984 except M3, M5, and M7. This flaw however can be argued with time, inhabitancy mode, and spectrum of permissible natural daylighting. M3 can be applied during nighttime where there is no need for natural daylighting. The innovative window should be completely shut during this time to avoid visibility from the outside, and hence promoting security aspect from the burglar. The innovative window also provides multiple modes of operation depending on the inhabitancy mode. M3, M5, and M7 can be applied when the dwellers are away from the property or away from the room. This inhabitancy modes do not require any natural daylighting to take place without jeopardising the security aspect. These multiple modes of operation also promote a spectrum of permissible natural daylighting. The design allows the dwellers to manually adjust their desirable daylighting and hence provides comfort to the individuals.

4.2.2 Window to wall ratio (WWR)

According to Mohd Sahabuddin and Gonzalez-Longgo, recommended value for opening area to external wall facing an open space is 15 – 25% [12]. The value is not much different compared to McCormick *et al.,* who suggested 25% is the optimum value for the WWR [19]. The higher value of WWR can promote better natural ventilation. A building that was equipped with larger opening will allow prevailing wind to circulate inside of the room. However, larger openings can also increase the risk of solar radiation penetration [18]. Careful consideration needs to be made to ensure natural daylighting and ventilation can be equally celebrated without jeopardizing the comfort of the dweller. Table 4 below summarizes the innovative design to the percentage of WWR offered.

Table 4
The relationship between opening area and external wall area

Model	Opening Area (m^2)	Floor Plan Area (m^2)	Opening Area to External Wall Area (%)
M1	1.44	7.75	18.58
M2	1.44	7.75	18.58
M3	0	7.75	0
M4	1.44	7.75	18.58
M5	0.72	7.75	9.29
M6	1.16	7.75	15
M7	0.58	7.75	7.48

From the table above, M1 and M2 have set a benchmark of standard WWR, which is 18.58%, 3.58% above minimum recommended value. On the other hand, the theoretical innovative design performs a range of WWR, from 0% to 18.58%, where M3, M5, and M7 recorded lower than 15%. This generally shows that the innovative design provides better daylighting penetration to the

inhabitants, where the louvres act as a shading device resulting in shady space for the room. Even though the design encountered an issue regarding natural ventilation, it can be supported by mechanical systems. The experts have mentioned that the air movement in tropical climate is inadequate and still needs to be supported by active systems. These systems are important to ensure the inhabitants can achieve indoor thermal comfort [20-22].

4.2.3 Average daylighting factor (ADF)

Recommended ADF that was suggested in the Malaysian Standards MS 2680 was used as a reference in identifying the response of the innovative window towards the natural daylighting aspect. Table 5 below shows the ADF percentage suggested [23].

Table 5
Daylight Factors and Impact [23]

DF (%)	Lighting	Glare	Thermal Comfort
> 6.0	Intolerable	Intolerable	Uncomfortable
3.5 – 6.0	Tolerable	Uncomfortable	Tolerable
1.0 – 3.5	Acceptable	Acceptable	Acceptable
< 1.0	Perceptible	Imperceptible	Acceptable

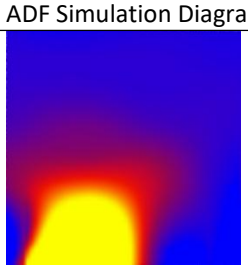
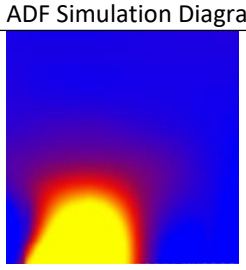
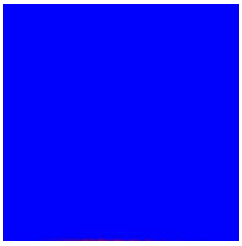
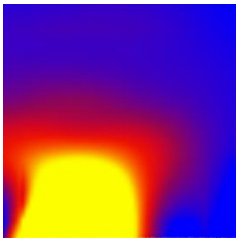
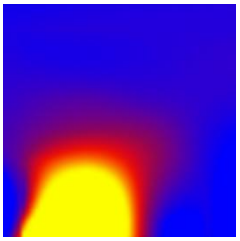
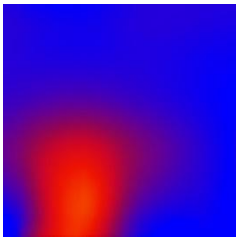
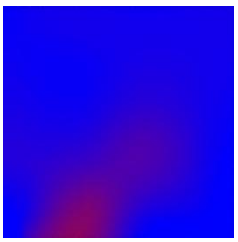
Simulation and 3D modelling was conducted through *Sefaira* Building Simulation and Sketchup respectively. Sky condition was maintained in the simulation process where clear blue-sky type was used. Furthermore, building typology, location, material, and *Sefaira* simulation baseline which is ASHRAE 90.1 – 2019 were also fixed throughout the process. The table below summarizes the parameter details adjusted in the software as suggested by Mohd Rodzi, Mohamoud, and Md Amin.

