Journal of Design and Built Environment
E-ISSN: 2232-1500 |Print ISSN: 1823-4208
https://ejournal.um.edu.my/index.php/jdbe
Special Issue IV, 2024, 01-26

Unveiling the Potential of Green Facade Retrofit for Commercial Shopping Malls in Kuala Lumpur, Malaysia

Mohd Tajul Izrin Mohd Tajul Hasnan[1,5], Julitta Yunus[2,5]*, Khairul Adzfa Radzun[3,5], Emma Marinie Ahmad Zawawi[2], Siti Aishah Ramli[4]

[1]School of Architecture and Interior Architecture, College of Built Environment, Universiti Teknologi MARA, Puncak Alam Campus, Selangor, Malaysia.
[2]School of Construction and Quantity Surveying, College of Built Environment, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.
[3]Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Selangor, Malaysia.
[4]School of Postgraduate Studies, College of Built Environment, Universiti Teknologi MARA, Shah Alam, Selangor.
[5]Bios.Built Special Interest Group, College of Built Environment, Universiti Teknologi MARA, Shah Alam, Selangor.

*Corresponding Author: julitta@uitm.edu.my

Article info:
Submission Date: 8 August 2024
Acceptance Date: 1 October 2024

Keywords:
green façade, building retrofit, shopping malls, building typology, qualitative score matrix

ABSTRACT

In dense metropolitan areas like Kuala Lumpur, Malaysia, commercial buildings encounter challenges from deteriorating conditions and insufficient maintenance. Building owners are increasingly adopting sustainable strategies to mitigate environmental impacts and improve urban life quality. Among these strategies, green facade retrofitting is a promising solution for commercial shopping malls. This study investigates the potential of green facade retrofitting in Kuala Lumpur's commercial shopping malls, particularly within the Golden Triangle, using empirical data, typological studies and case study observations. Next, the four primary criteria that Qualitative Comparative Analysis evaluated are Geometry, Optical, Thermal, and Physical features. The study also employs a scoring matrix which extended from relevant prominent studies for evaluating rating scores for each selected building. The findings show that the majority of older shopping centres constructed before the year 2000 have higher score ratings compared to newer ones. This also highlights opportunities for green facade retrofit development in these targeted areas, aiming to inform policymakers, urban planners, building managers, and stakeholders about sustainable urban transformation strategies applicable to Kuala Lumpur's Golden Triangle area.

1.0 INTRODUCTION

Commercial buildings, particularly shopping malls, are pivotal urban structures that facilitate diverse activities but also pose significant environmental challenges due to their extensive infrastructure. In Kuala Lumpur, a city marked by rapid urbanization and population growth, the urgency to address the ecological footprint of these buildings is paramount. The expansive facades of existing malls offer an untapped canvas for implementing green facade solutions, a strategy increasingly recognized for its potential to mitigate energy consumption and carbon emissions (Cao, Xie, & Ji, 2020; Niu, Li, Shen, & Karatas, 2021).

This study conducted a thorough typological analysis and comparative case study encompassing all shopping malls in Kuala Lumpur's Golden Triangle area. The primary objective was to assess the current conditions of these structures and pinpoint optimal locations for green facade retrofitting. By scrutinizing factors such as urban sun paths, building orientation, facade materials, and solar radiation, the research underscored not only the environmental benefits but also the aesthetic enhancements that green facades can bring. Recent research underscores the critical importance of tailoring green facade technologies to local environmental conditions and building characteristics for maximum effectiveness (Tan, Wong, & Tan, 2020).

The potential of green facade retrofitting extends far beyond individual buildings, offering a scalable solution to enhance the sustainability of commercial shopping malls globally. By showcasing the potential application of green facade retrofit in Kuala Lumpur's context, this research serves as a blueprint for informing decision-makers, urban planners, building managers, and stakeholders about strategic avenues for advancing sustainable urban development. Ultimately, integrating green facade solutions represents a tangible pathway toward creating resilient urban environments that prioritize both environmental stewardship and economic prosperity, fostering livable and vibrant cityscapes for present and future generations.

Additionally, implementing green facades in commercial shopping malls in Kuala Lumpur presents challenges despite their numerous benefits. A primary obstacle is identifying suitable locations for installation, which involves assessing factors like sunlight exposure, building orientation, and structural integrity (Wong et al., 2018). Moreover, integrating green facade technologies into existing mall structures requires meticulous planning and coordination among stakeholders such as mall owners, architects, engineers, and urban planners. Green facades are crucial for harmonizing built environments with natural ecosystems, yet a lack of technical knowledge can hinder their effective use and maintenance (Aung et al., 2023). The study also highlights challenges during implementation, including maintenance needs, initial costs, plant selection, and adapting to local climate conditions.

2.0 LITERATURE REVIEW

Kuala Lumpur has become one of the major commercial centres in the Asia region, comprising many multinational business organisations and mega shopping building complexes. Kuala Lumpur established the standard for carbon reduction initiatives by concentrating on all building typologies, particularly commercial buildings, which accounted for up to 49% of global greenhouse gas emissions (Ramli et.al. ,2022). About 28% of the city's land use, with a total of 242 km^2 is utilised for commercial and residential buildings where commercial buildings alone generate 10,329 $ktCO_2$ and the rest 2,152 $ktCO_2$ from residential buildings (KLCH, 2018). In fact, according to the Kuala Lumpur Structure Plan (2020), 80% of the commercial and residential supply in the city centre is made up of existing stock, urging the countermeasures for both new and existing buildings with the rapid growth of GDP in the city and expected increasing GHG emissions for about three times by 2030.

Commercial centres like shopping malls play a vital role in urban economies and serve as focal points for social and recreational activities. However, these structures often have significant environmental footprints due to their energy-intensive operations and large-scale infrastructure. Green facade retrofitting presents an opportunity to mitigate these impacts by integrating greenery into the built environment. This approach aims to reduce energy consumption, improve air quality, and enhance the overall sustainability of commercial development. Moreover, it encourages spontaneous occupancy and fosters a model of enhanced spatial cohabitation that supports diverse actions, needs, and behaviours (Li et al., 2020). Shopping malls, as prominent features of urban landscapes in Kuala Lumpur, significantly contribute to environmental degradation. These malls are characterised by their vast infrastructures, including extensive facades, air conditioning systems, and lighting, which consume substantial amounts of energy and resources (Niu et al., 2021). The construction and operation of shopping malls also generate considerable waste and emissions, contributing to pollution and ecological imbalance in the surrounding areas.

2.1. Typology of Shopping Malls in Kuala Lumpur

To date, shopping malls, as defined by Rahimi & Khazaei (2018), are structures recognized as aggregations of various commercial enterprises designed to create a unified marketplace aimed at boosting the general economy. Nonetheless, Xin Ying & Alias (2022) assert that consumers' choices in purchasing or deciding on types of products are varied. Therefore, developers need to conduct preliminary research to understand consumer preferences. Consequently, an essential consideration in mall construction is addressing consumer needs, as the design of shopping spaces must meet economic demands.

Table 1. Classification of Shopping Malls.
(Source: Xin Ying & Alias (2022), and Mohd Yusof et al. (2011))

Classification	Description
Neighbourhood Centre	To cater to the consumers' daily needs in the immediate purchase with one anchored supermarket and six to eight stores in the centre. It is normally located near high-density residential areas along major routes.
Community Centre	Generally, offers a broad range of goods including immediate needs, purchase after comparison to the consumers. It is commonly anchored by supermarkets and other small tenants with 10 to 15 stores in the centre. It is larger compared to neighbourhood centres and is located in urban areas or central business districts near residential areas.
Regional Centre	It delivers services in full depth and variety including special items. It is anchored by main tenants as the main attraction with 30 to 50 units of other stores. It is normally located in prime commercial land close to intersections of two or more highways in urban areas or where land is sufficient.
Superregional Centre	It draws consumers from a larger population base and has more anchors and a wider range of goods and special items. It contains 100 retail spaces with multilevel enclosed malls and integrated parking spaces.

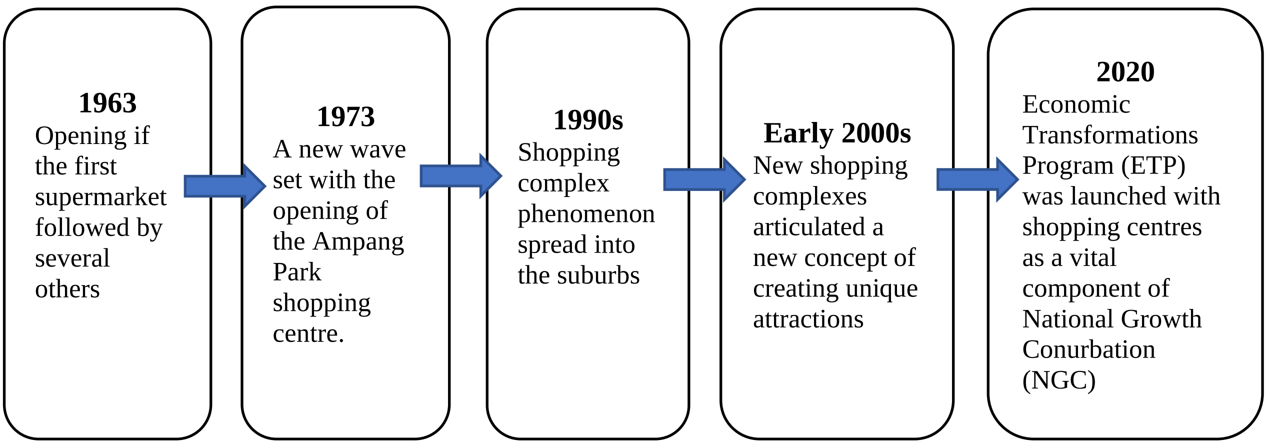


Figure 1. Chronological development of shopping malls in Kuala Lumpur.
(Source: Mohd Yusof et al. (2011))

As tabulated in Table 1, the shopping malls were further categorized into four main typologies namely neighbourhood centre, community centre, regional centre and superregional centre. Over the past few decades, shopping malls have expanded from urban to suburban areas, and their typology has evolved significantly since their early establishment in the 1960s.

