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PREFACE

السَّلاَمُ عَلَيْكُمْ وَرَحْمَةُ اللهِ وَبَرَكَاتُهُ

Dear All,

Journal of Architecture, Planning and Construction Management (JAPCM), Kulliyyah of Architecture and Environmental Design is one the official journals of International Islamic University Malaysia (IIUM), under IIUM Press. It embarked in 2011 and is dedicated to the publication of original articles on the specialized fields of Architecture, Planning, Landscape Architecture, Quantity Surveying, Building Technology and Engineering,Applied Arts and Design, Construction Management and those related to the Built Environment. JAPCM is also the ardent forum for the reports of research that bridged theBuilt Environment and the Islamic worldview.

Prof. *Ar.* Dr. Abdul Razak Sapian
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HOUSING CONDITION AND NEIGHBOURHOOD SATISFACTION IN LAGOS, NIGERIA

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ABSTRACT

Many researchers have studied residential adequacy in Nigeria, but most focus on informal settlements or government housing. Few empirical studies compare housing quality across demographic groups in various urban districts. This study examines housing conditions and neighborhood satisfaction among residents in Mushin, Lagos State. The main aim is to explore the relationship between housing quality and neighborhood satisfaction. A cross-sectional survey of Mushin residents used structured questionnaires to assess their views on their buildings and neighborhood environment. Data collection included field observations and documentary review. A random sample of 176 households was selected. Data were analyzed using descriptive and inferential statistics. Results show that most residential properties require significant repairs due to owners' and tenants' reluctance to invest in maintenance. Factors such as waste management, visual appeal, interpersonal behavior, and perceived safety at night were key determinants of neighborhood satisfaction. Importantly, there was a strong, statistically significant correlation between housing quality and neighborhood satisfaction.

Keywords: Housing conditions, Neighbourhood satisfaction, Residential quality, Mushin, Lagos.

1.0 INTRODUCTION

Poor living conditions in residential settings are a universal concern, particularly in rapidly urbanising countries such as Nigeria. Reports from the National Bureau of Statistics (NBS) indicate that the physical qualities of residential properties, including roofing systems, wall construction, flooring specifications, and the provision of basic infrastructure, have a significant effect on the overall quality of life of residents (Omole, 2001; NBS, 2013; Sanda & Jambo, 2010). These physical features have been examined against a wide range of liveability indices, including residential stock quality, accessibility of facilities, occupancy rates, environmental quality, building age, residential diversity, adequacy of shared infrastructure, and the spatial arrangement of residential premises. Together, these factors shape the lived experience and general well-being of urban residents.

Neighbourhood satisfaction refers to residents' evaluations of their local environment based on their expectations and needs (Deng, 2011; Hur & Nasar, 2014). Research consistently shows that the smaller the gap between desired and actual neighbourhood conditions, the higher the level of satisfaction residents experience. This dimension of residential life is a central concern for personal well-being and has become a key area of inquiry in built environment research. It also provides a valuable indicator for assessing the effectiveness of housing policy interventions and development programmes (Galster, 1987; Kearney, 2006; Al Haija, 2011; Wang & Wang, 2015; Davoodi & Dagli, 2019).

A substantial body of literature has examined housing conditions and neighbourhood satisfaction across Sub-Saharan Africa and Nigeria. Beyond the Nigerian context, international scholarship has advanced understanding of the determinants of residential satisfaction in diverse urban settings, including studies from China (Deng,

2011; Wang & Wang, 2015), Jordan (Al Haija, 2011), the United States (Hur & Nasar, 2014), and the Middle East (Davoodi & Dagli, 2019). These studies consistently identify physical housing quality, service provision, environmental aesthetics, and social cohesion as among the strongest predictors of neighbourhood satisfaction across different cultural and geographic contexts. However, most Nigerian studies have concentrated either on slum settlements (Omole, 2010; Sani, 2006; Yoade, 2015; Yoade et al., 2015) or government-built housing estates (Djebami & Al-Abed, 1998; Ibem & Alagbe, 2015; Ibem & Amole, 2011; Ilesanmi, 2010; Olotuah, 2015; Olotuah & Taiwo, 2013; Umoh, 2012), with mixed, privately-developed residential areas receiving comparatively limited empirical attention.

This inquiry is guided by three main research questions: (1) What types and conditions form the basis of housing in the Mushin area? (2) To what extent are Mushin residents satisfied with their neighbourhood? (3) What is the nature of the relationship between housing quality and neighbourhood satisfaction? Based on this, the following objectives are outlined: (a) to describe the current housing types and physical condition in Mushin, (b) to evaluate how satisfied residents are with their area of residence, and (c) to determine whether there is a statistically significant correlation between the quality of the housing and satisfaction with the neighbourhood.

1.1 Description of the Study Area

Mushin Local Government Area lies in the north of the Lagos city centre, some 10 kilometres up the main road leading to Ikeja. Mushin, a largely residential neighbourhood with a high population density, has been facing perennial issues of poor sanitation infrastructure and a shortage of housing. In 2006, census data reported a population of about 633,009 in the area. Over the decades after Nigeria achieved independence in 1960, this locality experienced a high influx of people into its peri-urban areas, leading to overcrowding and unhealthy living conditions, which were attributed to poor sanitation infrastructure and a lack of housing facilities.

Despite these challenges, Mushin has developed into one of Lagos's notable manufacturing and commercial hubs. Economic activities in the area include textile and cotton processing, footwear production, bicycle and motorcycle assembly, and dairy product manufacturing. Although farming was historically a source of livelihood, the area has since transformed into a commercial hub centred on a well-known central market. Mushin is also served by a network of healthcare and educational facilities up to the secondary school level. The area lies at the intersection of major road routes connecting Lagos, Shomolu, and Ikeja, with Yoruba being the dominant language of communication among residents.

2.0 LITERATURE REVIEW

2.1 Theoretical Framework

This study is anchored in two complementary theoretical frameworks: Residential Satisfaction Theory and the Environmental Quality and Well-being model. Together, these frameworks provide the conceptual basis for understanding how the physical condition of housing shapes residents' evaluations of their neighbourhood environment.

Residential Satisfaction Theory, as developed by Galster (1987), holds that satisfaction with one's housing and neighbourhood is the outcome of a comparison process in which residents evaluate actual conditions against their aspirations and expectations. When actual conditions approximate desired conditions, satisfaction is high; when a significant deficit exists between the two, dissatisfaction results. This congruence model provides the theoretical rationale for examining how objective housing quality indicators such as building materials, structural condition, and sanitation facilities translate into subjective evaluations of neighbourhood satisfaction. The theory has been widely applied in housing studies across diverse urban contexts (Wang & Wang, 2015; Davoodi & Dagli, 2019) and directly justifies the core variables measured in this study.

The Environmental Quality and Wellbeing model (Hur & Nasar, 2014) complements this framework by demonstrating that the physical upkeep of the residential environment, including visible signs of deterioration such as cracked walls, defective roofing, and poorly maintained shared spaces, directly influences residents' perceptions of environmental quality, which in turn shapes their overall neighbourhood satisfaction. Drawing on both frameworks, this study proposes the following conceptual pathway: Physical Housing Conditions → Environmental Perception → Neighbourhood Satisfaction. This pathway guides the selection of variables, the design of the measurement instrument, and the interpretation of findings throughout the study.

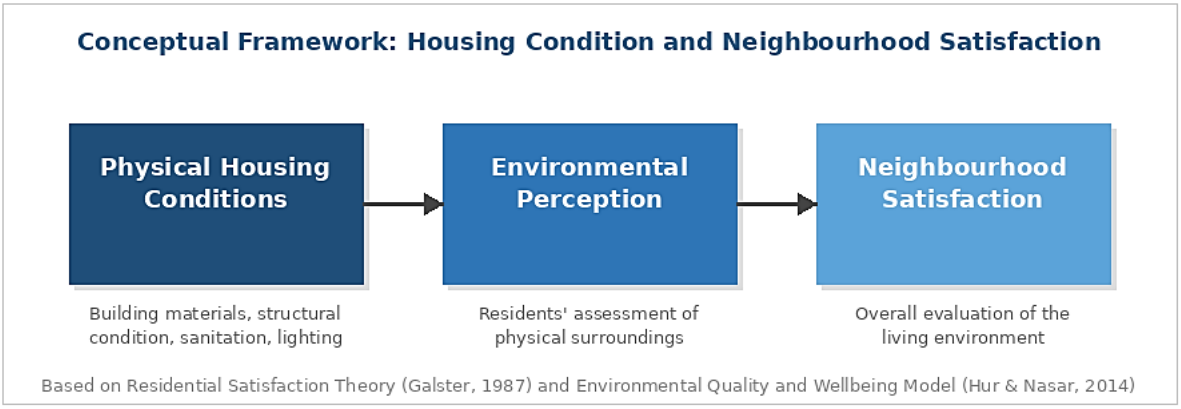

Fig. 1: Conceptual Framework for the Study (Authors, 2021)

Within the Nigerian context, Jiboye (2010) examined the relationship between housing standards and socio-demographic characteristics of household heads across three residential areas in Osogbo, establishing a statistically significant correlation between accommodation quality and household size. The study found that approximately 80 per cent of city-centre homes housed six or more occupants, identifying overcrowding as a primary driver of deteriorating housing standards in central urban areas relative to peripheral neighbourhoods. This pattern is directly relevant to the high-density context of Mushin, where comparable levels of residential crowding are prevalent.

Ilesanmi (2010) assessed the physical condition of residential structures across several low- and middle-income public housing estates in Lagos, revealing widespread structural deficiencies and identifying maintenance and renewal as critical and urgent needs. This study provides an important baseline for understanding housing deterioration patterns in Lagos, against which conditions in privately developed residential areas such as Mushin can be situated. Govender, Barnes, and Pieper (2011), writing from a South African context, further demonstrated that poor housing conditions, including inadequate sanitation, carry measurable negative consequences for residents' health, reinforcing the broader significance of housing quality research across Sub-Saharan urban environments.

Ibem and Amole (2011) investigated the adequacy of newly constructed residential buildings in Ogun State and found that overall housing quality fell below satisfactory levels. Critically, neighbourhood-level amenities were rated more poorly than individual dwelling-unit facilities, leading the authors to argue that communal infrastructure represents the most urgent priority for both government and private sector investment. This conclusion is reinforced by Ibem and Alagbe (2015), who found that shared neighbourhood facilities, including roads, drainage, and sanitation infrastructure, were the dimensions of housing adequacy most consistently rated as unsatisfactory by Lagos residents across income groups. Oladokun and Komolafe (2017) reported comparable findings in Ibadan, noting that housing condition deficits were significantly more pronounced in high-density residential areas, a pattern consistent with conditions observed in Mushin.

Internationally, Deng (2011) examined the impact of housing conditions on neighbourhood satisfaction using data from Chinese cities, finding that dwelling unit quality and shared facility standards were among the strongest predictors of overall satisfaction. Notably, sanitation and waste management services were identified as particularly influential, a finding with direct relevance to the Mushin context. Hur and Nasar (2014) similarly demonstrated, using data from American neighbourhoods, that physical upkeep and perceived environmental quality are consistent predictors of neighbourhood satisfaction, with visible signs of deterioration, such as cracked walls and poorly maintained public spaces, generating significantly lower satisfaction scores. Wang and Wang (2015) confirmed these patterns across multiple Chinese cities, further showing that residents' length of residence moderates the relationship: longer-term residents tend to hold higher expectations of their neighbourhood and are consequently more sensitive to quality deficits. Adeleye and Popoola (2019) reported comparable findings in Ikorodu, Lagos, noting that housing quality was largely substandard, with structural integrity and drainage infrastructure representing the most acute areas of deficiency.

The foregoing review reveals two important research gaps that this study seeks to address. First, while both Nigerian and international studies have examined housing conditions and neighbourhood satisfaction independently, few studies have empirically tested the direct statistical relationship between these two variables within the same neighbourhood-level study in a Nigerian context. Second, the existing Nigerian literature is heavily concentrated on either formal public housing estates or informal slum settlements, leaving

mixed, privately developed residential areas, which constitute a significant share of the urban housing stock in cities like Lagos, largely underexamined. This study addresses both gaps by providing empirical evidence from Mushin Local Government Area, a densely populated, predominantly privately developed residential district, and by directly testing the relationship between housing conditions and neighbourhood satisfaction using both descriptive and inferential statistical methods.

3.0 METHODOLOGY

This study adopted a quantitative research paradigm employing a cross-sectional survey design, which is appropriate for examining residents' perceptions at a single point in time and for testing associations between variables across a representative sample of households. Residents of Mushin Local Government Area were surveyed to assess their views on the physical condition of their homes and their satisfaction with the wider neighbourhood environment. Primary data were collected through structured questionnaires administered to selected households, supplemented by direct field observations. Secondary data were obtained from scholarly publications, institutional documents, government databases, and national statistical sources.

Based on projections derived from the 2006 national population census, the average household size in Lagos was estimated at six persons, with an average room occupancy of three persons. Applying these parameters to the Mushin Local Government Area yielded a total study population of 356,371 households. The required sample size was calculated using the Evans-Morris formula:

$$n = Nz^2Pq / [e^2(N - 1) + z^2Pq]$$

Where N is the total population (sample frame); P and Q are the assumed population proportions (conventionally set to 0.5 each); z is the confidence level coefficient (1.96 for a 95% confidence level); and e is the desired margin of error (set at 0.05, or 5%). Substituting these values into the formula yielded a minimum required sample size of 176 households.

Participants were selected using a three-stage sampling procedure. In Stage 1, purposive sampling was applied to delimit the study area to the jurisdiction of Mushin Local Government Area, ensuring geographic focus and relevance to the research objectives. In Stage 2, proportional stratified random sampling was employed by dividing Mushin into medium-density and high-density residential zones, following the residential density classification established by Onifade (2015). This stratification ensured that both density categories were proportionally represented in the final sample. In Stage 3, simple random sampling was used to select 176 households from each stratum, proportionate to the number of residential structures per density category. To qualify for inclusion, respondents had to be adults aged 18 or older and have resided in Mushin for at least 10 years, ensuring that responses reflected substantive familiarity with local housing and neighbourhood conditions.

The structured questionnaire comprised three sections. Section A collected socio-demographic information, including respondents' age, gender, household size, length of residence, and tenure status. Section B assessed housing conditions using ten items covering the physical state of key dwelling components — including walls, ceilings, floors, roofing, doors, windows, bathroom facilities, interior paintwork, lighting, and overall structural integrity, each rated on a five-point Likert scale ranging from 1 (Very Poor) to 5 (Very Good). Section C assessed neighbourhood satisfaction across four dimensions: public service quality (8 items covering sanitation, water supply, energy, healthcare, education, transport, waste management, and telecommunications), environmental aesthetics (4 items), social relationships with neighbours (5 items), and safety and security perceptions (5 items), each rated on a five-point Likert scale from 1 (Very Dissatisfied) to 5 (Very Satisfied). Questionnaires were administered through both interviewer-guided and self-completion formats, allowing respondents to choose the mode most suitable to them and minimising non-response bias.

Content validity was established through a review process involving five experts in urban planning, housing studies, and survey methodology, who assessed the relevance, clarity, and comprehensiveness of the questionnaire items prior to data collection. Minor revisions to the wording of the item were made based on expert feedback. Internal consistency reliability was subsequently assessed using Cronbach's Alpha coefficient. The housing conditions scale yielded a Cronbach's Alpha of 0.81, and the neighbourhood satisfaction scale yielded 0.84, both exceeding the widely accepted threshold of 0.70 (Nunnally, 1978), confirming adequate internal consistency for both instruments. Data were analysed using descriptive statistics (frequencies and percentages) to summarise housing typology and condition ratings, and the Summary of Weighted Values (SWV) method to compute neighbourhood satisfaction scores. Pearson product-moment correlation analysis was used to test the statistical relationship between housing conditions and neighbourhood satisfaction. This analytical approach was selected as appropriate for the study for three reasons. First, both housing conditions and

neighbourhood satisfaction were measured on continuous interval-level Likert scales, satisfying the parametric assumptions required for Pearson correlation. Second, the study's primary research objective was to determine the nature and strength of the relationship between the two key variables, a question that Pearson correlation directly and efficiently addresses. Third, with a sample size of 176, the study meets the minimum threshold recommended for reliable correlation analysis (Field, 2018). While more advanced multivariate techniques, such as multiple regression or Structural Equation Modelling, could provide additional explanatory depth, the cross-sectional design and the scope of the present study make Pearson correlation the most appropriate and defensible choice for addressing the stated research questions. These advanced techniques are recommended as directions for future research employing larger longitudinal datasets. A significance level of 0.05 (two-tailed) was adopted for all inferential tests.

4.0 RESULTS

Housing Typology and Condition

Survey data revealed that the most common housing type was flats, accounting for 38.1 per cent of respondents. Rooming houses were reported by 26.1 per cent, followed by single-room apartments (13.1%), traditional compound dwellings (9.7%), duplexes (8.0%), and miscellaneous housing arrangements (5.1%).

In terms of structural age, the largest share of buildings fell within the 0–10-year bracket, at 37.5 per cent. Buildings aged 11–20 years accounted for 27.3 per cent, those aged 21–30 years for 15.9 per cent, those aged 31–40 years for 9.1 per cent, those aged 41–50 years for 8.0 per cent, and buildings aged 50 years or older for 2.3 per cent.

Table 1: Distribution of Building Material Elements

Component / Material	Frequency (n=176)	Percentage (%)
Door Elements		
Aluminium	39	22.2
Iron	56	31.8
Timber/Wood	77	43.8
Others/Indifferent	4	2.2
Ceiling Elements		
POP	20	11.4
PVC	42	23.9
Asbestos	55	31.3
Ceiling Tiles	37	21.0
Concrete	22	12.5
Floor Elements		
Terrazzo	4	2.3
Mosaic	27	15.3
Plastered	74	42.0
Not Plastered	27	15.3
Tiles	44	25.0
Roof Elements		
Corrugated Iron Sheet	74	42.0
Light Aluminium Sheet	44	25.0
Concrete	42	23.9
Asphalt Shingle	16	9.1

Source: Field Survey, 2021

Building Material Composition

Analysis of the structural materials used in the surveyed buildings revealed the following patterns. For door construction, timber and wood were the most widely used materials (43.8%), followed by iron (31.8%), aluminium (22.2%), and other or unspecified materials (2.2%). For ceiling construction, asbestos was the most common material (31.3%), followed by polyvinyl chloride (PVC) (23.9%), ceiling tiles (21.0%), concrete (12.5%), and plaster of Paris (POP) (11.4%).

There was evidence of floor finishes reflecting plastered floors (42 per cent), tiles (25 per cent), mosaic and unplastered surfaces (15.3 per cent each), and terrazzo (2.3 per cent). The study observed that plastered floors and walls were common mainly because they are very affordable and easy to apply. Roofing materials were distributed as follows: corrugated iron sheets were the most common at 42 per cent, light aluminium sheets at 25 per cent, concrete at 23.9 per cent, and asphalt shingles at 9.1 per cent.

Subjective Assessment of Housing Conditions

Respondents rated the physical conditions of their homes on a five-point scale from 'very good' to 'very poor'. In terms of wall conditions, the respondents rated their walls most with 'poor' (33 per cent), followed by 'very poor' (32 per cent). A mere 13 per cent deemed their walls as being in very good shape, while 12 per cent rated them as good, and another 10 per cent considered them average.

Interior paintwork assessments were largely negative. Approximately 32 per cent of respondents rated the condition of the painting in their homes as poor, with an equal proportion rating it as average. Around 11 per cent considered it good, 10 per cent very poor, and 10 per cent very good. For roofing condition, the most common rating was average (37%), followed by good (22%), poor (16%), very good (12%), and very poor (11%). Of the respondents who reported on door status, 41% rated them in good condition, 28% average, 12% poor, 10% very poor, and 9% very good. A total of 33 percent rated window conditions as poor and 32 percent as very poor, whereas only 13 percent rated them as very good, 12 percent as good, and 10 percent as average. According to the report, floor conditions appear to be rated favourably. 52 per cent rated them as very good. 26 per cent rated them as good. 15 per cent rated them as average. 6 per cent rated them as poor. Finally, only 2 per cent rated them as very poor.

Regarding the condition of the bathrooms, respondents had mixed reviews. 40% said it was good, 20% said it was very good, 15% said it was average, 14% said it was very poor, and 10% said it was poor. Lighting conditions received particularly negative evaluations, with 38 per cent of respondents describing them as very poor, 33 per cent as poor, 19 per cent as very good, 6 per cent as good, and 4 per cent as average. According to the survey, 27 per cent of respondents rated the overall condition of the dwelling as poor, 22 per cent as very poor, 21 per cent as average, 18 per cent as good, and 12 per cent as very good.

Evaluation of Neighborhood Satisfaction

Neighbourhood satisfaction was assessed using the Summary of Weighted Values (SWV) method, whereby each response category was assigned a numerical weight: Very Satisfied (5), Satisfied (4), Average (3), Dissatisfied (2), and Very Dissatisfied (1). The SWV for each indicator was calculated by multiplying each response frequency by its assigned weight and summing the products. A Mean Weighted Value (MWV) was then derived by dividing the SWV by the total number of respondents.

Sanitation services ranked highest among the public-service satisfaction indicators, with an MWV of 4.064, indicating that residents viewed waste disposal and sanitation quality as the most influential factors in shaping their overall perception of the neighbourhood. The next in order were healthcare and public health services, with an MWV of 4.017, followed by water supply quality, with an MWV of 4.052. The quality of energy supply got an MWV of 3.972, which placed the service fourth; waste management services got an MWV of 3.869, which ranked the fifth; private and public education provided quality gained an MWV of 3.851, which ranked sixth; transport services were given a rating of 3.747, as it was categorized as the seventh and telecommunications services got the least ranking with a rating of 3.631.

In terms of the visual nature of the neighbourhoods, the overall environmental quality satisfaction had the highest mean score (4.052 MWV), followed by the overall aesthetic appearance satisfaction (4.064 MWV). General contentment with the appearance that enables easy pedestrian movement had the highest score (4.064), while contentment with neighbourhood aesthetics had the lowest (3.747).

Regarding social relationships, the perception that neighbours were sociable received the highest MWV of 4.017, followed by the willingness of neighbours to discuss local problems (3.972). Neighbourly respectfulness produced an MWV of 3.851, willingness to help others 3.747, and the sense of neighbours being vigilant received the lowest MWV of 3.631 in this category.

For safety and security perceptions, the highest-rated aspect was the overall sense of neighbourhood safety (MWV = 4.064), followed by the sense of personal safety at home during the night (4.052). The perceived

responsiveness of security personnel registered an MWV of 3.851, safety while walking at night, 3.747, and the general responsiveness of security operatives, 3.631.

Relationship Between Housing Conditions and Neighbourhood Satisfaction

The Pearson product-moment correlation analysis was conducted to test the relationship between housing conditions and neighbourhood satisfaction. The findings showed a correlation coefficient of 0.823, indicating a strong positive correlation between the two variables. In addition, the p-value was 0.029, and this p-value proved that this relationship was statistically significant at a 95 percent level. These results show that the physical quality of residential homes is an important factor in determining residents' satisfaction with their neighbourhood living environment.

Table 2: Correlation Between Housing Conditions and Neighbourhood Satisfaction

Variable	Statistic	Housing Conditions	Neighborhood Satisfaction
Housing Conditions	Pearson Correlation	1	0.823
	Sig. (2-tailed)		0.029
	N	176	176
Neighborhood Satisfaction	Pearson Correlation	0.823	1
	Sig. (2-tailed)	0.029	
	N	176	176

Correlation is significant at the 0.05 level (2-tailed). Source: Field Survey, 2021

5.0 DISCUSSIONS

The findings of this study confirm a strong, statistically significant positive relationship between housing conditions and neighbourhood satisfaction among residents of Mushin, Lagos ($r = 0.823$, $p = 0.029$), consistent with the predictions of Residential Satisfaction Theory (Galster, 1987). This result indicates that the physical quality of residential dwellings is a primary determinant of how residents evaluate their wider neighbourhood environment. The strength of the correlation observed here is notably higher than moderate associations reported in comparable Nigerian studies by Jiboye (2010) and Ibem and Amole (2011), which may reflect the particularly acute housing deterioration in Mushin relative to the areas studied by those authors, amplifying the sensitivity of neighbourhood satisfaction to physical housing quality. The predominance of flats as the most common housing type (38.1%) is consistent with the broader trend toward high-density multi-family residential forms documented in urban Lagos (Ilesanmi, 2010; Yusuf, 2021), and reflects the economic and spatial pressures that drive densification in rapidly urbanising African cities (Coker et al., 2008; Owolabi, 2017).

The predominance of timber doors (43.8%), asbestos ceilings (31.3%), corrugated iron roofing (42.0%), and plastered floors (42.0%) reflects a clear pattern of cost-driven material selection among Mushin residents. This pattern is consistent with findings from comparable low-income urban areas in Nigeria (Adeleye & Anofojie, 2011; Olotuah & Adesiji, 2005; Lawanson, 2006) and can be explained by the financial constraints that characterise informal and semi-formal housing development in rapidly urbanising African cities (Tipple, 1994; Payne, 1989). Critically, these material choices have direct consequences for neighbourhood satisfaction: cheaper materials tend to deteriorate faster, require more frequent repair, and generate visible signs of physical decay that residents associate with poor environmental quality, as demonstrated by Hur and Nasar (2014). The widespread use of asbestos as a ceiling material is particularly concerning beyond its aesthetic implications, given the well-documented respiratory health risks associated with asbestos exposure (Govender et al., 2011), and warrants specific attention in future housing policy interventions in the area.

The predominantly negative ratings for wall conditions (65% rated poor or very poor) and window conditions (65% rated poor or very poor) reflect the cumulative impact of deferred maintenance and the incremental construction practices common in informal housing development in Nigerian cities, whereby buildings are occupied before completion and rarely brought to a fully finished standard (Oladokun & Komolafe, 2017; Adeleye & Popoola, 2019). This pattern is consistent with Abdu and Hashim (2014), who identified deferred maintenance as the primary driver of structural deterioration in informal settlements, and with Olanrewaju and Akinbamijo (2002), who documented similar trends in roofing conditions across Nigerian urban centres. The relatively more positive ratings for door conditions (41% good) and floor conditions (52% very good) suggest that residents prioritise and maintain elements with direct daily functional significance — doors for security and

floors for comfort — while allowing structurally less critical elements such as walls and windows to deteriorate. This selective maintenance behaviour, driven by limited financial resources, has been documented in comparable African urban housing contexts by Tipple (1994) and Ibem et al. (2012).

The particularly severe lighting condition ratings — with 71% of respondents describing lighting as poor or very poor — represent one of the most significant findings of this study. Inadequate lighting is not merely a physical housing deficiency; it has direct consequences for residents' perceptions of personal safety and neighbourhood security, which in turn are among the strongest predictors of overall neighbourhood satisfaction (Hur & Nasar, 2014; Wang & Wang, 2015). This mechanism helps explain the strength of the observed correlation between housing conditions and neighbourhood satisfaction: poor physical conditions in individual dwellings, particularly those affecting safety-related perceptions such as lighting, compound to create a negative effect on neighbourhood-level evaluations. Bathroom condition ratings were similarly mixed, with 24% of respondents rating facilities as very poor, corroborating Govender et al.'s (2011) finding that inadequate sanitation infrastructure in Sub-Saharan urban housing carries both health and well-being implications for residents.

The overall structural integrity ratings further underscore the severity of housing conditions in Mushin, with 49% of respondents rating their dwellings as poor or very poor. This finding is consistent with the pattern documented by Ibem and Amole (2011) in Ogun State, where overall housing quality was similarly found to fall below satisfactory levels, and with Ilesanmi (2010), who identified widespread structural deficiencies across Lagos public housing estates. Taken together, the housing condition data paint a picture of a residential stock characterised by cost-effective but low-durability materials, incremental and often incomplete construction, and systematic deferred maintenance — a combination that, as this study's correlation analysis demonstrates ($r = 0.823$, $p = 0.029$), has a strong and measurable negative impact on residents' satisfaction with their neighbourhood environment. These findings reinforce the argument, advanced by Wang and Wang (2015) and Deng (2011), that physical housing quality and neighbourhood satisfaction are deeply interconnected, and that improvements to the former are likely to generate significant positive spillovers for the latter.

6.0 CONCLUSIONS AND RECOMMENDATIONS

This study examined housing conditions and neighbourhood satisfaction in the Mushin Local Government Area of Lagos State, Nigeria, drawing on a survey of 176 resident households. The evidence confirms that a significant proportion of the residential building stock in Mushin is in poor physical condition, with widespread deficiencies in wall integrity, window quality, lighting, and sanitation facilities. A strong, statistically significant positive correlation ($r = 0.823$, $p = 0.029$) was found between housing quality and neighbourhood satisfaction, supporting the central hypothesis derived from Residential Satisfaction Theory (Galster, 1987). Key determinants of neighbourhood satisfaction included sanitation services, water supply quality, environmental aesthetics, social cohesion, and perceptions of personal safety. These findings contribute empirical evidence to the underrepresented literature on housing conditions in mixed, privately developed residential areas in Nigerian cities, extending Residential Satisfaction Theory to the high-density Sub-Saharan African urban context. The persistence of poor housing conditions in Mushin can be attributed to a combination of factors: tenure insecurity and limited financial capacity among residents (Tipple, 1994; Payne, 1989; Ibemet al., 2012), the prevalence of informal and incremental construction practices that result in dwellings being occupied before reaching a finished standard (Ogu & Ogbuozobe, 2001; Shiferaw, 1998), and intergenerational property transfer patterns that leave inherited properties without sustained investment in maintenance or renovation.

The findings carry several specific implications for housing policy and urban planning in Lagos and comparable Nigerian cities. First, given the strong correlation between housing conditions and neighbourhood satisfaction, the Lagos State government should prioritise introducing a structured, mandatory housing inspection regime that requires property owners in high-density residential areas to meet minimum physical maintenance standards, with graduated financial penalties for persistent non-compliance. Second, the widespread use of asbestos ceiling materials identified in this study poses a documented public health risk (Govender et al., 2011) that warrants a targeted, phased replacement programme, supported by subsidised access to safer alternatives such as PVC and gypsum board for low-income property owners. Third, the highest neighbourhood satisfaction scores were recorded for sanitation and water supply services (MWV = 4.064 and 4.052, respectively), confirming that investment in communal infrastructure generates the greatest marginal gains in resident wellbeing; urban renewal plans for Mushin should therefore prioritise waste collection, drainage rehabilitation, and water supply improvement. Fourth, the prevalence of tenure insecurity as a barrier to housing maintenance investment underscores the need for simplified property regularisation processes to help informal owners formalise tenure arrangements, as formalised tenure has been shown to increase maintenance investment in comparable Sub-Saharan contexts (Payne, 1989; Ogu & Ogbuozobe, 2001).

This study is subject to several limitations that should be acknowledged. First, the cross-sectional design provides a snapshot of conditions at a single point in time and does not permit causal inference; the correlation observed between housing conditions and neighbourhood satisfaction, while strong, does not establish that poor housing causes low satisfaction. Longitudinal studies tracking changes in housing conditions and their effects on satisfaction over time would provide stronger causal evidence. Second, the study relied on residents' self-reported assessments of housing conditions, which may be subject to bias from subjectivity and social desirability; future research could complement survey data with objective physical condition assessments conducted by trained building surveyors. Third, the sample was restricted to Mushin, limiting the generalisability of findings to other Lagos neighbourhoods or Nigerian cities with different density profiles, tenure structures, and housing typologies. Comparative studies across multiple urban districts would help to establish the broader applicability of the findings. Future research could also productively apply qualitative or mixed method designs to elicit more nuanced insights into the mechanisms through which housing conditions shape neighbourhood satisfaction and employ Structural Equation Modelling to empirically test the full proposed conceptual pathway: Physical Housing Conditions → Environmental Perception → Neighbourhood Satisfaction in a single integrated analytical framework.

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REFERENCES

Abdu, A. & Hashim, A. H. (2014). Assessment of the physical condition of houses in informal settlements. International Journal of Social Science and Humanity, 4(1), 58–63.

Adeleye, O. A. & Anofojie, A. E. (2011). Housing quality in Ajegunle, Lagos, Nigeria. Journal of Geography and Regional Planning, 4(6), 328–334.

Adeleye, O. A. & Popoola, O. O. (2019). Assessment of housing quality in Ikorodu, Lagos, Nigeria. Ethiopian Journal of Environmental Studies and Management, 12(2), 155–167.

Adeoye, D. O. (2016). Building material selection in residential housing. Journal of Environmental Design and Management, 8(1), 22–34.

Al Haija, A. A. (2011). Jordan's housing sector analysis. Jordan Journal of Civil Engineering, 5(2), 258–270.

Coker, A. O., Awokola, O. S., Olomolaiye, P. & Booth, C. (2008). Challenges of urban housing quality and its association with neighbourhood environments. Journal of Environmental Health Research, 7(1), 21–30.

Davoodi, T. & Dağlı, U. (2019). Neighborhood satisfaction in residential environments. Open House International, 44(2), 50–59.

Deng, L. (2011). The impact of housing conditions on neighborhood satisfaction. Housing Studies, 26(2), 215–232.

Djebami, R. & Al-Abed, A. (1998). A study on the adequacy of public housing in Algeria. Habitat International, 22(3), 313–325.

Field, A. (2018). Discovering statistics using IBM SPSS statistics (5th ed.). SAGE Publications.

Galster, G. (1987). Homeowners and neighborhood reinvestment. Durham: Duke University Press.

Govender, T., Barnes, J. M. & Pieper, C. H. (2011). Housing conditions, energy sources and respiratory symptoms in informal settlement communities. BMC Public Health, 11(1), 689.

Hur, M. & Nasar, J. L. (2014). Physical upkeep, perceived upkeep, fear of crime and neighborhood satisfaction. Journal of Environmental Psychology, 38, 186–194.

Ibem, E. O. & Alagbe, O. A. (2015). Investigating dimensions of housing adequacy evaluation by residents. International Journal of Sustainable Land Use and Urban Planning, 2(2), 26–39.

Ibem, E. O. & Amole, D. (2011). Assessment of the qualitative adequacy of newly constructed residential housing. Property Management, 29(3), 285–304.

Ibem, E. O., Anosike, M. N. & Azuh, D. E. (2012). Challenges in public housing provision in the post-independence era in Nigeria. International Journal of Human Sciences, 8(2), 421–443.

Ilesanmi, A. O. (2010). Urban sustainability in the context of Lagos mega-city. Journal of Geography and Regional Planning, 3(10), 240–252.

Kearney, A. R. (2006). Residential development patterns and neighborhood satisfaction. Environment and Behavior, 38(1), 112–139.

Lawanson, T. O. (2006). Challenges of sustainability and urban development in Nigeria. International Journal of

Environmental Issues, 4(1–2), 127–141.
National Bureau of Statistics (NBS). (2013). Annual abstract of statistics. Abuja: NBS.
Nunnally, J. C. (1978). Psychometric theory (2nd ed.). McGraw-Hill.
Ogu, V. I. & Ogbuozobe, J. E. (2001). Housing policy in Nigeria: Towards enablement of private housing development. Habitat International, 25(4), 473–492.
Oladokun, T. T. & Komolafe, M. O. (2017). Assessment of housing condition in selected public estates in Ibadan. Journal of Building Performance, 8(1), 36–48.
Olanrewaju, D. O. & Akinbamijo, O. B. (2002). Housing conditions in Nigerian cities. Building and Environment, 37(3), 221–228.
Olotuah, A. O. (2015). Accessibility of low-income earners to public housing in Ado-Ekiti, Nigeria. Civil and Environmental Research, 7(1), 1–9.
Olotuah, A. O. & Adesiji, O. S. (2005). Housing poverty, slum formation and deviance in Nigerian cities. The Journal of the International Institute, 12(2), 15–20.
Olotuah, A. O. & Taiwo, A. A. (2013). Housing the urban poor in Nigeria through low-cost housing schemes. International Journal of Physical and Human Geography, 1(3), 1–10.
Omole, F. K. (2001). Basic issues in housing development. Ondo: FemoBless Publications.
Omole, F. K. (2010). An assessment of housing condition and socio-economic lifestyles of slum dwellers. Global Journal of Human Social Science, 10(4), 36–45.
Onifade, V. (2015). Residential density patterns in Mushin, Lagos. Urban Research Journal, 3(2), 45–58.
Owolabi, B. O. (2017). Housing preferences in urban Lagos. International Journal of Real Estate Studies, 11(4), 65–78.
Payne, G. K. (1989). Informal housing and land subdivisions in third world cities. Habitat International, 13(2), 5–18.
Sanda, A. & Jambo, N. (2010). Housing conditions and quality of life. Journal of Environmental Sciences, 14(2), 88–96.
Sani, R. (2006). The housing crisis in Lagos: Challenges and interventions. Nigerian Journal of Housing Research, 1(1), 42–51.
Shiferaw, D. (1998). Self-initiated transformations of government-built housing in Addis Ababa. Cities, 15(6), 437–448.
Tipple, A. G. (1994). The need for new urban housing in Sub-Saharan Africa: Problem or opportunity? African Affairs, 93(373), 587–608.
Turunen, M., Toyinbo, O., Putus, T., Nevalainen, A., Shaughnessy, R. & Haverinen-Shaughnessy, U. (2010). Indoor environmental quality in school buildings and the health and wellbeing of students. International Journal of Hygiene and Environmental Health, 217(7), 733–739.
Umoh, N. (2012). Exploring the enabling approach to housing through public private partnership. International Journal of Construction Management, 12(1), 49–64.
Wang, D. & Wang, F. (2015). Contributions of neighborhood conditions and personal factors to residential satisfaction. Social Indicators Research, 123(3), 891–909.
Yoade, A. O. (2015). Assessment of housing quality in Osogbo, Nigeria. Environmental Research Journal, 9(1), 14–22.
Yoade, A. O., Adeyemi, O. A. & Yoade, O. B. (2015). Housing quality measurement in slum areas. International Journal of Development and Economic Sustainability, 3(5), 37–46.
Yusuf, O. J. (2021). Residential building condition assessment in Lagos, Nigeria. Journal of Sustainable Architecture and Civil Engineering, 29(2), 133–148.

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FACTORS INFLUENCING THE ADOPTION OF ECO-FRIENDLY MATERIALS IN SUSTAINABLE CONSTRUCTION IN LAGOS, NIGERIA

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ABSTRACT

The construction industry is a significant contributor to economic development but also a major source of environmental degradation due to high level of resource consumption and carbon emissions. Sustainable construction, which utilizes eco-friendly materials such as bamboo, recycled concrete, recycled steel and recycled plastic, is crucial for mitigating these impacts. However, its adoption in Nigeria faces significant challenges. This study therefore assessed the factors influencing the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria. With a quantitative research approach, a well-structured questionnaire was administered on 174 firms and a total of 66 copies of the questionnaire were returned by respondents from 8 consulting firms, 39 contracting firms, 5 consortium firms, and 14 government ministries, departments and agencies located in Lagos. Data collected were analyzed using percentage, mean score, analysis of variance and factor analysis. The findings revealed that the primary factors motivating adoption are waste reduction, reduced greenhouse gas emissions, and decreased pollution, while the main inhibiting factors are a lack of expertise and technical capacity, limited technical guidelines, and limited training and awareness. The study concludes that eco-friendly materials are being adopted for sustainable construction but the level of adoption in Lagos is being hindered by a significant number of technical and institutional barriers. It recommends the need to develop strategies for enhanced technical capacity building, clear policies guidelines, and stronger government incentive schemes to foster a more sustainable practices in construction sector.

Keywords: Adoption, Eco-Friendly, Influencing Factors, Materials, Sustainability

1.0 INTRODUCTION

The construction industry is essential to the economic advancement of numerous nations and Nigeria is not exempted. It is making a significant contribution to gross domestic product and employment generation. Nevertheless, this sector is responsible for a notable portion of environmental degradation due to its pronounced consumption of resources, considerable waste production, and elevated carbon emissions (Uchehara et al., 2022). 39% of the total carbon footprint comes from construction processes and production with materials such as concrete, steel, and traditional bricks contributing significantly to this footprint (Dighade et al., 2024). The global construction carbon footprint is projected to more than double by 2050, with cement, brick, and metal use responsible for over half of emissions (Li et al., 2025). With increasing global environmental challenges, sustainable construction has emerged as a central approach for reducing the adverse impacts associated with the construction industry (Akindele et al., 2023).

Sustainable methods make use of eco-friendly materials and advanced technologies, consume minimal water, boost energy efficiency, preserve resources, reduce waste, and promote safer and healthier living conditions (Njeri et al., 2023). Eco-friendly construction materials are defined as materials that reduce energy consumption and environmental impact (Srivastava et al., 2019). Eco-friendly construction materials include bamboo, recycled concrete, insulation, cob, recycled steel, sheep's wool, reclaimed wood, cork, straw bales, recycled plastic, ashcrete, ferrock, hempcrete, recycled rubber, earth block and geopolymer cement, which protect the environment while maintaining building stability and functionality (Barbulianno, 2024; Hassan et al., 2022).

Eco-friendly construction materials reduce carbon footprint, minimize waste, result in long-term cost saving, reduce energy consumption, regulate indoor temperatures, promote better indoor air quality, operational efficiency, minimize water consumption, and conserve natural resources (Magicrete, 2024). The utilization of fly ash in concrete mix designs in the climate of Nigeria has shown that there is an opportunity to cut the quantity of cement used by as much as 30% (Adewumi et al., 2023).

Although the awareness of the advantages of sustainable construction is increasing, its adoption in Nigeria remains low due to numerous obstacles that restrict broad implementation. These challenges encompass a range of factors, including regulatory, organizational, social, cultural, and technological dimensions (Unegbu et al., 2025). Like, there are paucity of studies globally including Nigeria that specifically evaluated eco-friendly materials and factors influencing their adoption for sustainable construction, hence, this study. This study focusses on factors influencing the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria. The specific objectives examine the factors motivating and factors inhibiting the adoption of eco-friendly materials for sustainable construction with a view to minimizing the consumption of fossil fuel and generation of carbon emissions emanating from the production of conventional construction materials.

2.0 LITERATURE REVIEW

2.1 Factors Influencing the Adoption of Eco-Friendly Materials for Sustainable Construction

The adoption of conventional and non-conventional materials like eco-friendly materials for construction is being influenced by certain factors. These factors could be motivating or inhibiting and this paper grouped factors influencing the adoption of eco-friendly materials for sustainable construction in that order. Motivating factors are factors that encourage the usage of eco-friendly materials for sustainable construction, which include the possibilities of recycling and reuse of materials, water conservation, energy efficiency, use of renewable materials, waste reduction, positive social practices, and reducing air and noise pollution (Chepngeno & Letema, 2025). Bode (2024) opined that factors motivating recycling and reuse of building materials include waste reduction, energy saving, resource conservation, cost savings, job creation, innovation and market growth, cultural preservation, improved building quality and community engagement.

Vetrotech, (2024) also argued that adopting sustainable building practices is crucial for sustainable development for several reasons which include reducing environmental impact, enhancing energy efficiency, promoting health and well-being, market demand and economic benefits. According to Accacia (2025), the key benefits of using eco-friendly construction materials include reduced environmental impact, better energy efficiency, health indoor environments, long term cost savings, helps earn green certifications and boost brand and market value. Fluidconstruction (2023) argued that the benefits of eco-friendly constructions include improved indoor

air quality, energy efficiency, saving costs, environmental impact, community health, job creation, innovation and technology, long term investment and resilience. Abera (2024) in research identified forest conservation, thermal and acoustic qualities, lower greenhouse gas emissions, reduced pollution and employment as the drivers of eco-friendly material adoptions. Based on these reviews, the list of factors motivating the adoption of eco-friendly materials for sustainable construction are presented in Table 3.

Likewise, there are some factors inhibiting the adoption of eco-friendly materials for sustainability. In a study conducted by Chepngeno and Letema (2025), such factors inhibiting the adoption of eco-friendly materials for sustainable construction include the level of knowledge and awareness, market demand, cost of implementation, access to funding and green financing, compliance and enforcement of policies and regulations, availability of construction technologies, cooperation and commitment by project stakeholders, application of sustainable rating systems, expertise and technical capacity, and government support. These factors affect how stakeholders engage with and prioritize sustainable methods and adoption throughout building projects.

Accacia (2025) also identified barriers identified by Accacia (2025) such as high costs, limited awareness, and weak policy enforcement often inhibiting the adoption of eco-friendly materials for sustainable construction. Similarly, higher upfront costs, limited availability, knowledge and training gaps, lack of standardization, regulatory hurdles and perceived performance risks were identified by Isang (2023) as factors inhibiting the adoption of eco-friendly materials for construction. Some of the issues to be addressed for the adoption of eco-friendly materials for sustainable construction as identified by Abera (2024) include material performance, cost effectiveness, regulatory compliance and public acceptance. Hassan et al. (2024) argued that the barriers to adoption of eco-friendly materials include lack of local production, absence of incentives, limited awareness, lack of technical guidelines, market resistance and policy gaps in regulations. Table 1 highlights the factors motivating the adoption of eco-friendly materials for sustainable construction while Table 2 highlights the factors inhibiting the adoption of eco-friendly materials for sustainable construction.

Table 1: Factors Motivating the Adoption of Eco-Friendly Materials for Sustainable Construction

S/N	Motivating Factors	Sources
1	Reduced greenhouse gas emissions	Abera, 2024
2	Lower resource consumption	Bode, 2024
3	Decreased pollution	Chepngeno & Letema, 2025
4	Waste reduction	Chepngeno & Letema, 2025; Bode, 2024
5	Long term investment	Fluidconstruction, 2023
6	Biodegradability and recyclability	Chepngeno & Letema, 2025
7	Enhanced building performance	Bode, 2024
8	Improved thermal and acoustic properties	Abera, 2024
9	Improved water efficiency	Chepngeno & Letema, 2025
10	Reduce environmental impact	Bode, 2024; Vetrotech, 2024; Accacia, 2025; Fluidconstruction, 2023
11	Technology	Fluidconstruction, 2023
12	Resilience	Fluidconstruction, 2023
13	Helped earn green certification	Accacia, 2025
14	Innovation	Bode, 2024; Accacia, 2025; Fluidconstruction, 2023
15	Reduced noise pollution	Chepngeno & Letema, 2025; Abera, 2024
16	Market growth	Bode, 2024; Vetrotech, 2024; Accacia, 2025
17	Reduced air pollution	Chepngeno & Letema, 2025; Abera, 2024
18	Job creation	Bode, 2024; Abera, 2024; Fluidconstruction, 2023
19	Long term cost savings	Bode, 2024; Accacia, 2025; Fluidconstruction, 2023
20	Improved indoor air quality	Accacia, 2025; Fluidconstruction, 2023
21	Improved energy efficiency	Chepngeno & Letema, 2025; Bode, 2024; Vetrotech, 2024; Accacia, 2025; Fluidconstruction, 2023
22	Promote health and well-being	Vetrotech, 2024; Fluidconstruction, 2023
23	Improved community engagement	Bode, 2024,

Table 2: Factors Inhibiting the Adoption of Eco-Friendly Materials for Sustainable Construction

S/N	Inhibiting Factors	Sources
1	Expertise and technical capacity	Chepngeno & Letema, 2025
2	High cost of production	Chepngeno & Letema, 2025; Accacia, 2025; Isang, 2023
3	Material performance	Accacia, 2025; Abera, 2024
4	Insufficient Technology	Chepngeno & Letema, 2025
5	Limited awareness about eco-friendly materials	Chepngeno & Letema, 2025; Accacia, 2025; Hassan et al. 2024; Isang, 2023
6	Public acceptance	Abera, 2024; Hassan et al. 2024
7	Poor government support	Chepngeno & Letema, 2025; Hassan et al. 2024
8	Limited availability	Isang, 2023
9	Lack of local production	Hassan et al. 2024
10	Lack of standardization	Isang, 2023
11	Market demand	Chepngeno & Letema, 2025
12	Regulatory compliance	Abera, 2024; Isang, 2023
13	Access to funding	Chepngeno & Letema, 2025
14	Weak policy enforcement	Accacia, 2025; Hassan et al. 2024
15	Lack of technical guidelines	Hassan et al. 2024

3.0 METHODOLOGY

The aim of this paper is to assess factors influencing the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria with a view to reduce carbon footprint. The target population for this research comprises construction professionals, which include architects, quantity surveyors, builders, and engineers, in either consulting, contracting, consortium firms or government ministries, departments and agencies in the study area. The study employed quantitative research methods to achieve its aim and the data reported were gathered with the use of a well-structured questionnaire. The study population was categorized into four groups. The consulting firm comprises 121 architectural firms, 141 quantity surveying firms, 92 engineering firms and 70 building firms whose headquarters are located in Lagos, and this gives a sampling frame of 424 for consulting firms. This was derived from the list of registered firms in their professional institutions.

The sampling frame of the selected contracting firms includes 54 firms whose headquarters are in Lagos out of the 94 registered members of the Federation of Construction Industry (FOCI) while the sampling frame of the selected government ministries, departments and agencies (MDAs) is 85. However, since there is no direct source to the list of consortium firms in Lagos state, a pilot study was conducted to arrive at 15 consortium firms. This gave a total of 578 sampling frames. Out of the total sampling frame, a random sampling method was employed to determine the sample size for the study. A sample size of 30% of the sampling frame was randomly selected giving the study 173 sample size.

Data reported was gathered with the use of questionnaire. The research instrument was structured into sections. Background information about the respondents and firms was gathered in section A while sections B and C addressed the specific objectives of the study. The study employed physical method for the distribution of questionnaires to the respondents. However, a total of 66 responses were received at the end of the collection period out of 174 copies distributed. This gives a response rate of 38.2% of the sample size. Data received were analyzed using descriptive and inferential statistical techniques through Statistical Package for Social Sciences (SPSS) software. The descriptive statistics used were frequency distribution and mean score while the inferential statistics used were the analysis of variance (ANOVA) and factor analysis. Frequency distribution in percentage was used to present the demographic characteristics of respondents and the firms. While the mean score was used for questions on a 5-Likert-scale, which aims to assess central tendencies. Analysis of variance (ANOVA) was used to compare perceptions and test significant differences in responses among firms. Exploratory factor analysis (EFA) was employed to identify underlying factors motivating and inhibiting the adoption of eco-friendly materials for sustainable construction. The EFA also regroups these factors into a small group for ease of description.

4.0 RESULTS

This section presents the results obtained from the data analysis. These include results of the general profile of respondents. The section also presents results obtained in identifying the factors influencing the adoption of eco-friendly construction materials in the study area.

4.1 General Profile of the Respondents and companies

Table 3 presents the general profile of the respondents including the nature of organization, profession of respondents, professional membership, years of work experience among others. The result shows that 59.1% of the respondents are from contracting firms while 12.1%, 21.2% and 7.58% are from consulting firms, government ministries, and consortium firms respectively. This shows that majority (more than 80%) of the respondents are from contracting and government ministries, departments and agencies (MDAs).

The result on specializations shows that 42.4% specialized in building works. This is followed by civil work (27.3%), building work and civil work (19.7%) and industrial engineering (10.6%). Results on the year of establishment of the firms showed that 50% of firms have been in operation between in less than 5 years while 12.1%, 12.1% and 9.1% have 5 – 10 years, 11-15 years and 16-20 years respectively. However, 16.7% of the firms have been in operation for more than 20 years. The result on size of employees shows that 51.5% had less than 10 employees, while 24.2%, 15.2%, and 9.1% had 10-49, 50-249 and more than 250 employees respectively. The results also showed that 57.6% has an annual revenue of <50 million naira, 21.2% has >5 billion naira, 12.1% has 50 – 249 million naira, 6.1% has 250 – 999 million naira and 3% did not state their annual revenue. Result on the financial worth of assets of the firm shows that, 56.1% has a worth of <50 million, while 16.7%, 13.6%, 10.6% and 3% has a worth of 50 – 249 million, >5 billion, 250-999 million, and 1-5 billion respectively.

The result on respondents' professional designation showed that 33.3% of the respondents are architects, followed by both builders and quantity surveyors (22.7% each), and engineers (21.2%). However, results of their professional membership showed that 31.8% are fellow or member of the Nigerian Institute of Architects (NIA), while 22.7%, 22.7% and 21.2% are fellow or member of the Nigerian Institute of Builders (NIOB), Nigerian institute of quantity surveyors and Nigerian Society of Engineers (MNSE).

The result on the respondent professional registration shows that 31.8% are registered members of Architect Registration Council of Nigeria (ARCON), while 21.2%, 22.7% and 22.7% are registered members of Council of Registered Builders of Nigeria (CORBON), Council of the Registration of Engineering in Nigeria (COREN) and Quantity Surveyors Registration Board of Nigeria (QSRBN) respectively. Results on the highest academic qualification showed that 50.0% had B.Sc./B.Tech degrees, while 16.7%, 16.7%, 13.6%, and 3% had M.Sc./MBA, PhD, HND and ND degrees respectively. The result further showed that 51.5% of the respondents had less than 5 years of work experience, while 18.2%, 13.6%, 10.6%, and 6.1% had between 11–15 years, 5-10 years, >20 years and 16 -20 years of work experience respectively.

Table 3: General Profile of the Respondents and Firms

General Profile	Frequency	Percent %
Nature of respondent firms		
Consulting	8	12.1
Contracting	39	59.1
Consortium	5	7.58
Government ministries, departments and agencies	14	21.2
Total	**66**	**100**
Business operations/specializations		
Building works and Civil works	13	19.7
Building works	28	42.4
Civil works	18	27.3
Industrial engineering	7	10.6
Total	**66**	**100**

General Profile	Frequency	Percent %
Years of establishment		
<5 years	33	50
5-10 years	8	12.1
11-15 years	8	12.1
16-20 years	6	9.1
>20 years	11	16.7
Total	**66**	**100**
Size of employees		
<10	34	51.5
10-49	16	24.2
50-249	10	15.2
>250	6	9.1
Total	**66**	**100**
Annual revenue (in naira)		
>5 billion	14	21.2
<50 million	38	57.6
50-249 million	8	12.1
250-999 million	6	9.1
Total	**66**	**100**
Financial worth of assets (in naira)		
<50 million	37	56.1
50-249 million	11	16.7
250-999 million	7	10.6
1-5 billion	2	3
> 5 billion	9	13.6
Total	**66**	**100**
Professional Designation		
Architects	22	33.3
Builders/ Project managers	15	22.7
Engineers	14	21.2
Quantity Surveyors	15	22.7
Total	**66**	**100**
Professional Membership		
F/MNIA	21	31.8
F/MNIOB	15	22.7
F/MNIQS	15	22.7
F/MNSE	14	21.2
None	1	1.5
Total	**66**	**100**

Table 3: General Profile of the Respondents cont'd

General Profile	Frequency	Percent %
Professional Registration		
ARCON	21	31.8
CORBON	14	21.2
COREN	15	22.7
None	1	1.5
QSRBN	15	22.7
Total	**66**	**100**
Highest Academic Qualification		
B.Sc/B.Tech	33	50
HND	9	13.6
M.Sc /MTech	11	16.7
ND	2	3
Ph.D	11	16.7
Total	**66**	**100**
Years of work experience		
<5	34	51.5
5-10	9	13.6
11-15	12	18.2
16-20	4	6.1
>20years	7	10.6
Total	**66**	**100**

4.2 Factors Motivating the Adoption of Eco-Friendly Materials for Sustainable Construction

The analysis of the factors motivating the adoption of eco-friendly materials across different sectors within the construction industry was presented in Table 4. Respondents from various sectors, including consortiums, consulting firms, contracting companies, and government ministries, provided their perspectives on the drivers of their adoption. From the overall results, waste reduction was ranked the highest with a mean score (MS) of 4.00. This is followed by reduced greenhouse gas emissions (MS = 3.90) and decreased pollution (MS = 3.85. On the other hand, resilience (MS = 3.23) and improved water efficiency (MS = 3.20) were ranked lower.

In consulting firms, the top ranked motivating factor includes promoting health and well-being (MS = 3.86) and lower resource consumption (MS = 3.71). On the other hand, factors with the least motivating influence are improved water efficiency (MS = 2.71) and market growth (MS = 2.57). From the view of construction firms, the top-ranking factor motivating the adoption of eco-friendly material is waste reduction (MS = 4.05). Other factors with high motivating influence are reduced greenhouse gas emission (MS = 3.86), decreased pollution (MS = 3.82) and reduce environmental impact (MS = 3.64). The least ranked motivating factors are job creation and resilience with each having a mean score of 3.18.

From the view of consortium firms, the top-ranking factor motivating the adoption of eco-friendly material is reduced greenhouse gas emissions (MS = 5.00). This is strictly followed by long term investment (MS = 4.67), decreased pollution (MS = 4.33) and technology (MS = 4.33). While the least ranked motivating factors include job creation, improved indoor air quality and resilience with each having a mean score of 2.67.