Table 6
Simulation parameters adjustment for the assessment

Parameters	Adjustment		Recommendation
	Value/ Type	Level	
Typology	Residential		The parameter should be reflected to typology of the buildings
Location	Kuala Lumpur, Malaysia		The parameter should be reflected to location of the buildings.
Baseline	ASHRAE 90.1 - 2019		This is the updated recommended baseline.
ASHRAE Climate Zone	0 (Malaysia)		The climate zones are based on the location of the buildings.
Wall Insulation	56.79	Well Insulated	Even though the wall is not insulated, researcher can adjust the parameter to the maximum value.
Floor Insulation	56.79	Well Insulated	Even though the floor is not insulated, researcher can adjust the parameter to the maximum value.
Roof Insulation	56.79	Well Insulated	Even though the roof is not insulated, researcher can adjust the parameter to the maximum value.
Glazing U-Factor	0.71	1 Pane	The parameter should be reflected to the glazing U-Factor: 1 pane, 2 panes, or 3 panes.
Visible Light Transmittance	0.67	1 Pane	The parameter should be reflected to the glazing's visible light transmittance: 1 pane, 2 panes, or 3 panes.
Solar Heat Gain Coefficient	0.21	Reflective	The parameter should be reflected to the glazing's solar heat gain coefficient: clear single glazing, clear double glazing, reflective, or internal blinds.
Infiltration Rate	0.28	Normal Practice	This is the recommended infiltration rate.
Ventilation Rate	47.68	High	The parameter is not relatable to daylighting analysis.

Equipment	0.46	Ventilation Excellent	The parameter is not relatable to daylighting analysis.
Lighting	0.93	Good	The parameter is not relatable to daylighting analysis.

Table 7
Summary of the daylight simulation and ADF % obtained

Model	ADF Simulation Diagram	ADF (%)	Model	ADF Simulation Diagram	ADF (%)
Model 1 (M1) (*benchmark*)		2.18	Model 2 (M2) (*benchmark*)		1.54
Model 3 (M3)		0	Model 4 (M4)		3.29
Model 5 (M5)		1.98	Model 6 (M6)		0.86
Model 7 (M7)		0.35			

Based on the summary above, there are several inputs that can be taken. Model 1 and Model 2 were set as a benchmark to compare the performance of the innovative window. In general, based on the Table 5 adopted from the Malaysian Standard MS 2680, standard glass window provides an adequate amount of natural daylighting, glare, and thermal comfort to the inhabitants. The installation of the grill insignificantly reduces the ADF percentage. On the other hand, innovative window provides multiple operation and hence, lead to spectrum of ADF results.

Models 3, 4, and 5 involve in multiple operation of window frames, where Models 6 and 7 perform different operations involving window louvres. Model 3 blocking entire daylighting and results in 0% ADF. This result however could be argued where the operation of this innovative window only applicable to several situations: inhabitants are away from the house, and during night-time. In contrast, Model 4 and 5 shows the innovative window performing 100% and 50% of frame opening respectively. Those models able to provide adequate and acceptable daylighting amount to the inhabitants, where Model 4 allows 3.29% and Model 5 (1.98%). Louvres opening shown on the Models 6 and 7 unable to perform as a window. With the low ADF recorded, the

innovative window operations could only provide sufficient amount of thermal comfort to the inhabitants. Figure below shows the graph of the ADF percentage in relation to the percentage of innovative window's frame and louvres opening.