Figure 1 illustrates the chronological growth of shopping malls in Kuala Lumpur, from neighbourhood centres to the emergence of super regional centres in the early 2000s (Mohd Yusof et al., 2011). They also highlight the concentration of shopping mall development within Kuala Lumpur's Golden Triangle, establishing the city as a world-class shopping hub. The evolution of shopping malls in Kuala Lumpur began as neighbourhood centres in 1963 with the opening of the first supermarket, the Weld Supermarket in Weld Road (now known as Jalan Raja Chulan), followed by several others onwards. In the early 1970s, additional main features were added to the design of shopping complexes that served more as community centres in which a podium block that accommodated shopping areas and offices, parking facilities and small retail outlets were developed (Mohd Yusof et al., 2011). A new wave of this typology of shopping malls started with the opening of the Ampang Park shopping centre followed by the Campbell Complex, Wisma Stephen, Wisma Central and several others. Then, in the 1990s, the shopping complex phenomenon expanded to the suburbs triggered by urban surplus and bottlenecks in the city centre. The early 2000s oversaw a new concept of shopping malls that is, of designing unique attractions by accentuating the element of fun and entertainment. This was how the creation of shopping malls such as Mines Shopping Complex, Sunway Pyramid and Berjaya Times Square offered recreation and entertainment features on top of the typical qualities of a shopping mall. Later in the year 2010, the Economic Transformation Program (ETP) was launched by the government aiming to turn Malaysia into a high-income country by 2020 with the mission to implement high-impact projects to trigger a multiplier effect on overall economic growth. The wholesale and retail business along with the regional developments of Kuala Lumpur and the Klang Valley have been identified as two of the National Key Economic Areas and selected as the National Growth Conurbation (NGC) retail sector with shopping centres as a catalyst of an international trading centre of the country.

2.2. Potentials of Green Facade Retrofit Implementation

As one of the primary methods for reducing energy use and carbon emissions, retrofitting is now the best option for becoming green in already-existing buildings (Ramli et al., 2023). Retrofitting old shopping malls has become a prominent trend in urban redevelopment efforts, especially with the increasing focus on sustainability and energy efficiency. One scenario involves the adoption of green facade retrofitting, where living or vegetative systems are installed on the exterior of buildings to enhance their environmental performance and aesthetic appeal. Benefits include thermal insulation, noise reduction, and biodiversity enhancement, making it valuable for sustainable urban development, particularly for commercial shopping malls in Kuala Lumpur. Integrating vegetation into facades can decrease energy use by providing natural insulation and shading, reducing reliance on mechanical heating and cooling (Cao et al., 2020). Additionally, green facades act as carbon sinks, absorbing carbon dioxide and mitigating greenhouse gas emissions. They also improve air quality by filtering pollutants, providing habitat for urban wildlife, and enhancing biodiversity. Building envelopes offer significant potential for green facade implementation, particularly in commercial buildings with extensive facade areas exposed to direct sunlight. Retrofitting these envelopes can decrease energy consumption by adjusting thermal, physical, and optical design variables and geometry (Gupta & Deb, 2023). Ling (2022) highlights that vertical green retrofitting can particularly benefit densely built areas lacking green spaces, improving the thermal environment. This approach not only revitalises the appearance of ageing shopping malls but also improves their energy efficiency and indoor thermal comfort. In recent years, there has been a growing interest in green façade retrofitting as a sustainable solution for transforming outdated shopping malls into eco-friendly and visually appealing spaces (Zhang et al., 2020).

Several real-world case studies highlight the successful implementation of green facade retrofitting in old shopping malls around the world. For example, the Chadstone Shopping Centre in Melbourne, Australia, underwent a green facade retrofitting project that involved the installation of vertical gardens and green walls across its exterior surfaces. This initiative not only enhanced the mall's aesthetic appeal but also contributed to significant reductions in heat gain and energy consumption (Dixon & Jancovich, 2019). Similarly, the Mall of America in Minnesota, USA, implemented a green facade retrofitting program that included the installation of vegetation panels and trellises, resulting in improved thermal insulation and energy efficiency (Turner et al., 2018). Evidence from studies evaluating the impact of green facade retrofitting on old shopping malls in tropical climates have demonstrated tangible improvements in terms of reduced heat gain and enhanced energy efficiency. Research by Lim et al. (2020) conducted on a shopping mall retrofit project in Kuala Lumpur, Malaysia, found that the implementation of green facades led to a significant reduction in indoor temperatures and cooling energy demand. Another study by Tanaka et al. (2022) investigated the energy-saving potential of green facade retrofitting in shopping malls in Bangkok, Thailand, and reported substantial reductions in both peak cooling loads and overall energy consumption. These findings underscore the effectiveness of green facade retrofitting as a sustainable solution for improving the environmental performance of old shopping malls in tropical regions. This is also supported by strategies for low-carbon green buildings under KLCH that underline key strategic programs under Action 6 that are subjected to possible green retrofit façade action. Two of the key programs GB7 and GB8 are presented as critical actions of the building covering requirement to mitigate the urban heat island phenomenon. Other than that, it is further suggested that a green façade has the potential to reduce heat gain from direct solar radiation and retrofitting the existing building envelope plays a critical role in achieving sustainable design strategies among existing building stock. The blueprint also encourages the installation of renewable energy systems among commercial buildings and PV systems to achieve energy efficiency in buildings.

2.3. Challenges of Green Facade Retrofit Implementation

Despite the numerous benefits of green facades, their implementation poses several challenges in the context of commercial shopping malls in Kuala Lumpur. One of the primary challenges is the identification of suitable locations for green facade installation, considering factors such as sunlight exposure, building orientation, and structural integrity (Wong et al. 2018). Additionally, integrating green facade technologies into existing mall structures requires careful planning and coordination among various stakeholders, including mall owners, architects, engineers, and urban planners. Green façades form part of a larger, inclusive approach to building design and urban planning which strives to harmonize built environments with natural ecosystems, hence a lack of technical knowledge could limit the effective usage and maintenance of these systems (Aung et al., 2023). The same study also highlights issues during the implementation of green façades such as maintenance, cost, plant selection and local climate consideration. For commercial buildings, accessibility to building façade for maintenance purposes is crucial for the effectiveness of green façade performance such as cleaning and regular services. In terms of cost, the expected initial investment for green façade installation is typically more expensive than conventional facades, especially for large-scale projects (Hong et al., 2019). However, in the long term, the green façade presents long-term energy savings that can possibly offset these costs, offering an effective choice.

Table 2. Summary of challenges for the implementation of green facades.
(Source: Author)

Challenges	Description	Authors
Location	The identification of a suitable location for green facade installation is crucial considering factors such as sunlight exposure, building orientation and structural integrity	Wong et al. (2018)
Structural Integrity	Integrating a green facade system on existing buildings requires additional weight on the existing building envelope	Huang et al. (2021)
Technical Knowledge	A lack of technical knowledge from various stakeholders could limit the effective usage and maintenance of these systems.	Aung et al. (2023)
Maintenance	Implementing green facades requires regular maintenance to ensure long-term viability and effectiveness. The growth of plants is crucial for the effective performance of green facades which requires regular feeding, fertilising and pruning.	Samsudin et al. (2022)
Cost	The initial investment for installing green facades is typically higher than conventional facades and it can be prohibitive for shopping mall owners, particularly those with limited budgets.	Hong et al. (2019)
Plant Selection	Selecting plant species that can thrive in tropical climates while providing aesthetic and environmental benefits requires careful consideration and expertise.	Khalid et al. (2020)
Local Climate Consideration	Suitable plant species may vary depending on local climate conditions, which poses a challenge to the global applicability of green facades.	Kong et al. (2019)
Policy Support	Local building codes, zoning regulations, and environmental policies may impose restrictions or require approval for green facade retrofitting projects.	Tan et al. (2020)

The main challenge in implementing green façade retrofitting at existing shopping malls in Malaysia with a tropical climate is the selection of suitable plant species. Tropical climates pose unique challenges due to high temperatures, humidity and heavy rainfall, which can affect the health and growth of plants on vertical surfaces. Choosing plant species that can thrive in these conditions while providing the desired aesthetic and environmental benefits is crucial but requires careful consideration and expertise (Khalid et al., 2020). On another note, there is another question about whether the structural integrity of existing buildings can retain a green façade system. This is because retrofitting green facades involves adding additional weight to the building envelope, which may exceed the load-bearing capacity of older structures. Ensuring that a building can safely support the weight of green façade systems without compromising its structural stability requires thorough structural assessments and modifications (Huang et al., 2021).

Maintenance and upkeep also pose significant challenges as green facades require regular maintenance, including watering, pruning, and pest control, to ensure their long-term viability and effectiveness. However, according to Kong et al., 2019, maintenance practices must be adapted to suit the tropical climate and local environmental conditions to prevent problems like waterlogging, mould growth, and plant diseases. Further, cost considerations remain a major hurdle. While green facades offer long-term energy savings and environmental benefits, the initial investment required for installation and ongoing maintenance can be prohibitive for many shopping mall owners, particularly smaller businesses or those with limited budgets (Samsudin et al., 2022). Lastly, regulatory and permitting challenges can impede the implementation of green facade retrofitting projects. Local building codes, zoning regulations, and environmental policies may impose restrictions or require approval for modifications to building facades, adding complexity and potential delays to the retrofitting process (Tan et al., 2020).