Table 4: Factors Motivating the Adoption of Eco-Friendly Materials for Sustainable Construction

Motivating Factors	Overall		Consulting		Contracting		Consortium		Government MDAs		ANOVA	
	MS	R	MS	R	MS	R	MS	R	MS	R	F	Sig.
Reduced greenhouse gas emissions	3.90	2	3.43	9	3.86	2	5.00	1	4.00	11	1.315	.284
Lower resource consumption	3.73	5	3.71	2	3.55	8	4.00	5	4.13	6	.788	.509
Decreased pollution	3.85	3	3.57	3	3.82	3	4.33	3	4.00	11	.380	.768
Waste reduction	4.00	1	3.57	3	4.05	1	4.00	5	4.25	4	.576	.635
Long term investment	3.75	4	3.43	9	3.59	5	4.67	2	4.13	6	1.933	.142
Biodegradability and recyclability	3.70	6	3.57	3	3.50	11	3.67	10	4.38	3	1.873	.152
Enhanced building performance	3.70	6	3.29	12	3.59	5	3.33	13	4.50	2	2.367	.087
Improved thermal and acoustic properties	3.53	12	3.14	15	3.41	13	3.33	13	4.25	4	2.228	.102
Improved water efficiency	3.20	22	2.71	22	3.23	21	3.67	10	3.38	23	.967	.419
Reduce environmental impact	3.68	8	3.57	3	3.64	4	4.00	5	3.75	16	.164	.920
Technology	3.50	14	3.29	12	3.36	17	4.33	3	3.75	16	1.490	.234
Resilience	3.23	21	3.00	18	3.18	22	2.67	21	3.75	16	1.269	.300
Helped earn green certification	3.63	10	3.57	3	3.27	18	3.67	10	4.63	1	3.957	.015
Innovation	3.63	10	3.29	12	3.59	5	3.33	13	4.13	6	1.525	.225
Reduced noise pollution	3.48	17	2.86	21	3.41	13	4.00	5	4.00	11	2.306	.093
Market growth	3.20	22	2.57	23	3.27	18	3.00	19	3.63	20	1.214	.319
Reduced air pollution	3.28	20	3.00	18	3.27	18	3.33	13	3.50	22	.365	.778
Job creation	3.30	19	3.14	15	3.18	22	2.67	21	4.00	11	2.335	.090
Long term cost savings	3.50	14	3.14	15	3.41	13	3.33	13	4.13	6	2.167	.109
Improved indoor air quality	3.50	14	3.57	3	3.41	13	2.67	21	4.00	11	1.446	.246
Improved energy efficiency	3.53	12	3.43	9	3.55	8	3.33	13	3.63	20	.076	.972
Promote health and well-being	3.68	8	3.86	1	3.55	8	4.00	5	3.75	16	.342	.795
Improved community engagement	3.48	17	3.00	18	3.45	12	3.00	19	4.13	6	2.095	.118

In government ministries departments and agencies, the top ranked factors are helped earn green certificate (MS = 4.63), enhanced building performance (MS = 4.50) and biodegradability and recyclability (MS = 4.38). On the other hand, the least motivating factors are reduced air pollution (MS = 3.50) and improved water efficiency (MS = 3.38).

To test whether the opinions of the different stakeholder groups agree or disagree on how the identified factors motivate the adoption of eco-friendly materials, a one-way Analysis of Variance (ANOVA) was carried out. The test results reveal a significant difference in how the stakeholders
perceived helped earn green certification (Sig. = 0.015, $p<0.05$) as a motivating factor. This shows that their opinions differ significantly on how the prospect of earning green certification influences the adoption of eco-friendly materials. The result also reveals that the opinions of the stakeholders agree on all other factors motivating the adoption of eco-friendly materials for sustainable construction in the study area, as no other significant differences were found.

To assess the suitability of the collected data on factors motivating the adoption of eco-friendly materials for factor analysis, Table 5 presents the results of the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy and Bartlett's test of sphericity. The KMO statistic quantifies the proportion of variance among variables that might be common variance, with a value exceeding 0.5 considered the minimum requirement for factor analysis to proceed. Furthermore, Bartlett's test of sphericity must be statistically significant ($P \leq 0.05$) to reject the null hypothesis that the correlation matrix is an identity matrix, indicating that the variables are related and thus suitable for structure detection. The results obtained from the analysis show a KMO value of 0.841, which greatly exceeds the minimum threshold and falls within the 'meritorious' range according to conventional interpretations. Furthermore, Bartlett's test of sphericity was statistically significant (Approx. Chi-Square = 952.212, df = 253, Sig. = .000). This confirms that the correlation matrix is not an identity matrix and has adequate correlations to proceed. Collectively, these results demonstrate that the collected data on the factors motivating the adoption of eco-friendly materials are valid and highly suitable for factor analysis.

Table 5: KMO and Bartlett's Test of Factors Motivating the Adoption of Eco-Friendly Materials for Sustainable Construction

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.841
Bartlett's Test of Sphericity	Approx. Chi-Square	952.212
	Df	253
	Sig.	.000

4.3.1 Factor analysis of the factors motivating the adoption of eco-friendly materials

The result in Table 6 shows the principal factor extraction and varimax rotation of the factors motivating the adoption of eco-friendly materials for sustainable construction. The eigenvalues for the five extracted factors ranged from 2.239 to 4.329, and the percentage of variance explained by the 1st factor is 18.824%, the 2nd factor is 18.718%, the 3rd factor is 12.781%, the 4th factor is 10.270%, and the 5th factor is 9.734%. The cumulative percentage of variance explained by the extracted five factors accounted for 70.326%. Extraction method: Principal Component Analysis. The identified motivating factors are grouped into five principal factors as follows:

Factor 1: Health, Economic, and Environmental Co-benefits
Factor 2: Long-term Value and Environmental Stewardship
Factor 3: Regulatory and Impact Reduction Drivers
Factor 4: Market and Structural Resilience
Factor 5: Operational and Ambient Efficiency

Table 6: Principal factor extraction and varimax rotation of the Factors Motivating the Adoption of Eco-Friendly Materials for Sustainable Construction

Motivating factors	Factor loading	Total	% of Variance	Cumulative %
Factor 1: Health, Economic, and Environmental Co-benefits		4.329	18.824	18.824
Improved indoor air quality	0.849			
Job creation	0.767			
Improved energy efficiency	0.758			
Long term cost savings	0.664			
Promote health and well-being	0.655			
Reduced air pollution	0.633			
Improved community engagement	0.563			
Factor 2: Long-term Value and Environmental Stewardship		4.305	18.718	37.542
Long term investment	0.793			
Decreased pollution	0.764			
Biodegradability and recyclability	0.751			
Waste reduction	0.715			
Enhanced building performance	0.65			
Improved thermal and acoustic properties	0.601			
Factor 3: Regulatory and Impact Reduction Drivers		2.940	12.781	50.322
Reduce environmental impact	0.737			
Helped earn green certification	0.688			
Lower resource consumption	0.662			
Technology	0.586			
Reduced greenhouse gas emissions	0.524			
Factor 4: Market and Structural Resilience		2.362	10.270	60.592
Resilience	0.811			
Market growth	0.646			
Innovation	0.548			
Factor 5: Operational and Ambient Efficiency		2.239	9.734	70.326
Improved water efficiency	0.717			
Reduced noise pollution	0.668			
Extraction Method: Principal Component Analysis.				
Rotation Method: Varimax with Kaiser Normalization.				

Factor 1: Health, Economic, and Environmental Co-benefits. This factor accounts for 18.824% of the total variance of the motivating factors, with loading variables having a score that ranged from 0.563 to 0.849. The six components include improved indoor air quality (0.849), job creation (0.767), improved energy efficiency (0.758), long-term cost savings (0.664), promotion of health and well-being (0.655), and reduced air pollution (0.633). This factor represents a holistic motivation where direct human health benefits, such as better air quality, are intertwined with positive economic outcomes like job creation and cost savings, as well as broader environmental advantages.

Factor 2: Long-term Value and Environmental Stewardship. This factor accounts for 18.718% of the total variance, with loading variables having a score that ranged from 0.601 to 0.793. The five components include long-term investment (0.793), decreased pollution (0.764), biodegradability and recyclability (0.751), waste reduction (0.715), and enhanced building performance (0.650). This factor underscores motivation driven by a forward-looking perspective, emphasizing the enduring value of investments, the reduction of a project's lifecycle environmental footprint through waste management and circular economy principles, and the pursuit of superior performance.

Factor 3: Regulatory and Impact Reduction Drivers. This factor accounts for 12.781% of the total variance, with loading variables having a score that ranged from 0.524 to 0.737. The five components include reduced environmental impact (0.737), help in earning green certification (0.688), lower resource consumption (0.662), technology (0.586), and reduced greenhouse gas emissions (0.524). This factor highlights motivations linked to compliance and market recognition, such as achieving sustainability certifications, alongside a core objective of minimizing ecological damage and leveraging technology for greater resource efficiency.

Factor 4: Market and Structural Resilience. This factor accounts for 10.270% of the total variance, with loading variables having a score that ranged from 0.548 to 0.811. The three components are resilience (0.811), market growth (0.646), and innovation (0.548). This factor encapsulates the strategic motivations for adopting eco-friendly materials, focusing on enhancing the building's ability to withstand disruptions, capitalizing on expanding market opportunities, and fostering a reputation for innovation.

Factor 5: Operational and Ambient Efficiency. This factor accounts for 9.734% of the total variance, with loading variables having a score of 0.717 and 0.668. The two components are improved water efficiency (0.717) and reduced noise pollution (0.668). This factor represents motivations centered on optimizing resource use and improving the immediate environmental conditions for occupants, specifically targeting water conservation and acoustic comfort.

4.4 Factors Inhibiting the Adoption of Eco-Friendly Materials for Sustainable Construction

This section examines the extent to which certain factors inhibit the adoption of eco-friendly materials for sustainable construction, as perceived by the key stakeholders surveyed. The examination of these inhibiting factors was conducted cross-sectionally across four stakeholder groups: consulting firms, contracting firms, consortiums, government ministries, departments and agencies and the result is presented in table 7. From an overall perspective, the top-ranking factor that inhibits the adoption of eco-friendly materials is lack of expertise and technical capacity (MS=3.50). This is closely followed by public acceptance and a lack of technical guidelines, which are tied for the second rank (MS=3.48). On the other hand, material performance (MS=2.80), insufficient technology (MS=2.98), and market demand (MS=3.13) received the lowest ranks.

From the perspective of consulting firms, the highest ranked factor inhibiting the adoption of eco-friendly materials is limited training and awareness (MS=3.57). This is closely followed by expertise and technical capacity, public acceptance, limited availability, lack of standardization, and access to funding with each having a mean score of 3.29. On the other hand, material performance (MS=2.14) and insufficient technology (MS=2.29) were ranked the least inhibiting factors. Contracting firms most ranked inhibiting factor is lack of technical guidelines (MS=3.68), followed by weak policy enforcement (MS=3.59), high cost of production (MS = 3.45) and expertise and technical capacity (MS=3.41). Conversely, material performance (MS=3.09) and insufficient technology (MS=2.95) are the least ranked inhibiting factors.

For consortiums, the highest ranked inhibiting factor is access to funding (MS=4.00). This is strictly followed by expertise and technical capacity, limited training and awareness, limited availability, and poor government support which each have a mean score of 3.67. On the other hand, they ranked public acceptance (MS=2.33) and material performance (MS = 2.00) as their least important inhibiting factors. Government ministries, departments and agencies ranked public acceptance (MS=4.25) as the most significant inhibiting factor to adoption of eco-friendly materials. The second-ranked factor is poor government support (MS=4.00) followed by expertise and technical capacity (MS=3.88) and limited training and awareness (MS=3.75). On the other hand, they ranked high cost of production (MS=3.25), weak policy enforcement (MS=3.25) and material performance (MS = 2.88) as the least inhibiting factors influencing the adoption of eco-friendly materials.

To test statistical consensus among these diverse stakeholder perspectives, a one-way Analysis of Variance (ANOVA) was conducted. The test results reveal a significant difference only in the perception of public acceptance ($F=2.946$, Sig. = 0.046, $p<0.05$) as an inhibiting factor. This confirms the evident divergence, where government MDAs rank it highest and consortiums lowest. For all other factors, the opinions of the four stakeholder groups do not differ significantly, demonstrating a broad, cross-sectional agreement on the challenging landscape of technical, financial, and awareness-related barriers inhibiting the adoption of eco-friendly materials in the study area.

Table 7: Factors Inhibiting the Adoption of Eco-Friendly Materials for Sustainable Construction

Inhibiting factors	Overall		Consulting		Contracting		Consortium		Government MDAs		ANOVA	
	MS	R	MS	R	MS	R	MS	R	MS	R	F	Sig.
Expertise and technical capacity	3.50	1	3.29	2	3.41	4	3.67	2	3.88	3	.781	.512
High cost of production	3.28	10	2.86	7	3.45	3	3.00	10	3.25	13	.543	.656
Material performance	2.80	15	2.14	15	3.09	13	2.00	15	2.88	15	1.729	.178
Insufficient Technology	2.98	14	2.29	14	2.95	15	3.00	10	3.63	5	1.907	.146
Limited training and awareness	3.43	4	3.57	1	3.23	10	3.67	2	3.75	4	.584	.630
Public acceptance	3.48	2	3.29	2	3.41	4	2.33	14	4.25	1	2.946	.046
Poor government support	3.40	6	2.86	7	3.32	8	3.67	2	4.00	2	1.318	.284
Limited availability	3.43	4	3.29	2	3.41	4	3.67	2	3.50	8	.110	.954
Lack of local production	3.28	10	2.71	10	3.32	8	3.33	6	3.63	5	1.262	.302
Lack of standardization	3.30	8	3.29	2	3.23	10	3.00	10	3.63	5	.359	.783
Market demand	3.13	13	2.71	10	3.09	13	3.33	6	3.50	8	.823	.490
Regulatory compliance	3.23	12	2.43	13	3.41	4	3.33	6	3.38	11	1.930	.142
Access to funding	3.33	7	3.29	2	3.23	10	4.00	1	3.38	11	.549	.652
Weak policy enforcement	3.30	8	2.57	12	3.59	2	3.00	10	3.25	13	1.737	.177
Lack of technical guidelines	3.48	2	2.86	7	3.68	1	3.33	6	3.50	8	1.457	.243

To evaluate the suitability of the data on factors inhibiting the adoption of eco-friendly materials for factor analysis, Table 8 presents the results obtained from the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity. The value of KMO varies from 0 to 1, and a minimum value of 0.5 is advised for factor analysis to proceed. Also, the Bartlett's test of sphericity must be significant at $P \leq 0.05$. The results obtained from the analysis show a KMO value of 0.835, which greatly exceeds the minimum threshold and is classified as meritorious. Furthermore, Bartlett's test of sphericity was statistically significant (Approx. Chi-Square = 501.739, df = 105, Sig. = .000). This shows that the correlation matrix is factorable and that the collected data on the factors inhibiting the adoption of eco-friendly materials are valid and highly suitable for factor analysis.

Table 8: KMO and Bartlett's Test of Factors Inhibiting the Adoption of Eco-Friendly Materials for Sustainable Construction

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.835
Bartlett's Test of Sphericity	Approx. Chi-Square	501.739
	Df	105
	Sig.	.000

4.4.1 Factor analysis of the factors inhibiting the adoption of eco-friendly materials

The result in Table 9 shows the principal factor extraction and varimax rotation of the factors inhibiting the adoption of eco-friendly materials for sustainable construction. The eigenvalues for the three extracted factors ranged from 2.512 to 3.629, and the percentage of variance explained by the 1st factor is 24.196%, the 2nd factor is 20.167%, and the 3rd factor is 16.749%. The cumulative percentage of variance explained by the extracted three factors accounted for 61.112%. Extraction method: Principal Component Analysis. The identified inhibiting factors are grouped into three principal factors as follows:

Factor 1: Structural and Market Barriers
Factor 2: Institutional and Governance Barriers
Factor 3: Technical and Economic Barriers

Factor 1: Structural and Market Barriers. This factor accounts for 24.196% of the total variance of the factors inhibiting adoption, with loading variables having a score that ranged from 0.360 to 0.813. The seven components include poor government support (0.813), limited availability (0.723), access to funding (0.722), limited awareness about eco-friendly materials (0.653), lack of standardization (0.596), regulatory compliance (0.566), and market demand (0.360). This factor represents a broad cluster of challenges related to the fundamental market infrastructure and support systems necessary for eco-friendly materials to thrive, highlighting a critical lack of foundational enablement from both government and the market.

Factor 2: Institutional and Governance Barriers. This factor accounts for 20.167% of the total variance, with loading variables having a score that ranged from 0.496 to 0.868. The four components include weak policy enforcement (0.868), lack of local production (0.705), lack of technical guidelines (0.673), and public acceptance (0.496). This factor underscores deficiencies in the regulatory and institutional framework, where even when policies exist, their weak enforcement, coupled with a lack of supporting technical documentation and local manufacturing capacity, creates a significant impediment to widespread adoption.

Factor 3: Technical and Economic Barriers. This factor accounts for 16.749% of the total variance, with loading variables having a score that ranged from 0.666 to 0.966. The four components include exposure and technical capacity (0.966), material performance (0.786), insufficient technology (0.716), and high cost of production (0.666). This factor highlights the direct practical and financial concerns of stakeholders, focusing on a perceived or actual lack of technical expertise, uncertainties about the performance and durability of eco-friendly materials, and the economic disincentives driven by high production costs.

Table 9: Principal factor extraction and varimax rotation of the Factors Inhibiting the Adoption of Eco-Friendly Materials for Sustainable Construction

Inhibiting factors	Factor loading	Total	% of Variance	Cumulative %
Factor 1: Structural and Market Barriers		3.629	24.196	24.196
Poor government support	.813			
Limited availability	.723			
Access to funding	.722			
Limited awareness about eco-friendly materials	.653			
Lack of standardization	.596			
Market demand	.580			
Regulatory compliance	.566			
Factor 2: Institutional and Governance Barriers		3.025	20.167	44.363
Weak policy enforcement	.868			
Lack of local production	.705			
Lack of technical guidelines	.673			
Public acceptance	.496			
Factor 3: Technical and Economic Barriers		2.512	16.749	61.112
Material performance	.786			
Insufficient Technology	.716			
High cost of production	.666			
Expertise and technical capacity	.606			
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.				

5.0 DISCUSSIONS

The delivery of sustainable construction projects in Lagos, Nigeria is motivated by a range of factors, with waste reduction, reduced greenhouse gas emissions, and decreased pollution being the primary drivers. These findings are consistent with the research conducted by Bode (2024) and Chepngeno & Letema (2025), who identified environmental stewardship and resource efficiency as central motivations for adopting sustainable practices. Furthermore, the strong motivating influence of factors like improved indoor air quality and long-term cost savings aligns with the work of Fluidconstruction (2023) and Accacia (2025), who argued that the health and economic co-benefits of green buildings are significant incentives for stakeholders. The factor analysis further consolidated these drivers into five principal components, with Health, Economic, and Environmental Co-benefits emerging as the most significant cluster factors motivating the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria. This synthesis provides a more structured understanding that the motivation for adoption in Lagos, Nigeria is not monolithic but a confluence of health, economic, regulatory, and performance-related incentives.

However, the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria is hindered by several critical barriers. The most significant inhibiting factors identified in this study are a lack of expertise and technical capacity, a lack of technical guidelines, and limited training and awareness. These findings are consistent with the research conducted by Chepngeno & Letema (2025) and Hassan et al. (2024), who identified knowledge gaps and technical skill shortages as fundamental obstacles to sustainable construction. Similarly, the high ranking of limited availability and high production costs corroborates the work of Isang (2023) and Accacia (2025), who pointed to market immaturity and economic disincentives as major impediments. A notable divergence was observed in the perception of public acceptance, where government ministries viewed it as a top barrier while consortiums considered it the least. This suggests that the perceived market demand and social readiness for green construction vary significantly depending on the stakeholder's position in the industry. The factor analysis grouped these barriers to the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria into three principal components: Structural and Market Barriers, Institutional and Governance Barriers, and Technical and Economic Barriers. This categorization echoes the multi-faceted framework proposed by Chepngeno & Letema (2025), confirming that the challenges are not isolated but are deeply interconnected issues spanning the market, regulatory, and technical domains.

6.0 CONCLUSION

This study assessed the factors influencing the adoption of eco-friendly materials for sustainable construction in Lagos, Nigeria. The specific objectives analyzed the motivating and inhibiting factors influencing their adoption within the construction industry. A quantitative research approach was employed, utilizing a questionnaire survey to collect data from construction professionals, which was subsequently analyzed using descriptive and inferential statistical techniques. The paper concludes that the primary drivers for adoption of eco-friendly materials for sustainable construction are environmental and economic co-benefits, such as waste reduction and long-term savings. Conversely, major factors inhibiting the adoption of eco-friendly materials for sustainable construction are a lack of technical expertise, guidelines, and training, which can be categorized as Structural/Market, Institutional/Governance, and Technical/Economic barriers.

These findings highlight the need for a multi-pronged strategy. The government must enhance policy enforcement and provide incentives, while industry and educational institutions should focus on building technical capacity. Future research should develop localized technical guidelines for underutilized materials, investigate effective policy and fiscal incentives for local production, and design targeted interventions to overcome the identified barrier categories. Studies on strategies to boost public acceptance and market demand are also recommended.

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REFERENCES

Abera, Y. A. (2024). Sustainable building materials: A comprehensive study on eco-friendly alternatives for construction. *Composites and Advanced Materials, 33*, 1–17. https://doi.org/10.1177/26349833241255957

Accacia, (2025). Benefits & Challenges of Green Construction Materials. https://www.accacia.com/blog/benefits-challenges-of-green-construction-materials

Adewumi, T., Sanni, K., & Ajayi, F. (2023). Assessing local approaches to sustainable building in Nigeria: Opportunities and challenges. Journal of Environmental Engineering and Management, 17(4), 92–106.

Akindele, O.E., Ajayi, S.O., Toriola-Coker, O.L., & Oyegoke, A.S. (2023). Sustainable construction practice in Nigeria: Barriers and strategies for improvement. *Built Environment Project and Asset Management*, 13(4). https://doi.org/10.1108/BEPAM-06-2022-0085

Barbulianno. (2024). 18 Eco-Friendly Building Materials That Help You Save Energy And The Earth. https://www.barbuliannodesign.com/post/eco-friendly-building-materials-list

Bode T. A. (2024). Eco-Friendly Construction: Promoting the Recycling and Reuse of Building Materials. https://www.linkedin.com/pulse/eco-friendly-construction-promoting-recycling-reuse-building-adeyemi-k7xkc/

Chepngeno, P., & Letema, S. (2025). Factors influencing the adoption of sustainable construction practices in building development projects in Ruiru Municipality, Kenya. *Environmental Technology and Science Journal* 16(1):111-122. DOI:10.4314/etsj.v16i1.11

Dighade, R., Gomase, V., Peshattiwar, R., Selokar, A., Sangidwar, N., Peshattiwar, S., & Malve, S. (2024). Emission of carbon footprint from building construction materials: A review. *IOP Conference Series: Earth and Environmental Science*, 1409. DOI 10.1088/1755-1315/1409/1/012010

FluidConstructions. (2023). Use of eco-friendly materials in the future of construction. *FluidConstructions.com*. https://www.fluidconstructions.com/construction/use-of-eco-friendly-materials-in-the-future-of-construction/

Hassan, J., Barikdar, C. R., Rozario, E., Hossain, S., Ahmed, M. K., Saimon, A. S. M., & Alam, G. T. (2024). Emerging trends and performance evaluation of eco-friendly construction materials for sustainable urban development. *Journal of Mechanical, Civil and Industrial Engineering*. https://doi.org/10.32996/jmcie

Hassan, J., Barikdar, C.R., Rozario, E., Hossain, S., Kamal, M.F., Saleh, A., Saimon, M., & Alam, G.T. (2022). Emerging Trends and Performance Evaluation of Eco-Friendly Construction Materials for Sustainable Urban Development. *Journal of Mechanical, Civil and Industrial Engineering*, 2(2), 80-90.

Isang, I. (2023). A Historical Review of Sustainable Construction in Nigeria: A Decade of Development and Progression. *Frontiers in Engineering and Built Environment*, DOI: 10.1108/FEBE-02-2023 0010

Li, C., Pradhan, P., Chen, G., Kropp, J. P., & Schellnhuber, H. J. (2025), Carbon footprint of the construction sector is projected to double by 2050 globally. *Communications Earth & Environment,* 6(831), 1-11. https://doi.org/10.1038/s43247-025-02840-x

Magicrete. (2024). Advantages Of Eco-Friendly Construction Materials. https://www.magicrete.in/blog/advantages-of-eco-friendly-construction-materials

Njeri, P., Munala, G., & Letema, S. (2023). Environmental sustainability performance of eleven upgraded informal settlements in Kenyan cities. *Journal of Housing and the Built Environment*, 38(4), 2751–2772. https://doi.org/10.1007/s10901-023-10060-y

Srivastava, K., Srivastava, A., Singh, P., Jagadish, R.S., Verma, R., & Jaiswal, V. (2019). Role of Eco-Friendly Materials in Construction for Making Cities Smart: A Case Study of Noida and Greater Noida. *Making Cities Resilient*, 235-252. https://doi.org/10.1007/978-3-319-94932-1_17

Uchehara, I., Moore, D., Jafarifar, N., & Omotayo, T. (2022). Sustainability rating system for highway design: A key focus for developing sustainable cities and societies in Nigeria. *Sustainable Cities and Society*, 78, 103620. https://doi.org/10.1016/j.scs.2021.103620

Unegbu, H. C. O., Yawas, D. S., Dan-asabe, B., & Alabi, A. A. (2025). An analysis of challenges to achieving sustainable practices in Nigeria's construction sector. *Advances in Civil Engineering and Sustainable Architecture, 7*(1). https://doi.org/10.9744/acesa.v7i1.14464

Vetrotech. (2024). Can Buildings Be Good for the Planet? Exploring the Rise of Green Construction. https://www.vetrotech.com/en-in/education/role-of-glass-systems-in-green-construction

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ASSESSING THE FACTORS INFLUENCING FARMER-HERDER CONFLICTS (PHLCS) IN SUB-SAHARAN AFRICA: A CASE STUDY IN THE OKE-OGUN, NIGERIA

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ABSTRACT

Lately, there has been an upsurge in different forms of violent conflicts in Sub-Saharan Africa. This study focuses on Farmer-herder land conflict (FHLC) in Oke-Ogun, Nigeria, identifying and examining factors influencing farmer-herder land conflicts (FHLCs). Using both primary and secondary data, the study employed descriptive statistical analysis. Findings revealed that politics was the primary factor influencing FHLC (70.66%) in the Oke-Ogun Region OOR. Findings further identified that farming was subsistence-based (70.0%) and the predominant land use, with a Rate of Influencing Index (RII) of 4.50, while herding was mainly for prestige and commercial purposes, with 6.8% participation and an RII of 3.55. The remaining 23.2% of the respondents engaged in other land-use activities. The mean farm size was 488 hectares, and the average herd size was 460 cattle. The study has shown that farmer-herder land conflict is common in the study area. The conflict has the potential to affect the livelihoods of both the farmers and the herders. Thus, the government's weakness in leaving land administration and land conflict resolution to community leaders and individual families requires urgent attention. Apart from this, the conflict should be promptly and adequately managed through a conflict resolution method or procedure acceptable to all parties to prevent favouritism and marginalisation of any party, and to allow peace between the concerned parties.

Keywords: Farmer-herders conflict, Influencing factors, land uses, Oke-Ogun, Nigeria

1.0 INTRODUCTION

The manifestation of conflicts across different dimensions and the influence of stakeholders is a significant problem confronting world peace today. The society's cultural, political, and economic development can be truncated unless it is adequately addressed and managed, given its link to several aspects of human activities (Abdulbaqi & Ariemu, 2017; Antwi, 2018; Ivorgba, 2024). Marshall & Gurr (2005) and Rustard (2024) revealed that from developed to developing countries, conflicts are common occurrences. Across Nigerian states, significant conflicts among several ethnic and religious communities have been experienced and continue to be experienced (Aliyu, 2015; Nwogu et al., 2024). These vary significantly depending on the stakeholders involved, the process, and the dimension. Several factors attributed to these conflicts in developing countries include poor governance, human rights violations, poverty, and ethnic marginalisation (Utsaha et al., 2007; Sarafa & Monday, 2024). In other parlance, Adelakun et al. (2015) and Isiak et al. (2025) attributed conflicts to divergent value systems in the country and to resource control.

According to Usoro et al. (2014) and Ogbe et al. (2024), conflict can be found in many spheres of life and is as old as the family institution. Conflicts are defined as struggles for supremacy between individuals or groups that subjugate or even remove the opponent. In other parlance, Antwi (2018) defines conflict as changes in opinions, fights, and struggles among individuals, groups, or states. Based on differing opinions about the word "conflict," Galtung (2000) and Richetta and Wegenast (2025) viewed it as the incompatibility of goals among two or more parties, resulting in tension, crises, and sometimes violence among parties, states, or communities. Conflicts can occur between individuals, groups, and different positions in society. Others can be between different interests and beliefs, whether they have material existence or come into being only through discourse. Conflict also occurs between the same resource user group, such as one farming community and another, or between different user groups, such as herders and farmers (Momale, 2003; Atolagbe, 2024). These issues are significant because, as long as there is competition over the vital socioeconomic needs of individuals or groups, or over specific scarce resources, conflict is bound to occur. Land issues are vital resources that often result in conflicts among competing users (farmers and herders). A land conflict, therefore, can be understood as the misuse, restriction, or dispute over property rights to land (Imbush, 1999; Wehrmann, 2005; Alananga et al., 2024). The existence of two groups of incompatible land users in the same environment breeds competition and conflict, including inter-group, family, inter-personal, intra-personal, and farmer-herder conflicts, thereby calling for research intervention.

Li (2018), Shehu (2018), and Ioryue (2024) state that farmer-herder conflicts are rampant regarding resource use, mainly centred on land and water access and the struggle for grazing land. Abegunde (2011) and Obikaeze et al. (2023) itemised that environmental factors such as increased population, climate change, and poverty create avenues for conflict and its spread. However, customary and statutory land management systems have also been identified as a possible reason for the persistent conflict (Chikaire et al., 2017; Lamidi, 2025). Hence, a lasting solution to the conflict requires a clearer understanding of the root causes and the stakeholders' influence on farmer-herder land conflict over the years. The trend and pattern of the conflict within the country seem to suggest that most past government measures and research were carried out without the direct involvement of urban planners, who, by training, would have appropriately guided land allocation and management. The understanding thus far is based on very little information about the pattern of incidence and the socio-environmental effects of farmer-herder conflicts in Nigeria (Bolarinwa, 2007; Adebajo et al., 2014; Kums et al., 2024).

Literature has established that Southwestern Nigerians are the highest consumers of dairy products in sub-Saharan Africa (Bénard et al., 2010). The Oke-Ogun Region's guinea savannah landscape attracts herders from other local and international cattle-rearing regions. The nature of the land makes it suitable for crop farming and grazing, forming a natural habitat for pastoralists who would prefer to be located near the source of raw materials and markets. The presence of two groups in the same environment with incompatible land uses raises competition and conflicts, thereby calling for research intervention, and the stakeholders' influence on farmer-herder conflicts must be studied. The above discussions show that an explanation of the farmer-herder land conflicts in the form of the stakeholders' influence in the Oke-Ogun Region is overdue. Of importance to this study is the influence of stakeholders on farmer-herder land conflicts in the Oke-ogun region. This will provide information to help

policymakers develop a framework for effective land use planning and mitigate the menace of farmer-herder land conflicts, hence this study.

Studies on land conflict abound locally and internationally. These include Ofuoku and Isife (2009), Abegunde (2011), Abegunde (2014), and the International Crisis Group [ICG] (2017). Studies by Bolarinwa (2007), Adebajo et al. (2014), Abegunde (2014), Chikaire et al. (2017), and Atolagbe (2024) are most relevant to this study because they address the farmer-herder land conflict in Nigeria. Few of these studies that referred to the Oke-Ogun Region, Nigeria, were either solely on pastoralism or conflict-exclusive (Adebajo et al., 2014; Abegunde, 2014; Adebayo & Olaniyi, 2008). In addition, the indigenous studies focus on Nigeria's Middle Belt and North-Western zones. They also did not explore the influence of stakeholders on farmer-herder land conflicts. This current study, with a regional planning perspective, focuses on the Oke-Ogun Region in the Southwestern part of the country to bridge these gaps.

2.0 LITERATURE REVIEW

2.1. Grazing Reserves Law in Nigeria

The Grazing Reserves Act of 1964 was enacted to grant pastoralists access to grazing land, encourage sedentarisation, and address conflict, and it was meant to improve productivity and social amenities as well as improve the cattle market and control diseases (Awogbade, 1978; Ibrahim, 2012; Ingawa et al., 1989; Bella & Olanrewaju, 2024). This was an improvement on the previous Land Act of 1962. Further to this, the Land Use Act of 1978 granted citizens of Nigeria the right to live in any part of the country without hindrance, not as natives but as Nigerians (Rasak, 2011). By the provisions of this law, the Federal Government could redraw the boundaries between cattle routes, rangelands, and farmlands, as the case may be, to encourage the coexistence of various groups.

However, the level of implementation of the law was the problem, as the farmer-pastoralist conflict was not abated, and cattle production was significantly reduced. This led to the enactment of the National Agricultural Policy of 1988, which stipulated that at least 10% of the national territory, i.e., 9.8 million acres, should be allocated to grazing reserves.

However, the level of implementation was only 2.82 % (CIEL, 2006; Ibrahim, 2012; Amadi & Harrison, 2025). Then came the National Grazing Route and Reserve Commission Bill of 2011, which attempted to establish grazing routes and reserves across the 36 states and the FCT (Kumolu, 2014). Another attempt on 3 July 2012 was a bill titled “The National Grazing Route and Reserve Bill”, presented to the Nigerian Senate for deliberation (Daily Trust, 2012). However, it failed to scale the third reading, as the Senators were divided over whether the Federal Government was constitutionally empowered to create grazing reserves and stock routes in any state of the Federation (World Bank, 2012). Public opinion, particularly among host communities, showed apprehension towards the legalisation of land grabbing and culture clashes between migrants and their hosts. Sedentarisation would have succeeded as another government animal-rearing method to resolve the farmer-herder conflict. RECANIGER (2009), however, shows that pastoral systems are 20% more productive. This is because sedentarisation requires considerable encouragement for pastoralists to settle in designated areas and to maintain field biomass intensively to avoid depletion.

Abegunde (2014) and Kums et al. (2024) also attempted to understand the causal factors and

the dynamics of resource conflicts in Africa. In an attempt to achieve this, a comparative analysis of the Niger Delta situation in Nigeria and the Marikana situation in South Africa was considered. The study concluded that Africa is endowed with diverse natural resources; however, it described the resources in the continent as more of a curse than a blessing as a result of the unabated violent resource conflicts leading to the loss of millions of lives, destruction of property worth billions of dollars, displacement of people and the emergence of refugee camps in the continent instead of enjoying the endowed resources. Furthermore, the study identified leadership failure, greed, grievances, the growing demand for natural resource benefits, and the increasing complexity of resource conflicts across the continent as factors that make their management and resolution more challenging. The study submitted that it is essential to adopt resource conflict resolution strategies to mitigate the menace of resource conflict.

Perhaps the most robust approach to the study of farmer-herder conflicts so far is the study by Mohammed et al. (2015) and Ioryue (2024), which assessed farmer-herder conflict in Nigeria using GIS. The study identified the challenges that have bedevilled pastoralism in Nigeria over the years, thereby reducing productivity and affecting the nation's economy. These include degraded grazing lands and the blockage of livestock pathways due to land use, urbanisation, and agricultural expansion. Population explosion and some ecological problems resulting from climate change have affected farmers and pastoralists. The eventual competition over land has led to conflict and strife. Faulty land tenure systems and delays in the justice system have also exacerbated the situation. Johnson *et al*. (2017), Atolagbe (2024), and Owolabi et al. (2025) also examined pastoralism as a new phase of terrorism in Nigeria. The study, therefore, analysed the causes, evolution, dynamics, and solutions to the conflicts arising from farmers-herders clashes in Nigeria. The study also recommended the formulation of a national livestock development policy, an effective community policing model, demarcation of livestock grazing reserves, provision of constitutional roles and recognition for traditional rulers, and the convening of stakeholders' conferences on nomadic pastoralism as strategies for ensuring peace. The importance of socio-economic attributes emphasised by these previous studies served as a point of reference and consideration in the present study.

3.0 METHODOLOGY

The study adopted a geographical case study and a mixed-methods approach to examine the prevalent factors influencing farmer-herder land conflicts.

3.1 The Study Area

The study area is the Oke Ogun Region of Oyo State, comprising the Atisbo, Oorelope, Iseyin, Itesiwaju, Kajola, Irepo, Olorunsogo, Iwajowa, Saki East, and Saki West Local Government Areas (LGAs). The study area is also known as the northern part of Oyo State. The region derived its name from its location in relation to the River Ogun. It is in the elevated and somewhat northern area of the River Ogun basin, hence its name. The people in this region are Yoruba, whose origins are linked to Ile-Ife, believed to be the ancestral home of all Yoruba peoples. The area lies between longitudes $2^0 31'$ and $4^0 20'$ E and latitudes $7^0 40'$ and $9^0 20'$ N of the Greenwich meridian (Olayiwola, Ajala & Sangodipe, 2014), with a total land area of 13,537 $km^{2,}$ which presently represents about 60 per cent of Oyo State. The study area is bounded in the north by Kwara State, in the east by Osun State, in the south by Ogun State, and in the west by the Republic of Benin (Dahomey).

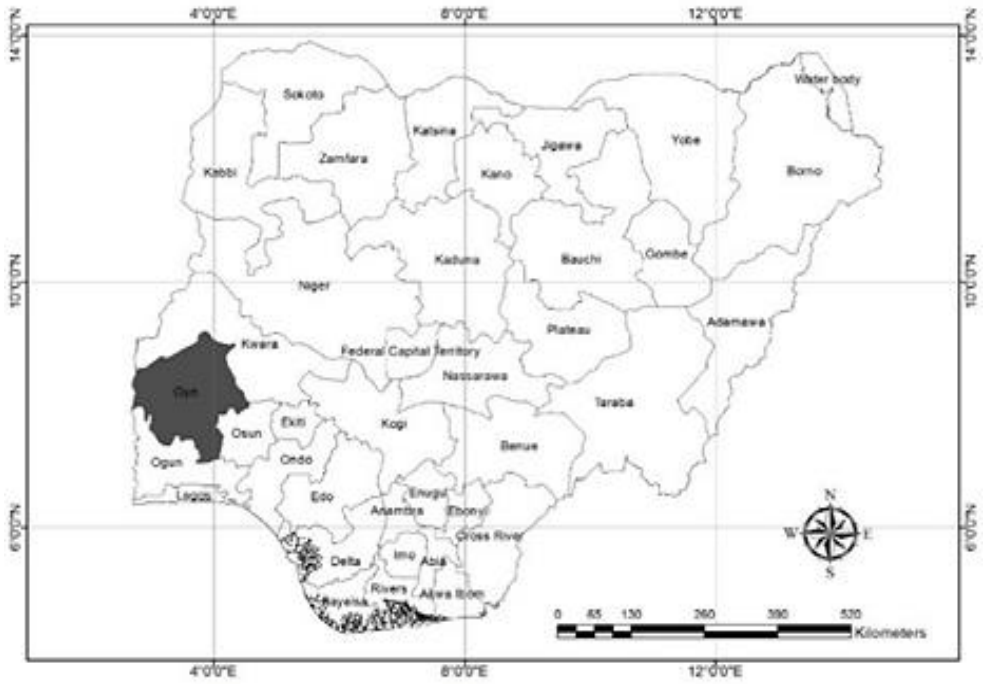

Fig. 1: Map of Oyo State in the context of Nigeria
Source: Co-operative Information Network (COPINE) (2024)

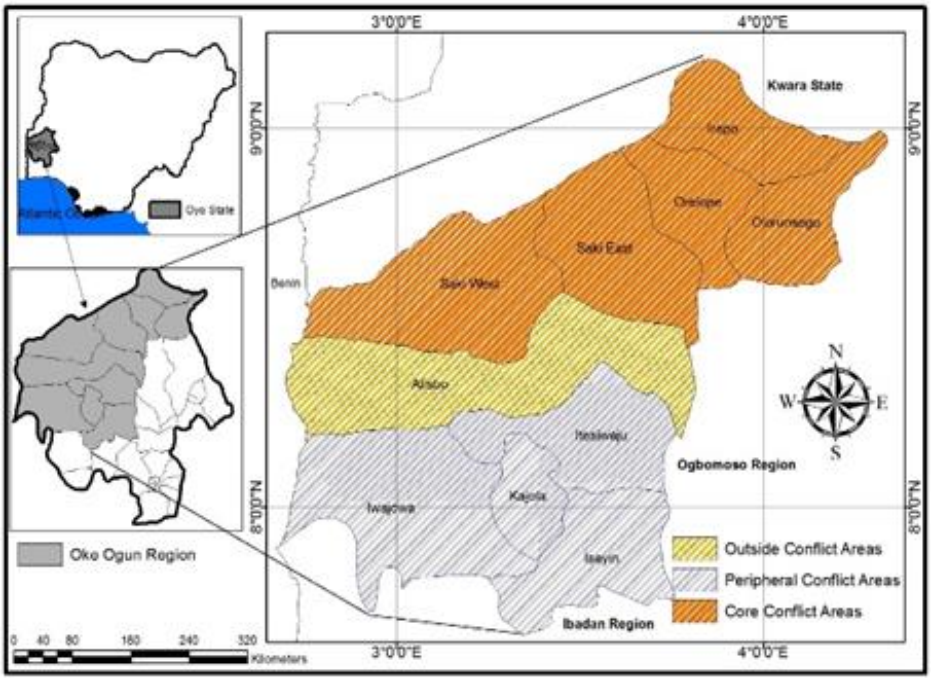

Fig. 2: Map of the Oke-Ogun Region
Source: Co-operative Information Network (COPINE) (2024)

3.2 Data Collection

Data collection was from both primary and secondary sources. Primary data were collected using a multistage sampling technique, with questionnaires administered to farmers and herders in the Oke-Ogu Region (OOR). The reconnaissance survey revealed that the incidence of farmer-herder land conflict (FHLC) was predominant in 598 communities located in Saki

West (183), Saki East (154), Irepo (74), Oorelope (139), and Olorunsogo (48) Local Government Areas. These communities were re-categorised by the number of buildings. They were classified as large (more than 100 buildings), medium (51-100 buildings), and small (fewer than 50 buildings). One in six communities in each category was systematically sampled. Thus, a total of 96 communities, comprising small (42), medium (32), and large (22), were selected. Physical observation revealed that there were 5,350 buildings in the selected communities, comprising small (910), medium (1,980), and large (2,460) buildings, respectively. Ten per cent of these, totalling 535, were randomly selected for questionnaire administration (277 to farmers and 258 to herders). Qualitative data were sourced through in-depth interviews (IDIs) with the overall leader of the farmers' and herders' community heads. Secondary data were sourced from the Ministry of Lands and Housing, Local Planning Authorities, Health Centres in the LGAs, Police Stations, and the Baptist Medical Centre, Saki. Data were analysed using correlation and regression analyses, and the chi-square test was employed to determine the relationships among the variables.

4.0 RESULTS

Findings are presented under the following subheadings.

4.1 Marginalisation along socio-cultural lines in the Oke-Ogun Region, Nigeria

The study revealed that the respondents in the small community types agreed with hate speeches and threat speeches from one religious or ethnic group to another, the preference for and initiation of laws that support one group over the other, an increase in the population of a religious or social group, and government or its agencies' support for one religious or ethnic group over the other with agreement RIIs of 3.99, 3.86, 3.74, and 3.58 respectively, influence the occurrence of farmer-herder land conflict. The respondents also agreed that the proliferation of a single religious or ethnic group in the state and public affairs (3.43) and the restrictions placed on the activities of one group more than on the other (3.16) influenced farmer–herder land conflict (Table 1). With RIIs of 4.01, 3.90, 3.79, and 3.57 respectively, the household representatives in the medium community type agree that hate speeches and threat speeches from one religious or ethnic group to another, the preference for and initiation of laws that support one group over the other, an increase in the population of a religious or social group, and government or its agencies' support for one religious or ethnic group over the other influence farmer-herder conflict in the Oke-Ogun Region. Whereas the respondents in the medium community type also agreed that the proliferation of a single religious or ethnic group in state and public affairs (3.43) and the restrictions placed on the activities of one group over the other (3.14) influenced farmer–herder land conflict.

Similarly, in the large community types in the Oke-Ogun Region, respondents agree that hate speeches and threat speeches from one religious or ethnic group to another (3.98), the preference for and initiation of laws that support one group over the other (3.91), an increase in the population of a religious or social group (3.79), and government or its agencies' support for one religious or ethnic group over the other (3.62) influence farmer-herder land conflict within the area. The household representatives in the large community types in the Oke-Ogun Region agree that the proliferation of a single religious or ethnic group in the state and public affairs (3.44) and the restrictions placed on the activities of one group over another (3.18) influence farmer-herder land conflicts within the area.

Table 1: Factors of Marginalisation along Socio-Cultural Lines in the Three Community Types of the Oke-Ogun Region, Nigeria

Marginalisation along socio-cultural lines	Community types											
	small				medium				large			
	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*
Hate speeches and threat speeches	90	359.00	3.99	0.36	197	789.00	4.01	0.37	245	976.00	3.98	0.33
Preference and initiation of laws that support one group over the other	90	347.00	3.86	0.23	197	770.00	3.91	0.27	245	959.00	3.91	0.26
Increase in the population of a religious or social group	90	337.00	3.74	0.11	196	743.00	3.79	0.15	244	924.00	3.79	0.14
Government or its agencies support for one religious or ethnic group over the other	90	322.00	3.58	-0.05	197	703.00	3.57	-0.07	245	886.00	3.62	-0.03
Proliferation of solely a religious or ethnic group in state and public affairs	90	309.00	3.43	-0.20	197	676.00	3.43	-0.21	245	843.00	3.44	-0.21
Restrictions placed on activities of one group than the other	90	284.00	3.16	-0.47	194	610.00	3.14	-0.50	244	777.00	3.18	-0.51
Mean				**3.55**			**3.65**				**3.65**	

(N- Sample Size; RII – Rate of Influencing Index; Dmn – Deviation about the Mean)

Source: Author's Field Work (2024).

This study therefore provides a broader socio-political perspective on the human factors influencing the occurrence of farmer-herder land conflicts, especially in the Oke-Ogun Region. These factors were delineated into six segments: marginalisation along socio-cultural lines, political legitimacy and elections, globalisation and perceived civilisation or westernisation, religious extremism, poverty and economic deprivation, and state failure. Each segment has several variables to which respondents responded. The representatives in each community type rated their agreement levels with the influence of the identified factors on farmer-herder land conflicts in the Oke-Ogun Region. The agreement indices were examined using a five-point Likert scale, namely**:** 5- strongly agree; 4- agree; 3- agree; 2- disagree; 1- strongly disagree.

Generally, in the Oke-Ogun Region, the agreement RIIs of hate speeches and threat speeches from one religious or ethnic group to another (3.99), and the preference for and initiation of laws that support one group over the other (3.90), revealed that the respondents agree that they influence farmer-herder land conflict (Figure 1). Also, the agreement RIIs of an increase in the population of a religious or social group (3.78), and government or its agencies' support for one religious or ethnic group over the other (3.59) showed that the household representatives agree that they influence farmer-herder land conflict within the area. However, the RIIs on the proliferation of a single religious or ethnic group in the state and public affairs (3.43) and the restrictions placed on the activities of one group over another (3.16) revealed that respondents agreed that these factors influence farmer-herder land conflict in the region.

Political Legitimacy and Elections Category

The identified factors influencing farmer-herder land conflict include situations where religious, social, or political groups do not see the current government in power as being legitimate, where the affairs of the state are not clearly separated from social, religious, and ethnic ties, where there is a general sense of political godfatherism influencing the affairs of the state and where the majority of the populace did not generally accept the results of previous elections. Others were post-election violence that was not properly contained and which degenerated over time; situations where opposing political parties sponsor conflicts to discredit the current government, and the political arming of youths for election violence.

As presented in Table 2, the study revealed that respondents in the small communities of the Oke-Ogun Region agreed that a general sense of political godfatherism influencing the affairs of the state (3.63), post-election violence that was not properly contained and which degenerated over time (3.63) the perception that some groups do not see the current government as legitimate (3.53) influence farmer-herder land conflict in the region. The respondents just agreed that factors such as opposing political parties sponsoring conflicts to discredit the current government (3.22) and the results of the previous elections not being generally accepted by the majority of the populace (3.21) influence the conflict. The other factors that respondents agreed influence the conflict were the political arming of youths for election-related violence (3.19) and the situation in which the affairs of the state are not clearly separated from social, religious, and ethnic ties (3.09).

Whereas the respondents in the medium community type agreed that a general sense of political godfatherism influencing the affairs of the state (3.64), religious, social, or political

groups not seeing the current government as legitimate (3.60) and post-election violence that was not properly contained and which degenerated over time (3.60) influenced farmer-herder conflict in the area. They however, just agreed that the farmer-herder land conflict was influenced by the political arming of youths for election violence (3.31), opposing political parties sponsoring conflicts to discredit the current government (3.25), the results of the previous elections not being generally accepted by the majority of the populace (3.24) and the affairs of the state not being clearly separated from social, religious, and ethnic ties (3.10).

On the other hand, respondents in the large community type in the Oke-Ogun Region agreed that the general sense of political godfatherism influencing the affairs of the state (3.68), religious, social, or political groups not seeing the current government as legitimate (3.65), and post-election violence that was not properly contained and which degenerated over time (3.64) influence farmer-herder land conflicts in the area. Other identified factors under the political legitimacy and elections category which the respondents just agreed influence farmer-herder land conflicts were the political arming of youths for election violence (3.43), the results of the previous elections not being generally accepted by the majority of the populace (3.24), opposing political parties sponsoring conflicts to discredit the current government (3.23) and the affairs of the state not being clearly separated from social, religious, and ethnic ties (3.06).

Overall in Oke-Ogun Region, the factor under the political legitimacy and elections which respondents most agreed influences farmer-herder land conflict, was the general sense of godfatherism influencing the affairs of the state (3.66). Others were post-election violence that was not adequately contained and which degenerated over time (3.62), and religious, social, or political groups not seeing the current government as legitimate (3.61). The factors which respondents just agreed influence the conflict were the political arming of youths for election violence (3.31), opposing political parties sponsoring conflicts to discredit the current government (3.24), the results of the previous elections not being generally accepted by the majority of the populace (3.24), and the affairs of the state not being clearly separated from social, religious, and ethnic ties (3.08)

Table 2: Factors of Political Legitimacy and Elections Influencing Farmer-herder Land Conflicts in the Oke-Ogun Region, Nigeria
(N- Sample Size; RII – Rate of Influencing Index; Dmn – Deviation about the Mean)

Factors of Political Legitimacy and Elections	Community Type																
	Small				Medium				Large				Oke-Ogun Region				
	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*	Rank
General sense of political godfatherism influencing affairs of state	90	327	3.63	0.28	197	717	3.64	0.25	245	901	3.67	0.26	532	1945	3.66	0.27	**1**
Post-election violence that was not properly quenched and degenerated over time	90	327	3.63	0.28	196	705	3.60	0.21	245	895	3.65	0.24	530	1921	3.62	0.23	**2**
Do not see the current government as legitimate	90	318	3.53	0.17	197	710	3.60	0.21	244	889	3.64	0.23	532	1923	3.61	0.22	**3**
The conflict was influenced by the political arming of youths for election violence	90	287	3.19	-0.16	196	649	3.31	-0.08	244	816	3.34	-0.07	530	1752	3.31	-0.08	**4**
Opposing political parties are sponsoring conflicts to discredit the current government	90	290	3.22	-0.13	197	641	3.25	-0.14	245	791	3.22	-0.19	532	1722	3.24	-0.15	**5**
The result of the previous election was not generally accepted by the majority of the populace	90	289	3.21	-0.14	197	638	3.24	-0.15	245	794	3.24	-0.17	532	1721	3.23	-0.16	**6**
Affairs of state are not clearly separated from social, religious, and ethnic ties	90	278	3.09	-0.27	197	611	3.10	-0.30	245	750	3.06	-0.31	532	1639	3.08	-0.33	**7**
Mean			**3.35**				**3.39**				**3.41**				**3.39**		

Globalisation and Perceived Civilisation or Westernisation.

Under this category, as shown in Figure 3, household representatives in the small community type of the Oke-Ogun Region mostly agreed that westernisation and the idea of formal education mainly fueled the conflict (3.79). They just agreed on other factors, such as the Western way being harmful and negatively influencing local culture (3.30), religious values being eroded by Western practices (3.24), and state laws promoting more Western practices as more popular than local and religious laws (3.22). Others were that the global sharing of information and culture fueled the conflict (3.13) and that religious and social groups could no longer tolerate the state's adoption of Western laws (2.96).

The respondents in the medium community type of the Oke-Ogun Region agreed that westernisation and the idea of formal education especially fueled the conflict (3.81). They just agreed that factors such as the Western way being harmful and negatively influencing local culture (3.40), State laws promoting more Western practices over popular local and religious laws (3.35), and Westernisation threatening the values and norms of society (3.03) are problematic. Likewise, they agreed that the global sharing of information and culture fueled the conflict (3.18), that religious values were eroded by Western practices (3.15), and that religious and social groups could no longer tolerate Western laws adopted by the state (3.05).

Similarly, respondents in the large community type in the Oke-Ogun Region agreed that westernisation and the idea of formal education (3.84) influenced the farmer-herder conflict in the area. The respondents, however, agreed that the Western way is harmful and has a negative influence on local culture (3.46), that state laws promote more Western practices over popular local and religious laws (3.46). That westernisation threatens the values and norms of society (3.37). Furthermore, they agreed that the global sharing of information and culture fueled the conflict (3.19), that religious values were eroded by Western practices (3.15), and that religious and social groups could no longer tolerate Western laws adopted by the state (3.02).

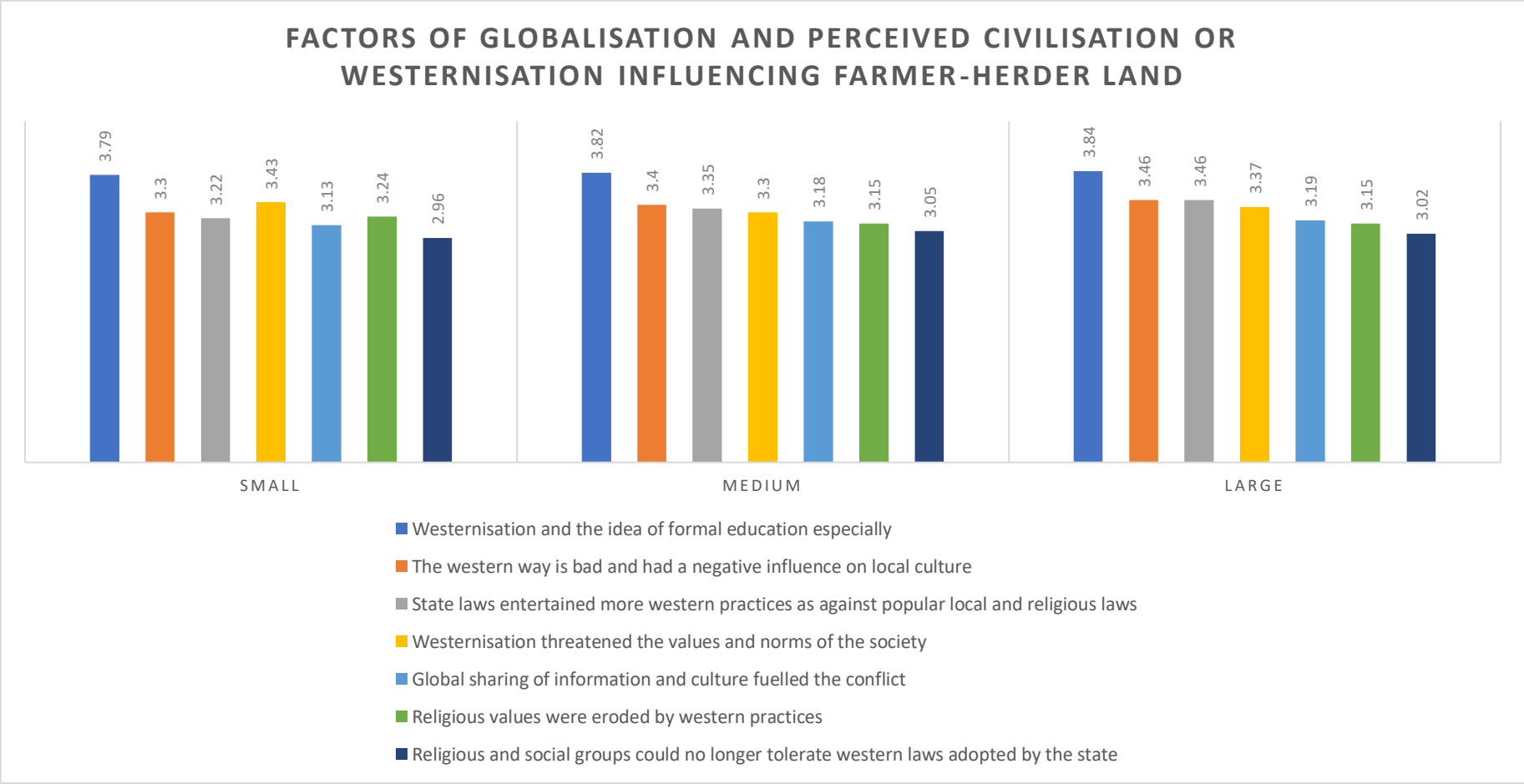

Fig. 3: Factors of Globalisation and Perceived Civilisation or Westernisation Influencing Farmer-herder Land in the Oke-Ogun Region, Nigeria
Source: Author's Field Work (2024)

Thus, generally in the Oke-Ogun Region, westernisation and the idea of formal education, with an RII of 3.82, were agreed by respondents to influence the farmer-herder land conflict in the region (Figure 2). RII, while they just agreed that the Western way is harmful and has a negative influence on local culture (3.41), State laws promoting more Western practices over popular local and religious laws (3.38), and Westernisation threatening the values and norms of the society (3.36) are among the factors influencing farmer-herder land conflict in the Oke-Ogun Region. Others were the Global sharing of information and culture fueling the conflict (3.17), religious values were eroded by Western practices (3.16), and religious and social groups no longer tolerated Western laws adopted by the state (3.02). These findings indicate that the prevailing social cum existential conditions in the region tend to exacerbate and further strain the farmer-herder relationship. Nchi (2013: 229) states that "the social, economic, and political context fosters the violence." Nchi goes on to note that the rising rate of youth unemployment, political, economic, and cultural isolation, poverty, corruption, the breakdown of the family and its values, poor upbringing of children with no sense of restraint, and weak governmental institutions that have purposefully failed to prosecute perpetrators of prior violence, encouraging impunity, all contribute to the perpetuation of a cycle of violence.