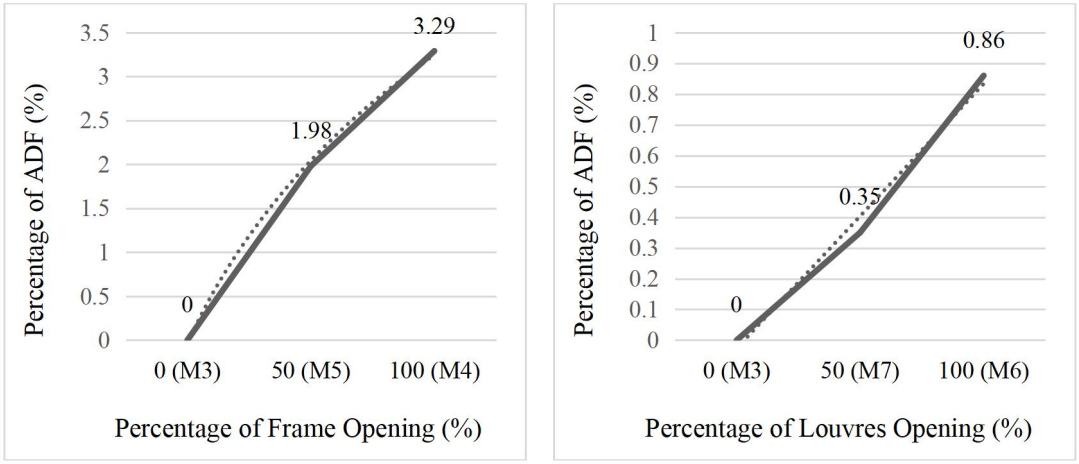


Fig. 5. Relationship between ADF percentage to innovative window operations. (a) Percentage of ADF to the frame opening. (b) Percentage of ADF to the louvres opening

5. Conclusion

From the research conducted, it can be concluded that the theoretical innovative housing window possesses multiple mode of operation and hence lead to spectrum reading of natural daylighting allowed. Table 8 below summarizes the analysis.

Table 8
Summary of the performance of innovative window design idea

Model	Opening Area (m²)	WFR (%)	WWR (%)	ADF (%)	ADF Impact			Compliance to 10% Natural Daylighting
					Lighting	Glare	Thermal Comfort	
M1	1.44	14.06	18.58	2.18	Acceptable	Acceptable	Acceptable	Yes
M2	1.44	14.06	18.58	1.54	Acceptable	Acceptable	Acceptable	Yes
M3	0	0	0	0	Perceptible	Imperceptible	Acceptable	No
M4	1.44	14.06	18.58	3.29	Acceptable	Acceptable	Acceptable	Yes
M5	0.72	7.03	9.29	1.98	Acceptable	Acceptable	Acceptable	No
M6	1.16	11.33	15	0.86	Perceptible	Imperceptible	Acceptable	Yes
M7	0.58	5.66	7.48	0.35	Perceptible	Imperceptible	Acceptable	No

From the table above, closed windowpanes can cause natural daylighting insufficiency. However, with the easy mechanism operation, a dweller can adjust the window opening according to his desirable conditions and inhabitancy mode. This study provides insight to the researchers on several aspects:

i. No overhang required because the innovative window can act as a self-shading device to the room.
ii. The materiality of the louvres needs to be reconsidered because there is an issue with ADF impact on lighting and glare. Opaque materials can be replaced with transparent or translucent materials to enhance the natural daylighting. Combination of opaque and

transparent materials is important to ensure the innovation celebrates the natural daylighting without compromising the security aspect.

iii. The overall size of the theoretical innovative window frame needs to be enlarged, reflecting the recommended WWR to support the natural ventilation.

The research is focussing on the daylighting aspect as the sustainable indicator. However, natural ventilation could not be ignored as this part plays a strong role in promoting health to the inhabitants. Plus, there was a study reported that public are considering indoor air quality as a priority in purchasing a property [24]. The simulation also has several limitations that may affect the actual reading. The study and findings can be updated with more precise readings to obtain more accurate data such as consideration on shaded context, thermal parameters such as materials U-value, solar absorptivity (α), wall thickness [18], and combining these data with natural ventilation study. As mentioned in the JBPM guidelines on window and grille installation, installation and maintenance cost need to be highlighted in the future research. Comparative study needs to be conducted with the window and grille installation to identify the affordability of this innovative housing window. A prototype can be built to identify the efficiency and practicality of this model to housing dwellers. OTTV of materials tested also need to be calculated to ensure the thermal transmission from the outside to the inside is at the optimum level.

Acknowledgement
This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through Tier 1 (vot H901). Author wishing to acknowledge Universiti Tun Hussein Onn Malaysia (UTHM) and Mr. Ts. Mohd Suffian Osman, a Public Safety and Health consultant from the Safety Management Academy for supporting and cooperating with this innovation project.

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