3.0 METHODOLOGY

This research employs qualitative comparative analysis of existing shopping malls to derive a nuanced understanding from several case specificities and seeks broader patterns for green retrofit potential. Prior to that, the study first obtained an in-depth insight into the related subject of green facade retrofit efforts, a comprehensive research strategy through a systematic literature review that was devised to identify relevant secondary data collection including literature, academic papers, reports, and government publications. The study then conducts several steps of the qualitative comparative analysis method in Figure 2 to analyse green retrofit potential among multiple cases of existing commercial buildings and seek to explain the relationship between causal conditions and key factors whose presence or absence may produce explanatory outcomes. It begins with the definition of a targeted set based on the 'change' the researcher intends to pursue, which in this research can be defined as potential retrofit among existing commercial buildings.

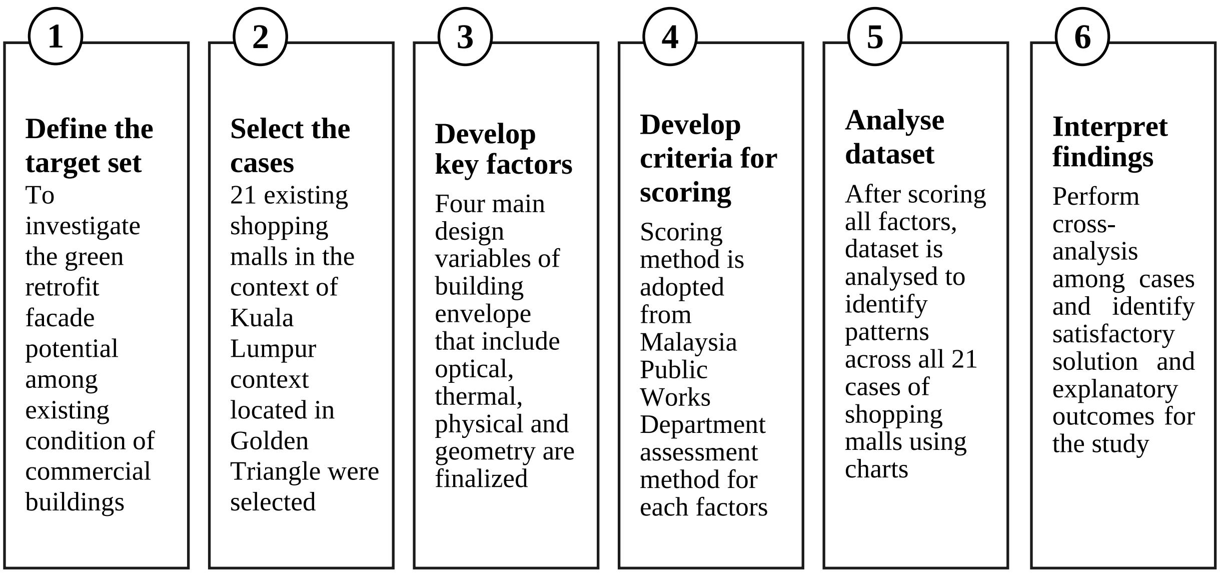


Figure 2. Steps of qualitative comparative analysis method conducted in this research.

The next step involves the selection process of several cases that are conducted through a typological study on all shopping malls in the selected region in Kuala Lumpur, Malaysia and it can be concluded that shopping centres in the Klang Valley are largely concentrated within Kuala Lumpur's Golden Triangle. The built environment of Kuala Lumpur is enriched by a diverse array of commercial shopping malls, each contributing uniquely to the city's urban fabric (Abdullah, 2020). This is not surprising as shopping centres have taken root in these locations since 1963 and they continued to be the focal point of shopping as a credit to their continued ability and capacity to meet the diverse requirements of modern consumers shopping. Figure 3 shows the location of these shopping malls that contribute to the vibrancy and diversity of Kuala Lumpur's retail landscape, offering unique experiences that cater to the diverse needs and preferences of shoppers and visitors. Figure 3 depicts the overall selection of cases located within the strategic Golden Triangle (highlighted in red) in Kuala Lumpur. This step is crucial in presenting which shopping malls are involved and provides an understanding of how different buildings and their associated organisations maintain buildings over time. By looking at these typology patterns in terms of timeline, scale, and context, the study gains background knowledge on the existing buildings that may further reflect their prevailing conditions and classifications. While the knowledge of the cases is investigated, the process requires direct observation of multiple case studies to identify commonalities, differences, and patterns across different contexts. This is conducted to explore the environmental benefits and aesthetic enhancements associated with green facade solutions.

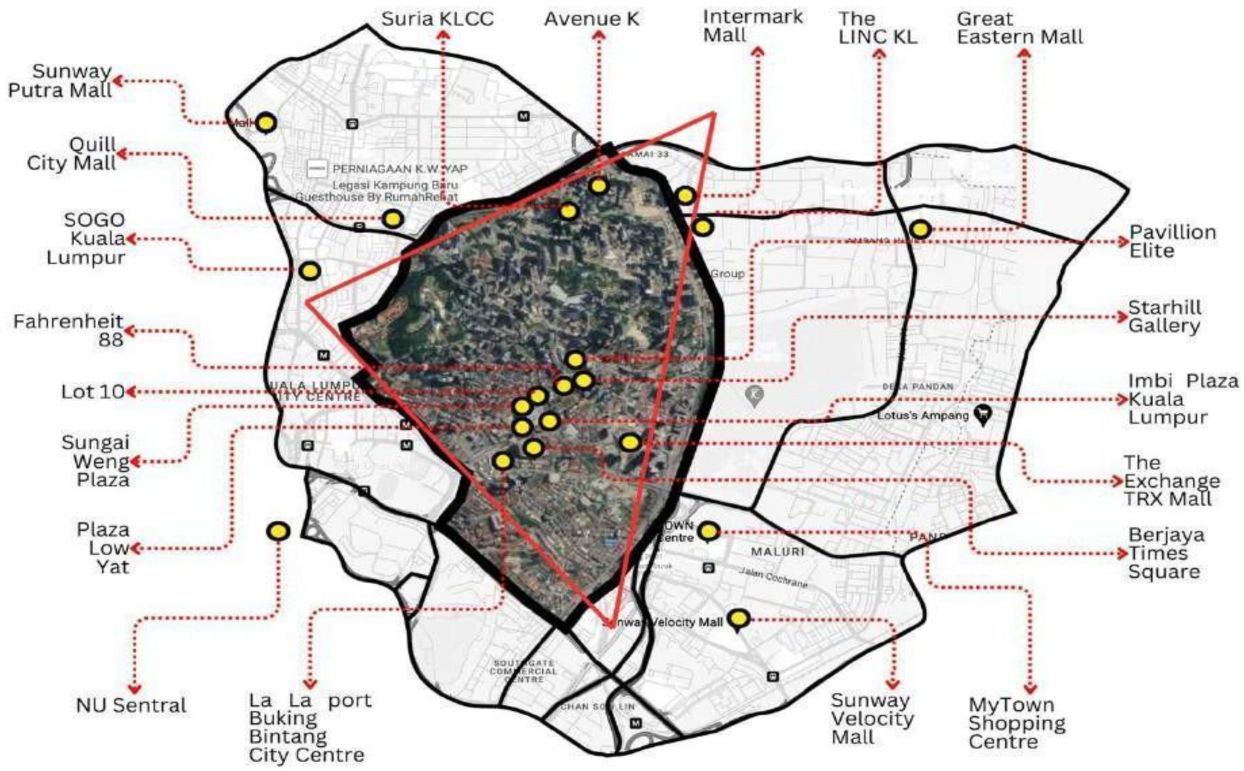


Figure 3. Illustration of existing shopping malls located in Kuala Lumpur, Malaysia.

Thirdly, the researcher creates a set of variables adapted from Gupta, V., & Debb, C. (2023), in which the four major building envelope design properties—optical, thermal, physical, and geometric variables are examined. These seek to draw insights into how different factors influence outcomes or phenomena in various settings. This analysis encompasses numerous factors, including urban sun path, geometry, building orientation, facade materiality, insulation, and physical and optical properties, to provide a wide interpretation of the potential impact of green facade retrofitting. It intends to comprehensively assess their current condition and identify suitable buildings with poor existing conditions that are strategically suitable for green facade retrofitting. The next step involves the development of the scoring method for the assessment of the factors for each case after the identification of cases and key factors were finalized. This study adopted the Malaysian Public Work Department's assessment which appraises the physical condition and maintenance implementation for existing buildings as outlined in Table 2. The original condition of the shopping malls was assessed based on the designated scale and graded from excellent to very poor condition. The study then proceeds with the analysis of the dataset in which evaluations of the factors and causal outcomes are perused into rating and matrix score based on its existing condition. This rating defines explicit actions of interventions required of the building envelope in Table 3 based on physical condition from scheduled maintenance, condition-based maintenance, upgrade works, major refurbishment or if the façade requires a replacement. Lastly, the findings were interpreted and discussed to answer the research objectives.