Religious Extremism in the Oke-Ogun Region, Nigeria

The study revealed that respondents in the small community types agreed that religious extremists were growing in popularity, as indicated by the Relative Importance Index (RII) of 3.53, which influenced farmer-herder conflict in their area (Figure 4). However, they just agreed that the proliferation of religious schools (3.49), the increased campaigns against Western education (3.78), foreign religious groups sponsoring more local youths to learn extreme religious practices (3.3), and parents sending their children to more religious schools than Western education schools (3.23) influenced farmer-herder land conflicts.

The household representatives in the medium community types of the Oke-Ogun Region agreed that farmer-herder land conflicts were influenced by extreme teachings growing popular (3.58) and the proliferation of religious schools (3.53). They, however, just agreed that farmer-herder land conflicts were influenced by increased campaigns against Western education (3.35), foreign religious groups sponsoring more local youths to learn extreme religious practices (3.34), and parents sending their children to more religious schools than to Western education schools (3.17). Respondents in the large community types of the Oke-Ogun Region, as revealed in the study, agreed that land conflicts between farmers and herders were influenced by extreme teachings growing popular (3.62) and the proliferation of religious schools (3.53).

According to the study, the respondents in the large communities of the Oke-Ogun Region agreed that the farmer-herder land conflicts were influenced by the increased campaigns against Western education (3.41), foreign religious groups sponsoring more local youths to learn extreme religious practices (3.33), and parents sending their children to more religious schools than Western education schools (3.20). Thus, overall, as revealed in the study, extreme teachings growing in popularity (3.62) and the proliferation of religious schools (3.53) were factors under religious extremism that household representatives in the Oke-Ogun Region agreed influenced the farmer-herder land conflict. Whereas they just agreed that increased campaigns against Western education (3.41), Foreign religious groups sponsoring more local youths to learn extreme religious practices (3.33), and parents sending their children to more religious schools than Western education schools (3.20) influenced the farmer-herder land conflicts.

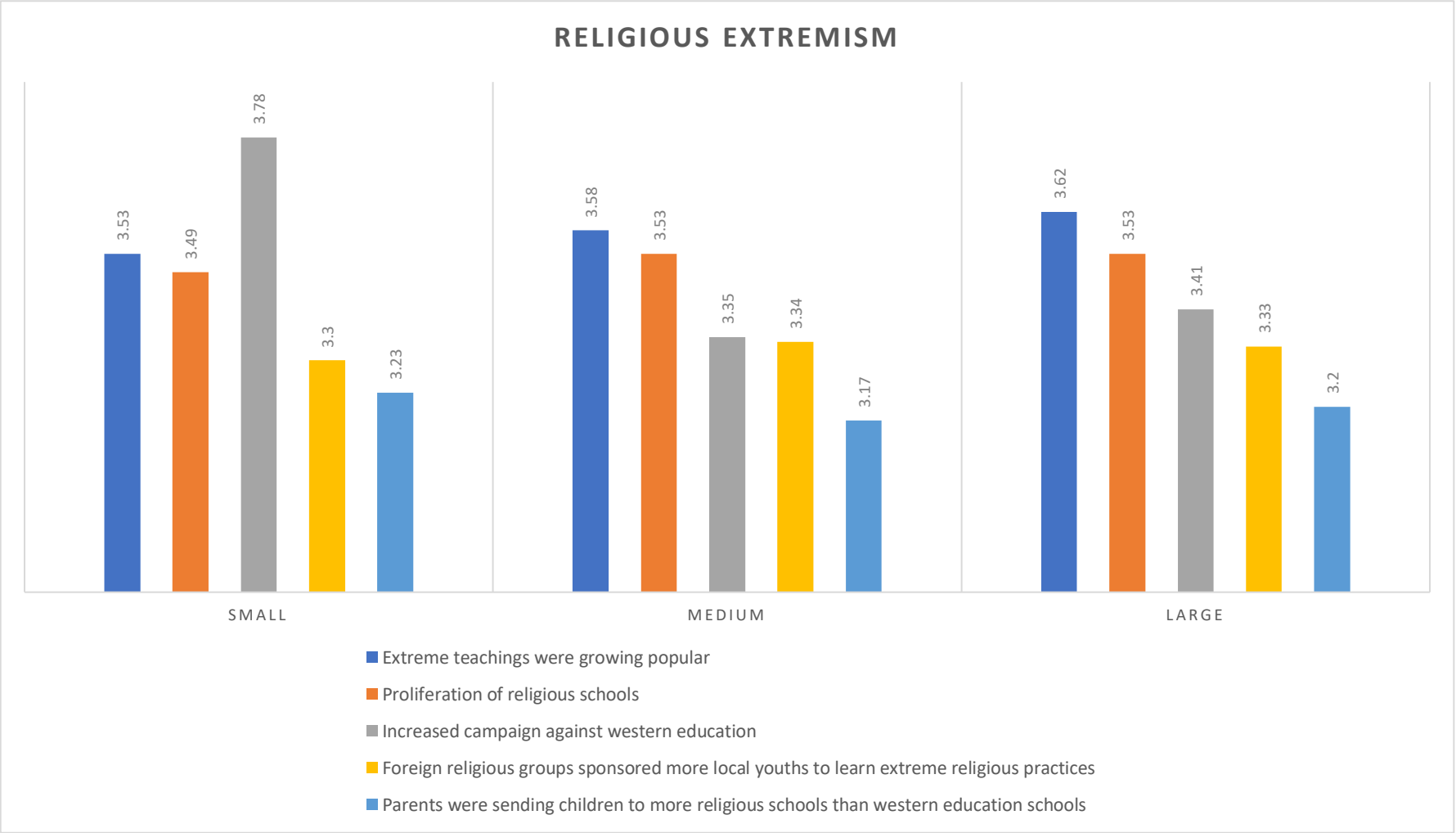

Fig. 4: Factors of Religious Extremism Influencing Farmer-herder Land Conflicts in Different Community Types in the Oke-Ogun Region
Source: Author's Field Work (2024

Poverty and Economic Deprivation in the Oke-Ogun Region, Nigeria

The study revealed that respondents in the small community type in the Oke-Ogun Region agreed that an increase in the population of the community without an equivalent increase in sources of livelihood, and a general perception of the unequal distribution of wealth, influenced the conflicts as depicted by the agreement RIIs of 3.74 and 3.60, respectively (Table 3). Other factors that respondents agreed influenced farmer-herder conflicts were the proliferation of youth unemployment and idleness (3.48), a lower standard of living (3.46), and the state's failure to meet the economic needs of the people (3.34). Other factors included the loss of a general sense of hope (3.26), bandit groups promising better living conditions and greater rewards (3.25), and an increase in the number of street and out-of-school children (3.14).

Similarly, in the medium community type, the respondents agreed that an increase in the community's population without an equivalent increase in sources of livelihood (3.69) and a lower standard of living (3.55) encouraged conflicts. The respondents also agreed to the proliferation of youth unemployment and idleness (3.53) and a general perception of the unequal distribution of wealth (3.53). However, the state not meeting the economic needs of the people (3.44), the loss of a general sense of hope (3.30), bandit groups promising better living and more rewards (3.22) and an increase in the number of street and out-of-school children (3.08) were factors that household representatives just agreed influenced farmer-herder land conflicts in the medium community type in the Oke-Ogun Region.

Likewise, in the large community type, the respondents agreed that an increase in the population of the community without an equivalent increase in sources of livelihood (3.72), a general perception of the unequal distribution of wealth (3.52), the proliferation of youth unemployment and idleness (3.51), and a lower standard of living (3.50) stimulated conflicts. However, factors such as the state not meeting the people's economic needs and bandit groups promising better living and more rewards, with respondents' agreement RIIs of 3.41 and 3.33, respectively, were just agreed upon by the representatives. Other factors were the loss of a general sense of hope (3.32) and an increase in the number of street and out-of-school children (3.14).

Generally, in the Oke-Ogun Region, as revealed in the study, an increase in the community population without an equivalent increase in sources of livelihood (3.72) was the factor most agreed upon by the sampled household representatives to influence farmer-herder land conflicts. They also agreed that a general perception of the unequal distribution of wealth, the proliferation of youth unemployment and idleness, and a lower standard of living encouraged conflicts, as reflected in RIIs of 3.54, 3.51, and 3.51, respectively. The representatives, however, just agreed with factors such as the state not meeting the economic needs of the people (3.41), the loss of a general sense of hope (3.30), bandit groups promising better living and more rewards (3.28), and an increase in the number of street and out-of-school children under the poverty and economic category of factors influencing farmer-herder land conflicts.

Table 3: Poverty and Economic Deprivation Factors Influencing Farmer-herder Conflicts in the Community Types of the Oke-Ogun Region, Nigeria

	Community Types											
	Small				Medium				Large			
	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*	N	Sum	RII	*Dmn*
The population of the community increased without an equivalent increase in sources of livelihood	90	337	3.74	0.33	198	730	3.69	0.27	245	911	3.72	0.29
A general perception of unequal distribution of wealth	89	320	3.60	0.19	198	703	3.55	0.13	245	863	3.52	0.09
Proliferation of youth unemployment and idleness	90	313	3.48	0.07	198	699	3.53	0.11	245	861	3.51	0.08
Lower standard of living encouraged conflicts	91	315	3.46	0.05	196	691	3.53	0.11	246	860	3.50	0.07
The state was not meeting the economic needs of the people	90	301	3.34	-0.07	196	675	3.44	0.02	246	840	3.41	-0.02
Loss of a general sense of hope	90	293	3.26	-0.15	198	654	3.30	-0.12	246	820	3.33	-0.10
Bandit groups promised better living and more reward	91	296	3.25	-0.16	198	638	3.22	-0.20	245	813	3.32	-0.11
The number of street and out-of-school children increased	91	286	3.14	-0.27	198	609	3.08	-0.34	246	772	3.14	-0.29
Mean			**3.41**				**3.42**				**3.43**	

State Failure

The study revealed that respondents in the small community type of the Oke-Ogun Region agreed that the perceived advantage given to one conflict party over another by state mediators and security officials contributed to farmer-herder land conflicts, as indicated by an RII of 4.09. Also, the variables further considered under this category include the lack of social amenities and government intervention (3.86), and the arrest and perceived unlawful detention of a religious group leader (3.77). Other factors were the improper handling and management, and the failure to resolve erupted inter-ethnic or inter-religious crises (3.65) and the proliferation of IDPs and the lack of care for them (3.65). However, respondents in the small community type in the region agreed that the flow of and support from global terrorist groups (3.48), corrupt practices by government officials (3.44), and the killing or perceived genocide carried out against a social or religious group (3.43) had influenced land conflicts in the area. Also, they just agreed with Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.41), the unchecked proliferation and inflow of arms (3.16), and the uncontrolled crackdown on civilians by security operatives (3.00).

The household representatives in the medium community type mostly agreed with the perceived advantage given to one conflict party over another by state mediators and security officials (3.93). They also agreed that the arrest and perceived unlawful detention of a religious group leader (3.79), the Lack of social amenities and government intervention (3.74), the improper handling and management, and the failure to resolve erupted inter-ethnic or inter-religious crises (3.56). The flow of and support from global terrorist groups (3.55) contributed to the farmer-herder land conflict in the medium community type of the Oke-Ogun Region. Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.43), corrupt practices by government officials (3.42), and the proliferation of IDPs and the lack of care for them (3.41) were just agreed upon by the respondents as contributing to farmer-herder conflicts in their area. Others included the Killing or perceived genocide carried out against a social or religious group (3.37), the unchecked proliferation and inflow of arms (3.16), and the uncontrolled crackdown on civilians by security operatives (3.03).

Likewise, respondents in the large community types agreed that the perceived advantages given to one conflict party over another by state mediators and security officials (3.90) and the lack of social amenities and government intervention (3.78) influenced farmer-herder land conflicts in the area. They also agreed that the arrest and perceived unlawful detention of a religious group leader (3.72), the flow of and support from global terrorist groups (3.55), the improper handling and management, and the failure to resolve erupted inter-ethnic or inter-religious crises (3.54) contributed to land conflicts in large communities in the Oke-Ogun Region. They, however, just agreed that corrupt practices by government officials (3.42), the proliferation of IDPs and the lack of care for them (3.40), and porous borders and unchecked inflow and outflow of immigrants and emigrants (3.38) influenced land conflicts. Other factors were the killing or perceived genocide carried out against a social or religious group (3.37), the unchecked proliferation and inflow of arms (3.13), and the uncontrolled crackdown on civilians by security operatives (3.00).

Overall, in the Oke-Ogun Region, the perceived advantage given to one conflict party over another by state mediators and security officials (3.94), the lack of social amenities and

government intervention (3.78), and the arrest and perceived unlawful detention of a religious group leader (3.76) were ranked highest on the respondents' agreement index under the state failure category of factors influencing farmer-herder land conflicts. The respondents agreed that the improper handling, management, and resolution of erupted inter-ethnic or inter-religious crises (3.57) and the flow and provision of support from global terrorist groups (3.54) are state-failure factors contributing to farmer-herder land conflicts. The respondents in the region, however, just agreed with corrupt practices by government officials (3.42), the proliferation of IDPs and the lack of care for them (3.41) and Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.40) as state failure factors influencing farmer-herder land conflicts in the region. Other state failure factors contributing to farmer-herder land conflicts in the region were the killing or perceived genocide carried out against a social or religious group (3.35), the unchecked proliferation and inflow of arms (3.15), and the uncontrolled crackdown on civilians by security operatives (3.01).

The perceived advantage given to a conflict party over the other by state mediators and security officials contributes to the farmer-herder land conflicts as depicted by an agreement RII of 4.09 (Figure 5). Also, the variables further considered under this category include: the lack of social amenities and government intervention (3.86) and the arrest and perceived unlawful detention of a religious group leader (3.77). Other factors were the improper handling and management, and the failure to resolve erupted inter-ethnic or inter-religious crises (3.65) and the proliferation of IDPs and the lack of care for them (3.65). However, respondents in the small community type in the region just agreed that the flow of and support from global terrorist groups (3.48), corrupt practices by government officials (3.44), and the killing or perceived genocide carried out against a social or religious group (3.43) influenced land conflicts in the area. Also, they just agreed with Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.41), the unchecked proliferation and inflow of arms (3.16), and the uncontrolled crackdown on civilians by security operatives (3.00).

The household representatives in the medium community type mostly agreed with the perceived advantage given to one conflict party over another by state mediators and security officials (3.93). They also agreed that the arrest and perceived unlawful detention of a religious group leader (3.79), the lack of social amenities and government intervention (3.74), the improper handling, management and the failure to resolve erupted inter-ethnic or inter-religious crises (3.56). The flow of and support from a global terrorist group (3.55) contributed to the farmer-herder land conflict in the medium community type of the Oke-Ogun Region. Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.43), corrupt practices by government officials (3.42), and the proliferation of IDPs and the lack of care for them (3.41) were just agreed upon by the respondents as contributing to the farmer-herder conflicts in their area. Others included the Killing or perceived genocide carried out against a social or religious group (3.37), the unchecked proliferation and inflow of arms (3.16), and the uncontrolled crackdown on civilians by security operatives (3.03)

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Likewise, respondents in the large community types agreed that the perceived advantage given to one conflict party over another by state mediators and security officials (3.90) and the lack of social amenities and government intervention (3.78) influenced farmer-herder

land conflicts in the area. They also agreed that the arrest and perceived unlawful detention of a religious group leader (3.72), the flow of and support from global terrorist groups (3.55), the improper handling and management, and the failure to resolve erupted inter-ethnic or inter-religious crises (3.54) contributed to land conflicts in large communities in the Oke-Ogun Region. They, however, just agreed that corrupt practices by government officials (3.42), the proliferation of IDPs and the lack of care for them (3.40), and porous borders and unchecked inflow and outflow of immigrants and emigrants (3.38) influenced land conflicts. Other factors were the killing or perceived genocide carried out against a social or religious group (3.37), the unchecked proliferation and inflow of arms (3.13), and the uncontrolled crackdown on civilians by security operatives (3.00).

Overall, in the Oke-Ogun Region, the perceived advantage given to one conflict party over another by state mediators and security officials (3.94), the lack of social amenities and government intervention (3.78) and the arrest and perceived unlawful detention of a religious group leader (3.76) were ranked highest on the respondents' agreement index under the state failure category of factors influencing farmer-herder land conflicts. The respondents agreed that the improper handling and management, the failure to resolve erupted inter-ethnic or inter-religious crises (3.57), and the flow of and support from global terrorist groups (3.54) constituted state failure factors contributing to the farmer-herder land conflicts. The respondents in the region, however, just agreed with corrupt practices by government officials (3.42), the proliferation of IDPs and the lack of care for them (3.41) and Porous borders and unchecked inflow and outflow of immigrants and emigrants (3.40) as state failure factors influencing farmer-herder land conflicts in the region. Other state failure factors contributing to farmer-herder land conflicts in the region were the killing or perceived genocide carried out against a social or religious group (3.35), the unchecked proliferation and inflow of arms (3.15), and the uncontrolled crackdown on civilians by security operatives (3.01).

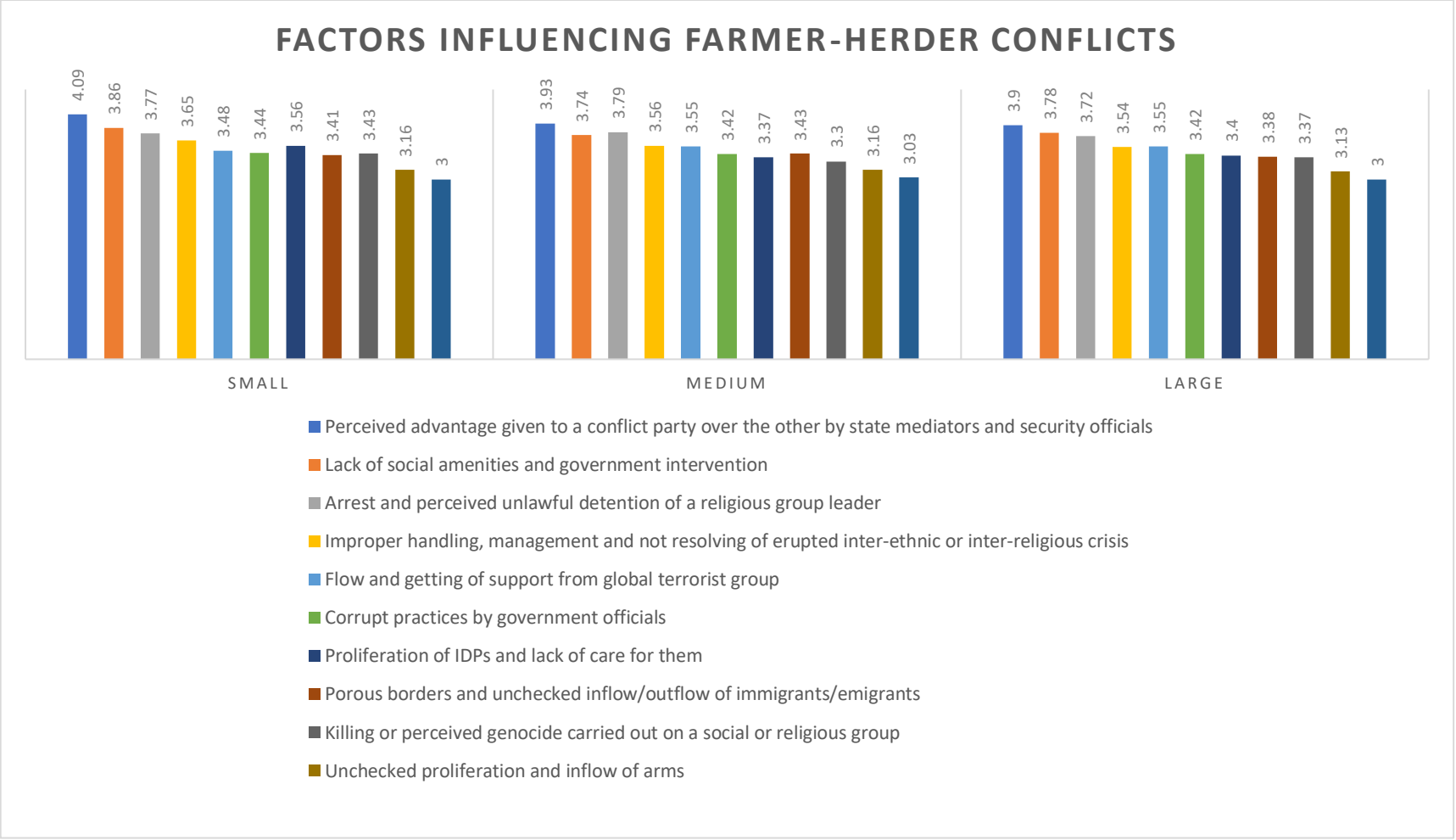

Fig. 5: State Failure Factors Influencing Farmer-herder Conflicts in the Community Types of the Oke-Ogun Region, Nigeria

6.0 CONCLUSION

The findings of this study revealed that the causes of farmer-herder land conflicts in the region are rooted in land administration and conflict resolution. These include political factors, socio-cultural and environmental factors, religious extremism factors, socio-economic related factors, and stakeholder factors. It also reveals the underlying issues of land resource sharing and the effects these issues may have on the eruption of conflict. The weaknesses of the government are evidently, though indirectly, revealed in cases where conflicts have been reported, particularly the government's and its agencies' inability to promptly and adequately manage conflicts through conflict resolution methods or procedures acceptable to all parties. In relation to a conflict, favouritism towards one party and marginalisation of the other were often observed.

Recommendations

Based on the conclusion of this study, it was generally established that factors influencing farmer-herder land conflicts include political, socio-cultural, environmental, religious extremism, socio-economic, and stakeholder factors, among others. In the Oke-Ogun Region, the situation arises from competition for land resources and the existence of two incompatible land uses (crop farming and open grazing), which often result in conflicts among the parties involved. To prevent or reduce the recurrence of farmer-herder conflict in the Oke-Ogun Region and beyond, this study recommends the review and harmonisation of land-use law and administration. With this, all land laws in the region and the country at large would be harmonised, and all stakeholders should agree upon a single administrator, whose role should be enshrined in law to guide land use and administration.

Furthermore, there should be sustainable conflict resolution strategies and a reduction in marginalisation. This will encourage all stakeholders – government, NGOs, traditional institutions, among others - to intensify efforts to build cooperation and peaceful coexistence between farmers and herders through public enlightenment, education, and campaigns in the region. Sensitisation of stakeholders, including farmers and herders, to the need for mutual coexistence and peace is essential. This would help to forestall needless provocations and opportunistic violence.

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REFERENCES

Abdulbaqi, S. and Ariemu, O. (2017). Newspapers Framing of Herdsmen-Farmers' Conflicts in Nigeria and Its Implication on Peace-Oriented Journalism. *The Creative Artists*, Vol. 11(2), pp. 77-105

Abegunde A. A. (2011). Land as the main cause of inter-communal conflicts in Africa: key natural resources against community development of third world nations. *Journal of Economics and Sustainable Development* 2.4 285-288.

Abegunde O. (2014). The changing context and dynamics of herder-farmer conflict across West Africa. *Geography Research Forum (24)1*. 83-97.

Adebajo, Bolarinwa and Omotayo (2014). Environmental Scarcities and Violent Conflict: Evidence from Cases' *International Security* 19(1).

Adebayo, O.O. & Olaniyi, O.A. (2008). Factors Associated with Pastoral and Crop Farmers Conflict in Derived

Savannah Zone of Oyo State, Nigeria. *Journal of Human Ecology*. Vol. 23(1), pp. 71-74.

Adelakun, O., Adurogbangba, B. and Akinbile, L. (2015). Socioeconomic Effects of Farmer Pastoralist Conflict on Agricultural Extension Service Delivery in Oyo State, Nigeria. *Journal of Agricultural Extension*. Vol. 19(2), pp. 59-70

Alananga, S. S., Mwasumbi, A., & Moyo, K. J. (2024). Land resource conflicts in Tanzania: Is there a way out? *African Journal on Land Policy and Geospatial Sciences, 7*(2), 412–438. https://doi.org/10.48346/IMIST.PRSM/ajlp-gs.v7i2.43651 (Revues IMIST)

Aliyu, A.S. (2015). Causes and Resolution of Conflict Between Cattle Herders and Crop Farmers in Katsina State. *A Published M.Sc. Dissertation by the School of Postgraduate Studies, Ahmadu Bello University, Zaria*, pp.1-74.

Amadi, C. O., & Harrison, S. (2025). Fulani herdsmen–farmer conflict and international humanitarian law: Implications for human security in Nigeria (2015–2024). *International Journal of Political Science and International Relations*. (zapjournals.com)

Anthony O., Albert A. A., Henry A, Temitope R. A., Olorunjuwon D. A. (2025). Assessing Stakeholders' Responses to Farmer-Herder Land Conflict: A Case Study of the Oke-Ogun Region, Nigeria. Urban Crime- An International Journal 6(1)

Antwi, S. (2018). Farmer–herder conflict and food security in Kwahu East District, Eastern Region, Ghana. *A Published M.Sc. Dissertation by the School of Postgraduate Studies, Norwegian University of Life Sciences*, Norway, pp.1-128.

Atolagbe, M. B. (2024). Causes and consequences of farmer–herder conflict on food production in selected agricultural zones of Kwara State, Nigeria. *Al-Hikmah Journal of Arts and Social Sciences, 6*(2). (alhikmahuniversity.edu.ng)

Awogbade M.O. (1978). Grazing reserves in Nigeria. *Nomadic Peoples. Vol.* 23: pp. 18-30.

Bella, F. T., & Olanrewaju, I. P. (2024). Farmer-herder conflict and the emergence of supra-vigilante security measures in Nigeria. *Perspektif, 13*(1), 155–163. https://doi.org/10.31289/perspektif.v13i1.10655 (ojs.uma.ac.id)

Bénard, C., Bonnet, B. and Guivert, B. (2010). Demand for farm animal products in Nigeria: An opportunity for Sahel countries? Grain de Sel, 51: 1415.

Bolarinwa, A. (2007). Political ecology and moral dimensions of resource conflicts: The case of farmer-herder conflict in the Sahel. *Political Geography*. 23, 863-889.

Chikaire N., Ani and Ukpongson (2017). Analysis of Land Tenure Regimes and Rights among the Local Farmers of Southeast Nigeria. *Innovative Techniques in Agriculture* 1(5) 218-226.

CIEL. (2006). CBPR database -Nigeria. Centre for International Environmental Law. Retrieved from http://www.ciel.org/Publications/CBPR_Nigeria_9-18-06.pdf(accessed on September 2, 2018).

Daily Trust (2012). Nigeria: Grazing Reserves Commission Bill Divides Senate. 4 July 2012. http://allafrica.com/stories/201207040466.html. Accessed 1 March 2018. American Planning Association, 58 (3), 288-300.

Galtung, J. (2000). Theories of conflict: Definitions, Dimensions, Negations and Formations, pp. 1-167 Transcend University Press 2008.

Ibrahim, A. (2012). Linking vision with reality in the implementation of policy framework for pastoralism in Nigeria. *Pastoralism: Research, Policy and Practice, 2*(7), 1-7.

Imbusch, P. (1999). The changing context and dynamics of herder-farmer conflict across West Africa. *Geography Research Forum (24)1.* 83-97.

Ingawa, S., Tarawali, C. and Kaufmann, R. (1989). Grazing Reserves in Nigeria: Problems, Prospects and Policy Implications. *International Livestock Centre for Africa (ILCA).*

International Crises Group (2017). Herders against Farmers: Nigeria's Expanding Deadly Conflict. *International Crisis Group Africa Report.* 252: pp.1-37

Ioryue, D. A. (2024). Farmer–herder conflict and national security in Nigeria: The Benue State in perspective. *Kashere Journal of Politics and International Relations, 2*(2), 245–259. (journals.fukashere.edu.ng)

Isiak, D. A., Egobueze, A., Onya, R., & Nwaoburu, L. (2025). From agitation to insecurity: Assessing the political roots and consequences of armed struggle in South-East Nigeria, 2014–2024. *International Journal of Innovative Legal & Political Studies*, 13(4), 113–124. (SEAHI Publications)

Ivorgba, E. A. (2024). The need for democratization of security in Nigeria. *International Journal of Research and Innovation in Social Science*, 8(5), 1320–1332. (rsisinternational.org)

Johnson, A.I., and Okunola, B.T. (2017). Pastoralism as a New Phase of Terrorism in Nigeria. Global *Journal of Human-Social Science* 17(4)

Kumolu, C., (2014). Fulani herdsmen, farmers' clashes: Furore over grazing reserves. Vanguard News.

http://www.vanguardngr.com/2014/04/fulani-herdsmen-farmers-clashes-furore-grazing-reserves/. Accessed 15 July, 2018.

Kums, S. N., Manga, J. S., Nansak, E. N., & Mijinyawa, A. (2024). Farmer-herder conflicts: A challenge to nation-building and development in Nigeria. *University of Jos Journal of Political Science, 1*(2), 217–241. (University of Jos Journals)

Lamidi, K. O. (2025). Farmers–herders' conflict in Nigeria: Causes, consequences and resolution mechanisms. *Journal of Cultural Analysis and Social Change, 10*(2). https://doi.org/10.64753/jcasc.v10i2.1564 (jcasc.com)

Land Use Act (1978), Federal Republic of Nigeria. Government Press, Lagos.

Li, N. (2018). Nigeria's Fulani Herdsmen-Farmers Conflict and Peace Building. *Global Journal of Agricultural Research*. Vol. 6(5), pp.1-15

Marshall, M. G., & Gurr, T. R. (2005). *Peace and Conflict 2005: A global survey of armed conflicts, self-determination movements, and democracy*. Center for International Development and Conflict Management, University of Maryland.

Muhammed, I., Ismaila, A. B., and Bibi, U. M. (2015). An assessment of farmer-pastoralist conflict in Nigeria using GIS. *International Journal of Engineering Science Invention, 4*(7), 23-33.

Nwogu, C. K., Egobueze, A., & Onyekwere, L. A. (2024). A nation in disarray: Communal conflicts and socio-political stability in Nigeria. *Open Social Science and Management Journal*, 14(1), 28–35. (STM Journals)

Obikaeze, C. V., Oduntan, J. O., Fajobi, T. A., Kayode, G., & Eteng, E. E. (2023). Herders–farmers conflicts over farmlands: Implications for human and food security in Nigeria. *ABUAD Journal of Social and Management Sciences, 4*(2). https://doi.org/10.53982/ajsms.2023.0402.10-j (ABUAD Journals)

Ofuoku, A. U. and Isife, B. I. (2009). Causes, effects, and resolution of farmers-nomadic cattle herders' conflict in Delta State, Nigeria. *International Journal of Sociology and Anthropology*. 1(2). 47-54

Ogbe, M. A., Abdullahi, M. S., & Ding, Y. (2024). Measuring how armed conflict impacts economic growth in sub-Saharan Africa through spatial analysis. *Frontiers in Political Science, 6*, 1433584. https://doi.org/10.3389/fpos.2024.1433584 (Frontiers)

Olayiwola, O. Ajala, J. and Sangodipe, A. (2014). Cattle management of pastoralist and conflict resolution strategies in the tropical humid rain forest zone of southern Nigeria. *Journal of International Scientific Publications: Agriculture and Food,* 2: 16-19.

Rasak, S. E. (2011). *The Land Use Act of 1978: Appraisal, problems and prospects* (LL.B. thesis). University of Ilorin, Ilorin, Nigeria.

RECANIGER (2009). Etude régionale sur les contextes de la commercialisation du bétail/Accès aux marchés et défis d'amélioration des conditions de vie des communautés pastorales. Regional Study on the contexts of livestock marketing/Market Access and challenges of improving the living conditions of pastoral communities. IRAM, SNV, p 96. Retrieved from http://www.recaniger.org/img/pdf/rapport_commercialisation_betail__iram_snv_2009.pdf%20(accessed on 20 January, 2018).

Richetta, C., & Wegenast, T. (2025). Land alienation and pastoral conflicts. *Journal of Peace Research, 62*(3), 643–659. https://doi.org/10.1177/00223433241252554 (OUP Academic)

Rustad, S. A. (2024). *Conflict trends: A global overview, 1946–2023*. Peace Research Institute Oslo (PRIO). (prio.org)

Sarafa, K., & Monday, A. (2024). Political and ethno-religious tensions in Nigeria: Historical dynamics and contemporary implications for national security. *American Journal of Political Science Law and Criminology*. (In Library)

Shehu, H. (2018). The Causes and Consequences of Fulani Pastoralist-Farmers Conflict in Nigeria. International Journal of Innovation and Research in Educational Sciences Vol. 5(3), pp.357-361.

Usoro, A., Ekpenyong, O. and Effiong, C. (2014). Conflict Management: The Nigerian Government's Strategies and the Question of Enduring Peace. *Business and Management Research*. Vol. 3(2), pp. 138-149.

Utsaha, J. Ugbah Y. and Evuleocha, O. (2007). Defining religious terrorism: a causal and anthological profile". *Studies in Conflict and terrorism*. 26: 105-134.

Wehrmann J. (2005). *Planning for Crime Prevention*. London and New York: Taylor and Francis Group.

World Bank (2012). Nigeria's Oil Production to End in 41 Years. http://www.informationng.com/2012/10/nigerias-oil-productionto-end-in-41-years-world-bank.html. Accessed 29 May 2018.

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SUSTAINABLE ROOFTOP GARDEN FOR MITIGATING URBAN HEAT ISLAND (UHI) IN KLANG VALLEY

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ABSTRACT

The rapid urbanisation in the Klang Valley, Malaysia, has exacerbated the Urban Heat Island (UHI) phenomenon, leading to elevated temperatures, poor air quality, and reduced livability. Rooftop gardens have emerged as a sustainable solution, utilising unused vertical spaces to reintroduce greenery into dense urban areas. This research investigates the effectiveness of rooftop gardens in mitigating UHI through environmental field monitoring and expert interviews. The case study is conducted on one rooftop at a Shopping Centre in the Klang Valley, comparing microclimatic conditions between densely and less-vegetated rooftop areas. The findings indicated significant reductions in air temperature and more stable relative humidity in vegetated areas. Interviews with industry professionals further revealed key environmental and design considerations, implementation challenges, and potential solutions to support wider adoption. This study concludes that rooftop gardens are an effective and multifunctional tool for sustainable urban development in tropical regions such as the Klang Valley.

Keywords: Green Roof, Klang Valley, Microclimate, Rooftop Garden, Urban Heat Island (UHI).

1.0 INTRODUCTION

The Urban Heat Island (UHI) effect is a growing environmental concern in rapidly developing cities, particularly in tropical regions such as Malaysia. The transformation of natural landscapes into impervious surfaces, such as asphalt and concrete, significantly increases ambient temperatures in urban centres. In the Klang Valley, Malaysia's economic hub, this temperature disparity contributes to increased energy consumption, heat-related health risks, and declining quality of life. Studies have identified the Klang Valley as one of the most heat-affected zones in the country, with UHI intensities exceeding 5°C during peak hours due to high-rise buildings, limited green cover, and concentrated energy use (Chee Sam & Sohaili, 2016; Ilham et al., 2012).

Rooftop gardens have emerged as a viable solution to enhance sustainability in urban areas. As a growing trend in urban design, they offer a promising solution to mitigate environmental, social and economic challenges. Rooftop garden is set as a sustainable solution by the United Nations, as it aligns with the Sustainable Development Goals (SDGs). The SDGs they achieved are Target 11, Sustainable Cities, and Target 13, Climate Action (He & Wen, 2023). By transforming traditional rooftops into functional landscapes, these gardens can help minimise urban heat, improve air quality, enhance biodiversity and provide habitats for local wildlife.

Furthermore, rooftop gardens promote human well-being by providing accessible green spaces that can positively impact mental health and community engagement.

According to Ismail et al. (2018), there is an increasing trend in developing countries of using rooftop gardens as a solution to mitigate the UHI effect. Despite the benefits, the adoption of rooftop gardens in Malaysia remains limited, primarily due to a lack of empirical research on the effectiveness of rooftop gardens as a climate adaptation strategy in the Klang Valley's urban environment (Tang et al., 2023). Therefore, this paper aims to explore the potential of rooftop gardens as a sustainable solution for UHI mitigation in the Klang Valley. The research aims to evaluate their impact on the microclimate through environmental monitoring and to gain insights into the operational roof gardens in the Klang Valley by interviewing experts.

2.0 LITERATURE REVIEW

Urban Heat Island (UHI) phenomenon is a climatic condition in which urban areas exhibit significantly higher temperatures than their rural surroundings. This temperature disparity results from the transformation of natural landscapes into urbanised environments dominated by artificial surfaces, limited vegetation, and high-density infrastructure (Chee Sam & Sohaili, 2016). This phenomenon is also prevalent in developing cities due to being an economic hub, lots of buildings and human activities take place.

2.1 Urban Heat Island Factors and Effects

UHI caused by the increase in construction in urban areas suggests that the centres of cities are prone to UHI. This happens because of the thermal capacity of building materials, reduced heat reflux from the underlying, reduced surface water drainage, increased anthropogenic heat, and reduced green spaces in cities (Irfeey et al., 2023). Physical development activities led to the clearance of vegetation to create space for further development. In Malaysia, notably in the Klang Valley, significant research has been conducted to investigate urban heating. As per Ilham Elsayed (2012), who investigated the urban heat island in the city of Kuala Lumpur, Malaysia, Sunday recorded the highest UHI intensity (5.5°C). Compared with the 1985 study, the intensity increased by 1.5°C. This value indicates that urbanisation intensified the heat island effect in developed areas. Beyond structural and environmental causes, UHI is also intensified by anthropogenic heat emissions. Vehicles, industrial machinery, residential heating and cooling systems, and other energy-consuming activities emit waste heat into the environment. In high-density areas, these emissions collectively raise local temperatures (Tang et al., 2023). For example, air conditioning units commonly used in Malaysian homes and offices release hot air into the streets, contributing to an ironic feedback loop: the hotter it gets, the more air conditioning is used, producing more heat and worsening the urban temperature problem.

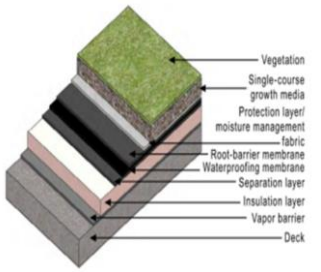
Since then, UHI has led to higher energy consumption, as urban residents in Malaysia's tropical climate rely more on cooling systems. Not only that, but it can also accelerate greenhouse gas emissions due to continued dependence on fossil fuels (Ibrahim et al., 2012). UHI further affects human comfort, especially for the elderly, children, and those with pre-existing medical conditions. Heat stress, heatstroke, and dehydration become more common during hot months, especially in densely populated, low-income areas with limited access to cooling (Tang et al., 2023). Moreover, Walters et al. noted that this added heat can cause more serious problems, such as changes in local weather patterns, less rain, and reduced

water availability. Urban plants may suffer, and the heat can damage important infrastructure such as roads and power systems (Walters et al., 2022). This is especially worrying in fast-developing places like the Klang Valley, where buildings are replacing green spaces. If cities do not plan properly for these changes, the costs of repairs and health impacts will continue to rise.

2.2 Roof Garden and Its Mechanism

Rooftop gardens are composed of several key elements, such as plants, a substrate to provide nutrients, a water system to promote root growth, and a drainage layer to shed excess water. Rooftop gardens are primarily classified as extensive, intensive, or semi-intensive systems (Tang et al., 2023). Extensive rooftop gardens are lightweight, with shallow substrates and low-maintenance plants such as grasses or sedum. At the same time, intensive systems are heavier, with deeper soil that supports shrubs, trees, and recreational spaces. Meanwhile, intensive gardens fall in between, offering moderate to high soil depth and more plant diversity, balancing accessibility with maintenance needs (Tang et al., 2023). Table 1 shows the differences between the types of roof garden and their classification.

Table 1: Types of roof garden with their classification
(source: Abass et al., 2020; Hossain et al., 2019)

Green System	**Intensive**	**Semi-intensive**	**Extensive**
			
Depth (mm)	150 – 1200	120 - 200	Less than 150
Weight (kg/m^2)	250 – 500	120 – 200	60 – 150
Cost	High	Medium	Low
Maintenance	High	Medium	Low
Separate drainage layer	No	Yes	Yes
Vegetation	Ornamental and succulent plants	Ornamental, meadow species, turf grass and woody perennial	Ground-level plant

Malaysia has introduced many developed high-rise buildings with rooftop gardens, particularly in residential buildings. Due to the scarcity of land, podiums, amenity facilities, parking areas, and other areas are equipped with gardens. In addition to residential areas, rooftop gardens are also recognised in commercial, office, and public areas (Ismail et al., 2018; Tang et al., 2023). Figure 1 shows roof gardens located in Malaysia, while Table 2 lists some green roof projects in Malaysia.

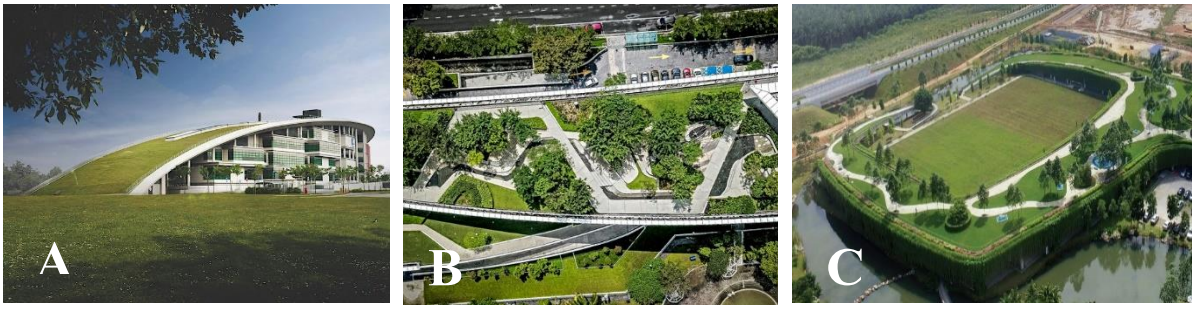


Fig. 1: (A) Extensive green roofs (Herriot-Watt University), (B) Intensive green roofs (Laman PKNS, Shah Alam), (C) Semi-intensive green roofs (Bandar Rimbayu, Shah Alam)

Table 2: List of some green roof projects in Malaysia
(source: Ismail et al., 2018; Tang et al., 2023)

Building	Location	Building Type	Green Roof Type	Accessibility
Secret Garden	Selangor	Commercial	Intensive	Public access
Tun Razak Exchange City Park (TRX)	Kuala Lumpur	Commercial	Intensive	Public access
Bandar Rimbayu	Selangor	Commercial	Semi-intensive	-
Suasana Sentral Condominium	Kuala Lumpur	Residential	Extensive	Private access
Sime Darby Oasis	Selangor	Commercial	Extensive	-
Herriot-Watt University Malaysia	Putrajaya	Institutional	Intensive	-
The Saffron	Kuala Lumpur	Residential	Intensive	Private access
Laman PKNS	Selangor	Commercial	Intensive	-

Various studies have been conducted to demonstrate the effectiveness of the UHI context. The field study conducted by Chee Sam & Sohaili (2016) on a building in Putrajaya concluded that the green roof was cooler by 4.3°C than the bare rooftop. Temperature reduction in roof gardens is mostly due to evapotranspiration, a natural process in which water is absorbed by plant roots and released into the atmosphere through stomata on leaves. This process consumes latent heat, leading to a localised cooling effect. Rooftop vegetation, when properly irrigated and maintained, can significantly reduce surrounding air temperatures by promoting evapotranspiration, especially during daytime when solar radiation is at its peak. (Hamdan & Rashid, 2008)

In tropical regions like Malaysia, where humidity is consistently high, evapotranspiration from green roofs contributes to both thermal comfort and the balance of the hydrological cycle, not only to building cooling. Green roofs provide direct shading to building surfaces, protecting rooftops from solar radiation. This reduces the amount of heat absorbed by the roof membrane and, subsequently, the interior of the building. Additionally, the substrate (soil or growing medium) and vegetation layers act as thermal insulators, decreasing indoor heat gain and lowering the need for mechanical cooling (Getter & Rowe, 2006). Not only that, studies by Niachou, A. et al. (2001) have shown that green roofs can reduce rooftop surface temperatures by 30 to 40°C during peak heat conditions compared to bare concrete roofs.

3.0 METHODOLOGY

3.1 Fieldwork – Environmental Monitoring

Environmental monitoring was conducted at the Secret Garden Rooftop of 1 Utama Shopping Centre, Petaling Jaya. The site was chosen for its accessible rooftop layout and variety of vegetation types. Two distinct zones were identified: a densely vegetated garden area and a less vegetated rooftop section. Air temperature (°C) and relative humidity (%) were measured using calibrated HOBO Pro V2 Data Loggers over three consecutive days from 12th to 14th April 2025. The data loggers monitor the environmental parameters for 12 hours, from 8:00 a.m. until 8:00 p.m., with 15-minute intervals.

Each data logger was placed at representative locations as shown in Figure 2. The purpose was to observe microclimatic differences influenced by vegetation coverage. The placement of equipment was based on the landscape supervisor's suggestions for the Secret Garden. Weather conditions, including rainfall, were recorded in Table 3.

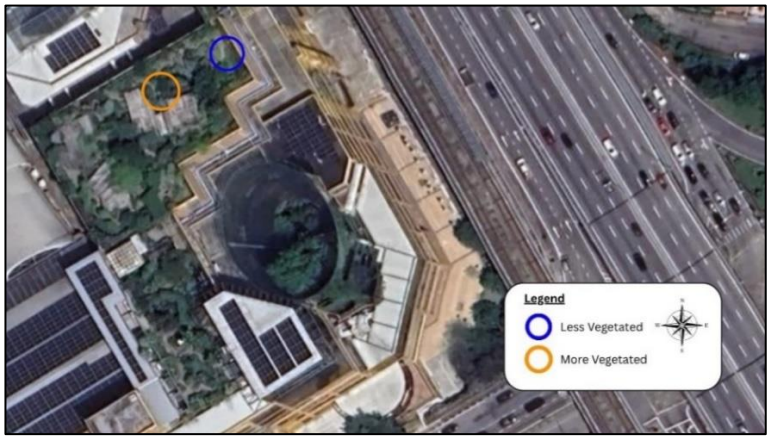


Fig. 2: Location of the data logger in the less densely vegetated area at Secret Garden

Table 3: Summarised weather conditions
(Source: Weather Spark)

Date	Day	Weather Condition			
		8:00-11:59 a.m.	12:00-2:45 p.m.	3:00-6:59 p.m.	7:00-10:00 p.m.
12/04/25	1	Light rain and fair	Fair	Fair	Fair
13/04/25	2	Partly Cloudy	Showers in the Vicinity	Thunderstorm with Heavy Rain	Thunderstorm with Light Rain
14/04/25	3	Fair	Fair	Thunderstorm with Rain	Thunderstorm with Light Rain

3.2 Semi-Structured Interviews

For this study, semi-structured interviews were conducted with two experts involved in the management and development of green areas. The interviews followed a semi-structured format, allowing for open-ended discussions guided by a set of key questions. Topics included the environmental benefits of rooftop gardens, practical challenges in their upkeep, public engagement, and the overall role of rooftop greenery in urban development. Interviews were conducted either in person or via online platforms, depending on participant availability. Thematic analysis was later used to identify common perspectives and extract meaningful insights relevant to the study objectives.

4.0 RESULTS

4.1 Environmental Monitoring

The environmental monitoring results, which are temperature and relative humidity, are interpreted using a combination graph of the three-day average of recorded air temperature values. This is to compare microclimatic differences between densely and less-vegetated rooftop areas.

4.1.1 Air Temperature

Figure 3 shows the combination of average dense and less vegetated air temperature between 8:00 a.m. and 8:00 p.m. The average air temperature over three days was recorded for both locations to enable a clearer, more accurate comparison between the less-vegetated and densely vegetated rooftop areas.

Notably, densely vegetated zones of the rooftop consistently showed lower temperatures than less-vegetated areas. At 8:00 a.m., both locations were at 26°C, the lowest temperature recorded by the data loggers. Temperature gradually increased at 15-minute intervals, reaching its peak in the afternoon before declining towards the evening. The highest average temperature recorded occurred at 3:15 p.m., with the less-vegetated area peaking at 35°C, while the vegetated zone reached 33°C. Throughout the day, vegetated areas remained consistently cooler, with differences up to 2°C compared to the less-vegetated section, particularly during the afternoon.

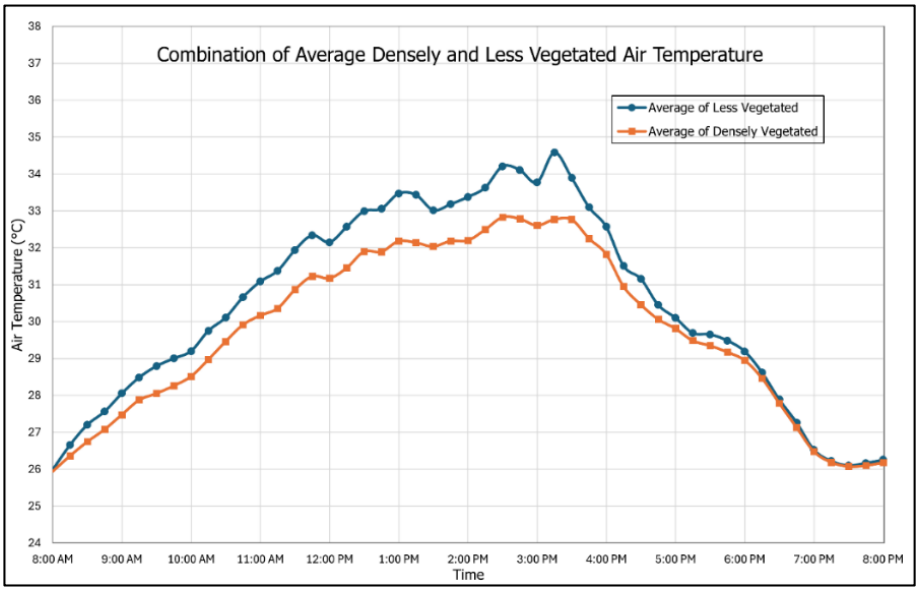


Fig. 3: Graph Combination for the air temperature of average less and densely vegetated areas

4.1.2 Relative Humidity

Figure 4 below compares average relative humidity (RH) between densely and less-vegetated rooftop zones throughout the day. At 8:00 a.m., the highest RH was recorded, with 92% at the least vegetated section, and 90% of the densely vegetated section. This is likely due to lower heat accumulation during the early hours, allowing both rooftop zones to retain higher moisture levels before the temperature began to rise. As shown, the vegetated area

maintained slightly higher RH levels between 10:00 a.m. and 2:00 p.m., likely due to moisture release from plants and soil, helping buffer midday humidity drops. During this period, the percentage difference is between 1-3%. The difference suggests that evapotranspiration from plants and soil contributed to the additional atmospheric moisture.

However, at 4:00 p.m., the less vegetated area showed unexpectedly higher RH, and this trend continued until 8:00 p.m. These variations highlight the dynamic influence of vegetation on humidity patterns and its interaction with temperature changes across the day.

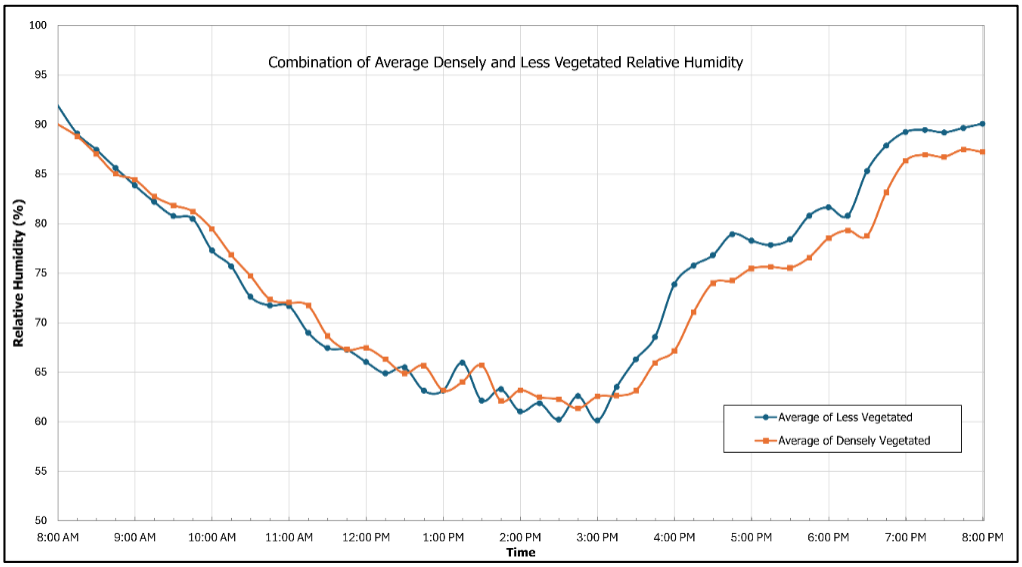


Fig 4: Graph Combination for the Relative Humidity of average less and densely vegetated areas

4.3 Semi-Structured Interview

Qualitative data were collected through in-depth structured interviews conducted in 2025 with two interviewees from different fields. In-depth interviews provide an understanding and description of people's personal experiences regarding the roof gardens' advantages, maintenance and challenges. The data was analysed thematically, i.e., organising the responses by themes. **Table 4** below shows summaries of the in-depth interview findings.

Table 4: Summarised Semi-Structured Interview

Questions	Interviewee A	Interviewee B
Part A: Demographic of Interviewee		
Occupation	Landscape Supervisor	Retail Development
Educational background	-	MS, Sustainable Urban Management
Working experience	More than 20 years	3 years
Part B: General Information of Green Roof		
Location of roof garden	Secret Garden, 1 Utama Shopping Centre	TRX City Park

Questions	Interviewee A	Interviewee B
When was the green roof installed?	Open to public in 2009	Open to public in 2023
What is the type of the rooftop garden	Intensive rooftop	Intensive rooftop
What is the purpose of building rooftop garden?	Marketing, to attract people to shopping in the mall	Focus on built environment and its community
Part C: Role of Rooftop Garden in UHI mitigation		
Do you think green roof can reduce urban temperatures?	Yes	Yes
Have you noticed any temperature differences?	Not so sure, but theoretically, rooftop has low temperature, as it windier	A bit hard to say, because no temperature monitoring is installed
Do rooftop gardens make buildings more eco-friendly and save energy?	Yes, but no energy data or analysis has been done to confirm it.	Yes, though no direct temperature monitoring has been done.
Besides temperature reduction, what other benefits that you observed	The rooftop garden supports urban farming, attracts birds and bees, and offers a peaceful space for visitors to relax and learn about plants.	The rooftop park is used for recreational activities, promotes biodiversity, and includes a rainwater harvesting system for sustainable water use.
Part D: Challenges and Maintenance of Rooftop Garden		
What are the maintenances of the green roof?	The maintenance was done for 4 days, Mondays to Thursday	The maintenance took place every day, during day and night, if it's during the day, they will put signage to indicate section is closed
What are the maintenance elements of the green roof?	Maintenance includes daily irrigation, pruning, removing dead leaves, and topping up soil.	Maintenance includes automated and manual irrigation, pruning, weeding, and pond cleaning.
Did you get any government support for the rooftop garden?	No	No
Are there any challenges encountered?	Mentioned plant theft and visitors plucking plants as the main challenges.	Not particularly, but the challenges to make the park more aesthetics, such as how to hide the plant room, air vents
Do you receive any feedback or comments from the customer about the rooftop garden?	Visitors often describe the garden as calm and educational, with interest in the labelled plants.	Visitors enjoy the space, but some complaints were made about slippery walkways and mosquitoes.
Do you see a growing demand in green roof in Malaysia construction?	Yes, green roof designs are becoming more popular in nearby developments.	Yes, especially in projects that integrate community and green features.