Table 3. Scale and grade of existing physical condition and maintenance adopted in this study. (Source: Public Work Department Malaysia (2022))

A) Physical Condition of Building Components	**B) Maintenance Implementation**	Max Grade Physical Condition of Building Components **(Max Score:5)** Maintenance Implementation **(Max Score: 5)**				
Excellent (1) No defects, in good condition and can function very well	Normal (1) No signs of defects or damage, components/elements are maintained well and no repair is needed	Multiplier Formula: A x B = Final Score	A	Excellent	Scheduled Maintenance	1 - 5
Good (2) Minor defects, in good condition and can function well	Routine (2) Minor damage/defects need to be monitored, repaired and replaced to avoid more serious defects/damage		B	Good	Conditions based maintenance	6 - 10
Moderate (3) Major defects, in moderate condition and can still function but need to be monitored	Upgrade (3) Major damage/defects need major repairs or replaced		C	Moderate	Upgrade works	11 - 15
Poor (4) There is no/there is defect either minor or major, in critical condition and unable to function according to the agreed service level	Recovery (4) Serious damage/defects, the need for repairs is urgent and immediate		D	Poor	Major refurbishment	16 - 20
Very Poor (5) In a very critical situation, not functioning and there is a risk that can cause accidents and/or injuries	Replacement (5) Damage/defects are very serious, need replacement / urgent repairs, immediate, and require a detailed inspection from experts		E	Very Poor	Replacement	21 - 25

The assessment scale for this research is further developed in Table 4 and comprised of four categories—Geometry, Optical, Thermal, and Physical—each divided into two parts which are the physical condition of building components and maintenance implementation. For Geometry, ratings assess Urban sun path, Building Orientation, Shape and geometry of the building while Maintenance evaluates upkeep effectiveness. Optical rates of Absorption and Reflectance of Facade Materiality and Emissivity and well-maintained cleaning frequency. Thermal assesses Exterior Insulation properties and building material thermal mass with Maintenance focusing on optimal performance practices. Physical evaluates Opening window-to-wall ratio with external shading alongside Maintenance's effectiveness in preserving these qualities. Ratings of Excellent to Very Poor and corresponding score matrices provide a structured approach to objectively evaluate building components and maintenance efforts across these critical dimensions, ensuring comprehensive assessment and management of building conditions. By integrating these factors, this analysis will offer valuable perspectives on identifying potentials within all these case studies, capable of efficiently implementing green facade retrofit solutions to enhance its poor condition and improve environmental sustainability and the visual appeal of its facade.

Table 4. Extended Rating and Score matrix adopted in this study.
(Source: Author)

Analysis	Description	Assessment Scale				
GEOMETRY Urban sun path, Building Orientation, Shape and geometry of the building. To assess the exposure of shopping malls to sunlight throughout the sun path in relation to the building shape, geometry and orientation of malls relative to the surrounding context	**A** **Physical Condition of Building Components**	Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
		Not a single area of the building frontage faces the East-West sun path position.	A small area of the building frontage faces the East-West sun path position	A moderate area of the building frontage faces the East-West sun path position	A large area of the building frontage faces the East-West sun path position	A very large area of the building frontage faces directly towards the East-West sun path position
	B **Maintenance Implementation**	Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
		The malls are well-maintained to ensure good sunlight exposure. Regular checks and adjustments are made to maximize sunlight throughout the day. Maintenance is prompt and consistent	The malls receive regular maintenance to monitor sunlight exposure, with occasional adjustments made to improve conditions. Maintenance is mostly timely	Maintenance is sporadic, with some checks on sunlight exposure but inconsistent adjustments. Maintenance schedules are irregular	Maintenance is minimal, with little consideration for sunlight exposure. Rare adjustments are made, but sunlight remains inadequate in many areas. Maintenance is often neglected	Maintenance is severely lacking, resulting in poor sunlight exposure throughout the malls. Sunlight needs are ignored, and maintenance issues go unresolved
	Max Score	**A x B = 25 (max score)**				

<table>
<tr><th>Analysis</th><th>Description</th><th colspan="5">Assessment Scale</th></tr>
<tr><td rowspan="7">OPTICAL

Absorption and Reflectance of Facade Materiality and Emissivity
To examine the suitability of existing windows and glass curtain walls on the building facade in terms of transparency, solar reflectance and emissivity</td><td rowspan="3">A
Physical Condition of Building Components</td><td>Excellent</td><td>Good</td><td>Moderate</td><td>Poor</td><td>Very Poor</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Excellent clarity, and unobstructed views. Excellent reflectance, minimal heat absorption. Excellent emissivity emits minimal to no heat</td><td>Clear transparency, minimal distortion. High reflectance, significant heat reflection. Low emissivity, emits little heat</td><td>Some transparency, moderate clarity Moderate reflectance, some heat reflection. Some emissivity, emitting minimal heat</td><td>Limited transparency and distortion are possible Limited transparency and distortion are possible. Moderate emissivity emits moderate heat</td><td>Heavy opacity, obstructing views. Absorbs most sunlight, high heat absorption. High emissivity, emits significant heat</td></tr>
<tr><td rowspan="3">B
Maintenance Implementation</td><td>Excellent</td><td>Good</td><td>Moderate</td><td>Poor</td><td>Very Poor</td></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>High-quality, regular cleaning. Well-maintained, reflective coatings Effective insulation, regular inspections</td><td>Regular cleaning, and occasional maintenance. Routine inspection, surface cleaning Routine maintenance, sealant application</td><td>Periodic cleaning, and minor repairs. Occasional surface maintenance. Occasional inspections, minor repairs</td><td>Infrequent cleaning, occasional replacement. Infrequent maintenance, partial damage Infrequent inspections,</td><td>Lack of maintenance, significant and extensive damage. Lack of maintenance, poor insulation</td></tr>
<tr><td>Max Score</td><td colspan="5">A x B = 25 (max score)</td></tr>
</table>

Analysis	**Description**	**Assessment Scale**				
		Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
THERMAL Exterior Insulation properties and building material thermal mass To assess the properties of the exterior insulation used on the building facade in terms of its Thermal mass capacity, thickness and density of the material	**A** **Physical Condition of Building Components**	High thermal mass, efficient heat storage Optimal thickness, sufficient insulation. High density, effective insulation	Adequate thermal mass, effective heat storage Adequate thickness, Moderate density, moderate insulation ,	Moderate thermal mass, moderate heat storage Moderate thickness, partial insulation Some density, partial insulation	Limited thermal mass, minimal heat storage Limited thickness, minimal insulation. Low density, minimal insulation	Negligible thermal mass, ineffective heat storage Insufficient thickness, no density no insulation
		Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
	B **Maintenance Implementation**	The building's insulation is well-maintained. Regular checks ensure it performs optimally, adjusting as needed for better thermal control. Maintenance is consistent, keeping indoor temperatures comfortable.	Regular checks are done on the insulation. Adjustments are made when necessary for decent thermal control. Maintenance is generally reliable, keeping indoor temperatures acceptable.	Maintenance is somewhat inconsistent. Checks are infrequent, leading to occasional issues with thermal control. Maintenance may be reactive, causing occasional discomfort.	Maintenance is minimal, with rare checks and little consideration for thermal control. Neglected maintenance results in discomfort due to poor thermal performance.	Insulation is severely neglected, with no maintenance plan. As a result, thermal performance is severely compromised, causing significant discomfort.
	Max Score	**A x B = 25 (max score)**				

Analysis	Description	Assessment Scale				
PHYSICAL Opening window-to-wall ratio with external shading To examine the balance of window-wall ratio, usage of exterior shading devices, and glazing properties according to the building's orientation	**A** **Physical Condition of Building Components**	Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
		The building's components, such as openings, window-to-wall ratio, exterior shading devices, and glazing, are well-maintained and optimally balanced according to its orientation for maximum functionality and energy efficiency.	Building components are well-maintained, with a balanced window-to-wall ratio and effective exterior shading. The glazing enhances energy efficiency and comfort, considering the building's orientation. Minor adjustments may be required for optimal performance.	Building components are satisfactory, though there may be imbalances in the window-to-wall ratio or the use of exterior shading devices. Glazing partially supports energy efficiency, but improvement is needed regarding the building's orientation.	Building components are in poor condition, with notable issues in the window-to-wall ratio and exterior shading usage. Glazing is ineffective for energy efficiency, and the building's orientation is not well considered. Significant adjustments are needed for improved performance.	Building components are in very poor condition, with severe imbalances in the window-to-wall ratio and a lack of exterior shading devices. Glazing fails to enhance energy efficiency, and the building's orientation is not considered. Major overhauls are needed to improve functionality and energy performance.
	B **Maintenance Implementation**	Excellent	Good	Moderate	Poor	Very Poor
		1	2	3	4	5
		Regular maintenance ensures ideal balance and adjustments for windows, shading, and glazing based on building orientation. Consistent assessments and prompt adjustments maintain high performance.	Maintenance is regular, and adjustments are made for windows, shading, and glazing according to orientation. Occasional lapses may lead to minor fluctuations, but overall performance is satisfactory.	Maintenance is somewhat inconsistent, with periodic assessments and adjustments for windows, shading, and glazing. Irregular schedules may result in noticeable variations.	Maintenance is minimal, with infrequent assessments and adjustments. Issues related to orientation are rarely addressed, leading to significant fluctuations in performance.	Maintenance is severely lacking, with no regular assessment or adjustment based on orientation. Ignored maintenance leads to severe issues and discomfort for occupants.
	Max Score	**A x B = 25 (max score)**				

4.0 RESULT AND DISCUSSION

After a thorough investigation through typological studies, there are 21 shopping centres altogether. Of these, five (5) were classified as superregional shopping centres, eight (8) regional, four (4) communities and four (4) neighbourhoods. Results of the typology analysis show that shopping centres in the Klang Valley are largely concentrated within Kuala Lumpur's Golden Triangle. The overall list of the Typological studies on 21 existing shopping malls selected in this research is included in *Appendix A*. The cases made up the landscape of KL and comprised the oldest shopping mall ever built, that is Sungei Wang Plaza (1977), to the Suria KLCC (1998) located within the iconic Petronas Twin Towers, as well as the new landmark The Exchange TRX (2023). All 21 shopping malls are further investigated through the rating and score matrix adopted in this study.

Table 5. Qualitative Comparative Analysis for Selected Shopping Malls (Lowest Score).