5.0 DISCUSSIONS

The results show that rooftop gardens deliver measurable microclimatic improvements by lowering temperatures, i.e., more vegetated areas have cooler temperatures than less vegetated areas (Tang et al., 2023). These findings indicate that vegetation helps reduce heat accumulation and moderate daily thermal fluctuations.

According to Chee Sam & Sohaili, roof gardens typically maintain higher humidity levels than bare rooftops. In which the increment of relative humidity shows the cooling effect of the surrounding area (Tang et al., 2023). However, after 4:00 p.m., the RH in the densely vegetated area decreased, indicating unusual patterns that external factors may have influenced during the monitoring, such as rainfall. It was observed that the data logger in the less-vegetated area was positioned closer to a wall and more exposed to rainfall and surface moisture, which could have led to artificially elevated RH readings. In contrast, the vegetated zone, with better moisture absorption through soil and plant coverage, may have regulated humidity more effectively, preventing excess moisture accumulation in the sensor area. Thus, the less-vegetated area has higher RH than the densely vegetated area.

Expert perspectives reinforced the environmental data, highlighting that while rooftop gardens can function as effective thermal buffers, their performance depends on careful plant selection, irrigation, and long-term maintenance. The emphasis on financial and technical barriers reflects broader literature, which identifies cost and lack of guidelines as the main constraints in Malaysia. Nevertheless, both experts recognised sustainable features and benefits, such as improved aesthetics, mental well-being, and biodiversity, proving that rooftop gardens are more than just climate adaptation tools.

6.0 CONCLUSION

This study demonstrates that rooftop gardens in the Klang Valley can reduce rooftop air temperature by up to 2°C while increasing relative humidity, thereby improving thermal comfort in tropical urban environments. 2°C temperature difference (reduction) between densely vegetated and less vegetated rooftop zones is quite significant for an urban area such as Klang Valley, which is located in an equatorial climate zone. This suggests their potential to help reduce heat in urban areas, though further studies are needed to confirm their broader impacts. The reduction in surrounding-area temperature can be significant if more roof gardens are introduced.

Combined with expert insights, the findings highlight both the measurable environmental benefits and the broader ecological and social value of rooftop gardens in Klang Valley.
Despite promising results, several barriers hinder widespread adoption. These include high initial costs, structural constraints, lack of localised design standards, and limited maintenance expertise. To unlock the full potential of rooftop gardens, policymakers, architects, and developers must collaborate to establish clear technical guidelines, financial incentives, and public education programs. Ultimately, rooftop gardens should be viewed not merely as aesthetic enhancements but as essential infrastructure for sustainable urban living

in Malaysia. As urban areas continue to grow, integrating green roofs into planning and building codes will be crucial in creating climate-resilient cities that are both livable and environmentally responsible.

REFERENCES

Abass, F., Ismail, L. H., Wahab, I. A., & Elgadi, A. A. (2020). A Review of Green Roof: Definition, History, Evolution and Functions. *IOP Conference Series: Materials Science and Engineering*, *713*(1), 012048. https://doi.org/10.1088/1757-899X/713/1/012048

Chee Sam, L., & Sohaili, J. (2016). *Urban Heat Island Mitigation by Introducing a Green Roof System*.

Getter, K. L., & Rowe, D. B. (2006). The Role of Extensive Green Roofs in Sustainable Development. In *HORTSCIENCE* (Vol. 41, Issue 5). https://journals.ashs.org

Hamdan Bin Ahmed, M., & Rashid, R. (2008). *Thermal Performance of Rooftop Greenery System in the Tropical Climate of Malaysia*.

He, J., & Wen, K. (2023). *Impact and management of rooftop garden - An example from China* (pp. 516–530). https://doi.org/10.2991/978-94-6463-344-3_58

Hossain, M. A., Shams, S., Amin, M., Reza, M. S., & Chowdhury, T. U. (2019). Perception and Barriers to Implementation of Intensive and Extensive Green Roofs in Dhaka, Bangladesh. *Buildings 2019, Vol. 9, Page 79*, *9*(4), 79. https://doi.org/10.3390/BUILDINGS9040079

Ibrahim, A. S., Mohamed Shuhaimy, N. F., Abu Bakar, A., Hj Mohd Ariffin, N. A., & Mohd. Din, S. A. (2012). *The effects of landscape design elements and mosque design on the thermal environment of the main prayer hall: a case study of the Tuanku Mizan Zainal Abidin Mosque, Putrajaya*. https://core.ac.uk/outputs/300429595/?source=1&algorithmId=15&similarToDoc=300449123&similarToDocKey=CORE&recSetID=1d9eb1c6-d406-47d4-b59b-0bba1feca061&position=3&recommendation_type=same_repo&otherRecs=187152280%2C199242464%2C300429595%2C231761854%2C573841257

Ilham S. M. Elsayed, I. S. M. E. (2012). A Study on the Urban Heat Island of the City of Kuala Lumpur, Malaysia. *Journal of King Abdulaziz University - Meteorology, Environment and Arid Land Agriculture Sciences*, *23*(2), 121–134. https://doi.org/10.4197/MET.23-2.8

Irfeey, A. M. M., Chau, H. W., Sumaiya, M. M. F., Wai, C. Y., Muttil, N., & Jamei, E. (2023). Sustainable Mitigation Strategies for Urban Heat Island Effects in Urban Areas. *Sustainability (Switzerland)*, *15*(14). https://doi.org/10.3390/su151410767

Ismail, W. Z. W., Abdullah, M. N., Hashim, H., & Rani, W. S. W. (2018). An overview of green roof development in Malaysia and a way forward. *AIP Conference Proceedings*, *2016*. https://doi.org/10.1063/1.5055460

Niachou, A., Papakonstantinou, K., Santamouris, M., Tsangrassoulis, A., & Mihalakakou, G. (2001). Analysis of the green roof thermal properties and investigation of its energy performance. *Energy and Buildings*, *33*(7), 719–729. https://doi.org/10.1016/S0378-7788(01)00062-7

Tang, Y. Y., Slimani, Y., Al-Ghazal, M. A., Talukdar, G., & Maharjan, A. K. (2023). Sustainable Urban Development in Malaysia: Enhancing Green Roofs with Integrated Technologies. *Civil and Sustainable Urban Engineering*, *3*(2). https://doi.org/10.53623/CSUE.V3I2.335

Walters, S. A., Gajewski, C., Sadeghpour, A., & Groninger, J. W. (2022). Mitigation of Climate Change for Urban Agriculture: Water Management of Culinary Herbs Grown in an Extensive Green Roof Environment. *Climate*, *10*(11). https://doi.org/10.3390/cli10110180

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CLASSROOM AESTHETIC AND STUDENT OUTCOMES: IMPACTS ON WELL-BEING AND ACADEMIC PERFORMANCE IN MALAYSIAN HIGHER EDUCATION INSTITUTIONS

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ABSTRACT

The physical and aesthetic design qualities of classrooms significantly influence students' psychological well-being, motivation, and academic performance. While international research consistently demonstrates that spatial layout, lighting, colour schemes, and ergonomic furniture influence learning outcomes, limited studies have contextualised these findings within Malaysian public institutions. This paper examines the relationship between classroom aesthetics and student experiences at Universiti Teknologi MARA (UiTM) Shah Alam. A qualitative approach was adopted, employing semi-structured interviews with 60 students across four faculties. Data were analysed thematically to capture perceptions of how the classroom environment affects concentration, engagement, and emotional well-being. Findings indicate that classroom aesthetics play a pivotal role in enhancing students' concentration, motivation, and emotional state, where 75% of participants highlighting the positive influence of well-lit, ventilated, and ergonomically furnished spaces. The study underscores how thoughtful classroom design acts not only as a physical attribute but also as a psychological enabler student well-being and improves learning outcomes. These findings bridge current realities with forward-looking design imperatives, offering evidence-based guidance for higher education facilities planning in Malaysia.

Keywords: classroom aesthetics, learning environment, student well-being, higher education

1.0 INTRODUCTION

The classroom environment profoundly influences on students' psychological well-being and academic achievement. Beyond curriculum and pedagogy, aesthetics and physical conditions of learning spaces, including lighting, furniture, and spatial arrangement may contribute to student engagement, motivation, and mental health. Research on context-specific public universities is scarce, despite growing awareness that poorly designed spaces may lead to fatigue, disengagement, and reduced motivation (Othman et al., 2022). This raises a crucial question: do existing classroom conditions in local universities align with contemporary students' needs and global best practices?

At Universiti teknologi MARA (UiTM) Shah Alam, classrooms serve thousands of students across diverse faculties. However, concerns regarding outdated furniture, inadequate lighting, and inflexible layouts persist. While many students perceive their learning environments as acceptable, others find them lacking in comfort and adaptability. Such disparities suggest that classroom aesthetics are not merely visual attributes but integral components influencing psychological well-being, motivation, and academic performance. This study therefore addresses the gap by examining the relationship between classroom aesthetics and student well-being at UiTM Shah Alam.

2.0 LITERATURE REVIEW

Classroom environment impacts both academic outcomes and psychological health. Previous studies consistently prove that design elements such as spatial arrangement, lighting, colour, furniture, sustainability, and technology integration have measurable impacts on student well-being and academic performance. (Wang & Degol, 2016).

The classroom environment has been conceptualised as a 'silent curriculum' that shapes student experiences through its physical and aesthetic qualities. Studies consistently prove that effective classroom design fosters concentration, reduces stress, and enhances academic outcomes. Barrett et al. (2013), in their large-scale 'Clever Classrooms' project, quantified that up to 16% of learning progress affected directly to physical classroom design factors. Despite such evidence, the contextualisation of these findings in Malaysian higher education remains limited, thus motivating the present research.

2.1 Spatial Arrangement and Learning Flexibility

The Spatial arrangement of classroom spaces has a direct impact on learning styles, collaboration, and participation. Traditional fixed rows of desks limit interaction, in contrast, flexible arrangements encourage communication, group work, and inclusivity (Fardlillah & Suryono, 2019; Castilla et al., 2017). Effective spatial design reduces barriers between students and teachers, fostering openness and engagement. Evidence from Active Learning Classrooms (ACLs) shows significant increases in participation and deeper conceptual understanding compared to traditional lecture halls (Peng et al., 2022).

The atmosphere of a classroom is influenced by its physical structure. Research in higher education has shown that open-plan and modular layouts promote a sense of belonging and active participation (Jamieson et al., 2000). A thoughtfully designed classroom guarantees that students have enough space to walk and take part in other activities without interruptions. Flexible layouts make it easy to rearrange furniture, while being particularly useful because they can be used by a wide variety of teaching techniques and learning styles. As stated by Fardlillah & Suryono, (2019) and Castilla et al., (2017), flexible seating arrangements facilitate collaboration or concentration during group discussions, individual sessions, and interactive activities.

The impact of spatial design goes beyond movement; it signals pedagogical intent. Environments designed for interaction empower students to co-create learning, while rigid structures reinforce hierarchical teacher-centred models (Jamieson et al., 2000). Thus, spatial functionality can be considered both a practical and symbolic element of learning. Furthermore, effective spatial design can reduce physical and psychological barriers between students and teachers, resulting in a more inclusive and engaging environment.

2.2 Lighting and Colour

Lighting and colour significantly affect attention, mood, and cognitive performance. Natural light has long been associated with improved concentration and reduced fatigue. Llinares et al. (2021) proved that higher illuminance levels improved attention and reduced error rates, while memory tasks performed better under lower levels. Added to this, natural light has been shown to improve learning abilities and keep young people energised throughout the day.

Adjustable lighting schemes thus allow classrooms to adapt to specific tasks. The aesthetic aspects and the physical environment of classrooms lighting and colour, have a major effect on students' memory retention, comfort, and general well-being. Several studies have investigated aspects of lighting such as correlated colour temperature, illuminance levels, and naturally and artificially lit conditions to improve educational settings. Colour affects emotional response and engagement. It complements lighting by influencing emotional responses. Warm colours such as yellow and orange stimulate energy, while cool shades such as blue and green promote calmness and focus (Cheryan et al., 2014; Liu et al., 2020). When harmonised, lighting and colour schemes can be tailored to balance stimulation and relaxation in classrooms, optimising both creativity and focus.

The Correlated Colour Temperature (CCT) also matters (Figure 1), with cooler lighting (6500K), providing a cooler and bluish tint, improving attention and memory (Llinares et al., 2021). Similarly, Castilla et al. (2017) emphasise the role of adaptable artificial lighting to support varied tasks such as group discussions or multimedia activities.

These results show the possibility of implementing adjustable lighting arrangements proper for different classroom activities to ensure that students can focus and learn best.

Fig. 1: *Demystifying Correlated Colour Temperature (CCT) in LED Lighting* (Source: *Ener-J (2023)*

2.3 Furniture and Equipment

Furniture impacts posture, comfort, and engagement. Ergonomic seating reduces fatigue, improving attention and academic outcomes (Kepez & Üst, 2024). Movable and modular furniture supports diverse teaching methods, enabling classrooms to transition between lecture, group work, and hands-on activities. Furniture designed thoughtfully upholds body health and raises cognitive ability through an environment conducive to attention and learning (Fardlillah & Suryono, 2019).

Activities that involve hands-on work or presentations require spaces that encourage movement and interaction. This flexibility helps make classrooms lively and capable of meeting diverse learning styles and teaching methods. In addition to seating and tables, such things as shelves, cabinets, and cubbies are vital components of a functional classroom for the storage of learning materials. Kepez & Üst (2024) proved that classrooms with modular tables and movable chairs fostered higher participation and collaboration. Students reported a sense of ownership of their spaces, which improved both motivation and social interaction. Ergonomically designed chairs and appropriately sized desks also reduced discomfort and promoted longer periods of focus. Conversely, poorly designed furniture contributed to back pain, distraction, and reduced attention spans.

Adding collaborative equipment like interactive smart boards, charging points, and digital displays can enhance the learning environment. According to Kepez & Üst, (2024), providing classrooms with these types of tools allows students to use blended and technology-intensive learning and helps them to deal with the materials more interactively. When integrated with flexible furniture, these technologies promote blended learning and collaborative pedagogy.

2.4 Sustainability Design and Environmental Quality

Sustainability in classroom design has gained global prominence. Green building strategies, such as energy-efficient lighting, natural ventilation, and eco-friendly materials, improve health while reducing ecological footprints. Classrooms built with sustainability improve students' health, encourage environmental consciousness, and align with international movements to address climate change (Tanner, 2013).

In addition, highly interactive hands-on educational opportunities occurred in classrooms with obvious eco-friendly elements, including energy-efficient equipment, green walls, or rainwater harvesting systems. These aspects cultivate environmental values in students and motivate them to embrace responsible practices. Students who are exposed to sustainable practices in their environments are more likely to grow up to be a person who understands the importance of taking care of things and have a keen sense of responsibility.

Malaysia's Putra Future Classroom, for instance, emphasises sustainable design with natural lighting, automated ventilation, and environmentally friendly finishes (M.K., 2022). Such classrooms also function as educational tools, reinforcing environmental values in students. Exposure to green design principles can cultivate lifelong sustainable behaviour (Tanner, 2013). These characteristics have been proven to help students' health and focus by lowering energy use and improving air quality. Another useful feature is automated controls, which are smart systems such as temperature and lighting controls that adjust conditions according to occupancy and time of day (M. K., 2022).

Sustainability extends beyond physical comfort: integration of greenery, recycled materials, and renewable energy systems cultivates a sense of ecological responsibility. M.K. (2022) argues that such designs can simultaneously enhance academic performance and instill environmental stewardship among students.

2.5 Technology Integration in Classroom Design

The 21st-century classroom increasingly incorporates digital technologies. Interactive whiteboards, VR/AR tools, and learning management systems extend the possibilities of active and blended learning (Strelan et al., 2020). Al-Sindi (2023) reported that technology-enabled classrooms enhance participation and support flipped classroom models, whereby students learn theoretical content at home and apply knowledge through collaborative tasks in class. Importantly, technology must align with spatial and ergonomic design to achieve its full impact.

Modern teaching techniques, such as flexible or flipped classrooms, further strengthen the impact of classroom design on learning. Flipped classrooms shift traditional instruction by allowing students to study new material outside of class and engage in discussions and problem-solving during class time. Strelan et al. (2020) conducted a meta-analysis that showed flipped classrooms lead to improved outcomes across multiple disciplines and educational levels. The approach supports active learning, deeper understanding, and stronger engagement from students. By designing classroom spaces that accommodate collaborative learning and critical thinking, educators can maximise the effectiveness of flipped and flexible models. Such integration shows the importance of pairing innovative teaching practices with supportive physical environments.

The classroom design becomes more efficient when technology and physical elements are thoughtfully integrated. Zhang et al. (2021) noted that blended classrooms incorporating flexible seating, proper lighting, and advanced technology create dynamic and creative learning environments. These features not only help students feel comfortable but also encourage participation and collaboration. Environmental conditions such as air quality, temperature, and illumination also play critical roles. Brink et al. (2024) found that the best indoor environments improve the cognitive functioning and performance of both students and teachers, while poor conditions can cause fatigue and lower productivity. Therefore, classroom design strongly influences academic success by combining effective layouts, innovative teaching, aesthetic appeal, and environmental quality. Institutions must intentionally embrace thoughtful design to foster engagement, creativity, and long-term achievement.

3.0 METHODOLOGY

The study used a qualitative approach, employing semi-structured interviews to collect in-depth data from students across various faculties. The study investigates the meanings students attach to classroom design features, thereby uncovering the nuanced ways in which lighting, furniture, colour, ventilation, and spatial arrangement shape concentration, engagement, and comfort.

This research was conducted at Universiti Teknologi MARA (UiTM) Shah Alam, one of Malaysia's largest public universities. Participating students were from four faculties representing diverse disciplinary contexts: Built Environment, Engineering, Law, and Computer and Mathematical Sciences. A purposive sampling strategy was employed to recruit participants who extensively use UiTM classrooms and could provide informed perspectives on their design and functionality. Interviews were scheduled based on participant availability to promote comfort and openness. A total of 60 students took part, with balanced representation across the four faculties. Recruitment was carried out via online platforms such as WhatsApp and email. While the sample size was modest, it was considered sufficient for thematic saturation (Guest et al., 2006).

Table 1: Demographic, Faculty Representation

Faculty	Number of Students
College Of Built Environment	15
College of Engineering	15
Faculty of Law	15
Faculty of Computer and Mathematical Sciences	15
Total	**60**

Data collection was using semi-structured interviews, which allowed participants to describe their experiences in depth while providing flexibility to probe further. The interview guide focused on key classroom aesthetic elements identified in the literature review: lighting and colour, furniture ergonomics, spatial layout, ventilation and thermal comfort, and integration of technology. Each interview lasted between 30 and 45 minutes with face-to-face or online, depending on participant availability. Interviews were audio-recorded with consent and later transcribed verbatim. Anonymity and confidentiality were guaranteed, and participation was voluntary. This process was bound under Ethical approval from UiTM.

Data were analysed using Braun and Clarke's (2006) thematic analysis framework: familiarisation, coding, theme development, refinement, definition, and reporting (Figure 2). Rigour was enhanced through triangulation across faculties, member checking, peer debriefing, and audit trails.

While this qualitative design provided rich insights, several limitations must be acknowledged. The reliance on self-reported data introduces potential response bias, as participants may portray views that they consider socially desirable. The sample, though diverse, was limited to one university, which restricts generalisability to other Malaysian institutions. Finally, time and resource constraints precluded mixed-methods triangulation with quantitative measures such as environmental performance data (e.g., lux levels, CO_2 concentration). Future research could integrate such measures to enhance validity.

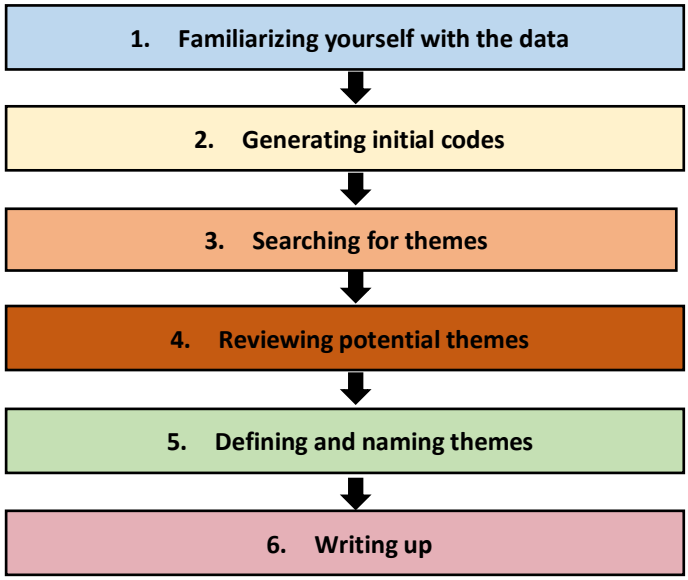

Figure 2: Steps of Thematic Analysis (Braun & Clarke, 2006)

4.0 RESULTS

This section expands these findings from semi-structured interviews with 60 students across four faculties at UiTM Shah Alam. Results are organised into three themes aligned with the study objectives: (1) Psychological Well-being, (2) Motivation and Engagement, and (3) Improvement Suggestions. Selected quotations illustrate key patterns, while percentages and simplified tables provide clarity. The following subsections expand on these findings.

4.1 Impact of classroom aesthetics on students' psychological well-being

The findings from Table 2 show that classroom design and physical conditions strongly influence students' well-being, focus, and academic performance. Students' perceptions of classroom aesthetics strongly influenced their psychological comfort and well-being. Many respondents (57%) expressed overall satisfaction with classroom conditions, citing sufficient lighting, ventilation, and basic furniture. However, a notable part (28%) described conditions as merely 'acceptable' or 'neutral,' while another 15% expressed dissatisfaction, particularly highlighting outdated furniture, inconsistent air-conditioning, and lack of cleanliness.

Table 2: Student Satisfaction with Classroom Conditions (n=60)

Response	Frequency	Percentage
Satisfied	34	57%
Neutral/Acceptable	17	28%
Dissatisfied	9	15%

Lighting appeared as the most often cited factor influencing concentration and alertness. In Table 3, 53 students (88.3%) reported that proper lighting keeps them alert and concentrated, while 7 students (11.7%) said lighting had no effect, showing that most learners depend on good lighting. Students also expressed that classrooms with good daylight exposure enhanced their mood, while dim or uneven lighting made them feel lethargic.

Table 3: Lighting and Concentration (n=60)

Lighting Effect	Frequency	Percentage
Affects concentration	53	88%
No effect reported	7	12%

"I need proper lighting to stay focused—if the light is too dim, I feel sleepy." (Participant, Faculty of Law)

"Lighting really affects concentration. Every classroom should have sufficient light for us to focus better." (Participant, Faculty of Engineering)

Ventilation and cleanliness also influenced comfort. Although most classrooms were described as 'generally acceptable,' students expressed discomfort in poorly ventilated or stuffy rooms. Participants from the Faculty of Built Environment, in particular, displayed heightened awareness of environmental design, noting the link between ventilation, air quality, and alertness. Such responses demonstrate that beyond functional adequacy, the psychological well-being of students is shaped by subtle elements of classroom maintenance and environmental quality.

Table 4 presents students' perceptions of how classroom environmental conditions influence their stress levels, emotional well-being, and overall comfort during learning sessions. The findings indicate that environmental discomfort was the most dominant concern, reported by 29 students (48.3%) who experienced a classroom with broken furniture or noise, followed by the influence of physical classroom conditions on mood and mental state, 25 students (41.7%). A smaller proportion of students expressed neutral perceptions (6.7%), while only a minimal number highlighted the role of visual aesthetics in enhancing comfort (3.3%). Overall, between 90% and 95% of students agreed that lighting, cleanliness, and aesthetics affect their comfort and focus. These results confirm that classroom conditions directly impact students' stress levels, concentration, and engagement. A pleasant and well-maintained classroom not only supports psychological well-being but also enhances motivation to learn. This result shows the importance of investing in classroom design as part of improving educational quality.

Table 4: Classroom Environment and Its Role in Student Comfort

Q10 Themes	Answers Quotations	Count of Q10 Themes
Environmental discomfort	"Broken chair or table makes me stress. Loud noise from the chair will disturb my concentration in class."	29
	"Lighting, seating arrangements, noise levels, and even temperature can influence how focused and relaxed I feel."	
	"When the classroom is Too crowded with students, it affects my anxiety"	
Physical condition impact mood or mental state	"By having a well construct ed and tidy environment it could influence the stress and peace level of while having a class."	25
	"If the room is clean and has comfortable chairs and tables, I feel more relaxed and focused."	
	"The environment of the class influences my overall mood. A comfortable class helps me feel calm and focused."	
Neutral	"I have no comment on this, because so far, I'm okay in my classroom"	4
	"It doesn't influence my stress, anxiety and comfort."	
	"The class is comfortable enough to conduct lecture thus making me to become more motivated"	
Visual appeal creates positive feeling	"If it more aesthetic surely will be more comfortable."	2
	"Its poor condition makes me feel less studying"	
Total		60

Figures 3 and 4 show images taken from one of the classes at the College of Built Environment. The classroom has proper lighting, ventilation and it is equipped with a projector. However, there are a few flaws which are, air conditioner is still an older version and some of the furniture has been broken.

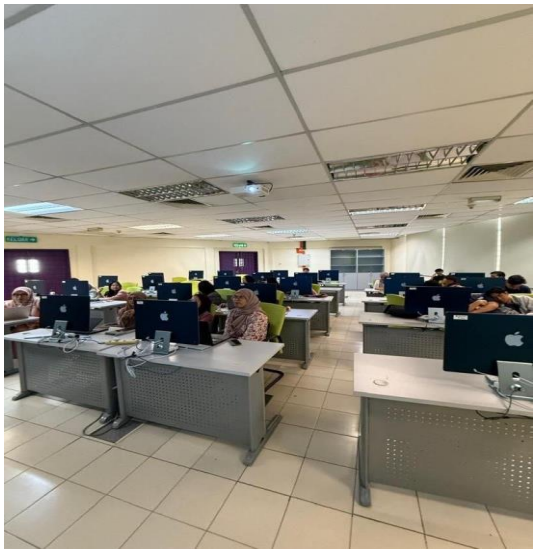

Figure 3: Computer Lab at Faculty of Computer and Mathematical Science

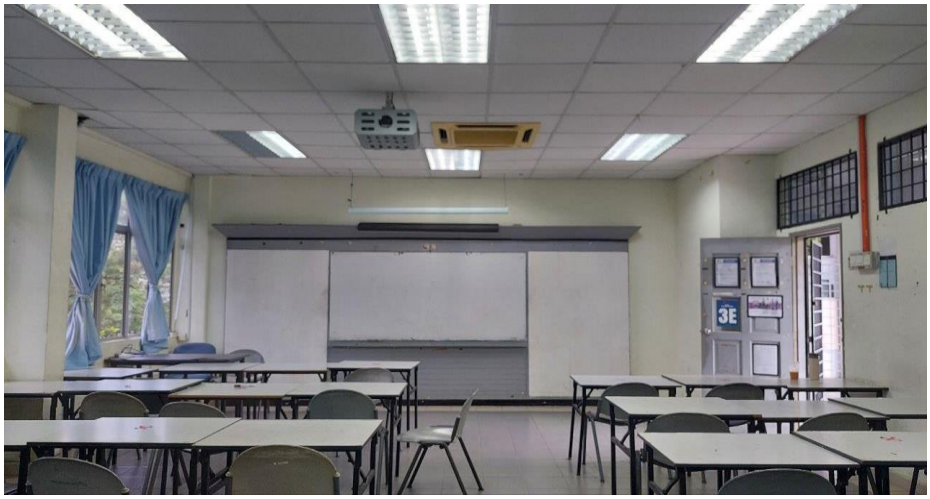

Figure 4: Classroom at Block C, Faculty of Built Environment

4.2 The relationship between classroom aesthetics and students' motivation and engagement

Motivation and engagement were influenced by classroom furniture and overall aesthetics. Students consistently reported that fixed or heavy desks limited flexibility, making group work challenging and reducing classroom dynamism. Ergonomic discomfort was a recurring issue, with chairs described as unsupportive for long lectures. This physical discomfort was linked to reduced concentration, fatigue, and lowered motivation (Table 5).

Table 5: Furniture and Comfort (n=60)

Response	Frequency	Percentage
Comfortable	22	37%
Neutral/Acceptable	18	30%
Uncomfortable	20	33%

"The chairs are uncomfortable, especially for long lectures—it makes it hard to stay focused." (Participant, Faculty of Built Environment)

"Group discussions are always difficult because the tables are heavy and fixed." (Participant, Faculty of Computer and Mathematical Sciences)

Conversely, students appreciated classrooms that offered movable, modular furniture. Such layouts gave them greater ownership of their learning space and supported interactive and collaborative activities. Several participants noted that flexible layouts signalled a more modern, student-centred approach to teaching.

Table 6 shows the data analysis of the question where it is related to the classroom environment affecting students' mood, focus, and engagement. A majority which is a considerable number of students said that their classroom environment positively influences their mood, focus, and engagement. Many described entering a calm, properly lighted, and organised classroom, at once making them feel more focused and ready to engage in a learning environment. They answered that when the space is neat and inviting, it is easier to concentrate and join in classroom discussions.

Table 6: How Classroom Environment Affects Students' Mood and Engagement

Q8 Themes	Answers Quotations	Count of Q8 Themes
Positive environment improves focus and engagement	"A good environment does effect student mood and focus, for example when the class is in a positive vibe and relax environment students will feel more at ease to study"	53
	"Classroom environment can really affect my mood, focus and engagement."	
	"Definitely. The better the environment, the better I can focus and stay engaged"	
	"For me I prefer a positive environment, I don't really like loud and crowd environment, it disturbs my mood"	
	"I prefer a positive environment"	
Environment has minimal effect	"For me it depends, I don't really feel the need to have good classroom environment, if I am too focus on study I easily forget about the environment"	7
	"Not really, I can still focus even the class is not aesthetics enough"	
	"Sometimes, it has to depend on the situation"	
Total		60

On classroom design, 35 students (58.3%) were satisfied and confirmed that well-maintained and aesthetically pleasing classrooms not only reduce stress but also improve motivation, engagement, and academic performance. This finding highlights the importance of investing in classroom design to support students' psychological well-being and learning outcomes. Table 7 below shows the answer from the students regarding aesthetic elements affecting their motivation.

Table 7: Student Perceptions of Aesthetic Elements

Theme	Illustrative Feedback
Colour & ambience	"Bright walls help me feel more energetic."
Spaciousness & flexibility	"Flexible layouts encourage group activities."
Cleanliness & order	"A tidy space keeps me more focused."

The "Engagement" Theme also varied across faculties. Built Environment students reported the strongest link between classroom design and motivation, often providing detailed observations of spatial arrangements and colour use. Law students, by contrast, emphasised the importance of lighting and quietness for concentration. Computer and Mathematical Sciences students appeared more tolerant of environmental shortcomings, citing reliance on digital devices as a compensatory factor.

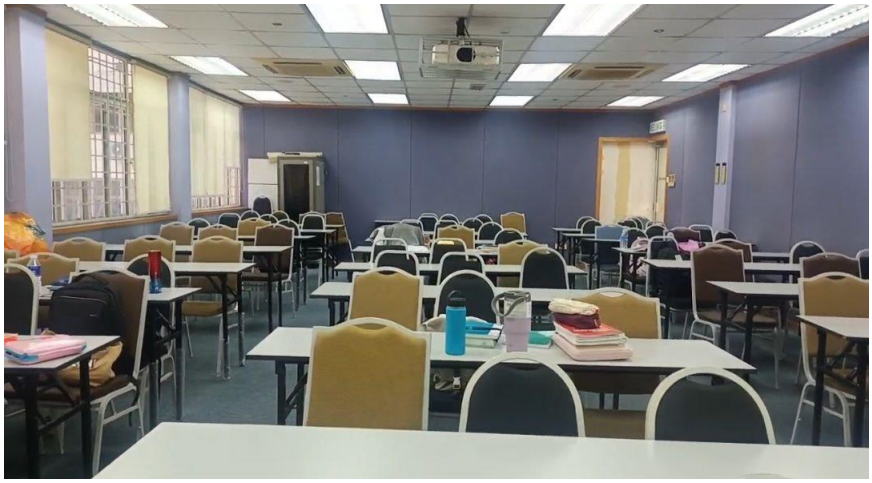

Figure 5: Classroom in Faculty of Law

Figure 5 shows the classroom at the Faculty of Law in UiTM Shah Alam. The classroom is fully packed, and the seats or chairs are not the same. The sitting arrangement also shows that the classroom was sometimes too crowded.

Figure 6: Classroom at the Faculty of Engineering

Figure 6 is an image of one of the classrooms at the College of Engineering. The classroom has limited space; however, it is equipped with a television, air conditioning, and a fan to keep a suitable temperature during learning.

4.3 The solutions for improving classroom environments to better support student learning performance.

When asked to suggest improvements, students offered a wide range of practical recommendations that clustered around three key areas: technology integration, furniture upgrades, and environmental quality (Table 8). These suggestions highlight the gap between current classroom conditions, and the immersive, flexible environments students envision.

Table 8: Student Recommendations for Future Classroom Design

Improvement Area	Key Suggestions	Frequency
Technology	Smart boards, charging points, Wi-Fi	42
Furniture	Ergonomic, movable, modular	39
Environment	Better lighting, ventilation, AC	36

Illustrative quotes further underscored these concerns: "Technology is essential—we still rely too much on personal laptops."

"Group work is difficult with fixed heavy tables."
"Some rooms are stuffy and not well ventilated."

Table 9: Technology Resources Impact on Students' Learning

Q7 Themes	Answers Quotations	Count of Q7 Themes
Technology enhances learning experience	"Adding advanced technology can attract more student to be motivated in studying"	49
	"Adding technology can motivate student, in my opinion I like having all the new technology like LCD or a better control system for classroom temperature, these technologies make student life easier"	
	"By using technology, I think it enhance student interest more, this is because student like something new and something interesting."	
Technology is necessary	"In a world where technology is used everyday, for me this is really important for students learning experience"	8
Neutral views on technology	"So far, I have been studying less with gadget, I get distracted easily but I also use kinda agree with having technology in class"	3
	"This depends; I can still study in a traditionally design classroom without any technology but having charging port might be better for certain student that uses gadgets."	
	"I love using gadget and technologies, but adding these technologies sometimes has their flaws, for example setting up projector might take time or if it has technical issue the class can b delayed, and for adding charging point, some students might get distracted easily when using their phones. So, i prefer a traditional classroom"	
Total		60

Table 9 shows that most students consider technology an essential part of their learning environment, with 49 out of 60 students (81.7%) reporting that it enhances their learning. They explained that reliable projectors, proper temperature control, and sufficient charging points help make lessons more engaging and reduce stress caused by technical issues. These results highlight that classroom design, including technology, influences students' well-being and concentration. Ensuring that tools are user-friendly, regularly maintained, and smoothly integrated into teaching can prevent disruptions that hinder learning.

5.0 DISCUSSIONS

This section provides a summary of the main finding's based on each research objective. This findings conclusion is based on interviews of 60 students in UiTM Shah Alam, with 15 students from each of the four different faculties each.

Classroom aesthetics significantly affect students' psychological well-being and overall well-being.

Based on the interview, most students reported that the physical appearance and condition of their classroom clearly affected how they felt and their emotions. Well- maintained, sufficient proper lighting and an organised classroom helped reduce stress and made students feel more at ease or feel more comfortable. Meanwhile, poor lighting or a not properly organised classroom made some students feel tired and anxious. This means that simple improvements in the classroom environment can really help students improve their comfort and mental preparation during learning classes.

The relationship between classroom aesthetics and students' motivation and engagement.

Many students from the interviews answered that a neat, organised, and visually pleasant classroom makes them feel more motivated and helps them stay focused. Influential factors like; comfortable chairs or furniture, sufficient space, and proper wall paint colours had a positive impact on students' mood and willingness to take part in class. While a few students answered that they could focus anywhere and it does not really affect them, the majority clearly valued a good learning atmosphere.

Classroom environments to better support student learning performance.

From the interviews, students gave several helpful suggestions and ideas. This includes fixing or upgrading old furniture, improving lighting and ventilation, and adding more aesthetic elements in the classroom. For example, add arts, wall arts, or plants to make the classroom livelier. Moreover, many students also highlighted how important it is to have technology in class. These technologies are achieved by having more advanced projectors, adding charging points, as it makes lessons more engaging. This is because all students use gadgets, and having more charging ports or points is particularly important. Based on the class schedule, some courses have classes from morning until late in the evening, so it is important to add more charging points. These ideas show that students are aware of what helps them learn better and feel more comfortable in class.

6.0 CONCLUSION

Classroom aesthetics and physical conditions at UiTM Shah Alam affect students' psychological and academic outcomes. The key improvements of classroom aesthetics such as improving lighting, upgrading old furniture, and efficient ventilation should be prioritised. This study contributes practical recommendations for creating supportive and effective learning spaces.

Findings confirm that classroom aesthetics significantly influence well-being and academic performance. Differences across faculties suggest inequities in facilities. Improvements in ventilation, ergonomic furniture, and sustainable design could enhance overall learning experiences.

In summary, these data analyses show that physical environments influence students' psychological well-being, motivation, and student engagement. The data suggests that most students in each of the four faculties acknowledged a clean, comfortable, and visually pleasant learning environment that can give benefits to their ability to concentrate, reduce stress, and improve motivation. For students, the most notable factors that had a positive effect on their experience were good lighting, comfortable furniture, adequate air circulation, and the general tidiness and organisation of classroom space. Although most students were positive, a significant minority noted issues such as, furniture being out of date, not well kept, or lacking aesthetically pleasing appeal. Overall, the data suggests that improving the classroom environment both aesthetically and physically will have a direct effect on learning outcomes and students' well-being at UiTM Shah Alam.

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REFERENCES

Al-Sindi, T., Putra, H. D., & Ghozi, S. (2023). Integrating technology into classroom training: New approaches in educational pedagogy. *Journal of Training, Education, Science and Technology*, 1–6. https://doi.org/10.51629/jtest.v1i1.168

Barrett, P., Zhang, Y., Moffat, J., & Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. *Building and Environment, 59*, 678–689. https://doi.org/10.1016/j.buildenv.2012.09.016

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brink, H. W., Lechner, S. C. M., Loomans, M. G. L. C., Mobach, M. P., & Kort, H. S. M. (2024). Understanding how indoor environmental classroom conditions influence academic performance in higher education. *Facilities, 42*(3/4), 185–200. https://doi.org/10.1108/F-12-2022-0164

Castilla, N., Llinares, C., Bravo, J. M., & Blanca, V. (2017). Subjective assessment of university classroom environment. *Building and Environment, 122*, 72–81. https://doi.org/10.1016/j.buildenv.2017.06.004

Cheryan, S., Ziegler, S. A., Plaut, V. C., & Meltzoff, A. N. (2014). Designing classrooms to maximize student achievement. *Policy Insights from the Behavioral and Brain Sciences, 1*(1), 4–12. https://doi.org/10.1177/2372732214548677

Fardlillah, Q., & Suryono, Y. (2019). Physical environment classroom: Principles and design elements of classroom in early childhood education. *Proceedings of the International Conference on Special and Inclusive Education (ICSIE 2018)*, Yogyakarta, Indonesia. https://doi.org/10.2991/icsie-18.2019.23

Guest, G., Bunce, A., & Johnson, L. (2006). How many interviews are enough? An experiment with data saturation and variability. *Field Methods, 18*(1), 59–82. https://doi.org/10.1177/1525822X05279903

Hamilton, B. (with International Society for Technology in Education). (2015). *Integrating technology in the classroom: Tools to meet the needs of every student* (1st ed.). International Society for Technology in Education.

Jamieson, P., Fisher, K., Gilding, T., Taylor, P., & Trevitt, A. C. F. (2000). Place and space in the design of new learning environments. *Higher Education Research & Development, 19*(2), 221–236. https://doi.org/10.1080/072943600445664

Kepez, O., & Üst, S. (2024). Furniture configurations in an active learning classroom make further differences in student outcomes. *Archnet-IJAR: International Journal of Architectural Research, 18*(1), 121–141. https://doi.org/10.1108/ARCH-06-2022-0132

Leong, L. C., Hassan, N., Md. Isa, F., & Ab Jalil, H. (2018). Mobile X-space design, teaching strategies and undergraduate students' collaborative learning behaviour: A case study in Taylor's University, Malaysia. *Malaysian Journal of Learning and Instruction, 15*(2), 175–205. https://doi.org/10.32890/mjli2018.15.2.7

Llinares, C., Higuera-Trujillo, J. L., & Serra, J. (2021). Cold and warm coloured classrooms: Effects on students' attention and memory measured through psychological and neurophysiological responses. *Building and Environment, 196*, 107726. https://doi.org/10.1016/j.buildenv.2021.107726

Liu, Q., Huang, Z., Li, Z., Pointer, M. R., Zhang, G., Liu, Z., Gong, H., & Hou, Z. (2020). A field study of the impact of indoor lighting on visual perception and cognitive performance in classroom. *Applied Sciences, 10*(21), 7436. https://doi.org/10.3390/app10217436

M. K., A. (2022). Investigation on the sustainability of an innovative physical learning environment in Putra Future Classroom, Universiti Putra Malaysia. *Alam Cipta: International Journal of Sustainable Tropical Design & Practice, 15*(1), 24–32. https://doi.org/10.47836/AC.15.1.Chapter04ac.id

Othman, A. R., Ruslan, N. A., & Zahrah, W. (2022). Impact of physical learning environment towards students' performance at Taylor's University. *Environment-Behaviour Proceedings Journal, 7*(19), 101–110. https://doi.org/10.21834/ebpj.v7i19.3099

Peng, L., Deng, Y., & Jin, S. (2022). The evaluation of active learning classrooms: Impact of spatial factors on students' learning experience and learning engagement. *Sustainability, 14*(8), 4839. https://doi.org/10.3390/su14084839

Shaheen, L. A., & Ibrahim, B. S. (2024). Developing quality learning environments: A comparison study. *International Journal of Engineering Research and Applications, 14*(8), 12–19. https://doi.org/10.9790/9622-14081219

Strelan, P., Osborn, A., & Palmer, E. (2020). The flipped classroom: A meta-analysis of effects on student performance across disciplines and education levels. *Educational Research Review, 30*, 100314. https://doi.org/10.1016/j.edurev.2020.100314

Tanner, C. K. (2013). A case for schoolhouse aesthetics. *Educational Planning, 21*, 32–38. http://www.efc.gwu.edu/wp-content/uploads/2014/05/a_case_for_schoolhouse_aesthetics_tanner.pdf

Wang, M. T., & Degol, J. L. (2016). School climate: A review of the construct, measurement, and impact on student outcomes. *Educational Psychology Review, 28*(2), 315–352. https://doi.org/10.1007/s10648-015-9319-1

Yasin, F. T., & Razie, S. (2020). The role of perception of classroom structure on students' mental health. *Educational Research and Reviews, 15*(10), 639–644. https://doi.org/10.5897/ERR2019.3793

Zhang, Q., Cheung, E. S. T., & Cheung, C. S. T. (2021). The impact of flipped classroom on college students' academic performance: A meta-analysis based on 20 experimental studies. *Science Insights Education Frontiers, 8*(2), 1059–1080. https://doi.org/10.15354/sief.21.re019

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ETHNOGRAPHIC INSIGHTS INTO TERRACE HOUSE RETROFIT PRACTICES: A CASE IN PETALING JAYA, MALAYSIA

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ABSTRACT

Existing residential buildings contribute to significant energy demand and greenhouse gas (GHG) emissions. Malaysia – dominant with the landed residential building were constructed under past building codes with limited attention to energy efficiency. Retrofitting this stock represents both a pressing challenge and a golden opportunity to promote national decarbonization efforts. However, retrofitting practices are often ad hoc and complicated, influenced by homeowners' physical extensions rather than environmental considerations. This research addresses the gap by exploring the retrofit practices of Malaysian terrace houses through an ethnographic, visual case observation approach. Fieldwork was conducted across four sites in Petaling Jaya, where alterations were systematically documented using field notes, sketches, photographs and video taking. These observations were supported by documentary analysis of existing retrofit policies and guidelines. Cases were classified according to scales of intervention – minor, intermediate, major and complete, reflecting both local authority definitions and practices observed in situ. The study uncovered widespread informal interventions, which were primarily motivated by functionality, privacy and cultural preferences rather than energy performance. The findings underscore the limitations of current retrofit policies, which remain advisory rather than mandatory, and highlight the need for frameworks that account for socio-cultural practices and homeowner decision-making. By adopting an ethnographic lens, this study demonstrates how retrofit strategies can be made more socially grounded, practical, and widely adopted, ultimately bridging global low-carbon ambitions with local housing realities.

Keywords: Case Observation, Ethnography, Retrofit, Terrace Intervention, Sustainable Housing.

1.0 INTRODUCTION

The urgency of addressing climate change has placed the built environment at the centre of global decarbonization efforts. Buildings account for nearly 40% of global energy consumption and greenhouse gas (GHG) emissions, prompting international frameworks such as the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) to call for transformative action in housing and urban development (United Nations Environment Programme, 2023). For developing nations, however, this transition comes with unique challenges, as the push for decarbonization must be balanced against the realities of rapid urbanization and economic constraints. As Falcone (2023) notes, these regions face a complex interplay of demographic growth and infrastructure gaps that make universal access to sustainable energy a significant capital impediment. Furthermore, the decarbonization rush can inadvertently divert social justice if the speed of implementation ignores

the localized socio-cultural factors that drive how residents modify their homes (Cravioto & Mosqueda, 2021; Hoffmann & Hoffmann, 2025). Residential buildings, which have been integral to human settlements since the earliest communities, thus exert far-reaching social, cultural, environmental, and typological impacts on urban development that require a more nuanced, bottom-up approach to policy than currently exists. It is widely recognized that emissions from this sector must be urgently reduced if climate goals are to be achieved. While promoting green buildings is an important step, Amirkhani et al. (2021) emphasize that retrofitting the vast stock of existing residential buildings holds significantly greater potential for advancing low-carbon transitions. Their comprehensive mapping of research trends confirms that the sheer volume and longevity of the existing built environment make it the most critical level for achieving large-scale environmental impact.

Malaysia, as a developing nation, has pledged commitments under the Paris Agreement and the SDGs. Rapid urbanization has contributed to a growing residential stock, particularly terrace houses and stratified apartments. Among these, terrace houses dominate both in volume and transaction value, representing the largest segment of the nation's housing market (National Property Information Centre (NAPIC), 2024). Yet, most of these homes were constructed under outdated building codes with limited attention to energy efficiency, making them carbon-intensive. Retrofitting this existing stock therefore presents both a pressing challenge and a significant opportunity to advance national decarbonization goals. National policies such as the National Policy on Climate Change (2009), the Green Technology Master Plan (2017–2030), and the Twelfth Malaysia Plan (2021–2025) emphasize sustainable development and green growth. Frameworks such as the Low Carbon Cities Framework (LCCF) and the Green Building Index (GBI) provide guidance to the local authorities and consultants, but their adoption has been limited. Much of the focus remains on new developments, while the extensive stock of terrace houses, Malaysia's most common urban housing typology continues to operate with minimal energy efficiency measures. Moreover, existing green guidelines are advisory rather than mandatory, particularly for landed homes, leaving sustainable retrofit decisions entirely voluntary. This creates both a challenge and an untapped opportunity to enhance terrace house performance through retrofitting, a pathway that could substantially contribute to Malaysia's decarbonization ambitions.

Despite this potential, retrofitting practices in Malaysia remain largely ad hoc, shaped by homeowners' immediate functional needs rather than environmental considerations. Extensions, space infills, and other modifications to a building envelope are common but rarely incorporate energy performance or carbon reduction goals. These interventions typically reflect individual priorities for comfort or additional space, with sustainability depending solely on the homeowner's awareness, knowledge, and sense of responsibility. As Pelenur & Cruickshank (2014) demonstrate, the 'Energy Efficiency Gap' persists because homeowners are primarily motivated by functional benefits like thermal comfort and lifestyle improvements rather than carbon reduction, often treating energy performance as a secondary outcome of necessary home modifications. Moreover, any physical alteration requires local authority approval, yet existing regulations often lack the depth needed to meaningfully guide sustainable retrofits. While guidelines for sustainable material selection exist, regulation and enforcement remain weak in many contexts (Cravioto & Mosqueda, 2021). As a result, retrofit activity is usually driven by functionality rather than carbon reduction, leaving sustainability goals as secondary, if considered at all. These informal practices reveal a crucial gap: current policies and guidelines fail to adequately account for the socio-cultural and behavioural factors that shape how households adapt and modify their homes. Consequently, national low-carbon strategies risk becoming misaligned with the lived realities. To bridge this gap, the movement should begin by observing existing modification trends, as these informal practices provide the 'situated knowledge' necessary for larger shifts. As Furman & Hadjri (2025) contend, utilizing such resident expertise can balance building and social needs, ensuring that low-carbon solutions are not only accepted but are effectively utilized by the people they are meant to serve.

Despite growing attention to building energy retrofits globally, much of the existing literature focuses on technological solutions, energy modelling, and policy frameworks. Limited attention has been given to how retrofit practices are actually enacted by homeowners in everyday contexts, particularly in developing countries where informal housing modifications are common. In Malaysia, terrace houses dominate the residential landscape, yet empirical studies documenting how homeowners modify these houses in reality remain scarce. This creates an important gap between formal retrofit strategies and the lived practices of households. Therefore, this study aims to explore terrace house retrofit practices through an ethnographic observation approach, focusing on how homeowners modify spatial elements and building envelopes in real contexts. By documenting these interventions, the study contributes a socio-cultural perspective to retrofit discourse, complementing existing technical and policy-oriented research.

2.0 LITERATURE REVIEW

2.1 Retrofitting and Scale of Interventions

A variety of terms are used to describe actions taken to improve building conditions, each with different implications for scope and scale. Among these, the term *retrofit* has gained increasing prominence in the built environment, where it refers to technical processes aimed at improving the performance of existing structures. Ma'bdeh et al. (2023) define retrofit as the modification of equipment, systems, or buildings to upgrade operations, enhance efficiency, improve energy performance, or achieve all of these outcomes simultaneously. More generally, retrofit can also be described as the act of providing a component or feature that was not originally included when the product was created. Applied to buildings, this implies adding or upgrading elements that were absent from the original construction. Broadly, retrofit research has often focused on energy-related aspects, reflecting global concerns about reducing environmental impacts. In practice, retrofit and refurbishment are closely related, since both involve replacing or upgrading building components. However, *refurbishment* is usually considered a more general term that refers to the renewal of older building conditions, while *retrofit* is more specifically associated with improving energy performance. In fact, the term '*retrofit*' has largely replaced *refurbishment* in many contexts where the emphasis is on enhancing the efficiency of existing buildings.

Awareness of retrofit benefits, national impacts, and the availability of retrofit schemes often depends on individual cases, including the feasibility of the retrofit and whether the intervention is shallow or deep. Basic retrofits are typically defined as alterations that enhance the energy efficiency of a building system or reduce overall consumption (Alabid et al., 2022). For example, installing wall insulation may be highly effective in cases where the building envelope accounts for significant heat loss (Regnier et al., 2018). Deep retrofits, on the other hand, take a more holistic approach by integrating multiple energy improvements. These may include reducing envelope heat losses, upgrading system efficiency, and achieving significant energy savings (Alabid et al., 2022). When the goal is to reach net-zero annual energy consumption, deep interventions are essential. Such efforts often combine extensive fabric retrofits with renewable energy installations and the upgrading of building services using low-carbon technologies. Galvin (2023) suggests prioritising retrofits for residential buildings based on their readiness and structural conditions – starting with those due for cyclical maintenance and presenting no major structural difficulties, followed by those not currently requiring major repairs, and lastly, those with significant structural challenges.

In Malaysia, the scale of residential retrofits is generally divided into four categories: Minor, Intermediate, Major, and Complete Intervention—as outlined by the Petaling Jaya City Council (PJCC) and illustrated in **Fig. 1**. These categories largely align with common practices, except for the *Complete* category, which involves more than 50% of retrofit work and may include partial demolition. This level of intervention is comparable to what the literature refers to as a deep retrofit. From the intermediate category onwards, interventions often involve the removal of existing components such as walls, windows, or roofs.

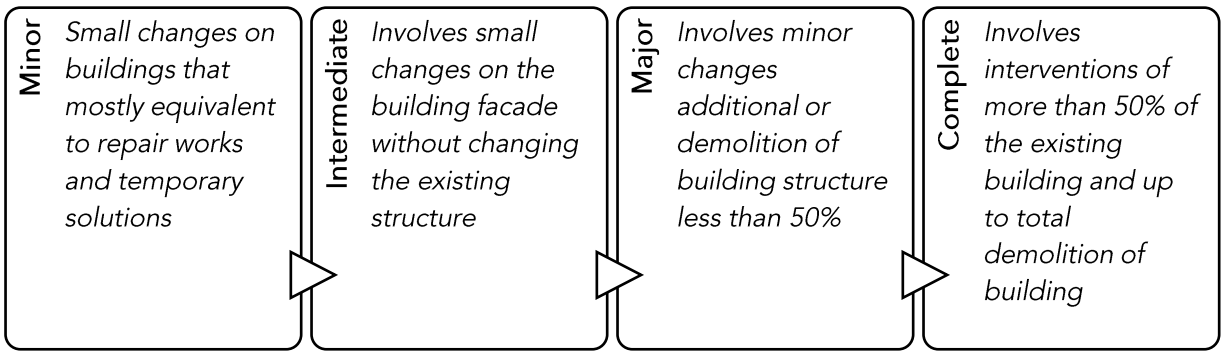


Fig. 1: Levels of interventions

As a developing nation committed to achieving net-zero by 2050, Malaysia faces the dual challenge of addressing the inefficiencies of its vast housing stock particularly terrace houses, which dominate the landed residential (National Property Information Centre (NAPIC), 2024), while ensuring that retrofit strategies remain practical, affordable, and widely adopted. Yet retrofitting is complicated not only by costs and regulatory constraints but also by widespread homeowner-led informal interventions (Charles, 2025). Many residents modify their homes

to meet immediate functional or cultural needs, such as extending kitchens, enclosing balconies, or covering courtyards, often without considering energy performance. This demonstrates that retrofits cannot succeed as purely technical solutions; they must be grounded in the lived realities of households, accounting for behavioural, cultural, and socio-economic dynamics.

Although national sustainability frameworks such as the Low Carbon Cities Framework and the Green Building Index exist, their implementation has primarily focused on new developments. Retrofit policies for existing landed houses remain largely advisory. Consequently, many terrace house modifications occur independently of sustainability considerations. Understanding these informal practices is essential for designing retrofit strategies that align with local behavioural patterns. Ethnographic observation provides a valuable methodological approach for capturing these everyday housing practices and revealing the social dynamics that shape retrofit behaviour.

Overcoming these challenges calls for a more integrated approach to retrofit governance. Recent studies highlight that retrofit should not be understood solely as a technical upgrade but as a socio-technical process shaped by everyday practices, governance systems, and household decision-making (Medrano-Gomez et al., 2025). From this perspective, building interventions emerge from interactions between physical structures, cultural practices, and institutional frameworks. Ethnographic observation provides a valuable methodological lens to capture these dynamics, enabling researchers to understand retrofit practices not only as engineering modifications but also as socially embedded behaviours within specific housing contexts. For Malaysia, this means moving beyond prescriptive technical standards toward frameworks that acknowledge informal interventions as part of the housing landscape, while actively involving homeowners in co-developing retrofit strategies. Embedding socio-cultural insights, particularly those revealed through ethnographic studies, into both policy and practice ensures that decarbonisation measures are not only technically sound but also socially relevant and economically viable. By bridging global low-carbon ambitions with the everyday realities of Malaysian households, retrofitting can serve as a transformative pathway for sustainable and equitable urban development.