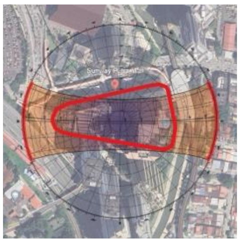
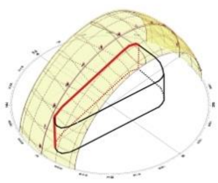
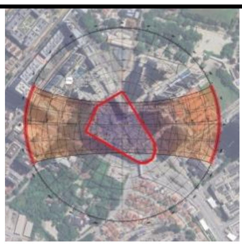
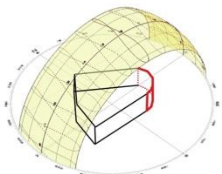
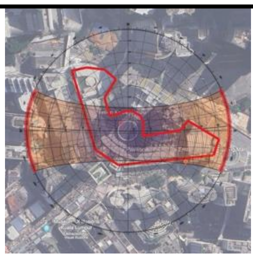
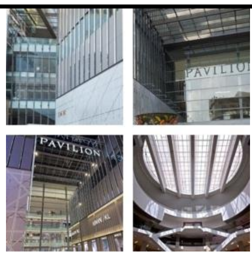
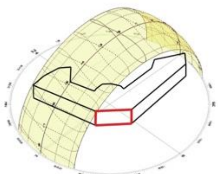
		Geometry					Optical					Thermal					Physical				
Score	Building	Urban sun path, Orientation, Shape and geometry of the building					Absorption and reflectance of Facade materiality and emissivity					Exterior Insulation properties and building material thermal mass					Opening window-to-wall ratio with external shading				
Lowest Score	Sunway Putra Mall (2015)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Final Score:**11/ 100**		2/25					3/25					3/25					3/25				
Second Lowest	Sunway Velocity Mall (2017)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Final Score: **13/100**		4/25					3/25					3/25					3/25				
Third lowest	Pavillion Elite (2016)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Final Score:**14/ 100**		2					4					4					4				

Table 6. Qualitative Comparative Analysis for Selected Shopping Malls (Highest Score)

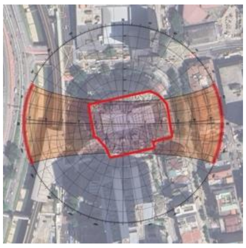
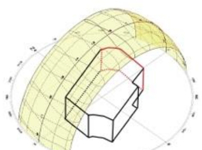
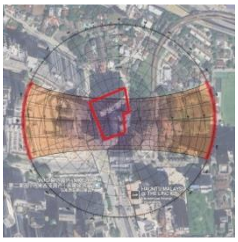
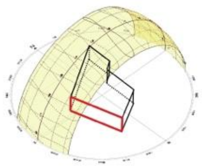
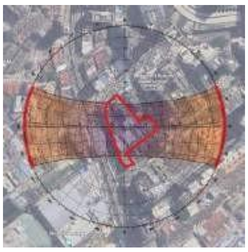
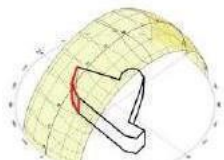
		Geometry					**Optical**					**Thermal**					**Physical**				
Score	Building	Urban sun path, Orientation, Shape and geometry of the building					Absorption and reflectance of Facade materiality and emissivity					Exterior Insulation properties and building material thermal mass					Opening window-to-wall ratio with external shading				
Highest Score	Sogo Kuala Lumpur (1994)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Final Score:**68/100**		20/25					16/25					16/25					16/25				
Second Highest Score	Intermark Mall (2012)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Final Score:**57/100**		15/25					15/25					12/25					15/25				
Third Highest Score	Lot 10 Shopping Centre (1990)																				
	A	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
	B	1	2	3	4	5	1	2	3	4		1	2	3	4	5	1	2	3	4	5
Final Score:**48/100**		16/25					8/25					12/25					12/25				

Table 5 provides a sample detailed analysis of these shopping centres based on the methodology outlined in Table 4. Initially categorized into four areas, Geometry, Optical, Thermal, and Physical, following the criteria specified in the methodology section. The assessment is further broken down into two parts: the physical condition of building components and maintenance implementation, as defined in Table 5. Utilizing the rating and score matrix from Excellent to Very Poor, as described in Table 4, the final score for each part is determined. This comparative analysis summarizes the evaluation of each shopping mall. According to Figure 4, the qualitative comparative analysis indicates that the majority of older shopping centres constructed before the year 2000 have higher score ratings compared to newer ones. Specifically, five (5) shopping centres scored above 40 out of 100, while three (3) others scored between 20 and 30 out of 100. This underscores the need for better environmental design considerations for older buildings, as their building frontage conditions tend to deteriorate over time. For example, Sungei Wang Plaza, built in 1977, underwent significant refurbishment from 2018 to 2019, implementing secondary gold cladding facade retrofitting. For instance, as shown in Figure 6, in the case of The Mall; built in 1987 which went through major refurbishment and replacement of its building envelope in 2015 and changed its overall look into the now Sunway Putra Mall. The mall managed to improve significantly in so many environmental aspects and this leads to an excellent score in all the available categories while others require immediate attention for retrofitting their old and poor building facade condition.

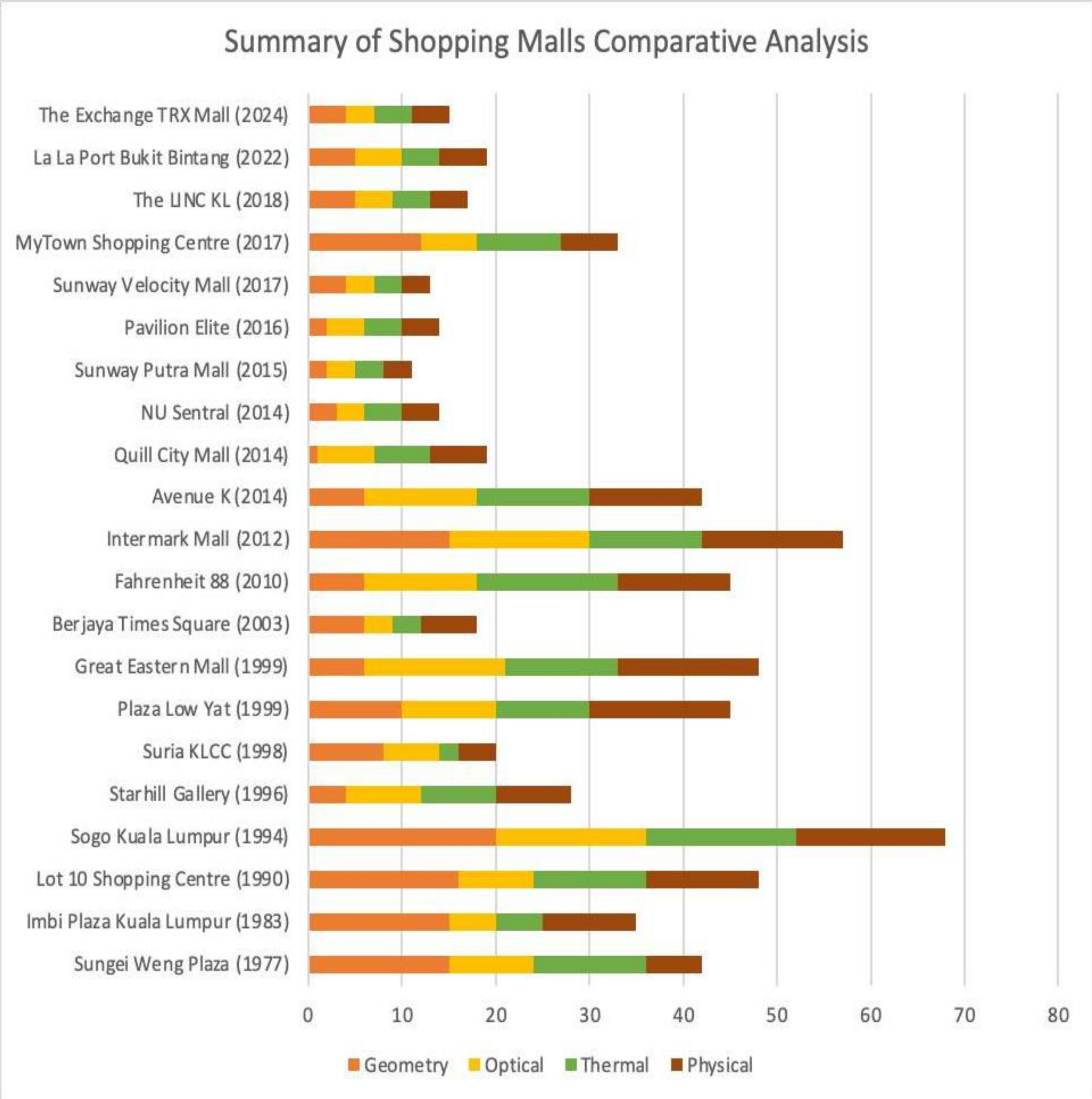


Figure 4. Summary of comparative analysis for each shopping mall

4.1. Time-based Comparative Analysis

According to the timeline, case study comparative analysis shows that the majority of the older shopping centres that have been built since the year 2000 and below has a higher score rating compared to the newest one, with five (5) shopping centres having a score of more than 40 out of 100 while another three (3) within the range of 20 to 30 out of 100. This shows that old buildings need better consideration toward environmental design and result in poor conditions of the building frontage in the long run. Some of the buildings constructed within this timeline such as Sungai Wang Plaza built in 1977 have already done major refurbishments from

2018 to 2019 by implementing secondary gold cladding facade retrofitting. For instance, this can also be seen in the case of The Mall; built in 1987 which went through major refurbishment and replacement of its building envelope in 2015 and changed its overall look into the now Sunway Putra Mall. The mall managed to improve significantly in so many environmental aspects and this leads to an excellent score in all the available categories while others require immediate attention for retrofitting their old and poor building facade condition.