2.2 Retrofit in Residential Building Context

Globally, residential buildings are among the largest contributors to energy demand and greenhouse gas (GHG) emissions (United Nations Environment Programme, 2025). These emissions are not only linked to their operational energy use but also to the embodied energy consumed during the extraction, procurement, and transportation of raw materials, as well as the construction process itself. Scaling up energy retrofits in existing housing stock is therefore critical to reducing carbon emissions and meeting climate targets. Within this context, research on building energy retrofits particularly in the residential sector, which plays a pivotal role in achieving national goals has largely focused on two key areas: (1) regulatory and policymaking approaches, which emphasize the importance of governance in supporting residential retrofit actions, and (2) the challenge of complex retrofit data, which highlights the need for more systematic and optimal approaches to identifying effective retrofit solutions.

Galvin (2023) argues that as energy efficiency standards become increasingly stringent, the marginal costs of both efficiency measures and CO_2 abatement rise. At the same time, however, energy consumption decreases, thereby reducing emissions. He contends that instead of pursuing ever-higher minimum standards for individual buildings, policymakers should prioritize retrofitting a greater number of houses to “modestly high” standards—just below the point where the marginal cost curve rises steeply. This approach, he argues, ensures the greatest overall reduction in CO_2 emissions within the financial resources available. Such a perspective reinforces the government’s responsibility to develop comprehensive retrofit policies that encourage widespread uptake, particularly among older residential buildings. As Tomrukcu & Ashrafian (2024) caution, the effectiveness of current envelope design standards is uncertain when faced with future climate conditions, as existing regulations lack dynamic provisions for adapting to evolving climate effects.

Beyond policy, the retrofit sector must also advance by generating more holistic and systemic retrofit information. Ali et al. (2020) stress that data-driven approaches can enhance the quality of existing building data, enabling the extraction of key features from complex datasets. They argue that scalable retrofit strategies for sustainable urban development will rely heavily on comprehensive building stock databases, which can support benchmarking and performance analysis for retrofit planning. Wise et al. (2025) add that retrofit discussions should move beyond narrow techno-economic considerations to include co-benefits such as

improved comfort, well-being, and social value. Raising homeowners' "retrofit literacy" and creating opportunities for households to directly experience retrofit outcomes are equally vital to increasing adoption. Yet, as Ali et al. (2020) point out, the creation of robust building stock databases is inherently complex and time-intensive, requiring both geometric and non-geometric data. Current data availability remains fragmented, inconsistent, and highly variable, which complicates the development of scalable retrofit solutions. Charles (2025) similarly emphasizes that the hindrance to residential retrofit extend beyond technical issues, being strongly influenced by financial, governance, and socio-cultural factors. In particular, fragmented ownership and inconsistent government funding significantly weaken the capacity to scale up retrofit initiatives.

In summary, while policy frameworks and technological solutions are crucial drivers of retrofit, their effectiveness ultimately depends on a robust understanding of the existing housing stock. Without reliable, comprehensive, and context-specific data, large-scale retrofit initiatives risk being misaligned with real conditions, resulting in limited adoption or underperformance. Residential buildings particularly older housing stock are diverse in form, function, and socio-cultural use, making a "one-size-fits-all" approach impractical. Before scaling up retrofitting efforts or developing national databases, there is a pressing need to systematically explore the complex realities of existing residential buildings. This includes not only technical and geometric characteristics but also the lived practices, cultural values, and behavioral patterns that shape household decisions. A nuanced, data-informed foundation is therefore essential to ensure that retrofit strategies are both technically effective and socially grounded, laying the groundwork for meaningful progress toward low-carbon housing.

3.0 METHODOLOGY

The study employed a qualitative case observation framework centered on existing terrace housing in Petaling Jaya (PJ), Malaysia. PJ was selected as a representative case study due to its historical significance as one of the country's first planned residential townships in Malaysia (Ju et al., 2011). Spanning housing generations from the 1960s to the 1990s, PJ provides a longitudinal cross-section of the nation's built environment. Following Yin's (2018) criteria for representative case studies, this selection allows for a robust observation of how retrofit practices and informal modifications have evolved across different housing generations. To ensure data consistency, the study utilized purposive sampling to capture diverse socio-economic contexts and intervention types. The focus was restricted to intermediate lots to maintain data consistency. Intermediate units represent the most standardized urban housing typology and present the most significant passive design challenges due to restricted front/rear façade and shared party walls.

Data collection was conducted through an ethnographic approach to capture the lived reality of retrofit practices, which often diverge from official discourse (Fischer, 2023). This method is particularly suited to navigating the complexities of energy retrofits, including ambiguous building codes and multi-stakeholder engagement (Murto et al., 2019). The study adopts a series of non-participant observations, recording physical extensions and spatial modifications through systematic field notes, architectural sketches, and visual documentation (photographs and video). These observations were guided by the standardized parameters outlined in **Table 1** to minimize bias and ensure scientific comparability across different housing generations.

Table 1: Parameters Setup for Observational Study

Parameters	Details
Duration of Observation	Short-term monitoring (several days up to a week) of the trend of retrospective and prospective renovations
Longitudinal Analysis	Define house clusters by development age to see if older buildings exhibit higher retrofit accumulation
Timing of Observation	Standardized time interval (5 to 10 minutes each house), taking up to a week to complete an observation of each specified area to capture the rhythm of the neighborhood
Frequency	Categorize houses by adoption rate of façade modifications, levels of modifications (Minor, Intermediate, Major and Complete) for a frequency count, and most frequently modified building components
Consistency	Maintain a specific type of terrace house (intermediate lot) to observe consistent and predictable modification patterns

The analysis followed a multi-stage process shown in **Fig. 2** below, beginning with a scoping phase to define the research boundaries and refine the inquiry within the selected neighborhoods. This initial stage established the parameters for identifying modified building components, assessing systematic intervention strategies, and mapping geometric patterns specific to intermediate terrace houses in PJ. By focusing on this specific typology across four distinct sites, the research established a controlled environment to examine the prevalence and rate of retrofit activity relative to existing urban density.

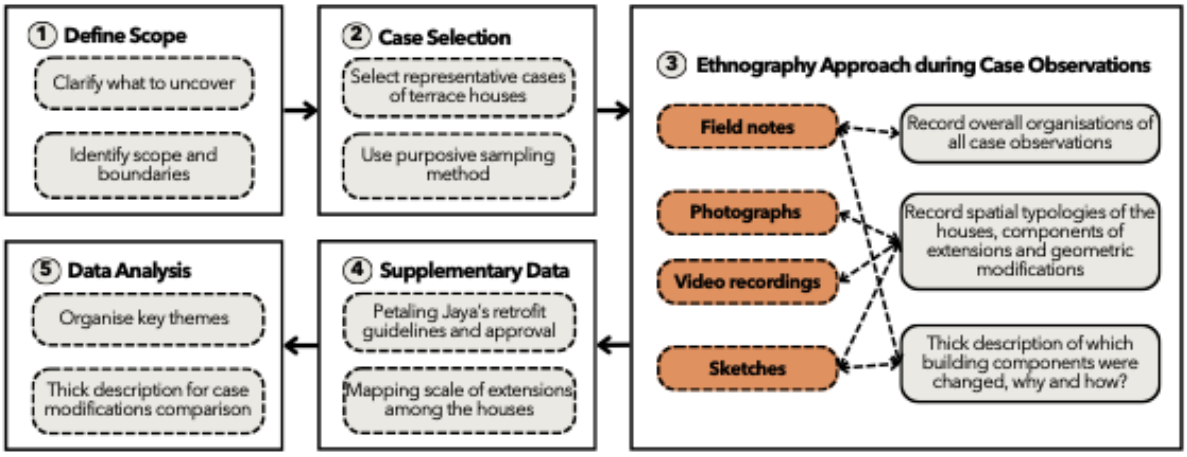


Fig. 2: Process of research methodology adopted in this paper

The empirical core of this study utilizes an ethnographic "visual" approach to examine Malaysian retrofitting practices. Site selection was guided by theoretical frameworks regarding intervention scales and a review of existing retrofit policies, allowing for the classification of cases based on the magnitude of physical change.

Table 2: Details of the observation on all cases

Case	Case A	Case B	Case C	Case D
Location	Section 17	Damansara Jaya	Kelana Jaya	Kota Damansara
Area	Section 17, PJ	SS22, SS22A	SS5	Section 6, PJU5
Built Year	1964	1975	1984	1990
Detail	Between Jalan Harapan and Jalan 17/1, PJ	Surrounded by three highways LDP (east), SPRINT (north) & NKVE (west)	Between Jalan Bahagia and Jalan Majlis, PJ	Between Persiaran Surian and Jalan Cecawi 6, PJ
Total Units	821 units	846 units	402 units	575 units
Housing Archetype Distribution				

This groundwork enabled a general understanding of the socio-technical processes shaping the built environment. To interpret these complex modifications, grounded theory principles were applied to sharpen theoretical sensitivity, facilitating the conceptualization of emerging categories and codes (Fitzgerald & Mills,

2022). Systematic data documentation played a central role in ensuring reflexivity and analytical rigor. The researcher maintained a comprehensive field diary, integrating written observations with architectural plans, sketches, and high-resolution photographs to create a robust audit trail. As detailed in **Table 2**, these records captured the total units observed and mapped various façade configurations across the study area. This material formed the basis for a frequency analysis, where mid-terrace units were manually identified and classified according to their degree of intervention, providing a clear taxonomy of extension patterns in the Malaysian context.

Supplementary data collection involved an extensive archival review of planning approvals, housing development guidelines and renovation drawings sourced from the local authorities. To ensure a systematic analysis, the study utilized a mapping intervention framework to categorize the subject houses into four distinct degrees of extension. Recognizing the researcher's architectural background and sustainability focused, a reflexive approach was adopted to navigate the dual role of observer and interpreter. Data were synthesized through organizational ethnography, categorizing field notes and visual data into themes. As summarized in **Fig. 3**, this dataset captures the original built forms and spatial typologies of the terrace houses. Finally, cross-case narratives were developed to identify commonalities and interventions across the samples.

a) Some of field notes taken during observations

b) Photographs captured during case observations

c) Video Recordings of the houses for cross-checking

d) Sketches produced of the intermediate terrace houses

Fig. 3: Summary of ethnography approach conducted in this research

4.0 RESULTS

The data for qualitative case observations are organized according to several key themes which identified through thematic analysis including: (1) built form elements and characteristics, (2) patterns of terrace house intervention, and (3) building envelope effects. The ethnographic approach reveals the scale of extensions resulted from ad hoc modifications carried out by the homeowners in PJ and how the terrace houses' spatial geometric such as balconies, courtyards and backyards were modified and impacted the overall building envelope. The description of the particulars is streamlined, compared across cases and represented through sketch and photograph illustrations for in-depth ethnographic insights of terrace house retrofit analysis in PJ.

4.1 Built Form Elements and Characteristics

The built form elements and characteristics of two-story terrace houses have not change much since the past years until now, possible variations can only be noted at the distinct building façade of the residential buildings due to derived developmental form by different developers. Despite that, the essence and vibes of the terrace house can be said similar only differ in sizes and openings of the land provided, the length of the house, and different provision of courtyard or light wells. Referring to the observations conducted among all 2644 number of terrace houses, the design typologies exuded almost similar characteristics. There are few design attributes that can be observed within the context of terrace house that are; 1) narrow and elongated with focus on two story types; 2) clearly addresses fronts and backs of the house with fronts addressing public streets, spaces or accessways, and backs are contained to the usual rear, usually back-to-back of the houses connected by back-lane in a parameter block arrangement; 3) connected by two adjacent shared party walls, except for end-lot and corner-lot units; 4) car parking is included for each units of the house; and 5) normally include small courtyard, terrace or garden at the front or back of the house.

Through the observation of the terrace house development in Petaling Jaya, there are some advantages emphasized from the design that can be highlighted in this study, despite that, it is also observed that there are some drawbacks to all the benefits associated with the terrace houses design including:

1) some cases are facing the issues on the lack of natural ventilation due to poor adoption of strategies among existing fenestration design
2) due to its narrow and elongated form, lack of daylight may result in dark interior which might hinder residents' productiveness and excessive use of artificial lightings but, if retrofitting is deployed accordingly, it will provide good cross ventilation due to its dual aspect form
3) any underrated upgrade works may fail to address the core concern of building occupants while exorbitant extension works may lack the bearing on environmental consideration
4) for old terrace houses, retrofitting without green consideration might lead to excessive energy consumption
5) extra piece of land is ample for house owners to make use of their space, by turning their terrace into small garden; and it is thermally efficient due to a reduced external wall area exposed to direct sunlight.

Therefore, the focus orients towards retrofit measures among intermediate unit houses as they have limited means of retrofitting due to their characteristics. Some of the outcome from direct observations are outlined in **Fig. 4**.

a) narrow and elongated

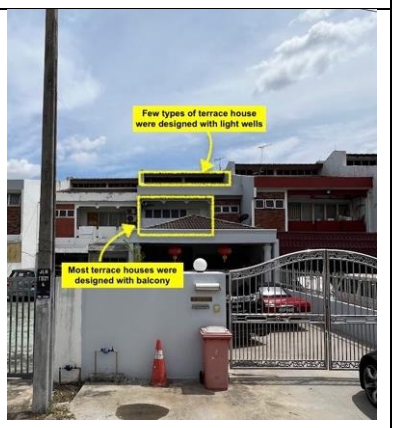
b) connected by backlane

c) connected by two adjacent party walls

d) front of the terrace houses addressing public street or accessways

e) designated car porch for each house

f) area for small garden or private terrace



g) significant building facade components

Fig. 4: Direct observations of built form elements and characteristics of the intermediate terrace houses (Source: Author)

With thorough observations on the cases, in classifying the rate of retrofitting and defining the interventions, the design attributes and characteristics of the terrace houses were carefully captured and documented. Then, the key building components involved in the residential retrofitting context were determined. It includes the understanding of the common layout of the existing houses and to which extent the retrofit works were carried out. For the two-storey terrace houses, the common spaces that can be evaluated inside the building are illustrated in **Fig. 5** and described in **Table 3**. This stage of investigation employed socio-technical perspective to assess the retrofit performance of terrace houses. More specifically, the task evaluated how various residential archetypes affected the application of green retrofit strategies through typological research.

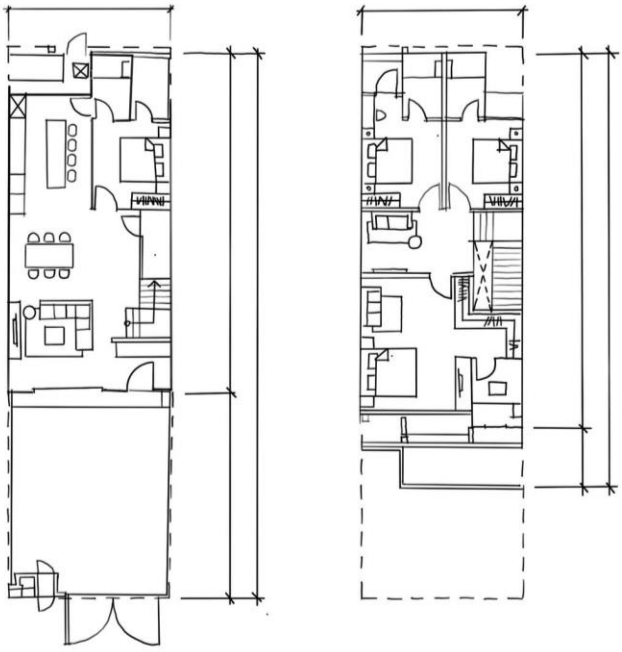


Fig. 5: The common layout for intermediate terrace house in Malaysia
(Source: Author)

Table 3: Common spatial layout arrangements in Intermediate terrace houses

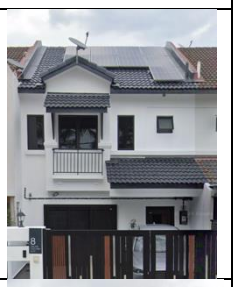
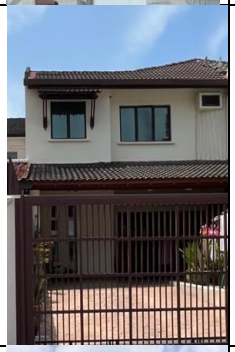
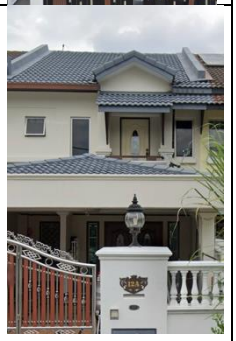
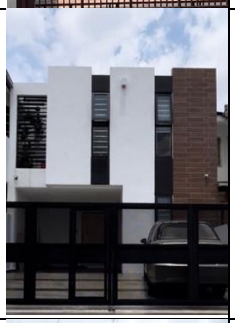
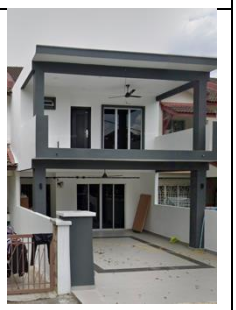
Level	Common Spaces	Common Building Components
Ground Floor	1) Living Area, 2) Dining Area, 3) Kitchen, 4) Guest Room 5) Bathroom 1 6) Backyard, 7) Car Porch	1) Wall 2) Windows 3) Door 4) Stairs 5) Ground Floor Slab 6) Porch 7) Backyard
First Floor	1) Master Bedroom 2) Master Bathroom 3) Family Area 4) Bedroom 2 5) Bedroom 3 6) Bathroom 2 7) Balcony	1) Wall 2) Windows 3) First Floor Slab 4) Roof 5) Balcony

For the past few decades, the layout has not changed much, the common width of the house normally starts from 20 feet with a wider design can go up to 24 feet with depth of minimum about 75 feet. Though the layout of interior spaces is predetermined by the residential housing developer, the common spaces provided in each terrace house remain the same with very few minor differences in term of arrangement. While the basic layout and spatial organization of terrace houses have remained consistent over the decades, direct observations in PJ reveal diverse typologies and façade variations that reflect distinctive design patterns and interventions. There is tremendous design of two-story terrace houses identified within the four locations, accumulating to 30 designations of patterns making up for different façade illustration.

4.2 Patterns of Intermediate Terrace House Interventions

The details of the retrofit levels examined in this study are summarized in **Table 4**, which outlines behavioural interventions across four categories: minor, intermediate, major, and complete. Retrofit activities were generally initiated in response to household needs, such as extending walls by enlarging balconies, removing courtyards, replacing glazing systems, or transforming backyard areas into usable kitchen spaces. Minor retrofits typically involve repair and maintenance works. Under Petaling Jaya City Council (PJ) guidelines, this category also includes the installation of solar panels without altering the roof structure, as demonstrated in Case D – Minor. Intermediate retrofits involve wall extensions that do not affect the house's original structural framework. Major retrofits, by contrast, encompass modifications that require structural changes. Finally, complete retrofits are the most extensive, requiring a building dilapidation report and involving the demolition of more than 50% of the existing structure.

Table 4: Observed cases under different retrofit levels

Intervention	Case A	Case B	Case C	Case D
Minor				
Intermediate				
Major				
Complete				

The observation reveals an exceptionally high intervention rate. Out of 2644 surveyed houses, 2403 (over 90%) have undergone visible interventions, particularly noticeable on the building façade as data presented in **Table 5**. These modifications, driven by individual homeowners, result in significant variation in design and contribute

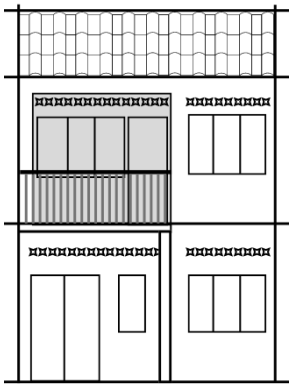
to the evolving visual characteristics of the built environment. It can be concluded that the rate of interventions among terrace houses in PJ is very densely acclimatised.

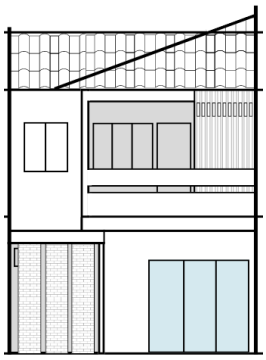
Table 5: Rate of retrofitting according to levels of interventions

Intervention Level	Case A	Case B	Case C	Case D	Overall Statistics
Total Unit	821	846	402	575	**2644 (100%)**
Minor	324	268	110	99	**801 (30.3%)**
Intermediate	274	439	174	148	**1,035 (39.1%)**
Major	127	57	45	110	**339 (12.8%)**
Complete	39	37	27	125	**228 (8.6%)**

Most retrofit works range from minor repairs to intermediate-level upgrades, which are generally insufficient for achieving significant energy savings. The high rate indicates that minor and intermediate intervention is becoming a must-do-task among the homeowners, might be due to change of owners—from older generation to the younger ones—has instigated intervention, condition of the house is getting worse, building materials deteriorating and the need to retrofit the old building system, and the demand to suit a growing family. Carrying out intermediate intervention requires the building approval from the local authority, specifically through the building standard plan, developed by each local authority, which means that all small extensions under minor and intermediate intervention must undergone the approval process and obtain the permissible permit. **Table 6** presents the summary of the intervention patterns of terrace houses for each area.

Table 6: Summary of retrofitting rate according to levels of interventions

<table>
<tr><th colspan="3">Case Description</th></tr>
<tr><th colspan="3">Case A</th></tr>
<tr><td colspan="3">Has the largest area that covers 321.23 acres. It consists of 821 units of two-story terrace houses with 13 different types of façade configurations</td></tr>
<tr><th>Intervention</th><th>Analysis</th><th>Images</th></tr>
<tr><td>The intervention rate for this case is:
Original: 44 cases (5.4%)
Minor: 324 cases (39.5%)
Intermediate: 274 cases (33.4%)
Major: 127 cases (15.5%)
Complete: 39 cases (4.8%)</td><td>Almost 40% of houses have carried out minor retrofit, followed by 33% for intermediate. This involves repair works and replacement of building materials without changing the structural elements of the house</td><td>  </td></tr>
</table>

<table>
<tr><th colspan="3">Case B</th></tr>
<tr><td colspan="3">It covers 294.05 acres, with mostly consist of two-story terrace houses. There are 5 types of 846 units with 4 of them were designed with balcony.</td></tr>
<tr><th>Intervention</th><th>Analysis</th><th>Images</th></tr>
<tr><td>The intervention rate for this case is:
Original: 45 cases (5.3%)
Minor: 268 cases (31.7%)
Intermediate: 439 cases (51.9%)
Major: 57 cases (6.7%)
Complete: 37 cases (4.4%)</td><td>More than half of the houses have conducted intermediate retrofit alone. This involves the extension of external wall at the balcony area</td><td>  </td></tr>
<tr><th colspan="3">Case C</th></tr>
<tr><td colspan="3">The area covers 261.93 acres that mostly consist of single-story terrace houses. There are 3 types of 402 units of two-story terrace houses: with the least number of 34 and biggest up to 233 units. All design typologies were built with balcony.</td></tr>
<tr><th>Intervention</th><th>Analysis</th><th>Images</th></tr>
<tr><td>The intervention rate for this case is:
Original: 46 cases (11.4%)
Minor: 110 cases (27.4%)
Intermediate: 174 cases (43.3%)
Major: 45 cases (11.2%)
Complete: 27 cases (6.7%)</td><td>In this case, most of the cases were observed have conducted intermediate retrofit which commonly involve the conversion of existing balcony into a usable space</td><td>  </td></tr>
<tr><th colspan="3">Case D</th></tr>
<tr><td colspan="3">The area covers 235.57 acres, with 8 types of 575 units with the least 16 units and biggest up to 108 units. Only 2 types of houses were built with balcony.</td></tr>
<tr><th>Intervention</th><th>Analysis</th><th>Images</th></tr>
<tr><td>The intervention rate for this case is:
Minor: 99 cases (20.5%)
Intermediate: 148 cases (30.7%)
Major: 110 cases (22.8%)
Complete: 125 cases (25.9%)</td><td>Minor and intermediate intervention accounted for more than half of the houses. The area oversees higher rate of major and complete intervention compared to previous cases.</td><td>  </td></tr>
</table>

4.3 Building Envelope Effects

Early results of close monitoring revealed building envelope as the key building components as they are the largest surface exposed to direct sunlight. Therefore, to attain strategic building envelope designs that are responsible in the augmentation of existing building performances, identifying each component to steer the

application of strategic green retrofit practice for each individual process of intervention is a critical task to curtail the excessive energy consumption. **Fig. 6** illustrates the building envelope components: roof, windows, wall, and balcony which is due to the party walls sandwiching the house-responsible to the heat transfer of the building.

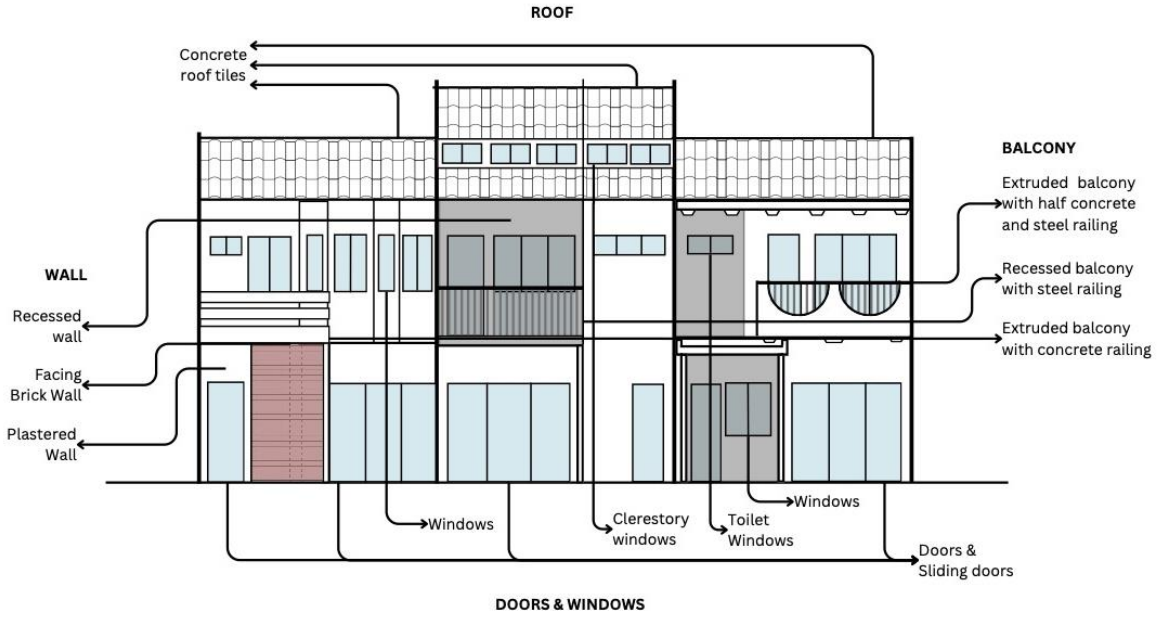


Fig. 6: Building envelope components in terrace house retrofit
(Source: Author)

For landed residential property, roof is the largest surface exposed to the sunlight as it serves as a critical building component in retrofitting, compared to high-rise residential buildings. Due to its longitudinal deep plan, roof provides a wider setting for retrofit technologies to curtail the issue of daylight scarcity especially at the middle of terrace houses. Thorough investigations also revealed that majority of roof in residential buildings were built with lack of insulation that resulted in increased indoor temperature as there is no thermal barrier between roof and ceiling. On the similar instance, wall is another building component that is lacking insulation on both exterior and interior surface despite the approach is yet another good option for noise reduction. Majority of the houses were not designed with light wells which is contrast to the UBBL requirement 40, that necessitates each residential building to have one. Light wells deficit has induced initiatives such as jack roof installation as secondary option for increased daylighting and foster stack ventilation among certain cases following their interventions.

Fenestration refers to the openings in a building's façade that affects a building's practicality and comprised of windows, doors and skylights. These elements are concerned with buildings' aesthetics as it made up the entire building façade, therefore the choice of material size, shape, operation type, colour, finish, glazing system, security and locks for windows, doors and skylights are detail considerations for the selection. Additionally, balcony, a geometric design that is made up of small built-up space, plays a part in reducing the heat gain of the interior spaces. However, starting in the 1990s, Case D exhibits very minimal practice of balcony. It is understandable to say that its practicality has slowly diminished with the feasible use of air-conditioning, inefficient use of the area and the safety concern of the building owners. Thus, it is becoming less practical to fully utilize the space and homeowners ended up opting for full extension of the balcony into enclosed space. Hence, balcony has been highlighted as one of the key building components in terrace house intervention as older terrace houses were built with this feature. Following the high rate of intervention among intermediate level, **Table 7** summarizes the detail modification analysis of the four main building components involved that are walls, windows, roofs and balconies.

Table 7: Building components commonly involved in the retrofit practices

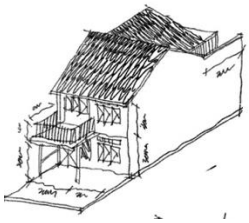
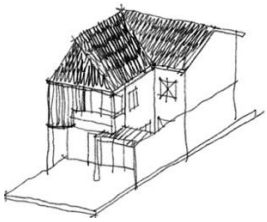
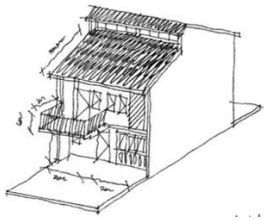
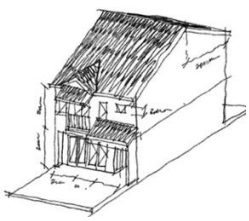
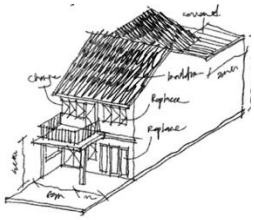
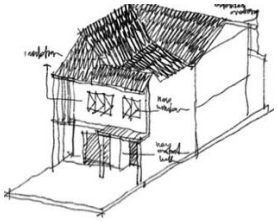
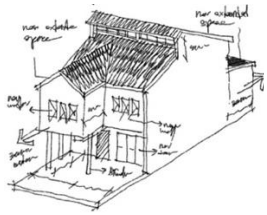
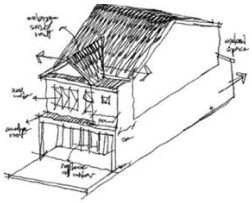
Building Components	Analysis
Wall 	Intermediate level presents the built of new wall from the extension from existing building walls. Fenestration design also affects the new wall configuration as the placement of windows and door can be totally altered. The extension also can either implicate ground floor in which living area will be affected or first floor in which bedroom and bathroom area will be affected. Since the existing wall is not built with insulation, there remains potential for more sustainable option in the new built wall.
Window 	Intermediate retrofit involves replacement of existing louvred windows to clear single glazed windows. Due to new wall existence, placement of windows and door can be totally altered. Opening size, materials and type also may differ from the existing component such as use bigger size of single glazed windows as well as tinted reflective layer on glass. In the meantime, additional shading devices for windows or doors also is being used
Roof 	The extension of wall during this level requires the extension of roof as well. This has prompted either the replacement of the entire existing concrete roof tiles to the owners' preferable roof tiles colour, or the extension of roof from the existing structure. Another possible intervention is the use of lightweight roof structure as awnings to shade the uncovered balcony.
Balcony 	Intermediate retrofit involves works to turn existing balcony into fully covered or semi-enclosed area. It shows that due to new wall existence, the balcony can be totally removed or extended into a bigger area. It can be concluded that the main motive for intervention is to cover the open balcony area as it lacks the purpose to serve building owners in the tropical climate weather. The replacement of materials is also recognized.

These building envelope components have mostly undergone changes and alterations due to retrofit intervention, hence highlighting the focus of building envelope in modifications for the minor and intermediate interventions. Within the guidelines developed by PJCC, the intermediate intervention must select and follow the ten (10) standard plans (in which 5 of them) are relevant to the mid-unit of terrace houses as follows: 1) an additional ground floor wet kitchen area (back), which requires a new roof; 2) an extension of the front wall (living area); 3) the conversion of the existing balcony into new spaces; 4) the replacement of the existing roof tiles; and 5) the installation of a new fenestration system. In this regard, the existing guideline can serve as a validation mechanism to the observational findings on building envelope components as they are consistent with the common components of modifications. It is sufficient to note that building envelope components as critical components to be regarded during terrace houses interventions.

5.0 DISCUSSIONS

This observation approach presents four case-study units representing different development timelines of terrace houses in PJ, spanning the 1960s, 1970s, 1980s, and 1990s. Despite differences in construction periods and built-up areas, the selected cases share notable design similarities. Each case represents a significant period in the development history of terrace houses and exhibits a clear tendency toward intermediate intervention. **Table 8** presents four detailed case profiles (Cases A, B, C, and D), offering an in-depth fact-to-case analysis. Understanding the existing house conditions following their characteristics, intervention patterns and issues that lead to their modifications is critical to provide in-depth insights into the current state of each case, enabling the researcher to better interpret how intervention behavioural patterns are influenced by the original design.

Table 8: Summary of four cases observation analysis

Item	Case A	Case B	Case C	Case D
Glazing Problems	The use of frosted single glazed louvred & deteriorated wooden frame	Single glazed side hung with clear glass & deteriorated wooden frame	The use of frosted single glazed louvred & deteriorated wooden frame	Single glazed side hung clear glass windows with aluminium frame
Physical Problems	Balcony can act as an extra thermal barrier, but the absence of shading devices exposed façade directly which causes overheating	Side courtyard allows daylighting to the middle area without light well however, it can be overlooked if not utilized efficiently when retrofit	Balcony and the only case with provided light wells on the roof that allows for more daylight to the family area at first floor.	AC ledge was designed & useful when the owner opted for air-conditioner. Natural ventilation is possible but limited across all spaces.
Thermal Problems	Poor insulation on existing façade and designed with ventilation blocks for natural air flow	Poor insulation on façade, there is presence of thermal bridge if efficient fenestration design is not employed	Poor insulation on roof & wall, there is light well that allows daylight & provides ventilation to middle area	Lack of insulation on roof and wall. Lack of passive strategy to allow daylight into the middle of the house
Existing Condition				
Modified Condition				
Modifications	When modified, semi-open balcony area is removed to cater for more built-up space, and the open backyard was covered with lightweight roof.	When modified, the existing courtyard area is fully covered, with extension at the back area. The existing balcony is removed, and turned into usable area	Balcony is replaced by a new space and the back kitchen area is extended. The replacement of new opening system is also possible during modifications.	When modified, the front façade area is extended. It provides extra overhang for the porch area. The entire back kitchen area is also extended

This study sets out to explore the existing state of retrofit practices in Malaysian terrace houses through an ethnographic case observation approach. The findings reveal that there are active incremental interventions happening in the Malaysian terrace houses landscape that are deliberate, primarily driven by immediate functional or socio-cultural needs rather than considerations for energy efficiency and carbon reduction. This finding reflects the view asserted by Medrano-Gomez et al. (2025) that retrofit is framed by everyday practices and household decision-making rather than a technical upgrade. Common modifications indicate the prevalence of intermediate intervention such as extending wet kitchen at the backyard, removing balconies into full usable space and enclosing courtyards, which involve extending existing walls without altering the building's primary structural system. They reflect the daily facts of retrofitting trends in dense urban neighbourhoods that significantly shape the thermal performance of the house and long-term sustainability of the housing stock.

These insights underscore a critical gap in the current retrofit discourse: while the policies and guidelines in Malaysia accentuates the low-carbon targets and technical standards, they pay limited attention to the lifestyle and practices of homeowners who are the true perpetrator of transformation at the household level. As noted by Cravioto & Mosqueda (2021), sustainable retrofit approach should be culturally compatible and environmental friendly tailored to local needs. By examining the course of interventions based on the socio-cultural needs, can the most workable green strategies suit to the context of Malaysian terrace houses can be proposed. This study offers an alternative lens through which retrofit can be understood, framing it not purely as a technical procedure, but as a socially embedded practice. Given that intermediate-level modifications have emerged as the dominant trend within the terrace housing landscape, local policies and guidelines should pivot toward green strategies tailored specifically for this level. By addressing these prevalent, incremental changes first, policymakers can establish a foundational sustainable framework before transitioning toward more intensive deep renovation strategies.

On another note, this observational study reveals the most prominent changes observed in the building façade are walls, windows, balconies, and roofs. Although roofs were the least often altered, they remain the largest contributor to thermal transfer due to their direct and prolonged exposure to sunlight. The prevalence of these physical interventions suggests that current envelope design standards may be insufficient; as Tomrukcu & Ashrafian (2024) caution, the effectiveness of existing regulations is increasingly uncertain, as they lack the dynamic provisions required to adapt to evolving climate conditions and future thermal demands. Additionally, this observation also revealed a widespread preference among homeowners for air-conditioners, a trend accelerated by the availability of increasing affordable models. This amasses use of mechanical cooling reflects households' immediate response to thermal discomfort, but also highlights a critical gap, in the absence of effective retrofit measures, homeowners default to energy-intensive solutions that directly increase carbon emissions. Furthermore, the effective implementation of high-performance ventilation system in ageing houses requires complementary measures such as enhanced building envelope airtightness to maximise its operational efficiency. As Liu et al. (2019) demonstrate, without a sufficiently airtight envelope, mechanical energy recovery systems cannot fully reach their full potential, as uncontrolled infiltration bypasses the system's ability to regulate thermal gain. This technical gap suggests that without interventions grounded in socio-cultural realities and made accessible to average homeowner, Malaysia's low-carbon housing aspirations risk being undermined. In the absence of such integrated strategies, residents are likely to resort to a growing dependence on energy-intensive air-conditioning as their primary means of managing comfort within an increasingly inefficient built environment.

In summary, the detailed investigations that were summarised in **Table 8** are pivotal attributes for the next stage of research, in which to select feasible strategies by analysing the state of before-after retrofit using a simulation stage. This research contributes to the diagnostic understanding of existing terrace house interventions, providing a necessary pre-retrofit evaluation that establishes a baseline for future sustainability measures. Beyond mere observation, this initial dataset supports the benchmarking and performance analysis critical for strategic retrofit planning, as emphasized by Ali et al. (2020). By integrating both geometric and non-geometric data, these findings serve as foundational components for a robust building stock database, facilitating more sophisticated analysis of the complex residential landscape in Malaysian. Taken together, these insights highlight the need for retrofit strategies in Malaysia to move beyond prescriptive green technical standards and embrace a more integrated context-sensitive approach to sustainable advances. By beginning with ethnographic exploration of existing interventions, policymakers and practitioners can better appreciate the motivations, constraints and cultural values that drive household decisions. In this way, the study establishes a foundation for developing a socio-culturally informed retrofit framework that aligns Malaysia's low-carbon ambitions with the practices of terrace house owners, ensuring that decarbonisation efforts are both effective and practical.

6.0 CONCLUSION

This research reveals that homeowners are already active participants in modifying their built environment; however, these behaviours are currently driven by immediate functionality rather than long-term carbon reduction. While local authority guidelines capture some of these practices, they fail to integrate the green strategies necessary to transform ad-hoc interventions into sustainable retrofits. Consequently, sustainable retrofitting remains outside the mainstream among residents, leaving a significant opportunity for large-scale carbon reduction untapped.

The ethnographic approach employed here demonstrates that interventions—whether formally approved or not—are largely voluntary and home-driven. In the absence of robust regulatory standards for existing landed houses, these informal practices often unintentionally degrade thermal performance and increase energy demand. This suggests that retrofitting is not a neutral application of technology, but a socially embedded practice situated within the lived reality of the household.

To move toward a resilient urban future, policy must shift from rigid structural oversight to a more dynamic framework that incentivizes thermal upgrades, particularly for high-impact areas like roofs within the existing pattern of incremental, functionality-driven modifications. Ultimately, recognizing these socio-cultural dynamics is essential for steering green retrofitting toward a future that is not only technically effective but also socially accepted and naturally accustomed to within the Malaysian terrace housing landscape.

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REFERENCES

Alabid, J., Bennadji, A., & Seddiki, M. (2022). A review on the energy retrofit policies and improvements of the UK existing buildings, challenges and benefits. *Renewable and Sustainable Energy Reviews*, *159*, 112161. https://doi.org/https://doi.org/10.1016/j.rser.2022.112161

Ali, U., Shamsi, M. H., Bohacek, M., Hoare, C., Purcell, K., Mangina, E., & O'Donnell, J. (2020). A data-driven approach to optimize urban scale energy retrofit decisions for residential buildings. *Applied Energy*, *267*(November 2019). https://doi.org/10.1016/j.apenergy.2020.114861

Amirkhani, M., Martek, I., Luther, M., Amirkhani, M., Martek, I., & Luther, M. B. (2021). Mapping Research Trends in Residential Construction. *Energies*, *14*(6106). https://doi.org/10.3390/ en14196106

Charles, H. (2025). Beyond the building: governance challenges in social housing retrofit. *Buildings and Cities*, *6*(1), 433–449. https://doi.org/10.5334/bc.524

Cravioto, J., & Mosqueda, A. (2021). Local Culture and Urban Retrofit : Reflections on Policy and Preferences for Wall and Roof Materials. *Frontiers in Sustainable Cities*, *3*(July), 1–16. https://doi.org/10.3389/frsc.2021.638966

Falcone, P. M. (2023). Sustainable Energy Policies in Developing Countries : A Review of Challenges and Opportunities. *Energies*, *16*(6682). https://doi.org/10.3390/ en16186682

Fischer, N. (2023). Direct Observation and Ethnography. *LIEPP METHODS BRIEF n ° 8*, *05*.

Fitzgerald, J., & Mills, J. (2022). The Importance of Ethnographic Observation in Grounded Theory Research. *Forum Qualitative Sozialforschung*, *23*(2). https://doi.org/10.17169/fqs-22.2.3840

Furman, S., & Hadjri, K. (2025). Wasted expertise : Why retrofit should include residents. *Energy Research & Social Science*, *119*. https://doi.org/10.1016/j.erss.2024.103894

Galvin, R. (2023). Policy pressure to retrofit Germany's residential buildings to higher energy efficiency standards: A cost-effective way to reduce CO2 emissions? *Building and Environment*, *237*(March). https://doi.org/10.1016/j.buildenv.2023.110316

Hoffmann, C., & Hoffmann, C. (2025). *Decarbonization rush ? The problem of speed in the energy transition Decarbonization rush ? The problem of speed in the energy transition*. *5147*. https://doi.org/10.1080/03085147.2025.2588931

Ju, S. R., Zaki, S. A., & Choi, Y. K. (2011). Contextual modernization; New town planning in Petaling Jaya, of Malaysia. *Journal of Asian Architecture and Building Engineering*, *10*(1), 93–100. https://doi.org/10.3130/jaabe.10.93

Liu, W., Yu, Z., Wu, J., Li, H., Gao, C., & Gong, H. (2019). Influence of Building Air Tightness on Energy Consumption of Ventilation System in Nearly Zero Energy Residential Buildings. *E3S Web of Conferences*, *4*(111), 03074. https://doi.org/10.1051/e3sconf/201911103074

Ma'bdeh, S. N., Ghani, Y. A., Obeidat, L., & Aloshan, M. (2023). Affordability assessment of passive retrofitting measures for residential buildings using life cycle assessment. *Heliyon*, *9*(2), e13574. https://doi.org/10.1016/j.heliyon.2023.e13574

Medrano-Gomez, L. E., Premier, A., & Boarin, P. (2025). When retrofit programmes meet everyday life : A socio-technical evaluation of retrofit practices in Aotearoa New Zealand. *Energy Research & Social Science*, *130*(October). https://doi.org/10.1016/j.erss.2025.104453

Murto, P., Jalas, M., Juntunen, J., & Hyysalo, S. (2019). Devices and strategies: An analysis of managing complexity in energy retrofit projects. *Renewable and Sustainable Energy Reviews*, *114*(June). https://doi.org/10.1016/j.rser.2019.109294

National Property Information Centre (NAPIC). (2024). *Property Market Report*.

Pelenur, M. J., & Cruickshank, H. J. (2014). Motivations to adopting energy efficiency measures in the home. *Proceedings of the Institution of Civil Engineers - Energy*, *167*(3), 103–116. https://doi.org/10.1680/ener.14.00013

Regnier, C., Sun, K., Hong, T., & Piette, M. A. (2018). Quantifying the benefits of a building retrofit using an integrated system approach: A case study. *Energy and Buildings*, *159*, 332–345. https://doi.org/10.1016/j.enbuild.2017.10.090

Tomrukcu, G., & Ashrafian, T. (2024). Climate-resilient building energy efficiency retrofit: Evaluating climate change impacts on residential buildings. *Energy and Buildings*, *316*(May). https://doi.org/10.1016/j.enbuild.2024.114315

United Nations Environment Programme. (2023). 2023 Global Status Report for Buildings and Construction: Beyond foundations - Mainstreaming sustainable solutions to cut emissions from the buildings sector. In *2023 Global Status Report for Buildings and Construction: Beyond foundations - Mainstreaming sustainable solutions to cut emissions from the buildings sector*. https://doi.org/10.59117/20.500.11822/45095

United Nations Environment Programme. (2025). Global Status Report for Buildings and Construction 2024/2025: Not just another brick in the wall - The solutions exist. In *Engineering and Technology* (Vol. 17, Issue 1). https://doi.org/10.1049/et.2022.0103

Wise, F., Gillich, A., & Palmer, P. (2025). Retrofit information challenges and potential solutions: Perspectives of households, retrofit professionals and local policy makers in the United Kingdom. *Energy Research and Social Science*, *119*(May 2024). https://doi.org/10.1016/j.erss.2024.103866

Yin, R. K. (2018). *Case Study Research and Applications: Design and Methods*. SAGE Publications.

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ADAPTIVE HOUSING PLANNING STRATEGIES FOR STRENGTHENING URBAN POOR COMMUNITIES IN POST-PANDEMIC CITIES

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ABSTRACT

This paper argues that adaptive housing planning is crucial for strengthening the resilience of urban poor communities in post-pandemic cities. The analysis focuses on how such planning addresses housing vulnerabilities exposed by COVID-19 and promotes equitable development. Synthesising recent literature, the review centres on participatory governance, sustainable design, and innovative policy and financing tailored to urban poor populations. Using resilience frameworks such as Holling's Resilience Theory, the Adaptive Capacity Framework, and the Social-Ecological Systems approach, the paper shows how adaptive housing operates at the intersection of infrastructure, socio-economic, and environmental factors. Results suggest that adaptive housing not only addresses immediate post-pandemic housing needs but also builds long-term resilience, inclusivity, and quality of life. The paper calls for increased collaboration among policymakers, urban planners, and researchers to expand context-sensitive adaptive housing strategies within broader resilience and poverty alleviation agendas.

Keywords: Post-Pandemic Adaptive Housing Strategies, Community Resilience, Planning Strategies, Inclusive Urban Development

1.0 INTRODUCTION

Rapid urbanisation has magnified housing challenges in developing countries, especially for low-income communities. The global urban population grew from 746 million in 1950 to about 4.7 billion in 2023; nearly 70% of people could live in cities by 2050 (United Nations, 2023; World Bank, 2023). This demographic shift exacerbates pressure on housing systems, with the urban poor often limited to informal housing lacking essential services. These conditions reinforce poverty and social exclusion, creating an urgent need for adaptive, inclusive housing strategies (UN-Habitat, 2024; Anderson et al., 2024; WHO, 2023). With urban poverty rising, a growing share of those in extreme poverty will live in cities by 2035. These trends complicate progress toward the Sustainable Development Goals (SDGs), including those on poverty eradication and sustainable cities. Equitable access to resilient housing now anchors global urban development agendas (Kufeoglu, 2022).

These structural inequalities became clear during the COVID-19 pandemic. The crisis exposed the critical link between housing conditions, public health, and urban resilience. Housing fragility in low-income settlements, where overcrowding and poor sanitation are common, greatly increases infection risks. These issues showed that housing quality directly affects public health outcomes. Inadequate housing is not just a social problem, but also a pressing public health concern (Varshney et al., 2022). Beyond the immediate health impacts, the pandemic highlighted the need for resilience and long-term sustainability in housing strategies to prepare cities for future disruptions (Escorcia Hernández et al., 2023; Callenberg et al., 2024).

In response to these challenges, adaptive, low-cost housing has emerged as a promising planning approach to enhance resilience in vulnerable urban communities. Such housing emphasises flexibility, incremental development, and responsiveness to evolving socio-economic and environmental conditions. Integrating social, environmental, and health considerations into development supports inclusive, sustainable urban growth (Askar et al., 2021; Akinsulire et al., 2024a). Incremental development and participatory planning empower residents in design and decision-making, strengthening local ownership and resilience (UN-Habitat, 2022). Implementing these strategies requires supportive governance and planning frameworks. Policy tools like inclusive zoning, land-use reforms, and financial innovations (such as micro-housing loans and community land trusts) enable participatory development (Asadzadeh et al., 2023; Mrani et al., 2025). Participatory governance and community-based planning provide platforms for residents to influence priorities and embed resilience in urban policies (Ahmadi Dehrashid et al., 2026; Castañeda Rodriguez et al., 2026). Although often seen as drivers of growth and innovation, cities' vulnerability to shocks—revealed by the COVID-19 pandemic—has increased attention on the importance of urban planning and design in enhancing resilience, particularly for marginalised groups (WHO, 2020; Capolongo et al., 2020; Wade, 2020). Housing quality and spatial organisation directly affect health, social stability, and adaptability in crises (Lak et al., 2020; Callenberg et al., 2024).

This study investigates the dimensions and characteristics of adaptive low-cost housing strategies that can strengthen resilience in urban poor communities. It uses resilience as an analytical framework to examine how housing interventions support post-pandemic recovery and long-term community stability. The research explores how adaptive housing addresses physical and social aspects of resilience in low-income urban areas, with direct impacts on well-being and vulnerability. This paper synthesises existing scholarship within broader urban planning and governance frameworks. Connecting resilience theory with housing planning provides a conceptual synthesis highlighting strategies to improve housing adaptability and community resilience in vulnerable urban settings. The findings aim to guide planners, policymakers, and researchers in developing more inclusive and resilient post-pandemic housing policies. This systematic literature review (SLR) and conceptual synthesis consolidates and critically interprets current knowledge to identify key strategies, gaps, and implementation pathways, rather than generating primary data.

2.0 METHODOLOGY

This study uses a systematic literature review (SLR) to examine adaptive housing strategies that enhance resilience among urban poor communities post-pandemic. The review follows systematic protocols to ensure transparency and methodological rigour (Page et al., 2021). A structured search was performed across Scopus, Web of Science, and Google Scholar, which together cover interdisciplinary urban studies and housing research. The search combined keywords related to housing adaptability, resilience, and pandemic contexts with Boolean operators. Terms included "adaptive housing," "housing resilience," "urban poor housing," "post-pandemic housing," and "COVID-19 housing strategies." The search covered publications from 2000 to 2026, capturing foundational works and recent scholarship. Initially, 1,500 records were found. After removing duplicates and irrelevant entries, 250 articles were shortlisted based on title and abstract, of which 150 met the preliminary criteria and were reviewed in detail. An additional 15 studies were found through snowball sampling. After final eligibility checks, 110 publications were retained for analysis.

To ensure analytical consistency, clear inclusion and exclusion criteria were applied. Eligible studies consisted of peer-reviewed journal articles and scholarly book chapters published in English that addressed themes related to adaptive housing, urban resilience, housing affordability, or post-pandemic urban recovery. Studies focusing exclusively on rural housing, non-urban contexts, or unrelated architectural topics were excluded. Conference proceedings, opinion pieces, and non-peer-reviewed materials were also removed to maintain academic rigour. Three sequential filtering stages were implemented: (1) primary screening, identifying studies addressing housing challenges in urban poor communities; (2) thematic screening, selecting literature discussing adaptability, flexibility, or resilience; and (3) analytical screening, retaining studies that explicitly examined adaptive strategies for low-cost or resilient housing systems.

For each selected study, key information was systematically extracted using a structured data-extraction framework. The extracted variables included author(s), publication year, geographical context, research methodology, key housing strategies, resilience dimensions addressed, and policy implications. This structured approach enabled the identification of patterns and thematic relationships across the literature while reducing potential selection bias (Page et al., 2021). To further enhance reliability, the screening and selection processes were independently reviewed by two researchers, and discrepancies were resolved through discussion to ensure consistency in study inclusion. The analysis employed an inductive thematic analysis, allowing themes to emerge

directly from the literature rather than being imposed a priori. Each selected study was carefully reviewed, and recurring concepts related to housing adaptability, resilience strategies, and policy interventions were coded. These codes were iteratively refined and grouped into broader analytical categories. Through multiple rounds of comparison and consolidation, the coding process produced several core thematic clusters that represent the dominant adaptive housing strategies discussed in the literature.

The thematic synthesis ultimately produced a conceptual framework identifying five interrelated domains of adaptive housing strategies: policy development, community participation, sustainable design, technological innovation, and financial mechanisms. These domains represent the most frequently cited mechanisms through which housing systems can strengthen resilience in vulnerable urban communities. The framework, therefore, provides an analytical structure for understanding how adaptive housing interventions operate across social, institutional, and physical dimensions.

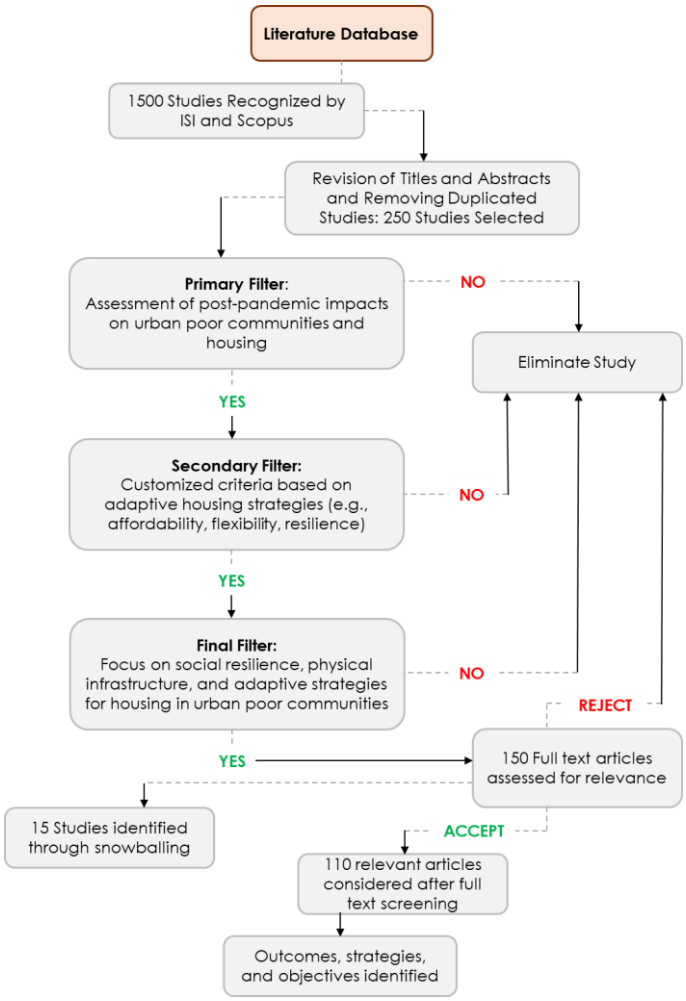

Fig. 1: Flowchart Illustrating the Literature Selection Process for Evaluation and Review

3.0 LITERATURE REVIEW

Understanding the complexities of urban poverty and housing requires a careful examination of the key concepts that underpin adaptive housing and resilience. At the outset, adaptive housing is defined by its capacity to foster sustainable living conditions for vulnerable populations, thereby positioning it as a practical response to entrenched inequalities in urban environments. Building on this foundation, the discussion turns to the COVID-19 pandemic, which disrupted everyday life and amplified the vulnerabilities of low-income urban communities, underscoring the urgent need for housing strategies that withstand systemic shocks.

To address these challenges, resilience frameworks in housing are introduced as theoretical lenses that help explain how built environments can adapt to crises while supporting social and physical well-being. These frameworks provide a basis for understanding adaptive strategies, linking conceptual discussions to practical

design and policy responses. The review then examines previous adaptive housing initiatives, drawing lessons from both successes and shortcomings to inform future directions.

Taken together, these conceptual explorations establish a coherent foundation for assessing the role of adaptive housing in strengthening resilience. They underscore how theory, lived experience, and practical initiatives converge to shape housing strategies that can enhance the well-being of low-income urban populations in the post-pandemic era.

3.1 Definition and Importance of Adaptive Housing

Adaptive housing is increasingly defined as a housing approach that responds to the evolving needs of urban populations amid rapid urbanisation. Unlike conventional designs, which often exclude user participation and fail to accommodate diverse social uses, adaptive housing emphasises flexibility and inclusivity. The COVID-19 pandemic underscored this necessity, as homes were compelled to perform multiple roles beyond their original design intentions (Pelsmakers & Warwick, 2022).