This highlights a common issue where older buildings often lack adequate consideration for environmental design, leading to deteriorating conditions of their building frontage over time. Many structures constructed during this period were not designed with energy efficiency or sustainability, resulting in inefficient building envelopes and poor thermal performance. As a result, these buildings may experience issues such as heat gain, air leakage, and increased energy consumption, contributing to higher operating costs and environmental impacts. In response to these challenges, some building owners have undertaken major refurbishments by implementing secondary facade retrofitting solutions. These retrofitting efforts involve adding new facade elements or improving existing ones to enhance energy efficiency, thermal comfort, and aesthetic appeal. However, many older buildings still require immediate attention for retrofitting their old and poor building facade condition to address performance deficiencies and meet modern sustainability standards. By prioritising facade retrofitting initiatives, building owners can improve the overall performance and longevity of their properties while reducing environmental impact and operating costs in the long run.

Figure 5. Before (left) and After (right) comparison photo of The Mall that was built in 1987 and underwent façade retrofit into Sunway Putra Mall in 2015

On the other hand, the majority of buildings that are built from the year 2000 and onwards have started to consider proper environmental considerations and therefore ten (10) shopping centres have a score value below 20 with a properly designed building facade. and except for three (3) shopping centres which have extensive use of glass and curtain wall facades throughout their building frontage. Shopping centres which extensively use glass and curtain wall facades throughout their building frontage often aim to create a modern and visually striking appearance. By incorporating large glass panels and transparent facades, these shopping centres maximise natural light, creating bright and inviting interior spaces. Additionally, the use of glass facades allows for panoramic views of the surrounding environments, enhancing the overall shopping experience for visitors. Moreover, the sleek and contemporary design of glass and curtain wall facades can attract customers and contribute to the branding and identity of the shopping centre. However, while these facades offer aesthetic appeal and functional benefits, they also present challenges such as increased solar heat gain, glare, and the need for regular maintenance due to the susceptibility of glass surfaces to dirt and weathering. Therefore, careful considerations of design, materials, and environmental factors are crucial in achieving a balance between aesthetics, functionality, and sustainability in shopping centres.

4.2. Geometric Comparative Analysis

According to the analysis, Geometry Score results indicate that five shopping malls have scores of 15 and above, which is considered poor and signifies a need for major refurbishment. This poor performance is largely attributed to the overall orientation of their building frontages, which face directly toward the east or west sun paths. This orientation exposes these buildings to significant direct sunlight throughout the day, negatively impacting their shape, geometry, and orientation relative to the surrounding context. The orientation of a building plays a crucial role in its energy performance and thermal comfort, particularly in tropical climates like Malaysia. Buildings with east or west-facing facades are more susceptible to solar heat gain, leading to higher cooling loads and increased energy consumption for air conditioning. Therefore, it is essential to address issues related to solar heat gain through passive design strategies, such as double facades, shading devices, overhangs, and orientation optimization, to improve energy efficiency and comfort in shopping malls. Additionally, advancements in building simulation tools and technology enable architects and designers to better predict and optimize the performance of building geometries. These tools help mitigate the adverse effects of solar exposure on building occupants and energy usage, ensuring that shopping malls can operate more sustainably and comfortably.

4.3. Optical Score Analysis

Next, nearly all of these shopping malls have achieved commendable Optical scores, with nine shopping centres rated as Excellent and seven in the Good category. This positive outcome is largely due to the building mass and volume, where the extensive surface area of the building frontage demands careful consideration of facade materials in terms of transparency, solar reflectance, and emissivity. The optical properties of building materials are crucial for determining the energy performance and thermal comfort of shopping malls, especially in urban environments with high-density development and intense solar exposure. Optimal transparency and reflective facade materials can minimize solar heat gain, reduce glare, and enhance natural daylighting, creating a more comfortable indoor environment for shoppers and occupants. Additionally, selecting facade materials with appropriate emissivity properties can further contribute to energy efficiency by promoting effective heat dissipation and reducing the need for mechanical cooling. Therefore, integrating sustainable and high-performance facade materials into shopping mall design is essential for optimizing energy use, enhancing occupant comfort, and reducing environmental impact in urban settings.

4.4. Thermal Performance Analysis

In addition, this is the same case for the Thermal performance category where ten (10) shopping centres acquire an Excellence grade. This represents half of the shopping malls on the list, with the majority of them being built in the year 2014 and above. This indicates that the recently built shopping malls have higher consideration towards selecting exterior insulation with good properties used on the building facade in terms of its thermal mass capacity, thickness and density of the material. The thermal performance of building facades is crucial for maintaining indoor comfort levels and reducing energy consumption, especially in tropical climates like Malaysia. Buildings with high-quality exterior insulation materials can effectively regulate internal temperatures, reduce heat transfer, and minimise thermal bridging, resulting in lower heating and cooling loads. Additionally, newer shopping malls may benefit from advancements in building materials and construction techniques, allowing for a more efficient and sustainable facade implementation. By prioritising thermal performance in building design, developers and architects can create healthier, more energy-efficient shopping environments that enhance the overall experience for visitors while reducing environmental impact.

4.5. Physical Score Analysis

Next, nearly all of these shopping malls have achieved commendable Optical scores, with nine shopping centres rated as Excellent and seven in the Good category. This positive outcome is largely due to the substantial building mass and volume, which necessitates careful consideration of facade materials in terms of transparency, solar reflectance, and emissivity. The optical properties of building materials are crucial for determining the energy performance and thermal comfort of shopping malls, especially in urban environments with high-density development and intense solar exposure. Facade materials with optimal transparency and reflectivity can minimize solar heat gain, reduce glare, and enhance natural daylighting, creating a more comfortable indoor environment for shoppers and occupants. Furthermore, selecting facade materials with appropriate emissivity properties can contribute to energy efficiency by promoting effective heat dissipation and reducing the need for mechanical cooling. Therefore, integrating sustainable and high-performance facade materials into shopping mall design is essential for optimizing energy use, enhancing occupant comfort, and reducing environmental impact in urban settings.

5.0 CONCLUSION

In conclusion, retrofitting building envelopes with green facades presents substantial opportunities, especially in commercial settings where large facade areas are exposed to direct sunlight. Adjusting thermal, physical, and optical design variables and geometry can effectively reduce energy consumption (Gupta & Deb, 2023). Additionally, vertical green retrofitting, as emphasized by Ling (2022), offers significant benefits in densely built areas with limited green spaces, enhancing the thermal environment. On the other hand, the study by Mohd Tajul Hasnan & Zaharin (2020) indicates that an innovative green facade using microalgae photobioreactors on the building envelope can reduce heat gain from solar radiation through the building facade, improving the interior's thermal conditions in addition to producing a sizable amount of biomass. These further suggest that this study reveals the potential of green facade retrofits within the context of Kuala Lumpur's commercial retail malls through a comprehensive approach incorporating qualitative comparative analysis. The parameters revolve around 4 main categories which are Geometry, Optical, Thermal, and Physical but the assessment only focuses on building frontages due to their primary role in the building's image and commercial value, making them ideal candidates for retrofitting measures. Smith, Brown & Jones (2021) discuss the challenges faced by older commercial buildings in maintaining their facade conditions and explore opportunities through retrofitting, emphasizing the benefits of integrating green facades for sustainability and aesthetic improvements. Older shopping malls require increased attention to maintain their building frontages, often necessitating upgrades or major refurbishments to optimize geometry, optical properties, thermal performance, and physical appearance. In contrast, modern shopping malls typically integrate environmental considerations early in the design process, with only minor adjustments needed during regular maintenance. This highlights the urgent need for retrofitting existing commercial shopping malls particularly older buildings with poor facade conditions and replacing them with green facades, leveraging their potential for significant environmental and aesthetic enhancements as they age. As the study is only limited to observational empirical data, further recommendations suggest utilizing advancements in building simulation tools and technology to identify opportunities for enhancing energy efficiency, performance, and thermal comfort for identifying the relationship between the building facade and building occupants. This holistic approach will contribute to sustainable urban development and improve the quality of life in commercial retail environments.

ACKNOWLEDGEMENT

We would like to thank Universiti Teknologi Mara Cawangan Selangor (UCS) in collaboration with Research Management Centre Universiti Teknologi MARA (RMC – UiTM) and Fundamental Research Grant Scheme FRGS 2023 for funding this paper [600-RMC/FRGS 5/3 (180/2023)]

6.0 REFERENCES

Abdullah, A. (2020). Urban renewal and its impact on the built environment: A case study of Kuala Lumpur, Malaysia. Journal of Urban Regeneration & Renewal, 13(4), 352-367.

Aung, T., Liana, S. R., Htet, A., & Bhaumik, A. (2023). Implementing green facades: A step towards sustainable smart buildings. Journal of Smart Cities and Society, 2(1), 41–51. https://doi.org/10.3233/scs-230014

Bernama. (2018, May 31). Ampang Point Shopping Centre to undergo refurbishment. The Edge Markets. https://www.theedgemarkets.com/article/ampang-point-shopping-centre-undergo-(http://www.theedgemarkets.com/article/ampang-point-shopping-centre-undergo-)refurbishment

Cao, M., Xie, P., & Ji, Y. (2020). Retrofitting existing buildings: A review. Renewable and Sustainable Energy Reviews, 117, 109507.

Chen, Y., Chen, C., & Jiang, Y. (2021). Energy-saving potential of green facade retrofitting for shopping malls in subtropical China: A case study in Hangzhou. Sustainable Cities and Society, 65, 102620.

Dixon, T., & Jancovich, L. (2019). Retrofitting commercial property for sustainability: Insights from a longitudinal study of energy efficiency and green technologies in shopping malls. Energy Policy, 129, 1035-1046.