Beyond pandemic pressures, adaptability emerges as essential throughout the building lifecycle, particularly in response to broader societal shifts such as digital work, migration, and demographic transitions like ageing populations. Turner's and Davis's seminal contributions remain relevant here, showing how urban poor residents negotiate trade-offs between affordability, location, and safety (Turner, 1976; Davis, 2006). In this sense, adaptability cannot be confined to spatial or physical design but must integrate social, economic, and environmental dimensions that reflect the lived realities of low-income communities (Ramalhete et al., 2015).

These multidimensional demands also extend to geographic and climatic contexts. Advocating for locally appropriate, sustainable materials is vital, since inadequate adaptability risks disrupting social cohesion by displacing households from established networks (Pelsmakers & Warwick, 2022). Conversely, facilitating long-term residence enhances community well-being and stability (Isik-Ercan et al., 2024). Thus, material choices and design strategies must simultaneously support ecological responsiveness and social continuity.

Linking adaptability with sustainability, scholars highlight how circular construction principles can prolong housing longevity while reducing demolition costs and waste (Askar et al., 2021). Although flexible designs may involve higher upfront costs, they create long-term value, provided residents perceive adaptability as a worthwhile investment (Watt et al., 2023). This reinforces the idea that adaptability is not only a technical feature but also a socio-economic negotiation shaped by affordability thresholds and household priorities.

At a broader scale, adaptive housing must also respond to systemic challenges in urban governance and environmental degradation. Policy frameworks have often failed to account for local contexts, resulting in ineffective housing provision (UN-Habitat, 2012; ASEAN, 2022). In regions such as Sub-Saharan Africa, rapid urban growth, high rates of informal settlements, and weak infrastructure intensify vulnerabilities (Hussainzad & Gou, 2024). Here, Turner's argument remains pertinent: the housing needs of rural migrants—who often settle in peripheral, underserved areas—are best understood through the trade-offs they navigate (Turner, 1976; Davis, 2006). The persistence of overcrowded slums without adequate infrastructure demonstrates that, without comprehensive policies that address housing, infrastructure, and socio-economic development simultaneously, adaptive housing will remain out of reach for the most vulnerable (Ramalhete et al., 2015).

3.2 The Impact of the COVID-19 Pandemic on Urban Communities

The COVID-19 pandemic, emerging in late 2019, rapidly escalated into a global crisis with over 753 million cases and 6.8 million deaths recorded by early 2023 (WHO, 2023). While health measures such as lockdowns and travel restrictions were necessary to curb its spread (WHO, 2020), they simultaneously exposed deep socio-economic vulnerabilities in urban contexts, including inadequate housing, entrenched health inequalities, and fragile social networks (Nicola et al., 2020; Hasan et al., 2024). These consequences reveal that pandemics act not only as health emergencies but also as stress tests of urban systems' resilience.

Although COVID-19 is unprecedented in scale, pandemics themselves are not new phenomena. They have historically been triggered by processes closely tied to urbanisation, global travel, and environmental change (Madhav et al., 2017). Past outbreaks such as smallpox, cholera, and notably the 1918 Spanish flu—which alone claimed over 20 million lives—demonstrate their capacity to reshape societies (Piret & Boivin, 2021). More recent crises, including H1N1 (2009), Ebola, and Zika, further emphasise the ongoing urgency of pandemic preparedness and highlight how recurring health shocks intersect with the dynamics of contemporary cities (Hasan et al., 2019; Jilani et al., 2024). Importantly, history shows that pandemics have also been catalysts for urban innovation. Europe's cholera epidemics, for instance, spurred advancements in public hygiene and sanitation, while large-scale interventions such as Haussmann's redesign of Paris and Ebenezer Howard's Garden City concept reflected broader shifts toward healthier urban environments. Similarly, the Modernist planning

principles that emerged in the wake of the Spanish flu emphasised the importance of green spaces, natural ventilation, and access to light—features that remain central to contemporary urban health debates. However, drawing parallels between past and present also reveals significant contrasts. The global recovery after the Spanish flu occurred in a context where only 14% of the population lived in cities, compared to 57% today. Moreover, the world of the 1920s was far less interconnected, and the absence of modern media-driven fear arguably allowed for a faster psychological and social recovery (Kozlowski et al., 2021). These differences underscore that while past pandemics provide valuable lessons, today's urban vulnerabilities—magnified by density, globalisation, and socio-economic inequalities—demand more complex and integrated responses.

3.3 Resilience Frameworks in Housing

Resilience frameworks in housing focus on communities' capacity to absorb, adapt, and recover from shocks such as pandemics, natural disasters, and economic crises. These frameworks provide conceptual and practical foundations for adaptive housing strategies, emphasising flexibility, sustainability, and community participation as central principles. By addressing both the physical and social dimensions of resilience, they enable housing systems and the communities they serve to better withstand disruptions and accelerate recovery (UN-Habitat, 2012; Kapucu et al., 2024).

Table1. Key Resilience Frameworks Applied to Housing

Framework	Core Idea	Housing Implications	Relevance to Urban Poor
Holling's Resilience Theory	Systems absorb shocks & reorganize (Holling, 1973)	Incremental, flexible housing design	Enables crisis responsiveness
Social-Ecological Systems (SES)	Interconnected social & ecological systems (Ostrom, 2009)	Governance, community action, ecological design	Fosters collective resilience
Adaptive Capacity Framework	Ability to adjust via resources, skills, networks (Folke et al., 2010)	Microfinance, skills training, disaster readiness	Strengthens coping capacity
Community-Based Resilience	Participation & local agency (Patel et al., 2017)	Co-design, community & trusts, participatory budgeting	Enhances ownership & institutional legitimacy

Central to these frameworks are adaptable housing designs that can be reconfigured to meet evolving household needs, alongside the use of sustainable building materials that reduce environmental impacts and support long-term durability. Equally important is community involvement in decision-making, which fosters stronger social cohesion, shared responsibility, and a sense of ownership. Such participation not only improves the relevance of housing solutions but also enhances collective resilience (Bucovetchi et al., 2024). Importantly, resilience in housing extends beyond the physical domain. It also entails strengthening social networks, promoting economic stability, and integrating environmental sustainability as mutually reinforcing pillars of resilience. In this way, housing frameworks position resilience as a multidimensional construct, preparing vulnerable communities to cope with uncertainty and adapt to future challenges. The following section highlights key resilience frameworks that specifically inform adaptive housing strategies:

3.3.1 Holling's Resilience Theory

Holling's Resilience Theory (1973) conceptualises resilience as a system's capacity to absorb shocks, reorganise, and continue functioning without losing its essential structure and purpose. When applied to housing, this perspective underscores the importance of designing environments that can withstand and adapt to diverse stressors (including economic instability, health crises, and climate variability) while maintaining their core utility and livability. In practical terms, Holling's theory informs strategies such as flexible housing design, mixed land use, and participatory community planning, which collectively enhance a settlement's adaptive capacity (Salinger et al., 2024). A notable example is incremental housing, in which residents can gradually expand or reconfigure their homes in response to shifting household needs and available resources. This approach not only supports long-term adaptability but also empowers residents to directly shape their living environments, thereby reinforcing both physical and social dimensions of resilience (Mota, 2021).

3.3.2 Integrated Social-Resilience Frameworks

While Holling's framework provides a foundational understanding of systemic adaptation, several complementary models, namely the Social-Ecological Systems (SES), Adaptive Capacity, and Community-Based Resilience frameworks, offer more holistic perspectives that integrate social, ecological, and institutional dimensions.

The Social-Ecological Systems (SES) Framework, developed by Ostrom (2009), emphasises the interconnectedness between built environments, social networks, governance structures, and ecological contexts. Housing resilience, within this perspective, emerges from the dynamic interaction of these elements. It stresses the importance of community cohesion, local governance, and collective action in coping with crises (Partelow, 2018). For example, the recovery process following Hurricane Katrina in New Orleans demonstrated how community-led initiatives significantly shaped rebuilding efforts (Kates et al., 2006), showing that resilience extends beyond physical structures to include social relationships and governance systems.

The Adaptive Capacity Framework (Folke et al., 2010) highlights the ability of individuals and communities to adjust to changing conditions by mobilising resources, knowledge, and social capital. This framework is particularly relevant to urban poor communities, where limited financial and institutional capacity constrains adaptive responses. Initiatives that enhance adaptive capacity—such as microfinance for home improvements, disaster preparedness training, and knowledge-sharing platforms—can strengthen long-term resilience (Lin & Lee, 2024). The Philippines' Build Back Better program exemplifies this by embedding risk reduction and community participation in housing reconstruction (Cruz & Pulumbarit, 2023).

The Community-Based Resilience Framework builds upon these ideas by emphasising local participation and agency. Rather than imposing externally defined solutions, participatory housing planning allows communities to co-develop strategies that align with their cultural and social realities (Patel et al., 2017). Post-earthquake reconstruction in Haiti illustrates this principle, where community engagement produced housing that was both locally relevant and culturally resonant (Pyles, 2015; Boston et al., 2024). These participatory approaches enhance social legitimacy, shared ownership, and long-term adaptability.

Together, these frameworks converge within what Yadav and Yadav (2024) describe as an Integrated Resilience Framework, combining systemic understanding (SES), adaptive strategies (Adaptive Capacity), and participatory governance (Community-Based Resilience). This synthesis recognises that effective housing resilience requires the alignment of physical design, social cohesion, and institutional support. By integrating health, social, and environmental considerations—such as access to green spaces, adequate ventilation, and communal facilities-adaptive housing can simultaneously improve living conditions and strengthen preparedness for future crises (Heydari & Abbasianjahromi, 2024; Diana et al., 2024).

3.3.3 Synthesis and Insights

Across these frameworks, several common principles emerge. Flexibility in housing design, social participation, and integration of ecological and governance systems are consistent drivers of resilience (Druta & Fatemidokhtcharook, 2023; Lang & Roessl, 2013; Maravalle et al., 2024). However, persistent challenges remain, particularly affordability constraints, fragmented policy support, and limited institutional coordination that often exclude low-income populations from adaptive housing initiatives. Moreover, while the frameworks provide valuable conceptual tools, their practical translation into policy and local implementation remains uneven, especially in resource-limited settings. Addressing these gaps requires not only technical innovation but also governance reforms that strengthen community participation and align resilience planning with social equity objectives.

Ultimately, resilience in housing should be understood as both a physical capacity to withstand disruption and a social process of empowerment and adaptation, ensuring that vulnerable urban communities can sustain well-being in the face of uncertainty.

3.4 Previous Strategies for Adaptive Housing

Adaptive housing strategies have gained increasing recognition as critical tools for enhancing the resilience of urban poor communities, particularly during crises such as the COVID-19 pandemic. Rooted in principles of flexibility, inclusivity, and community participation, these strategies aim to provide housing solutions that evolve with residents' changing socio-economic and environmental circumstances (Kapucu et al., 2024). By merging adaptive design with participatory processes, they not only mitigate short-term vulnerabilities but also promote long-term stability, well-being, and social cohesion. This section outlines the key strategies and their practical applications through selected case studies.

3.4.1 Incremental Housing

Incremental housing is a progressive construction model that allows residents—especially those in informal or low-income communities—to build or upgrade their homes over time as financial resources permit. This approach enhances affordability and empowers residents through gradual investment and self-determination. In Belapur Housing, Navi Mumbai, India, Charles Correa's 1980s design exemplified this approach by providing low-cost starter units clustered around communal courtyards, with additional space for future expansion. This design not only facilitated community interaction but also supported incremental development aligned with household growth. Similarly, Brazil's Incremental Housing Program under the Minha Casa Minha Vida initiative provides subsidies for basic housing units that residents can expand, promoting affordability, ownership, and localised resilience (D'Ottaviano & Bossuyt, 2024).

3.4.2 Flexible Housing Designs

Flexible housing design focuses on adaptable layouts and modular structures that respond to evolving household and community needs. Such designs extend the lifespan of housing, reduce displacement, and enhance functionality during social or environmental disruptions. The Netherlands' Flex Homes initiative offers prefabricated modular units for individuals in transitional crises, such as divorce, job loss, or displacement. These units are quick to assemble, cost-efficient, and relocatable, providing both immediate relief and long-term adaptability (Druta & Fatemidokhtcharook, 2023). Likewise, Switzerland's Neuwil Development by Metron-Architekten AG integrates an open-plan layout with a central technical core, enabling occupants to reconfigure internal spaces as family structures change. This design promotes sustainability, user autonomy, and adaptive reuse (Živković et al., 2021).

3.4.3 Community-Led Housing Initiatives

Community-led housing emphasises resident participation in decision-making, ensuring that design and management processes are grounded in local priorities. Such approaches strengthen social capital, reduce dependency on external actors, and ensure culturally and contextually relevant outcomes. Vienna's Cooperative Housing Model empowers residents through collective ownership and democratic governance, ensuring affordability and long-term community stability (Lang & Roessl, 2013). Similarly, the Community Land Trusts (CLTs) model in Nashville, USA, separates land from housing ownership, preventing market-driven displacement and preserving intergenerational affordability (Engelsman et al., 2016). Both models demonstrate how shared ownership and participatory governance can institutionalise resilience within urban housing systems.

3.4.4 Resilient Infrastructure and Disaster-Resistant Housing

Resilient and disaster-resistant housing integrates structural robustness, environmental sensitivity, and risk reduction into design and infrastructure planning. These approaches are crucial for communities exposed to climate hazards and environmental stress. After Hurricane Sandy, New York City's Housing Recovery Program introduced retrofitting initiatives—such as elevated structures, flood-resistant foundations, and green stormwater systems—to improve both safety and sustainability (Salmanian et al., 2024; Salmanian & Bayat, 2023; Petkova et al., 2017). In Japan, post-2011 disaster innovations introduced seismic-flexible structural systems, elevated foundations, and energy-efficient materials, reflecting a strong cultural emphasis on preparedness and collective resilience (Farhanrika et al., 2023). These cases underscore that integrating resilience into housing not only safeguards lives but also catalyses urban regeneration.

3.4.5 Government Policy and Support Programs

Government interventions play a pivotal role in scaling adaptive housing solutions by providing financial support, technical expertise, and regulatory incentives. Such programs institutionalise resilience through inclusive planning and policy integration. In Mexico, the Programa de Mejoramiento Urbano targets informal settlements with subsidies for housing upgrades and infrastructure improvements, enhancing community participation and reducing spatial inequalities (Maravalle et al., 2024). Similarly, Canada's National Housing Strategy incorporates adaptive housing principles through its Affordable Housing Program, emphasising affordability, adaptability, and support for vulnerable groups (Farhan, 2024). These examples highlight how state-led initiatives can translate adaptive principles into equitable and sustainable outcomes.

3.4.6 Technology-Driven Solutions

Technological innovation is reshaping adaptive housing by enhancing efficiency, sustainability, and responsiveness. Through digital tools, renewable energy systems, and data-driven design, housing can better adapt to changing conditions and resource limitations. In India, IoT-based housing solutions integrate smart monitoring systems that optimise energy use and improve affordability, making adaptive living feasible even in low-income contexts (Salmanian & Ujang, 2021; Sharma et al., 2020). In Sub-Saharan Africa, solar-powered housing systems have expanded access to stable electricity, reducing vulnerability and improving adaptive capacity in off-grid areas (Ajagun et al., 2024). Collectively, these innovations illustrate how technology complements social and policy-driven strategies by embedding resilience at multiple scales of housing.

3.5 Thematic Insights and Knowledge Gaps

Across these diverse strategies, common principles emerge: incremental growth, flexibility, participation, institutional support, and technological integration (Kapucu et al., 2024; Lang & Roessl, 2013). Each approach contributes to housing resilience by addressing different dimensions—social empowerment, physical adaptability, environmental safety, and governance inclusivity (Druta & Fatemidokhtcharook, 2023; Farhan, 2024). However, their effectiveness depends on context-specific implementation and multi-sectoral coordination. For low-income urban communities, the most successful adaptive housing models combine bottom-up participation with supportive policy frameworks and accessible technology, reinforcing the premise that housing resilience is achieved not through singular design solutions but through the alignment of physical, social, and institutional capacities.

Despite these advancements, several knowledge gaps persist. Existing literature tends to focus on conceptual frameworks and pilot projects, with limited empirical evidence on the long-term effectiveness of adaptive housing strategies in high-density, low-cost urban settings (Ajagun et al., 2024; Maravalle et al., 2024). Moreover, the intersection between housing adaptability, social well-being, and public health resilience remains underexplored, especially in the post-pandemic context (Farhanrika et al., 2023). Few studies examine how adaptive housing principles can be operationalised within government-led housing programs or how residents' lived experiences and informal adaptive practices can inform future housing design. Addressing these gaps requires multidimensional planning strategies that link physical flexibility, social networks, and institutional responsiveness to enhance the resilience of urban poor communities. While these studies provide valuable conceptual and practical insights, a significant empirical validation gap remains, particularly in high-density, government-led housing contexts. Many existing contributions rely on pilot projects or theoretical models, with limited evaluation of measurable outcomes such as occupancy conditions, environmental performance, and long-term maintenance. This gap highlights the need to integrate secondary empirical evidence and to develop assessment indicators, which this study begins to address through its synthesis and contextual analysis.

4.0 Findings and Discussion: Post-Pandemic Strategies for Resilient Urban Poor Communities

The COVID-19 pandemic revealed deep vulnerabilities within urban poor communities, amplifying challenges related to housing, health, and livelihoods. The COVID-19 pandemic revealed deep vulnerabilities within urban poor communities, amplifying challenges related to housing, health, and livelihoods. Economic disruptions, heightened social isolation, and persistent health disparities underscored the urgency of developing strategies that foster resilience and adaptability in housing systems (Escorcia Hernández et al., 2023; Heydari & Abbasianjahromi, 2024). Addressing these vulnerabilities requires targeted interventions that integrate inclusivity, sustainability, and community participation while leveraging technology and supportive policies (Sato et al., 2023).

This section synthesises four interrelated domains of adaptive housing strategies, policy frameworks, community engagement, sustainable design and technological innovation, and financial mechanisms, each contributing distinct yet complementary pathways toward resilience. Table 2 summarises the main domains, mechanisms, and examples identified in the reviewed literature.

Table 2. Comparative Summary of Post-Pandemic Adaptive Housing Strategies

Strategy Domain	Key Mechanisms	Illustrative Examples	Contribution to Resilience
Policy and Governance	Flexible zoning, inclusionary housing, and integrated urban planning	San Francisco inclusionary zoning (Wang & Balachandran, 2021); BRAC incremental housing policies	Enables mixed-income development, balances affordability and access
Community Engagement	Participatory planning, capacity building, grassroots advocacy	KDI School participatory model (Song, 2022); SDI community networks (Huchzermeyer, 2023)	Builds local ownership, strengthens social capital, and ensures contextual relevance
Sustainable Design & Technology	Modular construction, green roofs, passive design, smart monitoring	Kota Kita modular housing (Kurniasari et al., 2019); Bosco Verticale greenery (Liu, 2023)	Enhances energy efficiency, environmental quality, and adaptability
Financial Mechanisms	Microfinance, public–private partnerships, digital inclusion	Grameen Bank microloans (Nawaz et al., 2021); South Africa SHUP PPP (Akinsulire et al., 2024b); India's PMJDY digital banking (Gupta, 2023)	Expands access to funding, supports self-help improvements, and stabilizes livelihoods

4.1 Policy and Governance

Building resilience requires integrated governance frameworks that embed adaptive housing principles into broader urban systems. The pandemic exposed weaknesses in conventional planning that often separate housing policy from social welfare. Adaptive governance links spatial planning, financial assistance, and digital management tools, ensuring responsive decision-making and transparency (Kapucu et al., 2024).

Flexible zoning reforms, for example, permit incremental and mixed-use developments that better reflect the socioeconomic realities of urban poor households. Inclusionary zoning (such as that used in San Francisco) prevents exclusionary redevelopment and secures affordable units within higher-value areas (Wang & Balachandran, 2021). These approaches highlight that adaptive housing depends not only on design innovations but also on the institutional willingness to accommodate diversity and gradual upgrading.

4.2 Community Engagement and Participation

Community participation transforms residents from beneficiaries into co-producers of resilience. Participatory mechanisms (including community mapping, design charrettes, and participatory budgeting) encourage local input and accountability (Gil et al., 2019). The KDI School model in South Korea and SDI's transnational networks demonstrate how engagement builds social capital, promotes equity, and generates housing solutions that align with local customs (Song, 2022; Huchzermeyer, 2023). Crucially, participation enhances social cohesion and trust, which are essential in responding to shocks. Even in low-resource contexts, residents benefit from capacity-building training in construction or management (Bredenoord et al., 2020). These skills reduce dependence on external aid and embed adaptability within community systems.

4.3 Sustainable Design and Technology Innovations

Sustainable design emphasises resource efficiency, climate responsiveness, and long-term adaptability. Energy-efficient materials, passive cooling, and modular construction lower maintenance costs while supporting ecological goals (Bao et al., 2023). Projects such as Kota Kita's modular housing in Indonesia and Bosco Verticale in Milan reveal how integrating greenery and modular systems enhances liveability while addressing environmental degradation (Liu, 2023). Technological innovation further supports adaptive living. Smart housing systems, such as affordable energy-monitoring devices, can reduce energy use and improve safety in dense environments (Patience & Apaokueze, 2024). However, effective deployment requires digital equity, access to devices, connectivity, and literacy to prevent deepening existing inequalities.

4.4 Financial Mechanisms and Support Systems

Financial inclusion underpins adaptive housing implementation. Microfinance programs, like the Grameen Bank's women-led initiatives, enable incremental home upgrades and entrepreneurial resilience (Nawaz et al., 2021). Government subsidies (as seen in Finland's Housing First program) provide direct affordability support to vulnerable groups (Juhila et al., 2022). Public–private partnerships extend impact through shared financing and technical expertise, as illustrated in South Africa's Sustainable Housing for the Urban Poor project (Akinsulire et al., 2024). Meanwhile, digital finance initiatives such as India's PMJDY broaden access to banking, savings, and micro-insurance for low-income households (Gupta, 2023). These instruments illustrate that financial resilience is as critical as spatial or social resilience: without affordable, accessible financing, adaptive housing cannot be sustained.

4.5 Integrative Synthesis: Interdependence of the Four Domains

The four domains function not in isolation but as a synergistic system. Policy frameworks establish enabling conditions; community participation ensures contextual fit; sustainable design translates policy intent into practice; and financial mechanisms provide continuity. For instance, participatory budgeting (a governance tool) strengthens financial accountability, while modular design (a physical strategy) becomes viable only when supported by inclusive financing. This interdependence suggests that post-pandemic resilience relies on cross-sector collaboration rather than fragmented interventions. Adaptive housing thus emerges as both a design philosophy and a governance paradigm, bridging technical, social, and financial systems to foster sustainable urban recovery.

5.0 DISCUSSIONS

The reviewed literature identifies adaptive housing as a critical lever for strengthening resilience among urban poor communities in the aftermath of COVID-19. Beyond technical improvement, adaptive housing redefines how cities conceptualise vulnerability, linking physical design, social empowerment, and institutional reform. The pandemic underscored that resilience must be multidimensional, encompassing physical adequacy, financial flexibility, social inclusion, and ecological sustainability.

5.1. Revisiting the Analytical Framework

The findings align with five interrelated domains, policy, community, design, technology, and finance, identified in the methodological framework. Together, these domains shape a comprehensive resilience ecosystem. Policy reforms create institutional legitimacy; community participation embeds local relevance; sustainable and technological design ensures environmental responsiveness; and financial mechanisms guarantee continuity. Their convergence demonstrates that adaptive capacity is strongest when governance, design, and social capital are mutually reinforcing (Toyoda, 2021). This integrated model advances existing literature by reframing adaptive housing not as an isolated technical fix but as a systems-based governance approach to urban poverty reduction and public-health resilience.

5.2. Interpretation of Global Strategies

Global examples illustrate that adaptive housing succeeds when participatory structures and flexible financing are embedded in national policy. Incremental housing in Latin America and modular schemes in Asia exemplify bottom-up resilience, while social-housing retrofits in Europe demonstrate institutional adaptation. However, these cases also reveal tensions: balancing rapid urban redevelopment with affordability; maintaining cultural integrity while standardising designs; and reconciling sustainability targets with cost constraints. Thus, adaptive housing's greatest contribution lies in its capacity to evolve (technically, socially, and institutionally), rather than in any single architectural or financial model.

5.3. Challenges and Limitations

Despite its promise, adaptive housing faces significant obstacles:

- Policy capture and tokenism: Participatory initiatives may be co-opted by political elites, resulting in symbolic rather than substantive inclusion (Kamalipour & Dovey, 2020).
- Financial and institutional barriers: Limited budgets and fragmented responsibilities impede long-term maintenance and scalability.
- Digital inequality: Smart technologies remain inaccessible to many low-income households, risking a new form of exclusion.
- Socio-cultural resistance: Standardised housing designs often neglect local customs, reducing acceptance and long-term occupancy rates.

Acknowledging these challenges underscores that adaptive housing requires not only design innovation but also political commitment, capacity building, and equitable access to technology and finance.

5.4. Regional Context: Malaysia

In the Malaysian context, adaptive housing principles must be understood in relation to the structural and governance realities of the People's Housing Programme (PPR), as critically examined by the Khazanah Research Institute. Its report, Decent Shelter for the Urban Poor (2023), positions PPR as the country's primary social housing instrument while questioning its capacity to deliver not only basic shelter but also pathways for social mobility. Empirical evidence from Kuala Lumpur and Penang indicates that, although PPR has succeeded in formalising housing provision for former squatters, it often reproduces new forms of deprivation, including overcrowding, inadequate ventilation, poor maintenance, and limited communal spaces. These spatial and managerial deficiencies are compounded by socio-economic vulnerability, with a majority of residents remaining below the poverty line and engaged in precarious employment. Consequently, PPR developments—despite their central urban locations—frequently experience infrastructure deterioration, weak long-term management, and increasing social and health risks.

This diagnosis reframes the limitations of PPR from purely architectural shortcomings to systemic issues of governance, adaptability, and socio-economic integration. In this regard, earlier critiques of rigid design templates and constrained communal provision align with KRI's conclusion that PPR is often treated as a completed physical asset rather than a dynamic housing system requiring continuous management and adaptation. Therefore, enhancing resilience necessitates a shift from static delivery models toward adaptive, process-oriented frameworks.

KRI's proposed framework reinforces this transition through three interrelated strategies: adaptive household management (e.g., dynamic eligibility registries and structured exit pathways), adaptive stock management (e.g., diversification of unit typologies, universal design integration, and lifecycle-based upgrading), and systemic integration with the private housing sector via national-level data infrastructures. These recommendations directly complement design-oriented approaches such as incremental housing, participatory maintenance schemes, and digital community management systems, extending adaptability beyond the unit scale to institutional and policy dimensions.

Accordingly, recent policy dialogues—such as Kuala Lumpur City Hall's inclusive-neighbourhood initiatives—signal an emerging paradigm in which resilience is co-produced with residents rather than delivered through top-down mechanisms. Embedding such adaptive principles within Malaysia's National Affordable Housing Policy would therefore align national housing strategies with both KRI's evidence-based recommendations and broader global shifts toward resilient, inclusive, and transition-oriented urban housing systems.

5.5. Advanced Knowledge and Practice

This synthesis contributes to the growing body of research on urban resilience by emphasising adaptability as a social process in which governance, design, and community engagement intersect. It advances understanding in three ways:

1. Conceptually, by positioning adaptive housing as a multidimensional resilience strategy.
2. Empirically, by consolidating global practices and their relevance to Malaysia's low-income housing context.
3. Practically, by identifying cross-domain linkages that inform policy integration and participatory planning.

In conclusion, adaptive housing offers a transformative framework for post-pandemic recovery, grounded in equity, flexibility, and sustainability. Its success depends on how effectively urban governance systems integrate policy coherence, community empowerment, sustainable technology, and financial inclusion to ensure that resilience is not merely built, but continually renewed.

6.0 CONCLUSION

Based on the synthesis of the reviewed literature, adaptive housing can be operationalised through a structured implementation process linking policy, design, community, and financial mechanisms. The process begins with identifying key housing vulnerabilities, including physical deficiencies, socio-economic constraints, and governance limitations. This is followed by the selection and integration of appropriate adaptive strategies across the four domains

identified in this study. Implementation requires coordinated action among stakeholders, ensuring that design interventions, policy instruments, and financial support systems are aligned with local needs. Finally, continuous monitoring using measurable performance indicators—such as occupancy density, environmental quality, and resident satisfaction—enables evaluation and iterative improvement of housing outcomes. This framework provides a practical bridge between conceptual strategies and real-world applications.

This review underscores that adaptive housing represents more than a technical response to urban poverty; it is a multidimensional strategy for strengthening resilience in the face of ongoing and future crises. As the discussion highlighted, adaptability must be understood across physical, social, economic, and environmental dimensions. Flexible designs and incremental upgrading allow housing to evolve with household and financial changes, while community-driven processes ensure cultural relevance and inclusivity. Grounding adaptive housing within resilience frameworks such as Holling's Resilience Theory, the Social-Ecological Systems Framework, and the Adaptive Capacity Framework further emphasises its role as part of broader socio-ecological systems, capable of absorbing shocks while enabling long-term sustainability.

Global experiences, from Latin America's incremental housing to Switzerland's adaptable social housing and Japan's disaster-resilient models, demonstrate the practical value of adaptive approaches. At the same time, technological innovations such as modular construction, renewable energy systems, and passive cooling strategies expand opportunities for sustainable housing solutions. Yet, as discussed, these advances must be carefully aligned with local contexts, financial realities, and participatory governance to avoid exclusion or inequity.

Ultimately, adaptive housing provides a viable pathway to address housing inadequacies, strengthen community resilience, and advance post-pandemic recovery. Achieving this potential requires integrated planning that combines supportive policy frameworks, technological and design innovation, and meaningful resident participation. For rapidly urbanising regions such as Malaysia, embedding adaptive strategies into housing policies and urban planning is not optional but imperative, ensuring that housing functions not only as shelter but as a foundation for resilience, equity, and dignity in uncertain futures.

The findings highlight the need for policymakers to adopt integrated, resilience-oriented approaches to urban housing. Urban development strategies should prioritise adaptive and flexible housing designs that accommodate evolving household needs and demographic shifts. Policies must also promote community engagement through participatory planning, ensuring that residents' local knowledge and cultural practices shape housing solutions. Financial mechanisms, including subsidies, microfinance, and public-private partnerships, are crucial for supporting incremental upgrades and ensuring long-term affordability for low-income households. Furthermore, technological innovations—such as modular construction, energy-efficient systems, and climate-responsive materials—should be implemented in ways that are accessible, contextually appropriate, and environmentally sustainable. Ultimately, effective coordination across governance levels is crucial for aligning urban planning, social services, and infrastructure development with adaptive housing objectives. By integrating these measures, governments can enhance the resilience, equity, and sustainability of housing for urban poor communities, while preparing cities to respond effectively to future crises.

REFERENCES

Ahmadi Dehrashid, Parsa & Mansourian, Hossain & Sharifi, Ayyoob. (2026). Healthy cities as catalysts for sustainable development: A systematic review of co-benefits, trade-offs, and solutions to the SDGs. Progress in Planning. 101032. 10.1016/j.progress.2025.101032.

Ajagun, A. S., Mao, W., Sun, X., Guo, J., Adebisi, B., & Aibinu, A. M. (2024). The status and potential of regional integrated energy systems in sub-Saharan Africa: An Investigation of the feasibility and implications for sustainable energy development. *Energy Strategy Reviews*, *53*, 101402. https://doi.org/10.1016/j.esr.2024.101402

Akinsulire, A. A., Idemudia, C., Okwandu, A. C., & Iwuanyanwu, O. (2024a). Public-Private partnership frameworks for financing affordable housing: Lessons and models. *International Journal of Management & Entrepreneurship Research*, *6*(7), Article 7. https://doi.org/10.51594/ijmer.v6i7.1326

Akinsulire, A. A., Idemudia, C., Okwandu, A. C., & Iwuanyanwu, O. (2024b). Sustainable development in affordable housing: Policy innovations and challenges. *Magna Scientia Advanced Research and Reviews*, *11*(2), 090–104. https://doi.org/10.30574/msarr.2024.11.2.0112

Anderson, R. K., Pasciuti, D. S., & Sellers, C. M. (2024). Livability vs. Affordability; Disability and Housing in the United States. *Social Sciences*, *13*(6), Article 6. https://doi.org/10.3390/socsci13060291

Asadzadeh, Asad & Fekete, Alexander & Khazai, Bijan & Moghadas, Mahsa & Zebardast, Esfandiar & Basirat, Maysam & Kötter, Theo. (2023). Capacitating urban governance and planning systems to drive transformative resilience. Sustainable Cities and Society. 96. 104637. 10.1016/j.scs.2023.104637.

ASEAN Secretariat. (2022). Study on urbanization, people mobility, and inclusive development. *ASEAN*. https://asean.org/wp-content/uploads/2022/06/Study-on-Urbanization-People-Mobility-Inclusive-Development-FINAL.pdf

Askar, R., Bragança, L., & Gervásio, H. (2021). Adaptability of Buildings: A Critical Review on the Concept Evolution. *Applied Sciences*, *11*(10), Article 10. https://doi.org/10.3390/app11104483

Bao, X., Zhang, T., Zeng, Q., & Dewancker, B. J. (2023). Adapting to changes in the COVID-19 pandemic: Research and recommendations on spatial layout and resident experience in MURBs. *City and Built Environment*, *1*(1), 12. https://doi.org/10.1007/s44213-023-00014-z

Boston, M., Bernie, D., Brogden, L., Forster, A., Galbrun, L., Hepburn, L.-A., Lawanson, T., & Morkel, J. (2024). Community resilience: A multidisciplinary exploration for inclusive strategies and scalable solutions. *Resilient Cities and Structures*, *3*(1), 114–130. https://doi.org/10.1016/j.rcns.2024.03.005

Bredenoord, J., Park, J., & Kim, K. (2020). The Significance of Community Training Centers in Building Affordable Housing and Developing Settlements. *Sustainability*, *12*(7), Article 7. https://doi.org/10.3390/su12072952

Bucovetchi, O., Georgescu, A., Gheorghe, A. V., & Popescu, G. (2024). Understanding Resilience – a Conceptual Framework. *Proceedings of the International Conference on Business Excellence*, *18*(1), 2377–2385. https://doi.org/10.2478/picbe-2024-0201

Callenberg, M., Barnwal, A., & Bakarr, M. I. (2024). COVID-19 Pandemic and Sustainable Urban Transformation: Perspectives on City-Level Actions and a Framework for the Future. *Land*, *13*(7), Article 7. https://doi.org/10.3390/land13071093

Capolongo, S., Rebecchi, A., Buffoli, M., Appolloni, L., Signorelli, C., Fara, G. M., & D'Alessandro, D. (2020). COVID-19 and Cities: From Urban Health strategies to the pandemic challenge. A Decalogue of Public Health opportunities. *Acta Biomedica Atenei Parmensis*, *91*(2), 13–22. https://doi.org/10.23750/abm.v91i2.9615

Castañeda Rodriguez, L. d. R., Galvez-Nieto, A., Aguilar Chunga, Y. A., Ccalla Chusho, J. A., & Salinas Romero, M. E. (2026). Transformative Urban Resilience and Collaborative Participation in Public Spaces: A Systematic Review of Theoretical and Methodological Insights. Urban Science, 10(1), 51. https://doi.org/10.3390/urbansci10010051

Cruz, N., & Pulumbarit, C. (2023). Building Back Better After Disasters: Enhancing Community Resilience Through In-City Resettlement in Valenzuela City, Philippines. *Climate Disaster and Development Journal*. https://doi.org/10.18783/cddj.v005.i02.a01

D'Ottaviano, C., & Bossuyt, D. M. (2024). Vertical incremental housing in São Paulo. The case of Minha Casa Minha Vida – Entidades. *International Journal of Housing Policy*, 1–26. https://doi.org/10.1080/19491247.2024.2308716

Davis, M. (2006). *Planet of Slums*. Verso.

Diana, L., Sommese, F., Ausiello, G., & Polverino, F. (2024). New Green Spaces for Urban Areas: A Resilient Opportunity for Urban Health. In A. Cheshmehzangi, M. Sedrez, H. Zhao, T. Li, T. Heath, & A. Dawodu (Eds.), *Resilience vs Pandemics: Innovations in Public Places and Buildings* (pp. 37–53). Springer Nature. https://doi.org/10.1007/978-981-99-8672-9_3

Druta, O., & Fatemidokhtcharook, M. (2024). Flex-housing and the advent of the 'spoedzoeker' in Dutch housing policy. *International Journal of Housing Policy*, *24*(4), 737–754. https://doi.org/10.1080/19491247.2023.2267834

Engelsman, U., Rowe, M., & Southern, A. (2016). Community Land Trusts, affordable housing and community organising in low-income neighbourhoods. *International Journal of Housing Policy*, 1–21. https://doi.org/10.1080/14616718.2016.1198082

Escorcia Hernández, J. R., Torabi Moghadam, S., Sharifi, A., & Lombardi, P. (2023). Cities in the times of COVID-19: Trends, impacts, and challenges for urban sustainability and resilience. *Journal of Cleaner Production*, *432*, 139735. https://doi.org/10.1016/j.jclepro.2023.139735

Farhan, B. Y. (2024). Canada's leadership and housing affordability: Evidence from the Canadian real estate market. *Journal of Urban Management*, *13*(1), 52–61. https://doi.org/10.1016/j.jum.2023.11.001

Farhanrika, N., Sarpono, S., Kusuma, K., & Widodo, P. (2023). Advancing Resilience and Fostering Sustainable Development through Strategic Investments in Cutting-Edge Technology and Innovative Methodologies for Disaster Risk Reduction: Japan Experiences. *International Journal Of Humanities Education and Social Sciences (IJHESS)*, *3*. https://doi.org/10.55227/ijhess.v3i1.589

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. *Ecology and Society*, *15*(4). https://www.jstor.org/stable/26268226

Gil, O., Cortés-Cediel, M., & Cantador, I. (2019). Citizen Participation and the Rise of Digital Media Platforms in Smart Governance and Smart Cities. *International Journal of E-Planning Research*, *8*, 19–34. https://doi.org/10.4018/IJEPR.2019010102

Gupta, K. (2023). Pradhan Mantri Jan Dhan Yojana: History and Present Impact. *South Asian Journal of Social Studies and Economics*, *19*, 21–27. https://doi.org/10.9734/sajsse/2023/v19i2674

Hasan, M. Z., Rabbani, M. G., Ahmed, M. W., Mehdi, G. G., Tisha, K. I., Reidpath, D. D., Hanifi, S. M. A., & Mahmood, S. S. (2024). Assessment of socioeconomic and health vulnerability among urban slum dwellers in Bangladesh: A cross-sectional study. *BMC Public Health*, *24*(1), 2946. https://doi.org/10.1186/s12889-024-20425-9

Hasan, S., Saeed, S., Panigrahi, R., & Choudhary, P. (2019). Zika Virus: A Global Public Health Menace: A Comprehensive Update. *Journal of International Society of Preventive and Community Dentistry*, *9*(4), 316. https://doi.org/10.4103/jispcd.JISPCD_433_18

Heydari, A., & Abbasianjahromi, H. (2024). Evaluating the resilience of residential buildings during a pandemic with a sustainable construction approach. *Heliyon*, *10*(10). https://doi.org/10.1016/j.heliyon.2024.e31006

Holling, C. S. (1973). Resilience and Stability of Ecological Systems. *Annual Review of Ecology and Systematics*, *4*, 1–23.

Huchzermeyer, M. (2023). NGO Representation of Informal Settlements: The Case of Slum/Shack Dwellers International (SDI). In A. Mayne (Ed.), *The Oxford Handbook of the Modern Slum* (p. 0). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190879457.013.26

Hussainzad, E. A., & Gou, Z. (2024). Climate Risk and Vulnerability Assessment in Informal Settlements of the Global South: A Critical Review. *Land*, *13*(9), Article 9. https://doi.org/10.3390/land13091357

Isik-Ercan, Z., Lu, H.-T., Edwards, N. M., Fall, M., & Sebti, L. (2024). Social experiences, life satisfaction, and social support of immigrant families with young children in a highly urban city. *Early Child Development and Care*, *194*(9–10), 962–976. https://doi.org/10.1080/03004430.2024.2391884

Jilani, T. N., Jamil, R. T., Nguyen, A. D., & Siddiqui, A. H. (2025). H1N1 Influenza. In *StatPearls*. StatPearls Publishing. http://www.ncbi.nlm.nih.gov/books/NBK513241/

Juhila, K., Raitakari, S., & Ranta, J. (2022). Housing First: Combatting Long-Term Homelessness in Finland. In C. de la Porte, G. B. Eydal, J. Kauko, D. Nohrstedt, P. 't Hart, & B. S. Tranøy (Eds.), *Successful Public Policy in the Nordic Countries: Cases, Lessons, Challenges* (p. 0). Oxford University Press. https://doi.org/10.1093/oso/9780192856296.003.0024

Kamalipour, Hesam & Dovey, Kim. (2020). Incremental production of urban space: A typology of informal design. Habitat International. 98. 102133. 10.1016/j.habitatint.2020.102133.

Kapucu, N., Ge, Y., Rott, E., & Isgandar, H. (2024). Urban resilience: Multidimensional perspectives, challenges and prospects for future research. *Urban Governance*, *4*(3), 162–179. https://doi.org/10.1016/j.ugj.2024.09.003

Kates, R., Colten, C., Laska, S., & Leatherman, S. (2006). Reconstruction of New Orleans After Hurricane Katrina: A Research Perspective. *Proceedings of the National Academy of Sciences of the United States of America*, *103*, 14653–14660. https://doi.org/10.1073/pnas.0605726103

Kozlowski, M., Wooi, L., Kamal, M., Ishak, S., & Zaharin, K. (2021). The impact of COVID-19 on the cities in

Malaysia: Creating a pandemic resilient urban environment. *Architecture Malaysia*, *4*(33(4)). https://www.pam.org.my/images/publications/am2021/33-4/AM33.4.pdf

Kufeoglu, Sinan. (2022). SDG-11: Sustainable Cities and Communities. 10.1007/978-3-031-07127-0_13.

Kurniasari, Permata & Gabe, Rossa & Adianto, Joko. (2019). Spatial extension as a housing strategy in Kampung Kota : A case study from Kampung Kingkit, central Jakarta. IOP Conference Series: Materials Science and Engineering. 523. 012049. 10.1088/1757-899X/523/1/012049.

Lak, A., Shakouri Asl, S., & Maher, A. (2020). Resilient urban form to pandemics: Lessons from COVID-19. Medical journal of the Islamic Republic of Iran, 34, 71. https://doi.org/10.34171/mjiri.34.71

Lang, R., & Roessl, D. (2013). The Governance of Co-operative Housing: Current Challenges and Future Perspectives. *The International Journal of Co-Operative Management*, *6*, 8–12.

Lin, B. C., & Lee, C. H. (2024). Assessing the efficacy of adaptive capacity-building strategies in earthquake-prone communities. *Geomatics, Natural Hazards and Risk*, *15*(1), 2380908. https://doi.org/10.1080/19475705.2024.2380908

Liu, Y. (2023). Analysis of the Vertical Forest of Milan in Terms of High-Rise Architecture and Biodiversity. *Highlights in Art and Design*, *3*, 47–52. https://doi.org/10.54097/hiaad.v3i2.10043

Madhav, N., Oppenheim, B., Gallivan, M., Mulembakani, P., Rubin, E., & Wolfe, N. (2017). *Pandemics: Risks, Impacts, and Mitigation* (pp. 315–345). https://doi.org/10.1596/978-1-4648-0527-1_ch17

Maravalle, A., Sánchez, A. C., & González, A. (2024). Improving housing and urban development policies in Mexico. *OECD Economics Department Working Papers*. https://doi.org/10.1787/c2229c19-en

Mota, N. (2021). Incremental Housing: A Short History of an Idea. In *The New Urban Condition*. Routledge.

Mrani, R., Radoine, H., Chenal, J., & Kamana, A. (2025). Trends, Methods, Drivers, and Impacts of Housing Informalities (HI): A Systematic Literature Review. Urban Science, 9(4), 101. https://doi.org/10.3390/urbansci9040101

Nawaz, F., Al Ammary, O., & Sadiq, M. (2021). GRAMEEN Bank Promoting Women Employment under Social Entrepreneurship Model in Bangladesh. *Academy of Strategic Management Journal*.

Nicola, M., Alsafi, Z., Sohrabi, C., Kerwan, A., Al-Jabir, A., Iosifidis, C., Agha, M., & Agha, R. (2020). The Socio-Economic Implications of the Coronavirus and COVID-19 Pandemic: A Review. *International Journal of Surgery*, *78*. https://doi.org/10.1016/j.ijsu.2020.04.018

Ostrom, E. (2009). A General Framework for Analyzing Sustainability of Social-Ecological Systems. *Science*, *325*(5939), 419–422. https://doi.org/10.1126/science.1172133

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., … Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

Partelow, S. (2018). A review of the social-ecological systems framework: Applications, methods, modifications, and challenges. *Ecology and Society*, *23*. https://doi.org/10.5751/ES-10594-230436

Patel, S. S., Rogers, M. B., Amlôt, R., & Rubin, G. J. (2017). What Do We Mean by "Community Resilience"? A Systematic Literature Review of How It Is Defined in the Literature. *PLoS Currents*, *9*, ecurrents.dis.db775aff25efc5ac4f0660ad9c9f7db2. https://doi.org/10.1371/currents.dis.db775aff25efc5ac4f0660ad9c9f7db2

Patience, C., & Apaokueze, T. (2024). The Impact of Smart Home Technologies on Energy Efficiency, Cost Savings, and Environmental Benefits. *Journal of Energy Engineering and Thermodynamics*, *4*, 21–32. https://doi.org/10.55529/jeet.44.21.32

Pelsmakers, S., & Warwick, E. (2022). Housing adaptability: New research, emerging practices and challenges. *Buildings & Cities*, *3*(1). https://doi.org/10.5334/bc.266

Petkova, E., Beedasy, J., Oh, E., Sury, J., Sehnert, E., Tsai, W.-Y., & Reilly, M. (2017). Long-term Recovery From Hurricane Sandy: Evidence From a Survey in New York City. *Disaster Medicine and Public Health Preparedness*, *12*, 1–4. https://doi.org/10.1017/dmp.2017.57

Piret, J., & Boivin, G. (2021). Pandemics Throughout History. *Frontiers in Microbiology*, *11*. https://doi.org/10.3389/fmicb.2020.631736

Pyles, L. (2015). *Disaster Recovery in Post-Earthquake Rural Haiti: Research Findings and Recommendations for Participatory, Sustainable Recovery*. https://doi.org/10.13140/RG.2.1.2491.6320

Ramalhete, I., Amado, M., & Farias, H. (2015). Low cost adaptive housing model. *International Journal for Housing Science and Its Applications*, *39*, 181–192.

Salinger, A. P., Charles, I., Francis, N., Batagol, B., Meo-Sewabu, L., Nasir, S., Bass, A., Habsji, H., Malumu, L., Marzaman, L., Prescott, M. F., Jane Sawailau, M., Syamsu, S., Taruc, R. R., Tela, A., Vakarewa, I., Wilson, A., Sinharoy, S. S., & RISE Consortium (2024). "People are now working together for a common good": The

effect on social capital of participatory design for community-level sanitation infrastructure in urban informal settlements. World development, 174, 106449. https://doi.org/10.1016/j.worlddev.2023.106449

Salmanian, M & Ujang, N. (2021). EMERGING NEED FOR MICRO-CLIMATIC CONSIDERATIONS IN URBAN DESIGN PROCESS: A REVIEW. *Jurnal Teknologi (Sciences & Engineering)*, *84*(1), 129-148. https://doi.org/10.11113/jurnalteknologi.v84.15111

Salmanian, M., Mousavi, M. ., Nasirimehr, P. ., Takhmiri, H. ., Binti Ujang, N. ., Fairuz Shahidan, M. ., & Binti Dahlan, N. D. . (2024). EXAMINING THE INFLUENCE OF URBAN FORM ON THE THERMAL COMFORT OF STREET CANYONS IN TEHRAN: A CASE STUDY OF NARMAK NEIGHBOURHOOD. *Journal of Architecture, Planning and Construction Management*, *14*(1). https://doi.org/10.31436/japcm.v14i1.862

Salmanian, Mohammadhassan, and Akram Bayat. 2023. "Urban Heat Island: A Primary Guide for Urban Designers". Future Energy 2 (4):10-23. https://fupubco.com/fuen/article/view/72.

Sato, S. N., Condes Moreno, E., Rubio-Zarapuz, A., Dalamitros, A. A., Yañez-Sepulveda, R., Tornero-Aguilera, J. F., & Clemente-Suárez, V. J. (2023). Navigating the New Normal: Adapting Online and Distance Learning in the Post-Pandemic Era. *Education Sciences*, *14*(1), Article 1. https://doi.org/10.3390/educsci14010019

Sharma, M., Joshi, S., Kannan, D., Govindan, K., Singh, R., & Purohit, H. C. (2020). Internet of Things (IoT) adoption barriers of smart cities' waste management: An Indian context. *Journal of Cleaner Production*, *270*, 122047. https://doi.org/10.1016/j.jclepro.2020.122047

Song, J. (2022). Key Points in Planning and Design of Residential Communities Based on All-age Communities. *BCP Business & Management*, *33*, 109–115. https://doi.org/10.54691/bcpbm.v33i.2725

Toyoda, Yusuke. (2021). Survey paper: achievements and perspectives of community resilience approaches to societal systems. Asia-Pacific Journal of Regional Science. 5. 10.1007/s41685-021-00202-x.

UN-Habitat. (2012). Sustainable housing for sustainable cities: A policy framework for developing countries. *UN-Habitat*. https://unhabitat.org/sites/default/files/download-manager-files/Sustainable%20Housing%20for%20Sustainable%20Cities.pdf

UN-Habitat. (2022). Our city plans: An incremental and participatory toolbox for urban planning. *United Nations Human Settlements Programme*. https://unhabitat.org/our-city-plans-an-incremental-and-participatory-toolbox-for-urban-planning

UN-Habitat. (2024). World Cities Report 2024: The future of cities. *United Nations Human Settlements Programme*.

United Nations. (2023). World urbanization prospects: The 2023 revision. *United Nations Department of Economic and Social Affairs*.

Varshney, K., Glodjo, T., & Adalbert, J. (2022). Overcrowded housing increases risk for COVID-19 mortality: an ecological study. BMC research notes, 15(1), 126. https://doi.org/10.1186/s13104-022-06015-1

Wade, L. (2020). An unequal blow. *Science*, *368*(6492), 700–703. https://doi.org/10.1126/science.368.6492.700

Wang, R., & Balachandran, S. (2021). Inclusionary housing in the United States: Dynamics of local policy and outcomes in diverse markets. *Housing Studies*, *38*(6), 1068–1087. https://doi.org/10.1080/02673037.2021.1929863

Watt, H., Davison, B., Hodgson, P., Kitching, C., & Densley Tingley, D. (2023). What should an adaptable building look like? *Resources, Conservation & Recycling Advances*, *18*, 200158. https://doi.org/10.1016/j.rcradv.2023.200158

WHO. (2020). *Coronavirus disease (COVID-19) pandemic*. World Health Organization. https://www.who.int/emergencies/diseases/novel-coronavirus-2019

WHO. (2023). WHO coronavirus (COVID-19) dashboard. *World Health Organization*.

World Bank. (2023). Urban population growth (annual %). *World Development Indicators.* https://databank.worldbank.org

Yadav, V., & Yadav, N. (2024). Beyond Sustainability, Toward Resilience, and Regeneration: An Integrative Framework for Archetypes of Regenerative Innovation. *Global Journal of Flexible Systems Management*, *25*(4), 849–879. https://doi.org/10.1007/s40171-024-00418-8

Živković, M., Stamenković, M., & Petrović, V. (2021). Towards flexible housing: Basic design principles. *Facta Universitatis - Series: Architectur*

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ABSTRACT

This study investigates the relationship between the widely used Koppen-Trewatha-Horn (KTH) climate classification system of Nigeria and daylighting performance. It assesses the suitability of existing climate zones for assessing daylighting effectiveness through Climate-Based Daylight Modelling (CBDM) in test classrooms at 24 locations across the country. Data analysis using both supervised (Chi-square goodness-of-fit) and unsupervised (hierarchical clustering) statistical tests reveals a marked difference between the traditional climate zones and the empirically derived daylighting zones. The research provides new, evidence-based daytime zone maps for Nigeria using daylighting metrics such as Daylight Autonomy (DA), Useful Daylight Illuminance (UDI), and Daylight Uniformity Index (DAUI). The results indicate that the best-fit daylighting zones do not align with the conventional climate zone limits, suggesting that expert daylighting classification schemes should be employed in architectural design practices. The research forms the basis for the design of Nigerian and other tropical region-specific daylighting design guidelines.

Keywords: Daylighting zones, Koppen-Trewatha-Horn classification, Climate-based daylight modelling, Nigeria, Fenestration design

1.0 INTRODUCTION

Daylighting is the intentional introduction of natural light into buildings to provide functional and aesthetic advantages. Daylighting enhances people's health and productivity, improves energy efficiency, and supports sustainability, making it worthwhile to maximise the utilisation of natural light in buildings (Boubekri, 2008; Shishegar & Boubekri, 2016; Heschong, 2002; Kousalyadevi & Lavanya, 2019; Guzowski, 1999). This aspect is highly crucial in tropical regions like Nigeria, where unmanaged excessive sunlight exposure can cause overheating and glare.

Contemporary daylighting encompasses several key parameters, including available daylight, sky conditions, interior daylighting computations, glare analysis, user preferences, and window technology (Phillips, 2012; Tregenza & Mardaljevic, 2018). The two primary factors at the outset, daylight availability and sky type, depend largely on regional climate, suggesting a possible relationship between climate classification and the effectiveness of daylighting.

Effective daylighting prediction is now a computationally intensive area that requires computational capacity, facilities, time, and funding. Sadly, most architectural professionals cannot perform effective daylighting analyses, particularly in the early design phases. The classical "daylight factor" specification (a minimum of 2%) has been found wanting, especially in the tropics, as it was designed for overcast-sky conditions that prevail in northern latitudes. In response to this, more advanced methods, such as Climate-Based Daylight Modelling (CBDM), have evolved to deliver climate-specific, more precise daylight predictions. However, these methods are generally too sophisticated for most practising architects (Mardaljevic, 2015; Dubois et al., 2025).

In response to this challenge, the lighting and building design community has increasingly accepted the need for simple-to-use, regionally oriented daylighting guidance (Ander, 1995). Certain countries have encouraged the creation of regionally based daylighting zones aligned with their climatic conditions, which will be addressed in the literature review section. The initiatives suggest that regionally adapted daylighting zones could offer architects simple-to-use design parameters that take into consideration local conditions.

Nigeria, with its diverse geography that encompasses various climates, presents a strong case study for determining whether traditional climate classification schemes can reliably predict daylighting performance. The Koppen-Trewatha-Horn (KTH) climatic classification, chosen on the basis that it is the widest system employed for the description of Nigeria's climate (Ayoade, 1993), has three distinct climate types: hot semi-arid in the northern region, tropical wet and dry in the central zone, and tropical wet in the southern part of the country. Given the diversity of these climate categories, this research seeks to establish whether these classifications can effectively predict daylighting performance in Nigeria.

Despite the extensive worldwide literature on daylighting zones, the gap in research on the classification of comparable categories is enormous in the Nigerian context. The foundation of this study is the authors' previous work, conducted in Zaria, Nigeria, to optimise fenestration for daylight, which assisted in the development of prototype models for this research (Salisu, 2015).

Statistical tools of supervised and unsupervised learning are applied in this paper. Supervised learning methods are predictive inferential statistical methods, such as regression, correlation, and hypothesis tests. Unsupervised learning methods focus on discovering meaningful patterns and subgroups in data, with prediction not a goal. The method provides exploratory research with a valuable tool (James et al., 2013), allowing the detection of subgroups with similar characteristics and providing opportunities for data interpretation and theory construction.

1.1 Aim and Objectives

This research aims to generate daylight zones with equivalent daylight availability under the Koppen-Trewatha and Horn climate classifications using computer simulation and daylighting evaluation indicators. The objectives are as follows:

i. To determine whether the Koppen-Trewatha and Horn climate classifications for Nigeria can be used as a daylighting zone map.
ii. To establish empirically based daylighting zones for Nigeria by utilising Climate-Based Daylight Modelling (CBDM) simulation data through hierarchical cluster analysis.

1.2 Research Hypotheses

The null hypothesis (H_o) states that the distribution of towns across the KTH climate zones does not differ significantly from their distribution within the empirically established daylighting zones.

H_o: ρA (Towns in KTH Climate zones) = ρB (Towns in Daylighting zones)
The alternative hypothesis (H_1) is that the two are not similar in locations:
H_1: ρA (Towns in KTH Climate zones) ≠ ρB (Towns in Daylighting zones)

2.0 LITERATURE REVIEW

2.1 Daylighting Zones Internationally

Daylighting researchers and designers have been busy predicting and examining the quantity and quality of daylighting in relation to climate characteristics and climate zones internationally. The use of climate zones has been inextricably linked with climate files as a point of departure for daylighting design concepts.

i. **United States:** The American Architectural Manufacturers Association Skylight Handbook – Design Guidelines (SHDB-1) has divided the US into six daylight-availability zones, with a representative trial skylight design for each city, varied by climate for cooling (Ander, 1995).
ii. **Europe:** A European daylight standard has been proposed based on eight European climates, from the south of Europe (Madrid, Spain) to the northernmost part of North (Ostersund, Sweden) (Mardaljevic et al., 2013).

iii. **ASHRAE Standards:** In examining the daylighting requirements in ASHRAE Standard 90.1, six climate locations were selected to represent a combination of ASHRAE climate zones and three sky types to study. These three sky types were categorised into sky-type A with a mean annual sunshine percentage greater than 75%, sky-type B between 45%-75%, and sky-type C, less than 45% (Athalye et al., 2013).

iv. **North America:** Five daylight zones in North America were proposed in 2014 by Reinhart, based on similarities between daylight autonomy distributions in offices derived from simulations conducted using a climate-based daylight modelling methodology (Reinhart, 2014). This was corroborated by subjective occupant perceptions for students in 11 schools of architecture.

v. **China:** Five light-climate zones according to the 'Standard for Daylighting Design of Buildings' published by the Ministry of Housing and Urban-Rural Development of the People's Republic of China (Guan & Yan, 2016)

Given that daylighting zones are the unifying element of these global proposals, design professionals will likely develop fewer complex methods to derive daylighting design parameters from climate for different building types, such as schools, offices, and factories. Inappropriateness of prevalent climate classification systems for daylighting may have led to the creation of daylight-specific daylighting regions.

2.2 Climate Classification Systems

Climate is a process comprising climatic and non-climatic factors (topography, soil cover, human activities, etc.), with temperature and precipitation most commonly used to define it (Ayoade, 1993). Different climate classification systems are available, depending on specific needs, yet the Köppen-Geiger and Trewartha climate classification systems are the most widely accepted (Ayoade, 1993). This plan in effect connects the vegetation of a region to its climate and temperature, as well as its seasonal characteristics.

2.3 Climate Context of Nigeria

Nigeria is a 36-state country with a combined area of 910,770 km² and a population of more than 235 million as of 2024 (Obokoh & Obokoh, 2024). Nigeria has three climate types based on the Köppen-Geiger and Trewartha classification, as shown in Fig. 1.

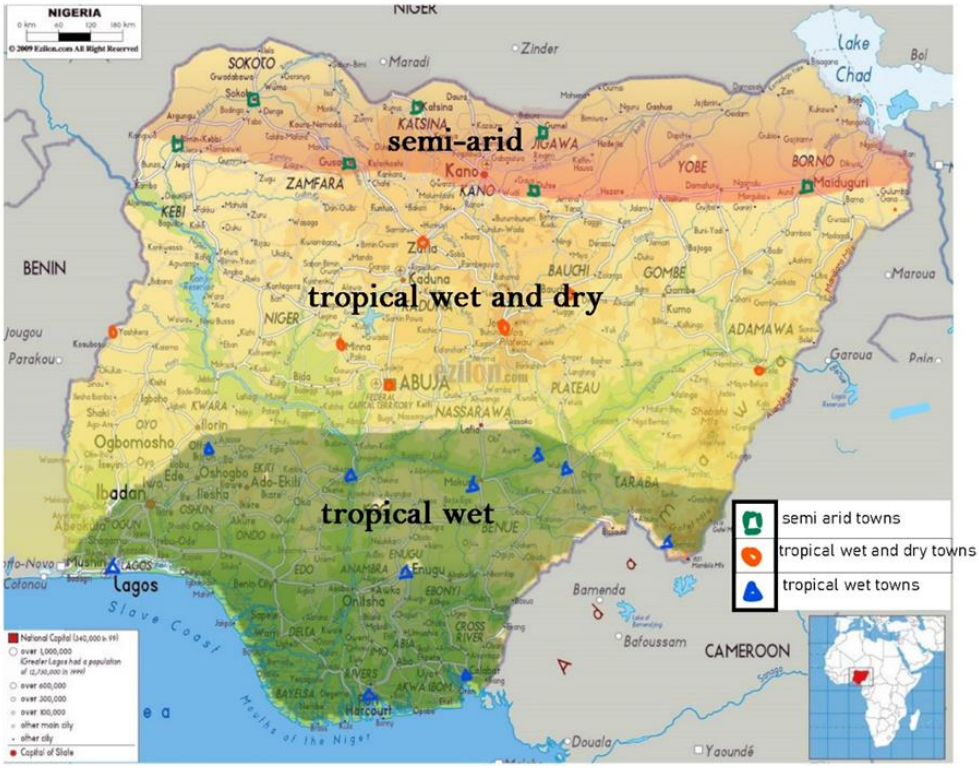

Fig. 1: Map of Nigeria showing the Three Climate Zones according to the Koppen-Trewatha-Horn classification scheme. (Source: Salisu, 2015).

i. **Hot** Semi-Arid: This region experiences clear skies and dryness for most of the year, receiving 250 to 750 mm of rainfall annually. The temperature fluctuates significantly between day (reaching as much as 44°C) and night (dropping to as little as 12°C).
ii. **Tropical Wet and Dry:** Annual rainfall in this zone is 1000-1500 mm for six months with a well-defined dry season. Monthly mean temperatures can reach as high as 40°C during the dry season.
iii. **Tropical Wet:** Southern Nigeria has an area that receives heavy rainfalls totalling 2000-4000 mm per year, along with high cloud cover and many overcast days from the middle areas to the coast.

2.4 Daylighting Assessment Metrics

Climate-Based Daylight Modelling (CBDM) has been established as the benchmark for daylighting assessment, using climate- and location-based parameters. Research scientists have suggested a multifaceted assessment on a climate- and location-based basis, incorporating climate change variables. This, along with user assessments, has aided in fulfilling various assessment metrics for Daylight Autonomy (DA), Useful Daylight Illuminances (UDIs), and Spatial Daylight Autonomy (sDA) over the last one and a half decades (Reinhart et al., 2006).

These assessment metrics have helped researchers but have not been particularly 'useful' to design professionals due to their complexity (Dubois, 2020; Tregenza & Mardaljevic, 2018). Additionally, some people's assumptions have been questioned (Brembilla & Mardaljevic, 2019), especially regarding different locations on Earth and users' adjustments to daylight illuminance and glare limits. In some locations, absolute illuminance cut-off levels might be more crucial than daylight distribution. In contrast, in other locations, daylight distribution (bearing on contrast and thus visibility) might be more important.

Consequently, rather than applying the most recently suggested sDA measures of the IESNA (Illuminating Engineering Society of North America), four measures are applied in this paper. The first DA of 500 lux was suggested by Zack Rogers of Architectural Energy Corporation in 2006 (Reinhart et al., 2006), and the $UDI_{100-2000}$ suggested by Nabil and Mardaljevic (2005) for daylight quantities. For daylight quality, UDI illuminance greater than 2000 lux and DA Uniformity distribution index (introduced due to the bilateral opposite or corner-wall windows characteristic of the tropics, especially classrooms). These performance requirements are discussed below:

i. **Daylight Autonomy (DA):** For a specified work plane (in this case, 750mm above floor level), it is the percentage of the year for which a minimum target is met by daylight alone. Typically, a DA of 60% of the work plane illuminance (500 lux) is acceptable daylighting, especially for classrooms.
ii. **Useful Daylight Illuminance of 100 to 2000 lux ($UDI_{100-2000}$):** At a specified work plane as described earlier, means useful daylight, and according to the British Society of Light and Lighting, a room that reaches a criterion value of 80% in this measure can be said to be successfully lighted (Society of Light and Lighting, 2011).
iii. **Excessive Daylight Illuminance in excess of 2000 lux ($UDI_{>2000}$):** At a specific work plane, as discussed earlier, is an excess of daylight that may produce visual distraction, solar gains, and thermal discomfort (Nabil & Mardaljevic, 2005).
iv. **Daylight Uniformity Index (DAUI):** For a specified work plane, it is the ratio of the maximum Daylight Autonomy to the average Daylight Autonomy of an area, which is unitless. The closer this value is to '1', the more uniform the daylight is distributed in the area. It is used for comparative tests with no cut-off point.

From the analysis above, there is a natural correlation between daylighting and climate zones; however, the link between traditional climate classifications and the amount of daylight available is complex, as highlighted by the varied zone-specific methodologies implemented globally. Importantly, the studies examined share a common drawback: they presuppose, rather than test empirically, the appropriateness of using climate classification systems as indicators for daylighting zone delineation. None has used CBDM to directly assess whether a country's existing climate zones can predict daylighting performance across its region. This deficiency is particularly prominent in sub-Saharan Africa, where there is currently no daylighting zone mapping based on CBDM. The current study tackles this deficiency by empirically examining the relationship between Nigeria's KTH climate zones and daylighting performance data derived from simulations.

2.5 Prototype Classroom Designs

Two virtual classroom designs were created from common configurations present in public secondary schools in Nigeria. These forms were also optimised for orientation, sun shading, and light redirection, suggesting their shared use within a tropical setting (Salisu, 2015). The models in Fig. 2 and Fig. 3 feature both glazed and unglazed window forms and measure 10,500 mm in length, 7,200 mm in width, and 3,000 mm in floor-to-ceiling height. They are to be utilised where there is no artificial light and operate between 8 a.m. and 6 p.m. on weekdays for students aged 6 to 14. Daylight readings were conducted at the floor height of 750 mm, and material photometric reflectance values were: 0.502 for walls, 0.302 for floors, 0.8 for ceilings, and 0.70 for desks and chairs.

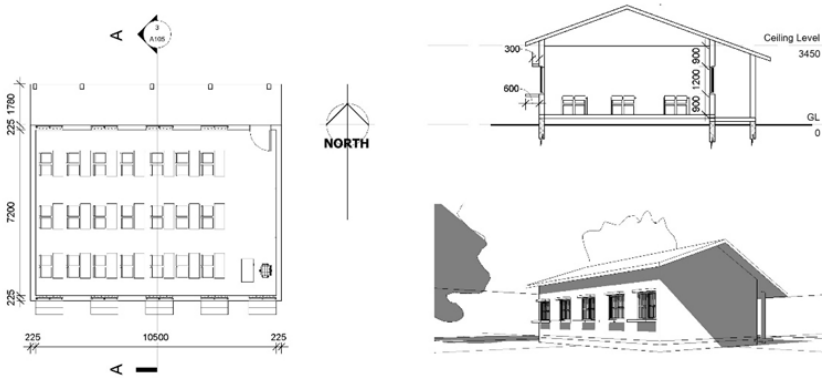

Fig. 2: Prototype Classroom Design 1 (glazed variant)
(Source: Salisu, 2015).

The prototype classroom features 3 mm single-glazed casement windows with a transmittance rate of 0.722. The Window-to-Wall Ratios (WWRs) were modified from a non-veranda window area of 7.80 m² (WWR of 24.76%) to a veranda window area of 6.24 m² (WWR of 19.81%), which is typical for public schools in Nigeria. On the non-veranda side, this design includes daylighting components such as a horizontal concrete sunshade measuring 300 mm × 1200 mm × 100 mm and a light shelf that extends 6000 mm, located beneath the windows, while a sloped roof over the veranda provides shade on that side.

The unglazed prototype classroom, on the other hand, features tropical steel casement windows with 2 mm thick panels and a surface reflectance of 0.755. The window areas have been slightly reduced, with a non-veranda window area measuring 7.20 m² (WWR of 22.86%) and a veranda window area measuring 5.76 m² (WWR of 18.29%). On the side without the veranda, a horizontal concrete sunshade (300 mm × 1200 mm × 100 mm) provides shading. Both room configurations share a consistent sill height of 900 mm and include burglar-proofing.

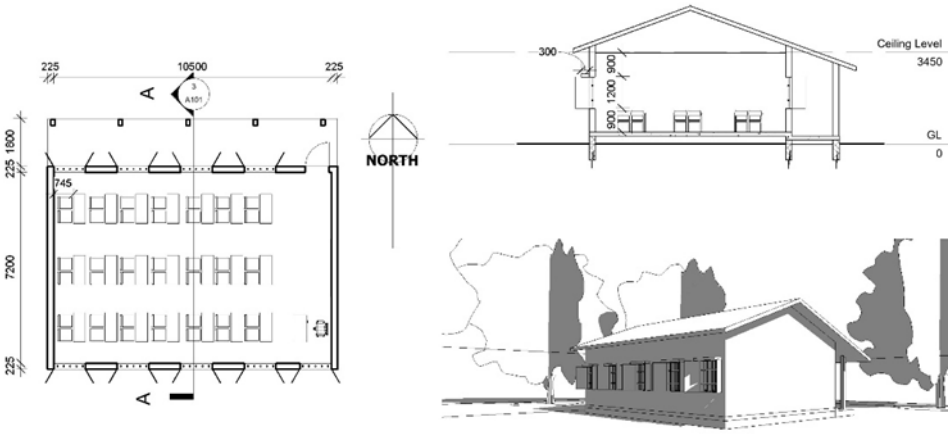

Fig. 3: Prototype Classroom Design 2 (unglazed variant)
(Source: Salisu, 2015).

3.0 METHODOLOGY

A post-positivist worldview was employed (Creswell & Creswell, 2018), with the assumption that location and climate significantly influence daylight provision. Data are collected to test the hypothesis that the Koppen-Trewatha-Horn climate classification schemes determine daylighting zones, and, where necessary, revisions and further testing would be performed. Quantitative research was used to follow the daylighting parameters of DA, UDIs, and DAUI to twenty-four (24) locations in the nation's three climate zones. Hierarchical clustering within clusters was used to establish the similarity and best fit of clusters in the sample locations.

3.1 Study Population and Sampling

The population under study comprises Nigerian towns lying between latitudes 4° and 14°N and longitudes 2° and 15°E across the three climate zones of the Koppen-Trewatha-Horn classification. Stratified sampling across the zones, as well as longitudinal factors, were applied in the choice of locations as follows:

i. Hot Semi-Arid zone (7 locations): Birnin-Kebbi, Sokoto, Gusau, Katsina, Gumel, Dutse, Maiduguri
ii. Tropical Wet and Dry (7 sites): Yashikera, Minna, Abuja, Zaria, Jos, Bauchi, Yola
iii. Tropical Wet (10 sites): Lagos, Offa, Lokoja, Port-Harcourt, Enugu, Makurdi, Calabar, Tunga, Wukari, Gembu

Ten locations were selected for the Tropical Wet zone, taking into account the hill country of Taraba and Plateau States. They were to provide a satisfactory stratified sample for testing glazed and unglazed fenestrations in the zones.

3.2 Research Design

The research adopted a quantitative design with an exploratory sequential approach. Phase one determined whether a "goodness of fit" existed between the Koppen-Trewatha and Horn climate classifications and daylighting zones derived from K-Means clustering of similarities based on the CBDM metrics for Nigeria's twenty-four selected sites.

The analysis was performed using climate-based daylight modelling (CBDM), a computer simulation technique that accounts for the year-round dynamic behaviour and variability of the tropical skies. The research equipment and techniques employed are given in Table 1.

Table 1: Research Method Schedule

Study	Instruments	Issues for Investigation	Statistical Analysis
Assessment of prototype Glazed and Unglazed classrooms in the three climate zones of Nigeria (24 samples)	Climate files Autodesk Ecotect Analysis 2011 IBM SPSS Statistics 21	Daylight Autonomy (DA). Useful Daylight Illuminances ($UDI_{100\text{-}2000}$ &$UDI_{>2000}$). Daylight Uniformity Index (DA_{UI})	*K*-Means clustering for both Glazed and Unglazed sample similarities within groups for *K*=3 based on the three climate zones as shown in Fig. 6. Descriptive maps based on clustering for both Glazed and Unglazed samples.
Comparison of Koppen-Trewatha and Horn Climate classification to both Glazed and Unglazed Daylighting zones from maps developed from Hierarchical clustering.	MS Excel Maps based on *K*=3 cluster sampling Tests	Hypothesis Ho – ρA (Towns in KTH Climate zones) = ρB (Towns in Daylighting zones). Hypothesis Ha –ρA ≠ ρB	Chi Square Test X^2 for test of goodness fit.

4.0 RESULTS

The primary data for CBDM indicators were developed through computer simulation using Autodesk Ecotect Analysis of the two secondary classroom building glazing prototypes at 24 locations across Nigeria, spread across the three climate zones. A K-Means clustering with K = 3, chosen a priori to correlate directly with Nigeria's three KTH climate zones, was analysed using IBM SPSS Statistics 21. This enabled a direct goodness-of-fit comparison between simulation-derived clusters and the traditional climate categorisation. The agglomerative approach and the default SPSS setting of squared Euclidean distance were used for this.

The similarities among the location clusters and their spatial locations are shown in Tables 2 and 3 and Figs. 4 and 5. Even though the recommendations for the glazed and unglazed options are closer together, it is evident that the ranges of locations across the two sets of climate zones and the three daylighting zones (obtained from the cluster analysis) vary. This is illustrated in Table 4.

Table 2: Glazed Illuminance Data and 3-Cluster Classification for the assessed 24 Locations across Nigeria

Town	DA	$UDI_{100-2000}$	$UDI>_{2000}$	DAUI	Cluster
Birnin-Kebbi	34.71	93.30	1.64	2.53	1
Sokoto	37.71	93.18	2.89	2.39	2
Gusau	35.41	95.72	1.61	2.46	2
Katsina	36.70	96.58	1.90	2.42	2
Gumel	38.26	97.05	2.01	2.45	2
Dutse	37.23	96.99	1.75	2.46	2
Maiduguri	38.51	96.74	2.24	2.48	2
Yashikera	33.55	91.04	2.26	2.57	1
Minna	34.22	94.81	1.61	2.64	1
Abuja	35.58	96.03	1.70	2.49	2
Zaria	35.94	97.31	1.57	2.51	2
Jos	32.59	94.67	2.11	2.63	1
Bauchi	37.58	96.67	1.80	2.41	2
Yola	37.72	96.59	2.02	2.52	2
Lagos	29.21	88.70	1.23	2.82	3
Lokoja	30.76	93.53	1.30	2.82	1
Port-Harcourt	27.14	90.52	0.97	3.04	3
Enugu	32.32	89.54	1.14	2.53	1
Makurdi	32.45	95.32	1.26	2.72	1
Calabar	27.92	90.62	1.38	2.92	3
Offa	34.17	96.32	1.41	2.66	1
Wukari	32.82	94.79	1.40	2.72	1
Tunga	35.98	95.96	1.99	2.58	2
Gembu	30.60	93.71	1.35	2.84	1

Table 3: Unglazed Illuminance Data and 3-Cluster Classification for the assessed 24 Locations across Nigeria

Town	DA	$UDI_{100-2000}$	$UDI>_{2000}$	DAUI	Cluster
Birnin-Kebbi	84.94	89.17	7.37	1.13	1
Sokoto	86.65	87.98	9.08	1.11	1
Gusau	87.61	91.10	7.41	1.12	1
Katsina	88.72	91.19	8.03	1.11	1
Gumel	91.59	90.84	8.64	1.08	1
Dutse	90.22	91.14	8.22	1.10	1
Maiduguri	91.61	90.39	8.99	1.08	1
Yashikera	82.03	87.35	8.39	1.15	1
Minna	82.79	91.43	7.45	1.18	2
Abuja	87.12	91.15	7.99	1.13	1

Town	DA	$UDI_{100-2000}$	$UDI_{>2000}$	DAUI	Cluster
Zaria	89.83	91.70	7.52	1.10	1
Jos	85.32	91.17	8.18	1.16	1
Bauchi	90.91	90.89	8.39	1.09	1
Yola	91.65	90.53	8.68	1.08	1
Lagos	73.28	87.76	6.87	1.24	3
Lokoja	79.59	91.38	6.88	1.21	2
Port-Harcourt	71.12	91.32	5.96	1.30	3
Enugu	75.40	89.86	6.31	1.23	3
Makurdi	83.01	91.91	7.17	1.18	2
Calabar	72.20	90.99	6.80	1.32	3
Offa	87.31	91.19	7.99	1.13	1
Wukari	82.69	91.50	7.38	1.18	2
Tunga	88.36	90.93	8.27	1.11	1
Gembu	80.54	91.88	6.81	1.18	2

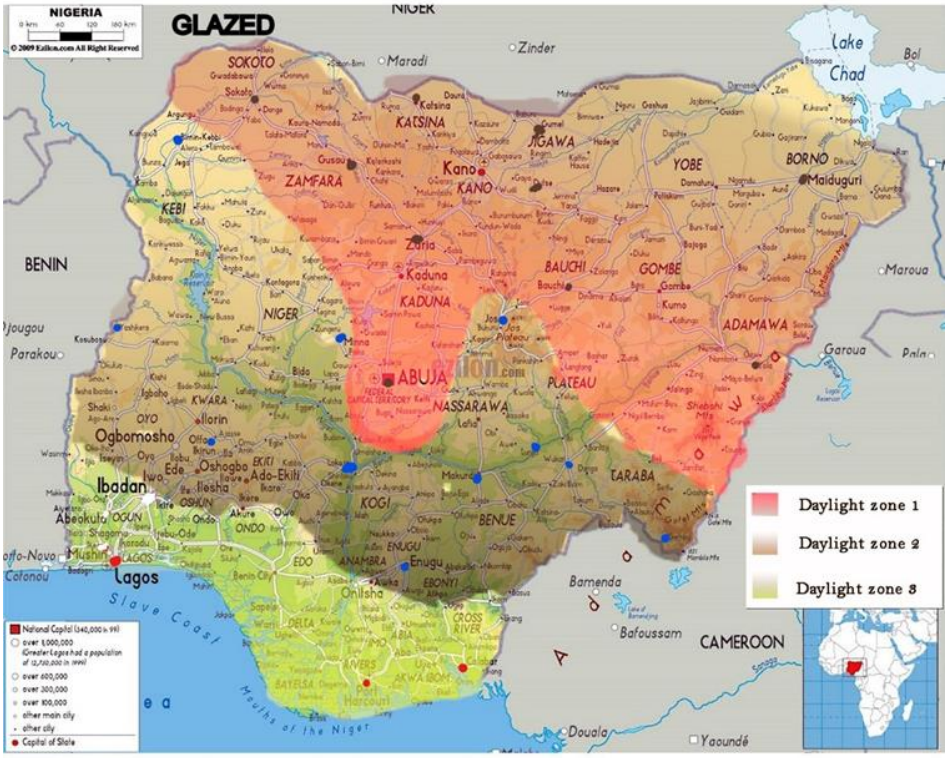

Fig. 4: Map of Nigeria showing the Three Daylighting Zones for Glazed classrooms according to the 3 Cluster classification schemes
(Source: Salisu, 2015).

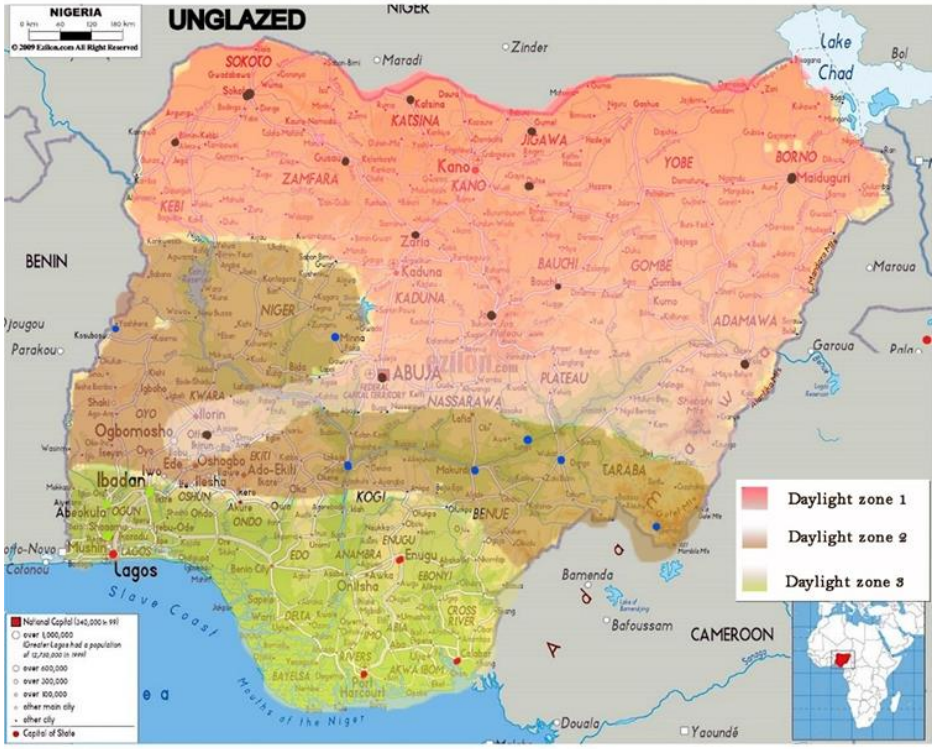

Fig. 5: Map of Nigeria showing the Three Daylighting Zones for Unglazed classrooms according to the 3 Cluster classification schemes
(Source: Salisu, 2015).

Table 4: Distribution of Locations for KTH Climate Zones and Proposed Daylighting Zones (Glazed & Unglazed) based on CBDM for the 24 Locations across Nigeria

Koppen-Trewatha-Horn Climate Zone			Proposed Daylighting Zone from K-Means Clustering, K=3 Analysis	
	Locations	Zone	Glazed: Locations	Unglazed: Locations
1.	7 no. Birnin-Kebbi, Sokoto, Gusau, Katsina, Gumel, Dutse & Maiduguri.	Semi-Arid	Zone 1: 10 no. Sokoto, Gusau, Katsina, Zaria, Abuja, Gumel, Dutse, Bauchi, Maiduguri & Yola.	Zone 1: 14 no. Birnin-Kebbi, Sokoto, Gusau, Katsina, Gumel, Dutse, Maiduguri, Yola, Abuja, Offa, Jos, Bauchi, Zaria & Tunga.
2.	7 no. Yashikera, Minna, Zaria, Abuja, Jos, Bauchi & Yola.	Tropical Wet & Dry	Zone 2: 11 no. Birnin-Kebbi, Yashikera, Offa, Minna, Lokoja, Enugu, Makurdi, Jos, Tunga, Wukari & Gembu.	Zone 2: 6 no. Yashikera, Minna, Lokoja, Makurdi, Wukari & Gembu.
3.	10 no. Lagos, Offa, Lokoja, Port-Harcourt, Enugu, Makurdi, Calabar, Tunga, Wukari & Gembu.	Tropical Wet	Zone 3: 3 no. Lagos, Port-Harcourt & Calabar.	Zone 3: 4 no. Lagos, Port-Harcourt, Enugu & Calabar.

Looking at Figs. 4 and 5 compared with Fig. 1, no visual compatibility is observed within the coastal regions, with 70% of the sites being outside the Tropical Wet zone, and over half of the sites in the semi-arid and tropical wet and dry are not in the relative Daylighting zones 1 and 2.

A Chi-Square Test of Goodness of Fit was applied after verifying its assumptions (the sample was drawn from a stratified selection across the three climate zones and there were more than five observations in each category) to determine if the observed and expected locations of the Climate map of Koppen-Trewatha-Horn and the Daylighting zones map from the 3-cluster analysis, are the same for both Unglazed and Glazed fenestrations groups. A p-value of less than 0.05 indicates grounds to reject the null hypothesis. The null hypothesis of the two types of fenestrations stated that the observed and expected locations are equal, as presented below:

i. H_o - ρA (Towns in KTH Climate zones) = ρB (Towns in Daylighting zones)
ii. Ha - ρA (Towns in KTH Climate zones) ≠ ρB (Towns in Daylighting zones)

The outcome of the Chi-Square test showed a significant difference between the two cases:

i. For glazed fenestrations: $\chi^2 = 19.93$; (df = 2; n = 24) p = .000
ii. For unglazed fenestrations: $\chi^2 = 14.02$; (df = 2; n = 24) p = .001

In both instances, the p-values were below 0.05, and therefore the null hypotheses were rejected. This implies that the KTH climate zones do not adequately represent daylighting zones in Nigeria.

4.1 Hierarchical Clustering Results

After the null hypothesis was rejected, the findings were again fine-tuned to achieve the goal of developing the "Daylighting Zones" map for the country based on CBDM. Hierarchical clustering was used to determine the optimal number of clusters for comparable cases. This was preceded by the agglomerative process, z-scores for normalising the data, and Ward's clustering method to create equal-sized clusters. The findings were as follows:

4.1.1 Glazed System

Based on the agglomeration schedule shown in Table 5, the largest relative distance covered is between stages 22 and 23, and the coefficient of variation is approximately 50%. This indicates that a two-cluster solution is the most stable and interpretable for the glazed classroom data. This is also supported by the dendrogram shown in Fig. 6, where the two dominant clusters are readily distinguishable.

Table 5: Agglomeration Schedule for Glazed Classrooms

Agglomeration Schedule						
Stage	**Cluster Combined**		**Coefficients**	**Stage Cluster First Appears**		**Next Stage**
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	16	24	.007	0	0	18
2	3	10	.061	0	0	8
3	6	13	.121	0	0	5
4	19	22	.200	0	0	11
5	4	6	.297	0	3	13
6	5	14	.406	0	0	7
7	5	7	.601	6	0	12
8	3	11	.869	2	0	13
9	9	21	1.150	0	0	11
10	15	20	1.723	0	0	15
11	9	19	2.317	9	4	18
12	5	23	2.994	7	0	17
13	3	4	3.795	8	5	17
14	1	12	4.886	0	0	16
15	15	17	6.102	10	0	22
16	1	8	7.483	14	0	19
17	3	5	9.486	13	12	21

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
18	9	16	11.952	11	1	20
19	1	18	16.396	16	0	20
20	1	9	23.175	19	18	22
21	2	3	30.083	0	17	23
22	1	15	46.335	20	15	23
23	1	2	92.000	22	21	0

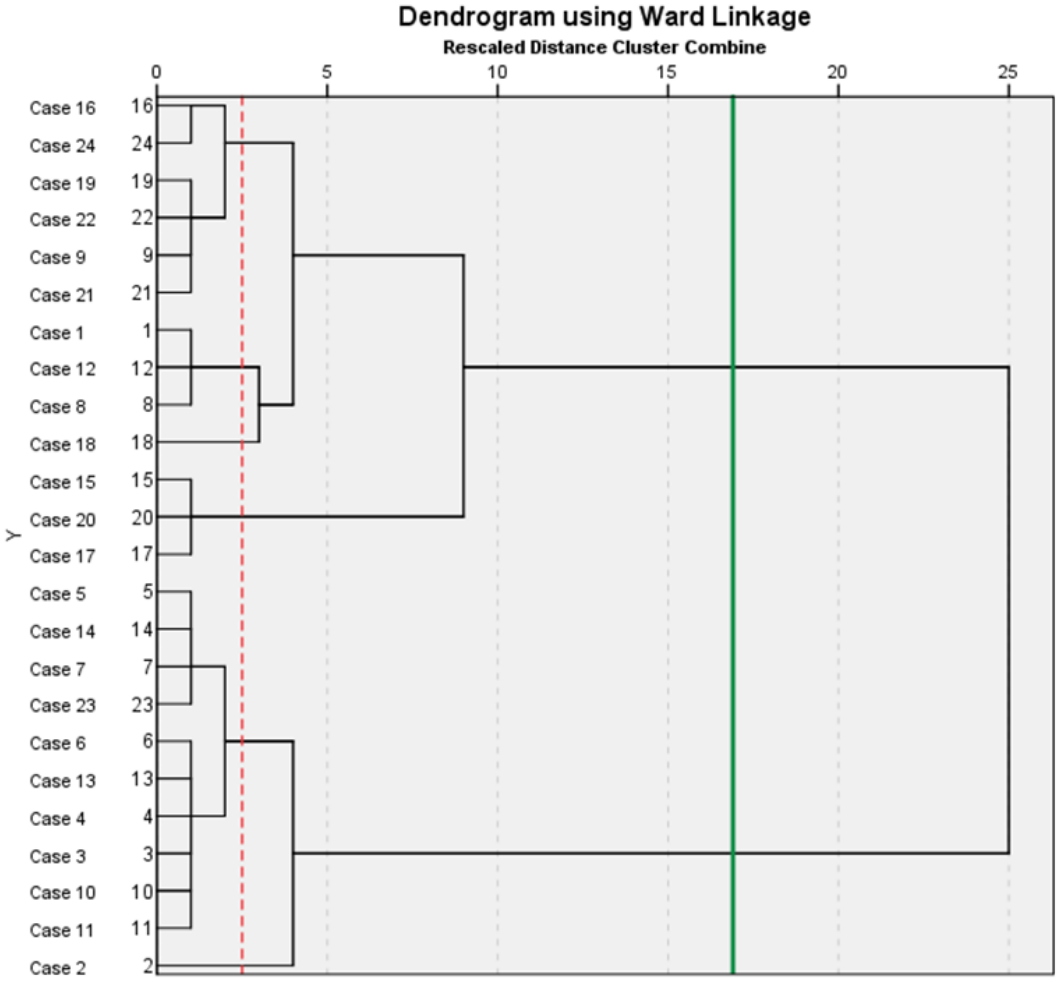

Fig. 6: Dendrogram Plot of Glazed Illuminance Data for 24 Locations showing Cluster relationships. (Source: Salisu, 2015).

4.1.2 Unglazed System

Similarly, the agglomeration schedule in Table 6 of the unglazed system shows the largest relative coefficient difference between stages 22 and 23, once again indicating a two-cluster solution as the most robust and stable. This is further supported by the dendrogram shown in Fig. 7 for the unglazed data.

Table 6: Agglomeration Schedule for Unglazed Classrooms

Agglomeration Schedule						
Stage	Cluster Combined		Coefficients	Stage Cluster First Appears		Next Stage
	Cluster 1	Cluster 2		Cluster 1	Cluster 2	
1	10	21	.001	0	0	8
2	9	22	.006	0	0	6
3	5	14	.037	0	0	7
4	6	13	.094	0	0	13
5	4	23	.157	0	0	8
6	9	19	.297	2	0	14
7	5	7	.436	3	0	13
8	4	10	.614	5	1	11
9	16	24	.806	0	0	14
10	3	11	1.031	0	0	16
11	4	12	1.465	8	0	16
12	17	20	2.063	0	0	20
13	5	6	2.663	7	4	19
14	9	16	3.365	6	9	21
15	2	8	4.276	0	0	18
16	3	4	5.316	10	11	19
17	15	18	6.957	0	0	20
18	1	2	9.666	0	15	22
19	3	5	13.662	16	13	22
20	15	17	18.528	17	12	21
21	9	15	31.521	14	20	23
22	1	3	45.072	18	19	23
23	1	9	92.000	22	21	0

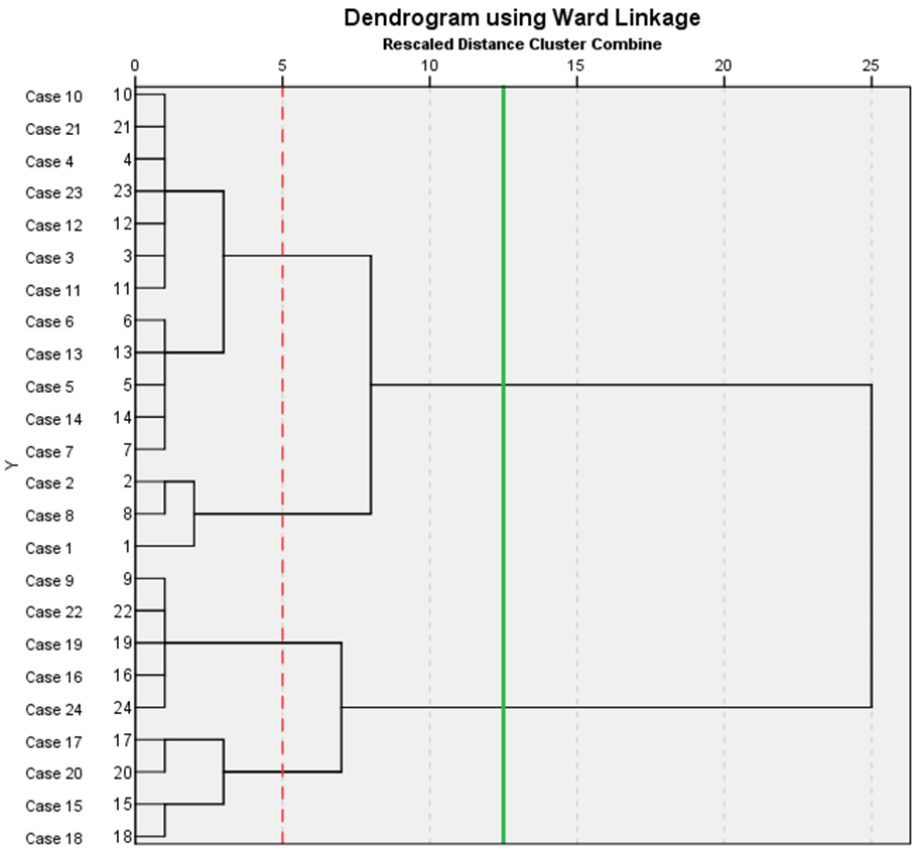

Fig. 7: Dendrogram Plot of Unglazed Illuminance Data for 24 Locations showing Cluster relationships. (Source: Salisu, 2015).

4.2 Proposed Two-Cluster Daylighting Zone Maps

Based on the two-cluster solution for both fenestrations, we recommend the daylighting maps given in Figures 8 and 9 for glazed and unglazed classrooms.

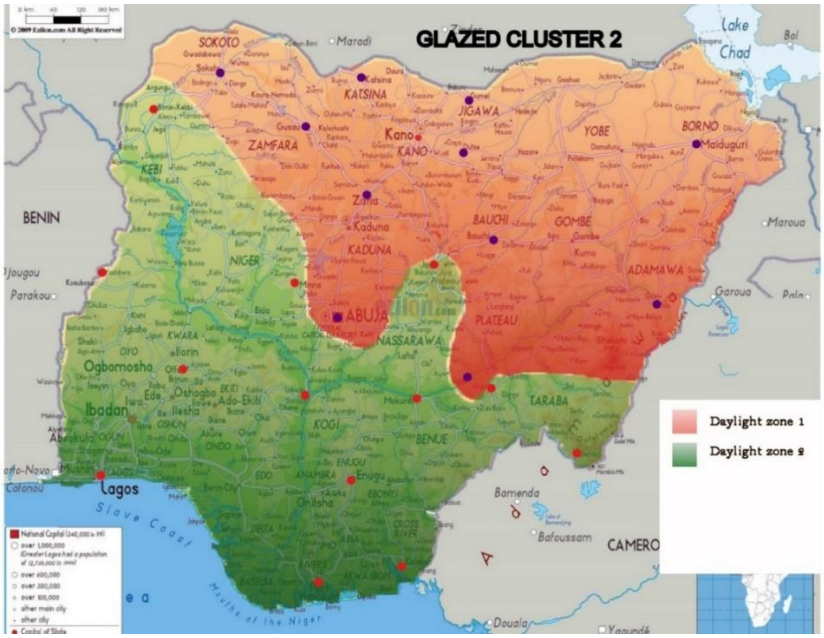

Fig. 8: Proposed Daylighting Zones for Glazed classrooms according to 2 Cluster Hierarchical classification schemes.
(Source: Salisu, 2015).

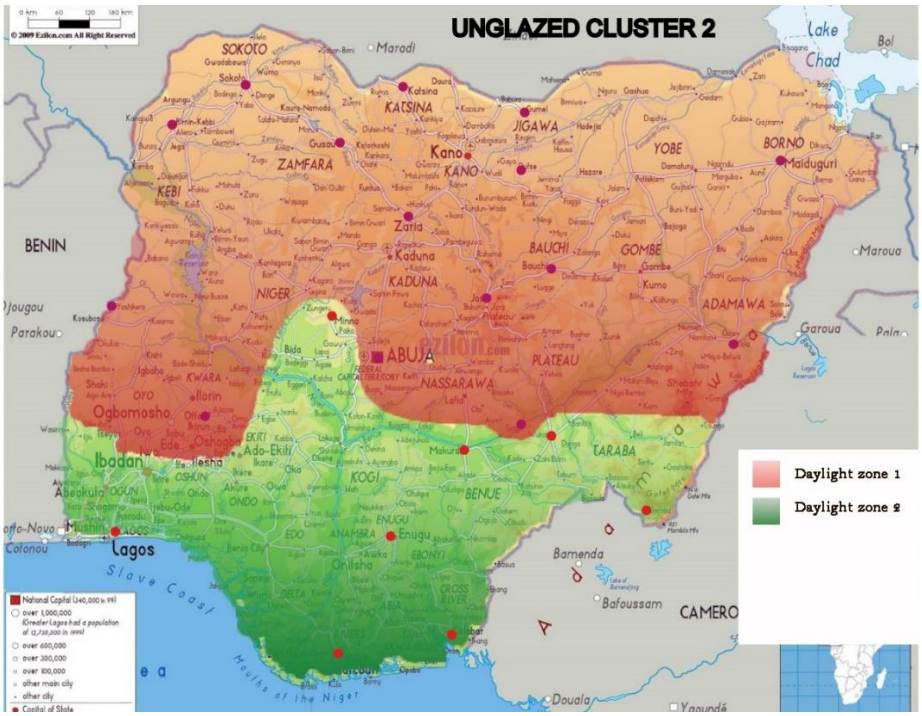

Fig. 9: Proposed Daylighting Zones for Unglazed Classrooms according to 2 Cluster Hierarchical classification schemes.
(Source: Salisu, 2015).

5.0 DISCUSSION AND SUMMARY OF FINDINGS

5.1 Principal Findings

Daylighting provision in Nigeria does not align with the Koppen-Trewatha-Horn climate zones, and the local environmental conditions have a more significant influence than latitude. Two daylighting zones were established based on the analysis. Zone 1, comprising coastal and highland areas, has less Daylight Autonomy (DA) but greater uniformity (DAUI) for glazed classrooms due to widespread cloud cover, which diffuses sunlight. In contrast, Zone 2, covering northern Nigeria, provides abundant daylight throughout the year with increased DA and lower uniformity, implying a higher glare potential. These performance trends are reversed in unglazed classrooms.

5.2 Implications for Architectural Practice

Given Nigeria's unpredictable electricity, these evidence-based daylighting zones allow architects to implement optimised design templates without resorting to location-specific simulations. This calls for a paradigm shift from generic solutions to region-specific strategies. In low-DA regions, such as the south, structures must have larger glazed areas to attain maximum light gain. In contrast, high-DA locations in the north must have effective shading and glare control to prevent visual discomfort. This empirical data forms a vital foundation for revising the Nigerian Building Code, which currently has inadequate daylighting recommendations, and can facilitate the development of simpler, zone-based design tools for practitioners.

5.3 Comparison with International Daylighting Zone Systems

Nigeria's two-zone system is simpler than the five or six zones used in the US and China. The simplicity reflects the more consistent tropical climate of Nigeria and the dominant effect of cloud cover patterns on the latitude differences. The distinction points out that daylighting zones must be separately established for specific geographic areas because the correlation between climate factors and daylighting performance is more complex than traditional climate classifications suggest.

6.0 SCOPE AND LIMITATIONS

The study is based on Autodesk Ecotect Analysis 2011 models of common classroom structures. The CBDM engine of this program has been used and cross-validated in peer-reviewed daylighting studies, and it remains technically suitable for the illuminance measures used in this work, even though it is no longer financially maintained (Mardaljevic, 2015; Brembilla & Mardaljevic, 2019). The EnergyPlus Typical Meteorological Year (TMY) datasets, which depict long-term average conditions but do not account for year-to-year fluctuation or anticipated climate change effects, provided the climate files utilised in the simulations. Therefore, without additional research, the conclusions are limited to classroom building typologies and cannot be applied to other building types, such as offices or residential buildings. The study also requires physical validation through field measurements and does not incorporate significant real-world variables such as occupant behaviour, cultural preferences, interior finishes, or future climate change impacts. Despite these limitations, the study provides a foundational and necessary step towards evidence-based daylighting design in Nigeria.

7.0 CONCLUSION

The study shows that the Koppen-Trewatha-Horn climate classification is not a reliable predictor of daylighting performance in Nigeria for the prototype secondary classroom typology modelled across 24 sampled locations. The results show that the 24 locations can be grouped into two simulation-based daylighting patterns, providing the first empirically derived daylighting zone maps for Nigeria and suggesting that local conditions more strongly shape daylighting provision than broad climate zone boundaries. These findings provide a foundation for architectural practice reform and building code updates, subject to further validation. The methodology employed in this study, which uses CBDM simulation data and cluster analysis to establish daylighting zones systematically, can be applied to other tropical countries where conventional climate classifications may struggle to predict daylighting effectiveness accurately.

7.1 Future Research Directions

Future research should focus on four priority areas. Firstly, to check modelled performance trends against real-world data by carrying out measurements on the ground at several representative locations within the two zones. Secondly, to test whether the two-zone approach applies to all building types, such as offices, dwellings, and health-care buildings, or whether sector-specific zoning is required. Thirdly, occupant behaviour patterns, user preferences for shading and ventilation, and interior finishing may be introduced in subsequent simulations to reduce the performance discrepancy between the prototype model and the actual building. Fourthly, as climate change is predicted to significantly alter patterns of cloud cover, solar radiation, and seasons in West Africa, longitudinal investigations are required to assess the long-term reliability of the modelled daylighting zones and formulate sustainable design guidelines for Nigerian architects.

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All authors contributed to the conception and design of the study. Abubakar Sadiq Salisu formulated the research idea and created the comprehensive design framework. Andrew Okotete Oghenekevwe was responsible for performing the daylighting simulations and analysing the data. Faruk Ibrahim Mukhtar prepared, formatted, and organised the manuscript for submission and publication. The initial draft of the manuscript was written by Abubakar Sadiq Salisu, with all authors reviewing and giving feedback on earlier drafts. All authors have read and approved the final version of the manuscript.

REFERENCES

Ander, G. D. (1995). *Daylighting Performance and Design*. Van Nostrand Reinhold.

Athalye, R., Xie, Y., Liu, B., & Rosenberg, M. (2013). Analysis of Daylighting Requirements within ASHRAE Standard 90.1. U.S. Department of Energy. Washington*: Pacific Northwest National Laboratory*, Richland, Washington 99352.

Ayoade, J. (1993). *Introduction to climatology for the tropics.* Ibadan: Spectrum Books Limited.

Boubekri, M. (2008). Daylighting, architecture and health. In *Routledge eBooks*. https://doi.org/10.4324/9780080940717

Brembilla, E., & Mardaljevic, J. (2019). Climate-Based Daylight Modelling for compliance verification: Benchmarking multiple state-of-the-art methods. *Building and Environment*, *158*, 151–164. https://doi.org/10.1016/j.buildenv.2019.04.051

Creswell, J.W. and Creswell, J.D. (2018). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches. *Sage, Los Angeles.*

Dubois, M., Gentile, N., Laike, T., Mattsson, P., Bournas, I., & Alenius, M. (2025). *Daylighting and lighting*. https://doi.org/10.37852/oblu.324

Guan, Y., & Yan, Y. (2016). Daylighting design in the classroom based on Yearly-Graphic analysis. *Sustainability*, *8*(7), 604. https://doi.org/10.3390/su8070604

Guzowski, M. (1999). *Daylighting for Sustainable Design*. McGraw-Hill Professional.

Heschong, L. (2002). *Daylighting and human performance*. https://www.semanticscholar.org/paper/Daylighting-and-Human-Performance-Heschong/afafafe10481b99eeec0d4261da461f77a8cffcb

James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An introduction to statistical learning. In *Springer texts in statistics*. https://doi.org/10.1007/978-1-4614-7138-7

Kousalyadevi, G., & Lavanya, G. (2019). Optimal investigation of daylighting and energy efficiency in industrial buildings using energy-efficient Velux daylighting simulation. *Journal of Asian Architecture and Building Engineering*, *18*(4), 271–284. https://doi.org/10.1080/13467581.2019.1618860

Mardaljevic, J. (2015). *Climate-Based daylight modelling and its discontents*. https://www.semanticscholar.org/paper/Climate-Based-Daylight-Modelling-And-Its-Mardaljevic/95d94ca9cbc46229403a241b6d7df73916604338

Mardaljevic, J., Christoffersen, J., & Raynham, P. (2013). A Proposal for a European Standard for Daylight in Buildings. *LUX European 12th European Light Conference*, (pp. 1-15). Krakow.

Nabil, A., & Mardaljevic, J. (2005). Useful daylight illuminance: a new paradigm for assessing daylight in buildings. *Lighting Research & Technology*, *37*(1), 41–57. https://doi.org/10.1191/1365782805li128oa

Obokoh, A., & Obokoh, A. (2024, December 31). *Nigeria ranked 6th in global population with 235 million people*. Nairametrics. https://nairametrics.com/2024/12/31/nigeria-ranked-6th-in-global-population-with-235-million-people/

Phillips, D. (2012). Daylighting. In *Routledge eBooks*. https://doi.org/10.4324/9780080477053

Reinhart, C. F., Mardaljevic, J., & Rogers, Z. (2006). Dynamic Daylight Performance Metrics for Sustainable Building Design. *LEUKOS the Journal of the Illuminating Engineering Society of North America*, *3*(1), 7–31. https://doi.org/10.1582/leukos.2006.03.01.001

Reinhart, C. (2014). *Daylighting Handbook 1. (R. Stein, Ed.)* Retrieved from www.DaylightingHandbook.com

Salisu, A. (2015). Optimising Fenestration for Daylight Provision in the Architecture of Secondary Schools in Nigeria using Climate-Based Daylight Modelling. Unpublished.

Society of Light and Lighting, SLL (2011). *SLL lighting guide 5: Lighting for education*. London: CIBSE.

Shishegar, F., & Boubekri, M. (2016). Natural Light and Productivity: Analysing the impacts of daylighting on students' and workers' health and alertness. *International Journal of Advances in Chemical Engineering and Biological Sciences*, *3*(1). https://doi.org/10.15242/ijacebs.ae0416104

Tregenza, P., & Mardaljevic, J. (2018). Daylighting buildings: Standards and the designer's needs. *Lighting Research & Technology*, *50*(1), 63–79. https://doi.org/10.1177/1477153517740611

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THE ROLE OF IMAGEABILITY IN STRENGTHENING PLACE ATTACHMENT IN UPGRADED ALLEYS: A SURVEY-BASED STUDY IN THE COMMERCIAL DISTRICT OF KUALA LUMPUR, MALAYSIA.

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ABSTRACT

This quantitative study investigates the correlation between imageability and place attachment, specifically in the context of urban alley regeneration in Kuala Lumpur. Although the alleys of Southeast Asian cities are increasingly being transformed into livable public spaces, few studies have investigated the visual and spatial characteristics that shape users' attachments to place. A quantitative survey approach was utilized to evaluate user perceptions of five upgraded alleys in Bukit Bintang. A total of 695 participants were assessed with a structured questionnaire. Both descriptive and inferential analyses were performed to examine the impact of perceived imageability on place attachment. Findings indicate that place imageability attributes, including distinctiveness, visual clarity, and legibility, significantly predict place attachment levels. Specifically, legibility significantly influences both emotional and functional user attachment to a space, while perceived distinctiveness strongly correlates with emotional attachment. Using empirical methods to validate how imageability shapes place attachment in reimagined micro-public spaces, this study advances the theoretical debate in urban planning and design related to the quality of public spaces from physical and emotional perspectives. Additionally, the findings support policymakers in developing urban regeneration policies that transcend the physical aspect of place within the dense urban context of the Global South.

Keywords: Imageability, Place Attachment, Urban Alleys, Urban Regeneration, Kuala Lumpur.

1.0 INTRODUCTION

Urban alleys have historically functioned as practical backstreets in congested cities, often serving as secondary infrastructure (Askarizad et al., 2024; Blazy, 2019). Recently, urban-regeneration discourses worldwide have foregrounded these overlooked spaces as potentially pivotal for fostering inclusive and livable public realms (Pan & Cobbinah, 2023). Alleyway upgrading programs are being implemented in cities across Asia, including Kuala Lumpur, to transform narrow corridors into animated pedestrian networks, culturally vibrant spaces, and green connectors (Zhang & Liu, 2024; Wartmann et al., 2021; Omar et al., 2016). However, despite growing interest in spatial revitalization, research on how users emotionally engage with urban alleys remains limited (Zhang et al., 2024; Liu et al., 2024). At the heart of this debate are two concepts: place attachment—the emotional and psychological bonds people form with a place (Moulay & Ujang, 2021a)—and imageability, which refers to how easily a built environment can be recognized and recalled based on its spatial characteristics (Moulay & Ujang, 2021b). Therefore, well-conceived upgraded alleys can offer more than visual or practical improvements; they can deepen human-place connections and contribute to urban livability and social sustainability (Zhang & Liu, 2024).

While the interaction between imageability and place attachment has grown in environmental psychology and urban design, it has received less attention in urban alley regeneration (McCunn & Gifford, 2021). Prior research has highlighted women's greater safety and spatial-legibility concerns in narrow urban spaces (Chen et al., 2024),

but less attention has been paid to how visual and spatial cues in upgraded alleys affect a broader range of users (Alamoush & Kertész, 2022; Wan, 2017). This gap is particularly pronounced in Southeast Asia, where regeneration often prioritizes form over meaning (ASEAN Sustainable Urbanisation Report, 2022; Jensen, 2021). Understanding how people perceive and inhabit these micro-urban spaces is crucial for inclusive design strategies that address both cognitive navigation and emotional belonging. These insights help urban planners, designers, and policymakers ensure upgraded alleys function as living extensions of the public realm, not merely aesthetic corridors.

To fill this gap, this study examines the effect of imageability on place attachment in five upgraded alleys in Bukit Bintang, Kuala Lumpur. The study has three goals: (1) to examine user perceptions of imageability features in upgraded alleys; (2) to investigate the link between imageability and place attachment; and (3) to assess how imageability influences long-term emotional attachment to these micro-spaces. The research questions are: How do users perceive imageability in Bukit Bintang's upgraded alleys? What is the relationship between perceived imageability and place attachment? How can imageability shape long-term emotional connections to these spaces? By answering these questions, the study provides empirical evidence for human-centered urban regeneration and informs design practice focused on spatial quality and psychological well-being.

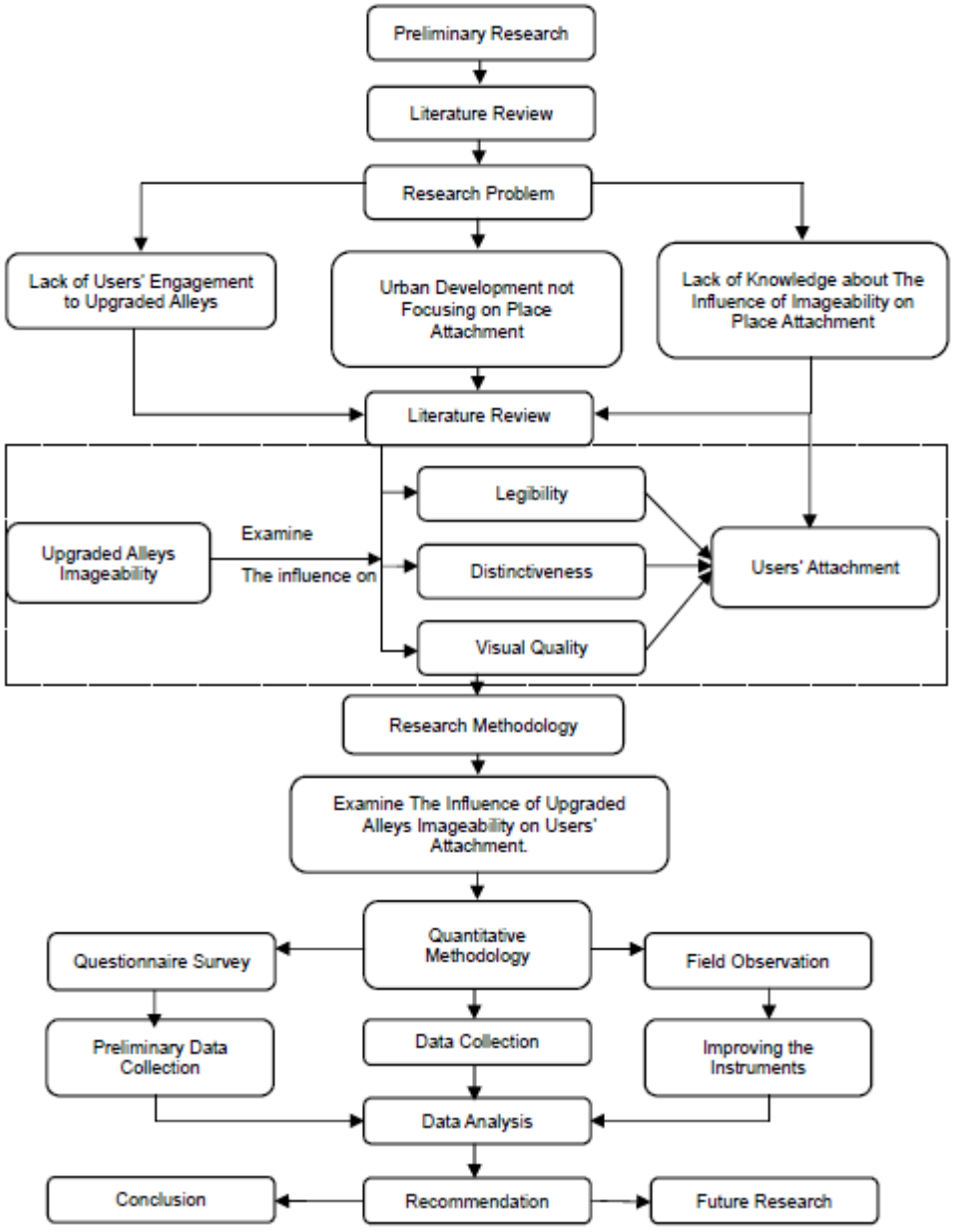


Fig. 1: Conceptual framework (Author, 2024).