Gupta, V., & Debb, C. (2023). Envelope design for low-energy buildings in the tropics: A review. Renewable and Sustainable Energy Reviews, 186, 113650. Retrieved from www.elsevier.com/locate/rser (http://www.elsevier.com/locate/rser)

Hong, Y., Deng, W., Ezeh, C. I., & Peng, Z. (2019). Attaining sustainability in built environment: Review of green retrofit measures for existing buildings. IOP Conference Series: Earth and Environmental Science, 227(4). https://doi.org/10.1088/1755-1315/227/4/042051

Huang, C. J., Goh, T. K., & Wong, N. H. (2021). Structural design considerations for retrofitting vertical greenery systems onto existing buildings. Journal of Building Engineering, 43, 103062.

Khalid, A., Abu Bakar, A. A., & Razak, M. R. M. (2020). Plant species selection for vertical greenery systems in the tropics: A review. Urban Forestry & Urban Greening, 54, 126748.

KLCH. (2018). Kuala Lumpur Low Carbon Society Blueprint 2030 (Issue Summary for Policymakers 4th Edition)

Kong, X., Lu, X., & Ren, S. (2019). Maintenance management strategy for vertical greenery systems in a tropical climate. Journal of Green Building, 14(1), 138-155.

Kuala Lumpur City Hall. (2019). Kuala Lumpur City Hall Annual Report 2019. Author.

Li, Z., Xie, L., Guo, S., & Meng, Q. (2020). Effects of different vertical façade greenery systems on pedestrian thermal comfort in deep street canyons. Building and Environment, 180, 107014. https://doi.org/10.1016/j.buildenv.2020.107014

Lim, J., Lee, S., & Ng, W. (2020). The impact of green facade retrofitting on energy efficiency in a tropical shopping mall: A case study in Kuala Lumpur, Malaysia. Journal of Sustainable Building Technology and Urban Development, 5(2), 123-135.

Ling, T. (2022). Rethinking greening the building façade under extreme climate: Attributes consideration for typo-morphological green envelope retrofit. Cleaner and Circular Bioeconomy, 3.

Mohd Tajul Hasnan, M. T. I., & Zaharin, P. M. B. (2020). Exploration of Microalgae Photobioreactor (PBR) in Tropical Climate Building Envelope. Environment-Behaviour Proceedings Journal, 5(14), 263–278. https://doi.org/10.21834/ebpj.v5i14.2166

Mohd Yusof, H., Suraiya, I., Abd. Hair, A., & Adib Akmal, S. (2011). Location and Typology of Shopping Centres as Catalyst for Economic Growth. World Applied Sciences Journal, 13(Special Issue of Human Dimensions of Development), 23–28.

Niu, X., Li, X., Shen, G. Q., & Karatas, M. (2021). A review of green building policies and strategies for cities. Renewable and Sustainable Energy Reviews, 135, 110177

Public Work Department Malaysia. (2022). Garis Panduan Pemeriksaan Dan Penilaian Keadaan Bangunan Sedia Ada.

Rahimi, A., & Khazaei, F. (2018). Designing shopping centers: The position of social interactions. Journal of History Culture and Art Research, 7(2), 239-248.

Ramli, S. A., Yunus, J., Mohd Nordin, R., Hassan, P., & Mohd Tajul Hasnan, M. T. I. (2023). AUSPICIOUS GREEN RETROFIT STRATEGIES IN TWO-STORY TERRACE HOUSES: CASE STUDY OF PETALING JAYA SELANGOR MALAYSIA. PLANNING MALAYSIA, 21(26). https://doi.org/10.21837/pm.v21i26.1256

Ramli, S., Yunus, J., Mohd Tajul Hasnan, M. T. I., Mohd Nordin, R., & Hassan, P. (2022). The Need for Sustainability Improvements in Residential Building Stock: A Case of Klang Valley, Malaysia. Malaysian Journal of Social Sciences and Humanities (MJSSH), 7(12), e002011. https://doi.org/10.47405/mjssh.v7i12.2011

RSP Architects. (2021). KL Gateway Mall. https://www.rsp.com.sg/kl-gateway-mall (http://www.rsp.com.sg/kl-gateway-mall)

Samsudin, S., Mohamad, N. A. N., & GhaffarianHoseini, A. (2022). Cost analysis of green façade retrofitting in tropical climates: A case study in Malaysia. Journal of Building Engineering, 54, 102269.

Smith, J., Brown, A., & Jones, C. (2021). Retrofitting of commercial buildings: A review of challenges and opportunities. Journal of Sustainable Architecture.

Tan, A. Y. K., Wong, N. H., & Tan, P. Y. (2020). Implementing green facade technologies for sustainable urban development: A review. Journal of Cleaner Production, 265, 121989

Tan, H. L., Chua, Y. P., & Wong, N. H. (2020). Regulatory challenges and opportunities for green facade retrofitting in urban environments: Insights from Malaysia. Sustainable Cities and Society, 65, 102619.

Tanaka, Y., Sato, T., & Watanabe, K. (2022). Green facade retrofitting for energy efficiency in tropical shopping malls: A case study in Bangkok, Thailand. Energy and Environment, 15(3), 267-280.

Turner, S., Geyer, R., & Stubbings, J. (2018). Green retrofitting retail environments: A holistic perspective. Journal of Retailing and Consumer Services, 43, 305-313.

Wong, N. H., Tan, A. Y. K., Tan, P. Y., & Goh, K. T. (2018). Green walls for a humid tropical city—Singapore. Building and Environment, 43(4), 673-681.

Xin Ying, Q., & Alias, A. (2022). Preliminary Study on the Critical Success Factors of Shopping Mall Developments in Klang Valley, Malaysia. Journal of Building Performance, 13(1). http://spaj.ukm.my/jsb/index.php/jbp/index

Zhang, S., Zhang, Y., Liu, J., & Yin, J. (2020). Sustainable retrofitting strategies of shopping malls for energy conservation: A review. Journal of Cleaner Production, 266, 122054.

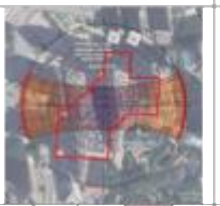
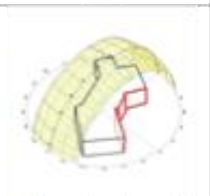
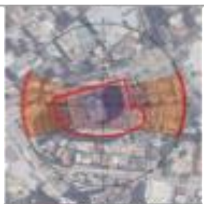
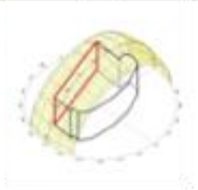
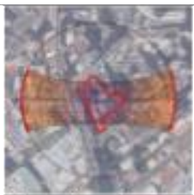
APPENDIX A.

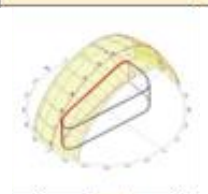
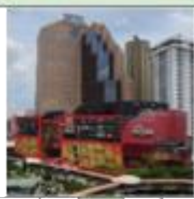
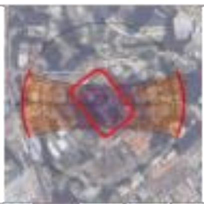
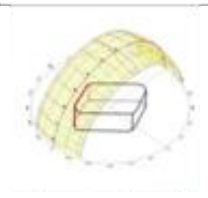
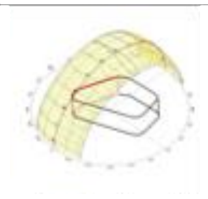
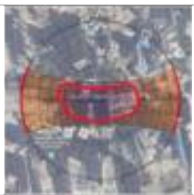
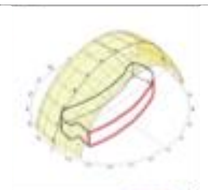
Typological studies on existing shopping malls selected for this study

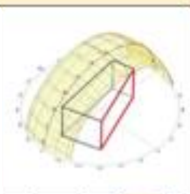
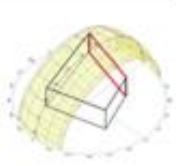
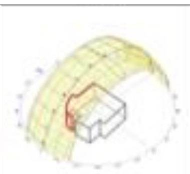
No	Building	Category	Size	Stories	Stores	Year Built	Owner	Designer
1	Pavilion Elite	Superregional Centre	250,000 sqft	8	200+	2016	Pavilion REIT	RSP Architects Sdn Bhd
2	Suria KLCC	Superregional Centre	1.5 million sqft	6	400+	1998	KLCC Property Holdings Berhad	Kumpulan Seni Reka Sdn Bhd
3	Berjaya Times Square	Regional Centre	7.5 million sqft	10	1,000 +	2003	Berjaya Assets Berhad	DP Architects Sdn Bhd
4	Lot 10 Shopping Centre	Community Centre	502,000 sqft	5	150+	1990	YTL Corporation Berhad	HTL Design Group Sdn Bhd
5	Sunway Putra Mall	Regional Centre	1 million sqft	5	200+	2015	Sunway Putra Mall Sdn Bhd	SA Architects Sdn. Bhd
6	Fahrenheit 88	Community Centre	300,000 sqft	5	150+	2010	Kuala Lumpur City Centre Sdn Bhd	RSP Architects Sdn Bhd
7	Starhill Gallery	Regional Centre	250,000 sq ft	7	160+	1996	YTL Corporation Berhad	Sparch Architects
8	Avenue K	Community Centre	750,000 sq ft	38	150+	2014	KIP Real Estate Investment Trust	Aedas (Malaysia) Sdn Bhd
9	NU Sentral	Super Regional Centre	1.3 million sq ft	9	200+	2014	Pelaburan Hartanah Berhad	RSP Architects Sdn Bhd
10	Sungei Wang Plaza	Regional Centre	800,000 sq ft	7	200+	1977	Sungei Wang Plaza Sdn Bhd	Jurubena Bertiga International (JBI) Sdn Bhd
11	MyTown Shopping Centre	Regional Centre	1 million sq ft	5	200+	2017	CapitaLand Malaysia Mall Trust	RSP Architects Sdn Bhd
12	Great Eastern Mall	Neighbourhood Centre	250,000 sq ft	4	200+	1999	Great Eastern Mall Sdn Bhd	Arkitek KDI Sdn Bhd
13	Quill City Mall	Regional Centre	800,000 sq ft	10	200+	2014	Quill Retail Malls Sdn Bhd	RSP Architects Sdn Bhd
14	Sogo Kuala Lumpur	Regional Centre	600,000 sq ft	25	500+	1994	Sogo (KL) Department Store Sdn Bhd	Veritas Architects Sdn Bhd
15	Plaza Low Yat	Community Centre	1million sqft	7	500+	1999	Plaza Low Yat Sdn Bhd	RSP Architects
16	La La Port Buking Bintang City Centre	Superregional Centre	2.5 million sqft	48	300+	2022	Buking Bintang City Centre Sdn Bhd	GDP Architects Sdn Bhd
17	The LINC KL	Neighbourhood Centre	500,000 sqft	7	200+	2018	The LINC KL Sdn Bhd	RSP Architects
18	Imbi Plaza Kuala Lumpur	Neighbourhood Centre	500,000 sqft	28	300+	1983	Berjaya Land Berhad	Berjaya Land Berhad
19	The Exchange TRX Mall	Superregional Centre	2,800,00 0 sqft	10+	300+	2024	TRX City Sdn Bhd	Woods Bagot
20	Intermark Mall	Neighbourhood Centre	1,000,000 sqft	2	100+	2012	Vista Tegap Sdn Bhd	GDP Architects
21	Sunway Velocity Mall	Regional Centre	1,400,000 sqft	7	400+	2017	Sunway Group	Veritas Design Group

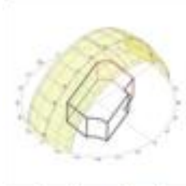
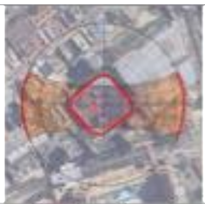
APPENDIX B

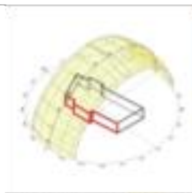
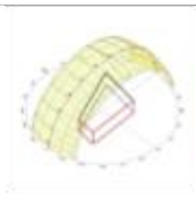
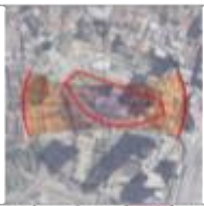
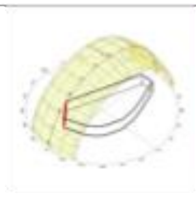
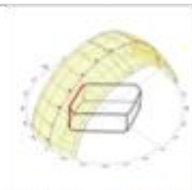
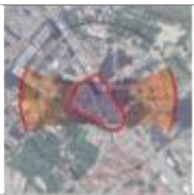
Case Study Comparative Analysis for Existing Shopping Malls in Kuala Lumpur

		Geometry	Optical	Thermal	Physical
Score	Building	Urban sun path, Orientation, Shape and geometry of the building	Absorption and reflectance of Facade materiality and emissivity	Exterior Insulation properties and building material thermal mass	Opening window-to-wall ratio with external shading
1	Pavillion Elite (2016)				
	A	1 **2** 3 4 5	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5
	B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **14/ 100**		2/25	4/25	4/25	4/25
2	Suria KLCC (1998))				
	A	1 2 3 **4** 5	1 2 **3** 4 5	**1** 2 3 4 5	1 **2** 3 4 5
	B	1 **2** 3 4 5	1 **2** 3 4 5	1 **2** 3 4 5	1 **2** 3 4 5
Final Score: **20/100**		8/25	6/25	2/25	4/25
3	Berjaya Times Square (2003				
	A	1 **2** 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	1 **2** 3 4 5
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **18/ 100**		6/25	3/25	3/25	6/25
4	Lot 10 Shopping Centre (1990)				
	A	1 2 3 **4** 5	1 **2** 3 4 5	1 2 **3** 4 5	1 2 **3** 4 5
	B	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5
Final Score: **48/ 100**		16/25	8/25	12/25	12/25

		Geometry	Optical	Thermal	Physical
Score	Building	Urban sun path, Orientation, Shape and geometry of the building	Absorption and reflectance of Facade materiality and emissivity	Exterior Insulation properties and building material thermal mass	Opening window-to-wall ratio with external shading
5	Sunway Putra Mall (2015)				
	A	1 **2** 3 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
	B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **11/ 100**		2/25	3/25	3/25	3/25
6	Fahrenheit 88 (2010)				
	A	1 **2** 3 4 5	1 2 3 **4** 5	1 2 3 4 **5**	1 2 3 **4** 5
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **45/100**		6/25	12/25	15/25	12/25
7	Starhill Gallery (1996)				
	A	**1** 2 3 4 5	1 **2** 3 4 5	1 **2** 3 4 5	1 **2** 3 4 5
	B	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5
Final Score: **28/ 100**		4/25	8/25	8/25	8/25
8	Avenue K (2014)				
	A	1 **2** 3 4 5	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **42/ 100**		6/25	12/25	12/25	12/25

		Geometry	Optical	Thermal	Physical
Score	Building	Urban sun path, Orientation, Shape and geometry of the building	Absorption and reflectance of Facade materiality and emissivity	Exterior Insulation properties and building material thermal mass	Opening window-to-wall ratio with external shading
9	NU Sentral (2014)				
	A	1 2 **3** 4 5	1 2 **3** 4 5	1 2 3 **4** 5	1 2 3 **4** 5
	B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **14/ 100**		3/25	3/25	4/25	4/25
10	Sungai Weng Plaza (1977)				
	A	1 2 3 4 **5**	1 2 **3** 4 5	1 2 3 **4** 5	1 **2** 3 4 5
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **42/100**		15/25	9/25	12/25	6/25
11	MyTown Shopping Centre (2017)				
	A	1 2 3 **4** 5	1 **2** 3 4 5	1 2 **3** 4 5	1 **2** 3 4 5
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **33/ 100**		12/25	6/25	9/25	6/25
12	Great Eastern Mall (1999)				
	A	1 **2** 3 4 5	1 2 3 4 **5**	1 2 3 **4** 5	1 2 3 4 **5**
	B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **48/ 100**		6/25	15/25	12/25	15/25

		Geometry					Optical					Thermal					Physical				
Score	Building	Urban sun path, Orientation, Shape and geometry of the building					Absorption and reflectance of Facade materiality and emissivity					Exterior Insulation properties and building material thermal mass					Opening window-to-wall ratio with external shading				
13	Quill City Mall (2014)																				
	A	**1**	2	3	4	5	1	2	**3**	4	5	1	2	**3**	4	5	1	2	**3**	4	5
	B	**1**	2	3	4	5	1	**2**	3	4	5	1	**2**	3	4	5	1	**2**	3	4	5
Final Score: **19/ 100**		1/25					6/25					6/25					6/25				
14	Sogo Kuala Lumpur (1994)																				
	A	1	2	3	4	**5**	1	2	3	**4**	5	1	2	3	**4**	5	1	2	3	**4**	5
	B	1	2	3	**4**	5	1	2	3	**4**	5	1	2	3	**4**	5	1	2	3	**4**	5
Final Score: **68/100**		21/25					16/25					16/25					16/25				
15	Plaza Low Yat (1999))																				
	A	1	**2**	3	4	5	1	**2**	3	4	5	1	**2**	3	4	5	1	2	**3**	4	5
	B	1	2	3	4	**5**	1	2	3	4	**5**	1	2	3	4	**5**	1	2	3	4	**5**
Final Score: **45/ 100**		10/25					10/25					10/25					15/25				
16	La La port Buking Bintang City Centre (2022)																				
	A	1	2	3	4	**5**	1	2	3	4	**5**	1	2	3	**4**	5	1	2	3	4	**5**
	B	**1**	2	3	4	5	**1**	2	3	4	5	**1**	2	3	4	5	**1**	2	3	4	5
Final Score: **19/ 100**		5/25					5/25					4/25					5/25				

17	The LINC KL (2018)					
		A	1 2 3 4 **5**	1 2 3 **4** 5	1 2 3 **4** 5	1 2 3 **4** 5
		B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **17/ 100**			5/25	4/25	4/25	4/25
18	Imbi Plaza Kuala Lumpur (1983)					
		A	1 2 **3** 4 5	**1** 2 3 4 5	**1** 2 3 4 5	1 **2** 3 4 5
		B	1 2 3 4 **5**	1 2 3 4 **5**	1 2 3 4 **5**	1 2 3 4 **5**
Final Score: **35/100**			15/25	5/25	5/25	10/25
19	The Exchange TRX Mall (2024)					
		A	1 2 3 **4** 5	1 2 **3** 4 5	1 2 3 **4** 5	1 2 3 **4** 5
		B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **15/ 100**			4/25	3/25	4/25	4/25
20	Intermark Mall (2012)					
		A	1 2 3 4 **5**	1 2 3 4 **5**	1 2 3 **4** 5	1 2 3 4 **5**
		B	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
Final Score: **57/ 100**			15/25	15/25	12/25	15/25
21	Sunway Velocity Mall (2017)					
		A	1 2 3 **4** 5	1 2 **3** 4 5	1 2 **3** 4 5	1 2 **3** 4 5
		B	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5	**1** 2 3 4 5
Final Score: **13/ 100**			4/25	3/25	3/25	3/25