2.0 LITERATURE REVIEW

Place attachment has long been acknowledged in environmental psychology and urban design as an important emotional and cognitive connection that humans develop with the physical environment (Balakrishnan & Bleibleh, 2025; Moulay et al., 2024). Place attachment includes the symbolic attachment to a place, referred to as place identity, and the functional attachment via spatial engagement, referred to as place dependence (Moulay & Ujang, 2021b; Scannell & Gifford, 2010; Tuan, 1974). Together, these two dimensions influence how people perceive meaning and function within their environments, thereby affecting their behavior, satisfaction, and long-term attachment to place. Place attachment in the urban context, especially in rapidly changing cities, has been associated with well-being, rootedness, and social belonging (Jones & Walker, 2023; Gillespie et al., 2022; Enssle & Kabisch, 2020). Micro-public spaces, like parks, laneways, or walkable alleys, have increasingly become important arenas to express these emotional bonds, especially when incorporated in people's daily lives (Falanga, 2022; Moulay et al., 2018). Southeast Asia's emerging research reveals that revitalizing underutilized urban backstreets into spaces that prioritize pedestrians and reflect local culture, promote a sense of belonging and identity among residents and visitors (Tan et al., 2024; Dameria et al., 2023).

At the same time, imageability has become a significant urban design concept contributing to the legibility and memory of space (Alamoush & Kertész, 2022; Constantinides et al., 2021). Lynch's theory of imageability offers useful concepts, paths, edges, landmarks, orientation, and coherence that help explain navigation and attachment. But applying these ideas uncritically to Southeast Asian cities risks overlooking hybrid, multitemporal contexts. In Bukit Bintang, alleys carry memory, social exchange, informal economies, and everyday rituals, not just visual cues, revealing the limits of treating imageability as an objective design quality. Key tensions include space fluidity, informal social life, cultural memory, and gendered experiences (Agustí et al., 2022; Jiang et al., 2017).

A Southeast Asian reading treats imageability as relational, multisensory, and layered in time. It should consider multisensory imageability (soundscapes, smells, textures); temporal rhythms (markets, festivals, day-to-night life); socially produced meanings from residents, vendors, and visitors; culturally grounded storytelling co-authored with communities; and inclusive accessibility for women, elders, migrants, and children. Cross-site comparisons across Southeast Asian cities can test transferability while honoring local specificity (Nakić et al., 2022; Tang et al., 2020; Wardhani & Wang, 2023; Nur, 2020; Zhang & Liu, 2024).

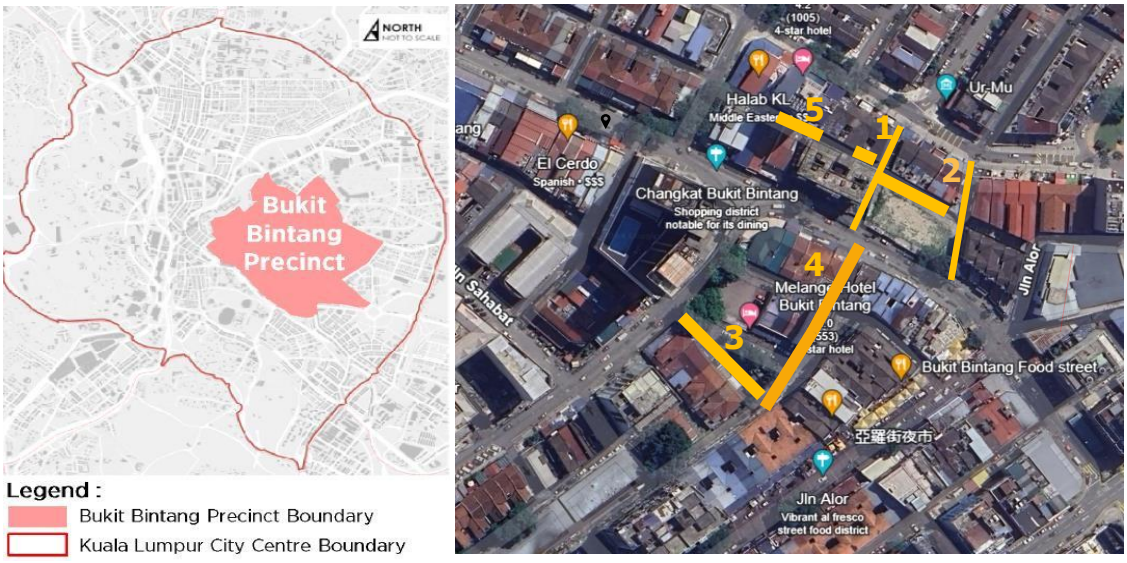
Imageability-related interventions—murals, lighting, paving, and signage—have driven alley regeneration globally. In Southeast Asia, cities such as Kuala Lumpur, Bangkok, and Jakarta upgrade service corridors to become thriving connectors and cultural pockets (Wardhani & Wang, 2023; Nur, 2020; Zhang & Liu, 2024). Many programs follow top-down logics of order, security, and beautification, which can overshadow lived experiences (Falanga, 2022). By contrast, user-centered design foregrounds daily perception, memory, and social interaction, yet the link between visual design and emotion remains underexplored; only limited regeneration frameworks assess whether enhanced legibility yields deeper emotional interpretation or richer human–place bonds (Shynu & Suseelan, 2023; Zhang et al., 2021).

In Bukit Bintang, alleys function as social filters, informal gathering spaces, and accumulative memory loci. Western imageability can guide design but must be adapted to reflect temporality, sensory cues, and local narratives co-authored with communities. Design should weave local stories into wayfinding while preserving informal uses and social practices, moving regeneration beyond visual polish toward approaches that embrace psychological complexity, cultural specificity, and everyday lived experience (Qwasmi et al., 2022; Wan, 2017). Gender and social diversity add complexity: women often prioritize safety, legibility, and spatial affordances, yet post-regeneration studies rarely account for differential experiences (Agustí et al., 2022; Jiang et al., 2017; Gong et al., 2023; Khalid et al., 2022). Ultimately, Western imageability theories offer valuable entry points, but Southeast Asian contexts demand an expanded, culturally responsive theorization that foregrounds lived experience, temporality, and communal meaning (memory, sound, scent).

To fill these gaps, the current study empirically examines how the visual-spatial cues intrinsic to upgraded alleys influence users' functional and emotional bonds to these narrow corridors. The research focuses on five upgraded alleys in Bukit Bintang, Kuala Lumpur, and attempts to link conceptual and contextual knowledge to facilitate more holistic and emotionally engaged urban regeneration approaches. It argues for a transformation from an predominantly visual design paradigm to one that incorporates psychological complexity, cultural particularity, and the everyday lived experience.

3.0 METHODOLOGY

This study was conducted in Bukit Bintang, a major business district in Kuala Lumpur City Centre, where approximately 35% of the area consists of streets (Wan, 2017). Fifty-two lanes account for 56.5% of Bukit Bintang's public walkways, making their effective use crucial to improving the city's standard of living (Wan, 2017). A comprehensive assessment of physical conditions and user experiences formed the basis for selecting the five alleys: *Alor, Komuniti di Alor, Laman Belakang, Alam Alor,* and *Kehidupan Alor* (Fig 2). The DBKL regeneration project, started in 2015, targeted these alleys because they lie near the bustling *Alor* Enclave in Bukit Bintang. Redevelopment in 2018 aimed to enhance visual qualities, community cohesion, social interaction, and functioning. To analyze current conditions, the study conducted extensive on-site inspections, ensuring each site offered distinct qualities relevant to regeneration. The evaluation collected data on landscaping, infrastructure, and general usage.



Source: KLCH, 2018

1. *Alor*
2. *Komuniti di Alor*
3. *Laman Belakang*
4. *Alam Alor*
5. *Kehidupan Alor*

Fig. 2: Location and names of regenerated alleys in Bukit Bintang, Kuala Lumpur (author, Google Map 2024).

The study employed quantitative methods to investigate the relationship between imageability and place attachment, specifically within the upgraded alleys of the Bukit Bintang commercial district. Utilizing quantitative approaches is advantageous for generating measurable and objective data, allowing for the identification of patterns and trends that qualitative methods might overlook. Jorgensen and Stedman (2006) point out that their quantitative framework effectively aligns place attachment with various environmental factors, establishing imageability as a significant predictor of attachment levels. This idea is further supported by Goldar and Daneshpour (2015) and Kamani Fard & Paydar (2024), who reiterate that imageable features significantly enhance residents' emotional connections to their environments. Furthermore, Ujang highlights the effectiveness of questionnaire surveys in quantitatively examining user attachment to urban spaces. Her findings reveal that specific characteristics, such as imageability, influence users' emotional ties to these places, thus demonstrating the empirical validity and practical application of quantitative methods in urban research (Ujang, 2010). Therefore, this study conducted a visual questionnaire survey of a sample of 695 randomly selected participants; the current study gathered quantitative data regarding perceptions of the upgraded alleys. The survey focused on physical features, visual appeal, and legibility, while also probing participants' feelings and connections to these spaces.

Table 1: Descriptive analysis for legibility, distinctiveness and visual clarity

	Items	Mean	Std. Deviation
Legibility (m= 3.51, SD= 0.67)	Very exciting views.	3.53	0.73
	Very clear signage and direction.	3.59	0.73
	Very clear layout, easy to move.	3.67	0.67
	Strong physical connection to adjacent streets.	3.73	0.67
	Attractive wayfinding signage.	3.20	0.63
Distinctiveness (m= 3.41, SD= 0.66)	Well-known by its international and modern image.	3.35	0.61
	Unique landscape features.	3.44	0.66
	Different lighting designs.	3.57	0.64
	Visually different from the rest of other places.	3.68	0.64
	More popular than other places.	3.52	0.70
	No place is comparable to this place	2.90	0.74
Visual clarity (m= 3.46, SD= 0.63)	Good image.	3.72	0.60
	Attractive mural art.	3.70	0.66
	Well decorated facades.	3.60	0.67
	Colorful place.	3.86	0.53
	Shaded all day.	3.02	0.51
	Attractive traditional/old buildings.	3.33	0.88
	More greenery /beautiful tree.	3.00	0.56

This large sample size enhances the study's reliability and validity, facilitating a detailed understanding of how the upgraded alleys encourage interaction among users, thereby reinforcing the importance of measurable attributes in fostering place attachment. Overall, this robust quantitative approach substantiates the findings that imageability in urban design plays a crucial role in fostering stronger emotional bonds between residents and their environments.

4.0 RESULTS

4.1 Perception of imageability

Visitors rated clear signage and layout highly (3.59–3.67) in Table 1, attributing this to effective upgrades such as better circulation, clear sightlines, and utilitarian signage that enhance wayfinding. A strong score for physical connections to adjacent streets (3.73) suggests that well-integrated alleys promote accessibility and perceived safety through visible entrances and cohesive design with surrounding streets. Colorful features and artwork received the highest ratings (3.86 for "Colorful place," 3.70, and 3.60 for murals/facades), because they were visually impactful and memorable, thus aiding orientation. Conversely, attractive wayfinding signage scored lower (3.20), indicating a distinction between functional but plain directional signs and aesthetically pleasing designs, which may have been neglected in favor of utilitarian elements. The lowest score (3.00) for greenery reflects limitations associated with hard-surfaced alleys, as planting opportunities were likely limited by design priorities focused on circulation and art rather than landscape enhancements.

The findings emphasize the importance of legibility in urban design, highlighting that clear navigation and spatial organization enhance cognitive mapping and a sense of place. High scores for color and distinct murals indicate that visual distinctiveness strengthens identity. At the same time, lower appreciation for greenery shows that users prefer navigation aids and recognizable cues over broad landscape features. The practical recommendation is to merge functional signage with memorable visual elements to improve both wayfinding and emotional connection, prioritizing simple, low-maintenance improvements that align with user preferences for integrated design strategies.

4.2 Users' attachment to upgraded alleys

The evaluation of urban alleys reveals several key findings (Table 2). Firstly, alleys score high for their "strategic location" (m = 3.83), as users find them convenient due to their proximity to homes, transit, markets, and workplaces. They facilitate quicker routes through dense urban areas, bolstered by visible improvements such

as paving and lighting, which enhance their functionality.
Conversely, the scores for "relevance to user interests" are moderate (m = 3.10), with some users enjoying recreational and social uses; however, the alleys lack adequate programming and amenities to fully cater to diverse needs, particularly for older adults and those with mobility limitations.
Economic opportunities receive lower scores (income m = 2.69; business activities m = 2.97) due to spatial constraints, regulatory challenges, and insufficient customer traffic, which hinder business viability. Furthermore, perceptions of alleys as secondary spaces limit commercial investment potential.
On a positive note, the alleys promote inclusivity and cross-cultural interaction (m = 3.87) by serving as neutral public spaces that encourage interactions among diverse groups through shared amenities and seasonal programming. The overall emotional attachment score is favorable (m = 3.38), indicating that upgrades have fostered pride and identity in these spaces. Frequent usage and community involvement amplify this emotional bonding.

Table 2: Descriptive analysis of functional and emotional attachment

	Items	Mean	Std. Deviation
Functional Attachment (m=3.02, SD= 0.67)	The Up-Graded Alley is the best place for what I like to do.	3.10	.67
	The Up-Graded Alleys is very important to me.	2.84	.71
	I like doing business in the Up-Graded Alleys.	2.97	.91
	The best place to earn money/ income	2.69	.60
	Strategically located	3.83	.56
	Strong physical connection to adjacent streets.	3.69	.60
Emotional Attachment (m=3.38, SD= 0.65)	Appropriate to my cultural background.	2.99	.75
	The place makes People-friendly.	3.25	.70
	Meeting place for people from different cultures.	3.87	.52
	I am attracted by the Up-Graded Alleys.	3.63	.70
	I feel secure being in the Up-Graded Alleys.	3.01	.56
	I have a positive impression about the Up-Graded Alleys.	3.73	.68
	I feel more comfortable being here than in any other place.	3.24	.65

Security and comfort perceptions are moderate (security m = 3.01; comfort m = 3.24), with recent improvements falling short due to ongoing maintenance issues and design gaps that affect long-term perceptions of safety.

High strategic location, complemented by emotional attachment to inclusive programming, underscores the importance of social function and opportunity structures in place attachment. While instrumental and socially welcoming spaces foster public engagement, moderate scores for programming and amenities indicate unmet potential for routine use. This aligns with social sustainability theories that highlight the need for accessible programming and inclusive design. The takeaway emphasizes the necessity for design and programming to address everyday needs and culturally inclusive activities to enhance both functional use and social belonging.

4.3 Effect of imageability on users' emotional attachment to upgraded alleys

The linear regression analysis unveils significant insights regarding the influence of imageability on emotional bonding with upgraded alleys in Kuala Lumpur (Table 3). Key findings indicate that legibility is the most substantial predictor of emotional attachment ($B = 0.506$, $t = 13.273$, $p < 0.001$). This relationship suggests that navigable and easily understood alley designs alleviate wayfinding stress and enhance perceived safety, thus promoting frequent use that fosters familiarity and belonging. Additionally, distinctiveness emerges as a crucial factor ($B = 0.195$, $t = 6.678$, $p < 0.001$), as unique features such as public art and memorable architecture cultivate identity and emotional connections through shared memories. In contrast, the study found that visual clarity has no significant impact ($B = 0.036$, $t = 0.963$, $p = 0.336$), suggesting that aesthetic clarity alone does not drive emotional engagement; instead, residents tend to value navigability and unique characteristics more than mere visual simplicity.

Consistent with imageability and place-identity theories, legibility emerges as the most influential predictor of emotional attachment, underscoring that easy navigation and predictable spatial cues foster safety and familiarity, which in turn strengthen affective bonds. Distinctiveness also plays a meaningful role, indicating that unique features of public art and notable architecture contribute to identity-anchored attachment through

shared memories and meaning. The lack of a significant effect for visual clarity suggests that mere aesthetic clarity without navigational or identity content is insufficient to drive emotional attachment. Place attachment is most robust when environmental cues support both wayfinding and identity construction.

Table 3: Linear regression analysis (imageability, emotional attachment)

Model	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	.684	.075		9.095	.000
Legibility	.506	.038	.557	13.273	.000
Distinctiveness	.195	.029	.269	6.678	.000
Visual Clarity	.036	.038	.039	.963	.336

a. Dependent Variable: Emotional Attachment

4.4 Effect of imageability on users' functional attachment to upgraded alleys

Several plausible mechanisms can explain the linear regression results (Table 4). Legibility's strong positive effect (B = 0.921, p = 0.000) likely reflects that clear spatial cues, coherent signage, and predictable paths reduce cognitive load, making alleys easier to navigate and therefore more useful in everyday routines; when people can find their way and anticipate how spaces connect, they form stronger functional attachments because the place reliably supports tasks (shopping, commuting, socializing). The non-significant effect of distinctiveness (B = 0.022, p = 0.239) suggests that novel or unique aesthetic features alone do not improve practical use. Distinctive elements may attract attention or foster identity, but if they don't improve wayfinding, comfort, or utility, they won't increase functional attachment. The negative association for visual clarity (B = -0.053, p = 0.032) can be interpreted as over-simplified or overly uniform visual environments reducing opportunities for meaningful affordances or landmarks; in upgraded alleys, too much minimalism may remove texture, seating cues, micro-activities, or perceptual richness that signal usability and human presence, thereby lowering people's practical engagement.

The importance of legibility in enhancing functional attachment to spaces aligns with theories of affordances and cognitive load. Clear cues improve usability for daily tasks, while distinctiveness alone does not enhance practical use unless it contributes to navigational or comfort benefits. Additionally, overly minimalistic designs may negatively impact visual clarity, reducing perceived usability and user engagement by lacking necessary texture and cues.

Table 4: Linear regression analysis (imageability, functional attachment)

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	.368	.049		7.536	.000
	Legibility	.921	.025	.957	37.165	.000
	Distinctiveness	.022	.019	.029	1.178	.239
	Visual clarity	-.053	.025	-.053	-2.152	.032

a. Dependent Variable: Functional Attachment

Overall, the regression analysis reveals that legibility is a crucial factor in users' emotional and functional attachment to upgraded alleys in Kuala Lumpur. Legibility enhances emotional attachment by creating user-friendly environments that foster safety and familiarity. In contrast, while distinctiveness also plays a role, its impact is less significant, and visual clarity may even detract from functional attachment (Fig 3), indicating that overly simplistic designs can result in a lack of user interaction. Urban planners should prioritize improving navigability through effective signage and intuitive layouts, while also incorporating distinctive architectural elements. This approach can strengthen emotional connections and enrich the overall user experience. Ultimately, enhancing legibility and thoughtful design integration will create vibrant urban spaces that address

both functional needs and users' emotional attachments.

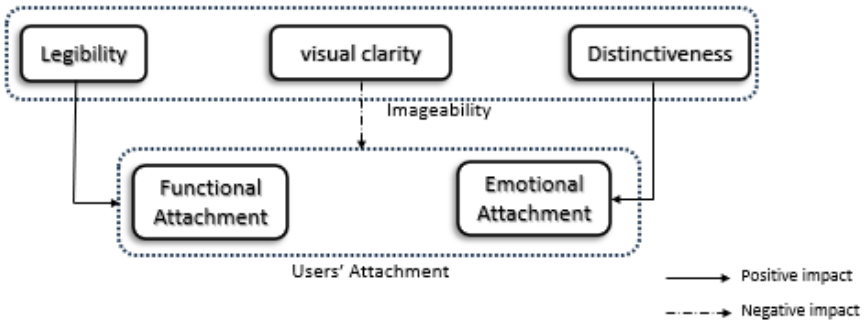


Fig. 3: Imageability and Users' Attachment Relationship
(Source: Author, 2024)

5.0 DISCUSSIONS

This study contributes to the growing body of knowledge on urban regeneration by examining the relationship between imageability and place attachment in Kuala Lumpur's upgraded alleys. It analyzes both functional and emotional attachments that users—residents and visitors—form with these spaces, offering insights into how design features such as legibility, distinctiveness, and visual clarity shape urban experiences and attachment. The findings underscore the need for an integrative urban-design approach that balances aesthetic and functional criteria while fostering community engagement and preserving cultural identity.

5.1 Perception of Imageability and Urban Connectivity

The study shows a strong connection between users and the urban alleys, indicated by a mean imageability score of 3.73. The alleys are legible, easily navigable, and well-integrated into Kuala Lumpur's urban fabric. Their connection to adjacent streets, such as Jalan *Alor*—a high-profile culinary destination—highlights the importance of spatial connectivity for user satisfaction. The physical links between the alleys and surrounding streets facilitate movement and accessibility, aligning with Cullen's (1997) theories of urban connectivity, which state that well-connected spaces foster cohesion and enhance the user experience.

Urban environments that prioritize spatial legibility are more likely to elicit positive emotional and functional responses from users (Abaas & Khalid, 2023). This study supports that legibility, distinctiveness, and visual clarity are key drivers of attachment, especially in Kuala Lumpur's diverse and dynamic context. Moreover, Jalan Alor's symbolic significance as a cultural and culinary landmark heightens the emotional resonance of the surrounding upgraded alleys. This integration suggests that urban regeneration projects can strengthen physical connectivity and community identity, thereby attracting diverse user groups, including residents and tourists.

The role of cultural and historical narratives in urban regeneration becomes evident in Jalan *Alor* and *Alam Alor* (Figures 4 and 5). These spaces, especially *Alam Alor*, are not only connectors within the urban grid but also repositories of local heritage. However, Moussaoui (2024) argues that regeneration projects often foreground narratives and aesthetics that serve broader economic and branding objectives, potentially sidelining organic community connections (Harizi et al., 2025). In Kuala Lumpur, the *Alor* Stream's historical origin of Jalan *Alor* illustrates a cultural narrative that could be more explicitly integrated into the urban landscape. While the alley's aesthetic improvements (e.g., murals depicting local flora and fauna) has enhanced its visual appeal, the absence of a consistent, clearly communicated narrative undermines deeper community connections. This echoes Zecca's (2019) observations on the commodification of space, where regeneration often prioritizes aesthetic transformation over local engagement.

Fig. 4. *Alor* Alley leads to *Changkat* Bukit Bintang street (author, 2025)

Fig. 5. *Alam Alor* links between *Jalan Alor*, *Tengkat Tong Shin,* and *Changkat* Bukit Bintang streets (author, 2025)

The lack of consistent and meaningful signage in *Alam Alor* fails to communicate the historical and cultural significance of the *Alor Stream*, resulting in a fragmented identity and hindering deeper user attachment. To address this, urban planners should embed cultural elements in the design process rather than treating them as superficial additions to reinforce local identity and foster community pride (Bavani, 2018).

Among the upgraded alleys, *Laman Belakang* (Figure 6) stands out as the most frequented by tourists. Residents and local stakeholders express strong sentiment toward its design concept, largely due to long-standing familiarity with the space. According to Natasha, the lead architect for alley regeneration, property owners along the alley show a high level of commitment to improving the area. One owner proposed the original design concept and continues to participate in routine cleaning and plant maintenance. In contrast, most residents in other alleys are tenants; while they may appreciate streetscape improvements, they generally do not show the deeper, sustained engagement associated with ownership.

The study also found that respondents prefer to spend more time in *Laman Belakang* than in the other alleys. This stems from its strategic location, drawing visitors from *Tengkat Tong Shin* Street and the availability of amenities such as benches that encourage lingering and enhance comfort. Consistent maintenance further strengthens its appeal. The alley's proportions balance spatial openness and enclosure, and its position within the commercial district contributes to its success and higher activity levels.

Findings indicate that legibility is strongly associated with fulfilling users' needs and intentions. In other words, the more legible a renovated alley is perceived to be, the more it satisfies users' expectations. *Laman Belakang*'s success, supported by easy access, clear signage, well-maintained murals, and overall spatial coherence, suggests that meaningful resident involvement and practical amenities are crucial. These factors create a legible and inclusive urban environment, not one that relies solely on aesthetic interventions. This helps avoid artwashing or arts-led regeneration, which can mask deeper urban issues behind superficial modernity or uplift "grit as glamour" (Lloyd, 2010; McIntosh, 2021) and related critiques (Zukin, 2010a).

Fig. 6: *Laman Belakang*, well-maintained alley (author,2025)

5.2 Emotional and Functional Attachment: A Dual Perspective

The findings on user attachment reveal a complex and nuanced relationship between space and emotional engagement. Functional attachment (mean 3.83) stems from the alleys' strategic positioning and their role in urban connectivity. *Alor* Alley exhibits high usage due to thoughtful design and proximity to key urban features. Clear sightlines, intuitive layouts, and good lighting help create spaces that are both functional and engaging. This aligns with Rennick and Jacobson (2003), who emphasize safety, security, and comfort as drivers of repeated visits and attachment.

Emotional attachment scores are lower (mean 3.38), indicating a more nuanced picture. The security score is lower (mean 3.01), suggesting safety and comfort remain barriers to deeper emotional connections. This aligns with literature that emphasizes safety and comfort as key to user attachment. The United Nations (2022) notes that perceived safety shapes decisions to use public spaces, especially in urban environments where crime and discomfort can deter visits.

Kominiti di Alor and *Alam Alor* (Figures 7 and 8) show how murals and distinctive architecture can boost emotional attachment. Their distinctiveness and role as a community-identity focal point foster belonging and social interaction. However, poor lighting, maintenance neglect, and mural deterioration (graffiti, water stains) raise concerns about long-term viability. Spatial degradation at *Kominiti di Alor* underscores the need for sustainable design and ongoing community involvement in maintenance and stewardship. Gürman and Buldan (2024) warn that art-led regeneration can detach from locals if seen as external branding rather than genuine community engagement.

Fig. 7: *Kominiti di Alor*, lack of maintenance (author,2025)

Fig. 8: *Alam Alor*, lack of maintenance and mural arts in the other part of the alley (author, 2025)

5.3 Imageability and Attachment: The Role of Design Features

This study shows imageability—especially legibility and distinctiveness—crucially fosters emotional attachment. Consistent with urban-design literature, legibility is the strongest predictor of both functional and emotional attachment. Easy navigation, supported by clear signage, effective wayfinding, and visual landmarks, boosts user confidence and comfort. This matters in Kuala Lumpur's alleys, where residents and international tourists interact.

5.4 Political Dimensions and Authentic Urban Regeneration

The findings reveal a tension between aesthetic transformation and authentic community engagement. As Moussaoui (2024) notes, regeneration often prioritizes commercial interests; urban branding shapes public-space aesthetics and function. These branding efforts can obscure deeper social roles and favor tourism over residents' needs (Harizi et al., 2025).

The *Alam Alor* case illustrates touristification versus community identity. Vibrant murals reflect a cultural aesthetic not fully integrated with the local narrative. Zecca (2019) and Harizi et al. (2025) warn that such interventions risk oversimplifying urban complexity, prioritizing visual appeal over deeper community ties. To avoid this, regeneration must balance aesthetics with spaces that reflect local heritage, social dynamics, and values. Consistent, meaningful communication of historical narratives through design and signage is essential to resonate with residents and visitors, fostering belonging and ownership.

In sum, the findings argue for a holistic, user-centered approach to urban regeneration. Legibility, distinctiveness, and visual clarity are key to spaces that are both usable and emotionally resonant.

6.0 CONCLUSION

This study shows imageability, legibility, distinctiveness, and visual clarity significantly shape place attachment in Bukit Bintang's upgraded alleys. Legibility is the strongest predictor of both functional and emotional attachment; distinctiveness enhances emotional bonds; visual clarity alone does not sustain attachment without coherent navigation. Extending Lynch's imageability to micro-scale alleys reveals parallel emotional and functional pathways influenced by local socio-cultural context. Practitioners should prioritise spatial legibility and meaningful distinctiveness, while ensuring cleanliness and amenities that support diverse users.

The study covers five alleys in a single district and relies on cross-sectional, self-reported data, which limits generalisability and may introduce biases. Future work should replicate in other districts and cities, employ longitudinal designs to track changes across regeneration cycles, and use mixed methods alongside quantitative measures. Include objective metrics and explore safety, social cohesion, and cross-cultural differences. Experimental or quasi-experimental studies could test the causal effects of legibility and distinctiveness on attachment.

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REFERENCES

Abaas, Z. R., & Khalid, Z. (2023). *Towards local sustainability: A case study to evaluate outdoor urban spaces in Baghdad using physiological equivalent temperature index*. *City and Environment Interactions, 20*, 100115. https://doi.org/10.1016/j.cacint.2023.100115

Agustí, D., Guilera, T., Lladós, M. (2022). Gender differences between the emotions experienced and those identified in an urban space, based on heart rate variability. Cities, 131(11), 104000. https://doi.org/10.1016/j.cities.2022.104000

Alamoush, S. J., Kertész, A. (2022 Accessibility as a factor for a livable cities: The case of Salt City in Jordan. Pollack Periodica, 17(3), 147–151. https://doi.org/10.1556/606.2022.00601

Alamoush, S., Kertesz, A. (2022). Imageability of cities in regards of attractiveness: A case of Salt City in Jordan. Pollack Periodica: An International Journal for Engineering and Information Sciences, 17(1), 168-172. https://doi.org/10.1556/606.2021.00385

ASEAN Sustainable Urbanisation Report. (2022). Sustainable Cities towards 2025 and Beyond. ISBN 978-623-5429-16-8 (EPUB). Retrieved on April 2025 from https://unhabitat.org/sites/default/files/2022/12/asean_sustainable_urbanisation_report_final_dec_2022.pdf?utm_source=chatgpt.com

Askarizad, A., Dauden, P., Garau, C. (2024). Exploring the role of configurational accessibility of alleyways on facilitating wayfinding transportation within the organic street network systems. Transport Policy, 157(13), 179-194. https://doi.org/10.1016/j.tranpol.2024.09.001

Balakrishnan, G., Bleibleh, S. (2025). A phenomenological study of place attachment to food spaces: Expatriates and eateries in Dubai. Habitat International, 160, 103399. https://doi.org/10.1016/j.habitatint.2025.103399

Blazy, R. (2019). Archetype of Alleys in the Cities-A Retrospective Approach. IOP Conference Series: Materials Science and Engineering, 603(4). https://doi.org/10.1088/1757-899X/603/4/042101

Bavani, M. (2018, February 27). Artistic alleys. *The Star Metro*.

Boeing, G. (2021). Spatial information and the legibility of urban form: Big data in urban morphology. International Journal of Information Management, 56(1), 102013. https://doi.org/10.1016/j.ijinfomgt.2019.09.009

Chen, S., Lin, S., Yao, Y., Zhou, X. (2024). Urban Public Space Safety Perception and the Influence of the Built Environment from a Female Perspective: Combining Street View Data and Deep Learning. Land, 13(12), 2108. https://doi.org/10.3390/land13122108

Clara, S., & Swasty, W. (2017). Pictogram on Signage As an Effective Communication. Jurnal Sosioteknologi, 16(2), 166–175. https://doi.org/10.5614/sostek.itbj.2017.16.2.2

Constantinides, M., Joglekar, S., Šćepanović, S. (2021). Imagine a Walkable City: Physical activity and urban imageability across 19 major cities. EPJ Data Science, 10(1),56-68. https://doi.org/10.1140/epjds/s13688-021-00313-7

Cullen, G. (1997). *The concise townscape*. Architectural Press.

Dameria, C., Indradjati, P. N., Tjokropandojo, D. S., & Winarso, H. (2023). The Relationship Between Residents' Sense of Place and Sustainable Heritage Behaviour in Semarang Old Town, Indonesia. Open House International, 10(1), 24-42. https://doi.org/10.14246/irspsd.10.1_24

Enssle, F., Kabisch, N. (2020). Urban green spaces for the social interaction, health and well-being of older people – an integrated view of urban ecosystem services and socio-environmental justice. Environmental Science & Policy, 109, 1–9.

Falanga, R. (2022). Understanding place attachment through the lens of urban regeneration. Insights from Lisbon. Cities, 122, 264–275.

Gillespie, J., Cosgrave, C., Malatzky, C., Carden, C. (2022). Sense of place, place attachment, and belonging-in-place in empirical research: A scoping review for rural health workforce research, Health & Place, 74(2), 102756. https://doi.org/10.1016/j.healthplace.2022.102756

Goldar, M., & Daneshpour, S. A. (2015). Assessment of Correlation between Length of Residence and Good Image: Parand New Town. Procedia - Social and Behavioral Sciences, 201(February), 333–341.

https://doi.org/10.1016/j.sbspro.2015.08.183
Gong, W., Huang, X., White, M., Langenheim, N. (2023). Walkability Perceptions and Gender Differences in Urban Fringe New Towns: A Case Study of Shanghai. Land, 12(7), 1339; https://doi.org/10.3390/land12071339
Gürman, A., & Buldan, E. (2024). *From gated-community to gated-neighbourhood: The case of a housing estate bank in Mavişehir, Izmir*. Nakhara: Journal of Environmental Design and Planning, 23(2), Article 412. https://doi.org/10.54028/NJ202423412
Harizi, H., Ariffin, N. F. M., Ujang, N., & Kozlowski, M. (2025). Legibility of Regenerated Alleys as Social Spaces: The case of Kuala Lumpur Commercial District. *Journal of Architecture, Planning and Construction Management*, *15*(2), 145-162.
Huang, Chuli, Fang Wei, Sijia Qiu, Xuqing Cao, Lu Chen, Jing Xu, Jiayang Gao, and Qing Lin. 2023. "Interpreting Regenerated Post-Industrial Lands as Green Spaces: Comparing Public Perceptions of Post-Industrial Landscapes Using Human Factor Design Framework." Ecological Indicators 157(July):111282. doi: 10.1016/j.ecolind.2023.111282.
Imai, H., & Gibert-Flutre, M. (2020). The future of Asian alleyways. Asian Alleyways, 211.
Jensen, C. B. (2021). Material Itineraries: Southeast Asian Urban Transformations. East Asian Science, Technology and Society: An International Journal, 15(2), 124-134. https://doi.org/10.1080/18752160.2021.1917840
Jiang, B., Mak, C., Larsen, L., Zhong, H. (2017). Minimizing the gender difference in perceived safety: Comparing the effects of urban back alley interventions. Journal of Environmental Psychology, 51(3), 117-131. https://doi.org/10.1016/j.jenvp.2017.03.012
Jones, A., Walker, I. (2023). Place attachment, identity threat, and wellbeing in bushfire affected areas. Wellbeing, Space and Society, 5(1), 100179. https://doi.org/10.1016/j.wss.2023.100179
Jorgensen, B. S., & Stedman, R. C. (2006). A comparative analysis of predictors of sense of place dimensions: Attachment to, dependence on, and identification with lakeshore properties. *Journal of Environmental Management, 79*, 316–327.
Khalid, N., Abdullah, Y., Redzuan, A., Mahdzar, S. (2022, 20-23 Jun). 13th International Space Syntax Symposium (13SSS) Vols 5. Women, Perceived Safety and Spatial Configuration of Urban Streets. ISBN: 9798331313029
Kamani Fard, A., & Paydar, M. (2024). Place Attachment and Related Aspects in the Urban Setting. Urban Science, 8(3), 135. https://doi.org/10.3390/urbansci8030135
Lee, J. (2018). Lesson for New Urbanism from the Traditional Space in East Asia. International Journal of Advanced Culture Technology, 6(4), 143–151.
Liu, W., Li, D., Meng, Y., Guo, C. (2024). The Relationship between Emotional Perception and High-Density Built Environment Based on Social Media Data: Evidence from Spatial Analyses in Wuhan. Land, 13(3), 294. https://doi.org/10.3390/land13030294
Lynch, K. (1960). The image of the city. MIT Press.
Marcheschi, E., Vogel, N., Larsson, A., Perander, S., Koglin, T. (2022). Residents' acceptance towards car-free street experiments: focus on perceived quality of life and neighborhood attachment. Transportation Research Interdisciplinary Perspectives 14: 1–10.
Markusen, A., & Schrock, G. (2006). The artistic dividend: Urban artistic specialisation and economic development implications. Urban studies, 43(10), 1661-1686.
McCunn, L., Gifford, R. (2021). Place imageability, sense of place, and spatial navigation: A community investigation. Cities, 115(8), 103245 https://doi.org/10.1016/j.cities.2021.103245
McIntosh, E. (2021). An Examination of artwashing in changing urban communities. Who is to blame for artwashing and how can artists minimise their contribution to gentrification (Bachelor Dissertation, Goldsmiths University of London).
Moulay, A., Ujang, N. (2021b). FUNCTIONAL NEEDS AND RESIDENTS' MOTIVATION TOWARDS VISITING A NEIGHBORHOOD PARK. International Journal of Sustainable Society, 13 (1), 34-54. https://doi.org/10.1504/IJSSOC.2021.115681
Moulay, A., Ujang, N. (2021a). Insight into the issue of underutilized parks: what triggers the process of place attachment?, International Journal of Urban Sustainable Development, 13(2), 297-316. https://doi.org/10.1080/19463138.2021.1885039
Moulay, A., Ujang, N., Maulan S., Abu Bakar N., Ahmad N. (2024). Linking park utilisation and place attachment: towards liveable neighbourhoods. Proceedings of the Institution of Civil Engineers – Urban Design and Planning, 177(1), 21-31. https://www.icevirtuallibrary.com/doi/full/10.1680/jurdp.22.00043

Moulay, A., Ujang, N, Suhardi, M. and Sumarni, I. (2018). Understanding the Process of Park's Attachment: Interrelation Between Place Attachment, Behavioural Tendencies, and the Use of Public Place. City, Culture and Society, 14, 28-36. https://doi.org/10.1016/j.ccs.2017.12.002

Moulay, A., Ujang. N. (2016). Legibility of Neighborhood Parks and its Impact on Social Interaction in Planned Residential Areas. Archinet-IJAR, International Journal of Architecture Research. 10-1, 184-194. DOI: 10.26687/archnet-ijar.v10i1.686.

Moussaoui, M. El. (2024). Aesthetics, authenticity & city place-making. *Open Edition Journals*, *85*, 35–49. https://doi.org/10.4000/12tq9

Nakić, J., Kosović, I., Franić, A. (2022). User-Centered Design as a Method for Engaging Users in the Development of Geovisualization: A Use Case of Temperature Visualization. Applied Science, 12(17), 8754; https://doi.org/10.3390/app12178754

Nur, K. W. (2020). Alley activation: Genius loci to construct a resilient city. Journal of Architecture and Urbanism, 44(1), 63–68. https://doi.org/10.3846/jau.2020.11015

Omar, S. S., Sakip, S. R., & Akhir, N. M. (2016). Bringing the New to the Old : Urban regeneration through public arts. Procedia - Social and Behavioral Sciences, 234, 515–524. https://doi.org/10.1016/j.sbspro.2016.10.270

Organização das Nações Unidas - ONU. (2022). Envisaging the Future of Cities. In World City Report 2022.

Pan, Y., & Cobbinah, P. B. (2023). Embedding place attachment : Residents ' lived experiences of urban regeneration in Zhuanghe , China. Habitat International, 135(5) 102796. https://doi.org/10.1016/j.habitatint.2023.102796

Qwasmi, R., Abdullah, A. bin, Noor, N. M., & Asmawi, Z. bt. (2022). Discovering the Relationship Between the Accessibility and Covid 19 Using Analytic Hierarchy Process (AHP) Case Study Bukit Bintang, Kuala Lumpur. American Journal of Agricultural Science, Engineering, and Technology, 6(3), 103–112. https://doi.org/10.54536/ajaset.v6i3.962

Rennick, K. L. (2003). Process: A strategy for developing community life and place attachment. Unpublished masters' thesis), Virginia Polytechnic Institute.

Scannell, L., & Gifford, R. (2010). Defining place attachment: A tripartite organizing framework. Journal of Environmental Psychology, 30, 1–10

Scannell L and Gifford R (2014) Comparing the theories of interpersonal relations and place attachment. In Place Attachment: Advances in Theory, Methods, and Applications (Manzo LC and Devine-Wright P (eds)). Routledge, New York, NY, USA, pp. 23–36.

Silva, C., Kastenholz, E., & Abrantes, J. L. (2018). Linking Mountain Image With Place-Attachment. Journal of Spatial and Organizational Dynamics, 6(2), 140–152.

Su, L., Chen, W., Zhou, Y., Fan, L. (2023). Exploring City Image Perception in Social Media Big Data through Deep Learning : A Case Study of Zhongshan City. Sustainability, 15(4), 3311. https://doi.org/10.3390/su15043311

Sugano, K., Hooimeijer, S., Van de ven, F. (2024). A collaborative hybridity design approach: enhancing urban water resilience and spatial legibility. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 8(3), 723-745. https://doi.org/10.1080/17549175.2024.2333528

Shynu, R., Suseelan, A. (2023). Human cognition and emotional response towards visual environmental features in an urban built context: a systematic review on perception-based studies. Architectural Science Review, 66(6), 468–478. https://doi.org/10.1080/00038628.2023.2232339

Tan, R., Wu, Y., Zhang, S. (2024). Walking in Tandem with the City: Exploring the Influence of Public Art on Encouraging Urban Pedestrianism within the 15-Minute Community Living Circle in Shanghai. Sustainability, 16(9), 3839; https://doi.org/10.3390/su16093839

Tang, P., Sun, X., Law, E., Wang, Q., Cobb, S., Zhou, X. (2020). User-Centered Design Approaches to Integrating Intellectual Property Information into Early Design Processes with a Design Patent Retrieval Application. International Journal of Human–Computer Interaction, 36(10), 911–929. https://doi.org/10.1080/10447318.2019.1699747

Tuan, Y. F. (1974). Topophilia: A study of environmental perception, attitudes, and values. New Jersey: Prentice Hall.

Ujang, N. (2010). Place Attachment and Continuity of Urban Place Identity. Procedia - Social and Behavioral Sciences, 49, 156–167. https://doi.org/10.1016/j.sbspro.2012.07.014

Wan, W. 'Iffah binti. (2017). Little Streets and Hidden Routes : A Study on Alleys Little Streets and Hidden Routes : A Study on Alleys of Kuala Lumpur City Centre. Journal of Built Environment, Technology and Engineering, 2(1), 223-234. http://dx.doi.org/10.13140/RG.2.2.26505.06246

Wardhani, M. K., Wang, Z. (2023). Spatial Dialogues of Historic Alley Through Serial Vision Theory (Case Study :

Pontocho Roji and Jalan Rukunan). UNDIP, 23(1), 22–29. https://doi.org/10.14710/mdl.23.1.2023.22-29
Wartmann, F. M., Stride, C. B., Kienast, F., & Hunziker, M. (2021). Relating landscape ecological metrics with public survey data on perceived landscape quality and place attachment. Landscape Ecology, 36(8), 2367–2393. https://doi.org/10.1007/s10980-021-01290-y
Zhang, K., Liu, J. (2024). Towards Sustainable Development of the Old City: Design Practice of Alleyway Integration in Old City Area Based on Heritage Corridor Theory. Sustainability, 16(18), 8158; https://doi.org/10.3390/su16188158
Zhang, R., Casanovas, M., González, M., Sun, S. (2024). Revitalizing Heritage: The Role of Urban Morphology in Creating Public Value in China's Historic Districts. Land, 13(11), 1919. https://doi.org/10.3390/land13111919
Zhang, Z., Zhuo, K., Wei, W., Li, F., Yin, J., Xu, L. (2021). Emotional Responses to the Visual Patterns of Urban Streets: Evidence from Physiological and Subjective Indicators. Int. J. Environ. Res. Public Health, 18(18), 9677; https://doi.org/10.3390/ijerph18189677
Zecca, C. (2019). Challenges and opportunities in the reuse of abandoned urban space. Robert Gordon University Repository. https://rgu-repository.worktribe.com/output/842190/challenges-and-opportunities-in-the-reuse-of-abandoned-urban-space%0Ahttps://rgu-repository.worktribe.com/output/842190/challenges-and-opportunities-in-the-reuse-of-abandoned-urban-space.
Zukin, S. (2010a) Naked City: the death and life of authentic urban places. New York: Oxford University Press.

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IMPACT OF DEVELOPMENT-INDUCED DISPLACEMENT ON SOCIO-ECONOMIC WELL-BEING OF MAKKAH RESIDENTS, SAUDI ARABIA

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ABSTRACT

In the 21st century, the provision of urban infrastructure and services to meet growing needs and aspirations has intensified displacement, particularly in informal settlements. The Kingdom of Saudi Arabia, particularly Makkah, is undergoing massive urban development projects cutting across informal settlements, which have displaced several households. The study explored the impacts of development-induced displacement on households displaced from Jabal Al-Sherasheef due to urban development and the expansion of Masjid Al-Haram. It is underpinned by the Impoverishment Risk and Reconstruction (IRR) framework. A case study design was employed to collect data from 415 displaced persons and 10 in-depth interviews. Data collected were subjected to both descriptive (frequencies and percentages) and inferential tests (paired t-test). Findings demonstrate that there exists a statistically significant difference before and after displacement in the socio-economic parameters such as family type, tenure type, household size, income, expenditure, and access to services. Interpreted in line with the Impoverishment Risk and Reconstruction (IRR) framework, the findings imply that the Haram expansion and supporting infrastructural projects have impacted the displaced people both in terms of socio-cultural relations as well as economic well-being. There was a significant decrease in the size of displaced households and monthly income after displacement. Furthermore, there was a significant increase in the monthly expenditure after displacement. Similarly, qualitative insights indicate disruption of social structure and reduced access to services. The findings suggest that despite resettlement to formally planned areas of Makkah, the displaced persons still experience material and non-material loss and declining socio-economic well-being. The contribution of the study is to empirically operationalise the Impoverishment Risk and Reconstruction framework within the context of urban Makkah. The study recommends that policy and decision-makers integrate livelihood restoration and support, social network preservation and improved access to services into resettlement planning policies, strategies and implementation to overcome the long-term impact of development-induced displacement.

Keywords: Development, Displacement, Informal Settlement, Socio-Economic Well-Being

1.0 INTRODUCTION

In the 21st century, population growth coupled with a rapid urbanisation continues to place cities and urban areas under intense pressure. This necessitated continuous upgrade and provision of infrastructure to support the growing needs of the urban populace, provide a better, safer, livable and sustainable urban environment. It has been estimated

that 68% of the world's population will live in urban areas by the year 2050 (UN-HABITAT, 2022). This has led to the evolution and proliferation of informal settlements inside the urban boundary and the transition zones. Informal settlements have similar characteristics such as concentration of housing units constructed by either temporary and or permanent materials with no legal documents, no building permits, non-conformance with land use planning regulations, lack of infrastructure and urban services (Srinivas, 1994; UN-Habitat. 2003; UN-Habitat. 2005; Srinivas, 2005; Willis, 2009; Wekesa et al., 2011; Dovey, 2015; Adam, 2014).

A high rate of urbanisation, coupled with inability of governments to provide affordable housing and control urban developments, is among the major causes of informal settlements (Simon, and Ngereja, 2025; Bikis, and Pandey, 2023; FIG, 2008). The proliferation of informal settlements is the major challenge facing the urban areas of the 21st century (Alene, 2022; Davis, 2006). The United Nations Economic Commission for Europe Secretariat (2009) highlighted the following as factors responsible for the spread of informal settlements: (i) speedy growth of urban areas and migration of the populace to selected developed areas; (ii) conflict and regular catastrophes causing people trooping to safer ground in search of means of livelihood; (iii) paucity of improper layout and lack of affordable houses; and (iv) ineffective governance, poor land administration and fragile planning. Most of the causes of informal settlements are attributed to urban development projects and provision of infrastructure and services (Bikis and Pandey, 2023; Cahliková and Stojanov, 2013; Vesalon and Creţan, 2012), which subject the people to socio-cultural and economic hardships (Kaida and Miah, 2015). Urban infrastructure projects accounted for six million more displaced each year (Dodman et al. 2023; Otsuki, 2019; Internal Displacement Monitoring Centre, 2008; Robinson, 2003; Terminski, 2013). According to the World Bank Environment Department's (WBED) report, transportation has caused about 24.6% of resettlement projects. The situation is not different in the Kingdom of Saudi Arabia (Development Commission of Makkah Al-Mukarramah and Mashaaer, 2008). Causes of informal settlement in Makkah are: (i) increased revenue from oil the 70s which is reflected in the country's infrastructural development and the need to attract foreign labour to advance the construction which brought about large migration to the Kingdom's cities especially Makkah; (ii) imbalance in regional development which has led to large migration of people from the Kingdom villages to Makkah in search of work and urban services; (iii) failure of the existing real estate market to find adequate housing for the urban poor as well as land prices which is beyond their reach; (iv) lack of administrative control due to the weakness of the administrative system; (v) lack of land administration guidelines or policies on land ownership; (vi) desire of rural unemployed to have land in the urban center; (vii) failure of planning system to provide affordable housing for the urban poor. Nearly one-third of the built-up areas of Makkah city are informal settlements (Al-Shareef, 2002).

While studies indicate that displacement of people with or without resettlement is undesirable (Dovey, 2015), some suggest displacement with resettlement (Abbott, 2002; Choguill, 1999; Choguill et al., 1993). Various approaches, including upgrading, redevelopment, renewal and resettlement, have been adopted by different nation-states to address informal settlements. However, pointing out one best out of the many approaches remains contested. While some studies views that resettlement is a pathway for improved living conditions, others hold contrary opinion as they critique it due to its negative impacts such as social network disruption, diminishing cultural identity, declining economic strength, loss of land, job, reduced access to resources, reduced income and increased expenditure, and aggravation of poverty among households (Bandara, 2025; Cernea et al., 2007; Hoshour and Kalafut, 2007).

2.0 CONCEPTUAL FRAMEWORK

The displacement of people, mostly the underprivileged, in the name of development has been a common practice across the globe. This has subjected most of those affected to several socio-cultural and economic hardships, as well as exposure to dangers. This is due to a lack of a legal framework that guides the displacement of the urban poor. In an effort to curtail the consequences of development-induced displacement on the less privileged, the World Bank has developed a framework for the displacement of people for any kind of development or project (Cernea, 1990; Cernea, 1997; Cernea, 2000a).

In response to the displacement of people in the name of development, Michael Cernea was motivated by the injustice and developed the Impoverishment Risk and Reconstruction (IRR) framework to address the inequalities caused by development (Cernea, 1990; Cernea, 1997; Cernea, 1996; Cernea and McDowell, 2000; Cernea, 2000b; Cernea, 2000c). This framework serves as an "equity compass" that guides government and international agencies saddled with development and resource allocation to minimise the risks of impoverishment. The framework presents various typologies of displacement risks and possible solutions to mitigate those risks (Cernea, 2000). Cernea highlighted the risk of displacement to consist of one or a combination of the following: landlessness, joblessness, homelessness, marginalisation, food insecurity, increased morbidity, loss of access to common property and community disarticulation.

According to Cernea (2000), the IRR framework is both empirical and theoretical. Empirically, it is based on

factual findings on resettlement studies conducted by researchers in various parts of the world during the last four decades. Theoretically, it benefits from the latest innovations or ideas in the field of resettlement research during the same period. The IRR framework emphasised the economic and social aspects of the displacement and resettlement process. The model has two core fundamental concepts: risk impoverishment and reconstruction. These two core concepts have their respective variables that explain their roles in either risk impoverishment or reconstruction. Due to the consequences of development-induced displacement, the World Bank have developed a policy to guide displacement and resettlement, measures/procedures to be followed (World Bank, 2001).

While the Impoverishment Risk and Reconstruction (IRR) framework developed by Michael Cernea offers a comprehensive lens for studying and understanding displacement risks, it has also been critiqued for being economically dominant, with much emphasis on economic indicators/measures, thereby giving less emphasis on cultural and psychological dimensions of displacement. Furthermore, the IRR model is widely applied in large-scale development projects, thereby subjecting it to a series of queries regarding its adaptability to localised urban contexts. Therefore, while the IRR framework remains the backbone for development-induced displacement and resettlement studies, its application in this study is critically adapted to reflect the economic and socio-cultural realities of the study area.

3.0 CRITICAL REVIEW OF METHODOLOGIES

Beyond conceptual differences, existing studies on development-induced displacement and resettlement also reveal notable methodological limitations. Quite number of literature in the field of development-induced displacement and resettlement relies on cross-sectional case studies with descriptive analyses (Bandara, 2025; Singh, I., & Muhuri2024; Cheau, 2026; Mbatta, 2025), limiting it to assessing the long-term socio-economic well-being of the displaced population. This further limits the ability to relate urban development projects in our cities with displacement outcomes. Similarly, a significant number of studies relied on secondary data mainly from relevant authorities or institutions, and affected persons are rarely engaged, which raises concern about the actual displaced and their actual experiences before and after displacement. As such, a number of gaps exist. Empirical evidence from rapidly urbanising areas like Makkah, where religious and socio-cultural values differ from regions where similar studies have been carried out. Previous studies mostly focused on conceptual discussion or policy analysis, with limited integration of field-based data. Few out of the existing studies assessed the practical implications of Cernea's IRR model within a specific urban context. These subsequently hinder an in-depth understanding of the sustainability of resettlement interventions. This study, therefore, addresses these gaps by undertaking a study in Makkah, which is one of the most urbanised areas of Saudi Arabia, whose religion and socio-cultural values differ from those of other areas where similar studies have been conducted. This study aims to integrate and discuss development-induced displacement, empirical findings from primary-sourced data and Cernea's IRR impoverishment risk. Finally, the study assessed the implications of Cernea's IRR model within the context of Makkah, Saudi Arabia.

4.0 PROBLEM STATEMENT

Informal settlements are widely characterised by a wide range of economic, social and cultural issues such as insecure land tenure, inadequate infrastructure, and non-compliance with planning regulations (Srinivas, 1994; UN-Habitat, 2003; Dovey, 2015). Intensity of the challenges depends on the context, setting and how it is viewed. For instance, the UN-Habitat adopts a general framework in explaining informal settlement, while scholars like Dovey argue that this is a phenomenon that can be better understood as adaptive socio-spatial systems. This indicates a conceptual gap in the way and manner informality is framed.

Informal settlements have been categorised as unplanned settlements or slums (Karimi and Parham, 2012). They may be seen as a purely urban problem, but it is a product of political, economic and social factors. The Municipality of Jeddah (2009) stated that there are about 50 unplanned/informal settlements in Makkah, distributed within and at the urban boundary of Makkah with an estimated population of one million, and this remains the major challenge to the Holy City (Al-Shareef, 2002). In an effort to improve the urban image of Makkah, several development programmes have been proposed, some of which are undergoing implementation. The implementation of these urban development projects, comprising roads, hotels/accommodation and other urban infrastructure, has resulted in the displacement of households living in informal settlements. The development project in Makkah is expected to displace 25,000 households (Al-Khudairi, 2012). In the Kingdom of Saudi Arabia, previous research on informal settlements focused on evolution, identification, their locations and subsequent problems (Alrasheedi et al. 2023; Majrashi, 2017; Al-

Shareef and Seraj, 1992; Al-Shareef, 2003; Al-Zahrani, 2014; Al-Sobhi, 20114). These studies were based on documentary sources and focused on only the predictive approach. The authors failed to adopt survey research to explore an in-depth understanding of the phenomenon or investigate the direct and indirect socio-economic impacts of displacement on the affected people. Empirical studies on development-induced displacement and self-resettlement in Makkah are lacking. Therefore, the contribution of this research will be the in-depth investigation of the impact of development-induced displacement on the people. Also, to determine the direct and indirect consequences of displacement on the people.

5.0 STUDY AREA

Makkah city is located between latitude 39° 35¹E and 40° 02¹E and longitude 21° 09¹N and 21° 37¹N, in the western part of the Kingdom of Saudi Arabia, as shown in Figure 1. It is one of the largest cities in the Kingdom of Saudi Arabia, and the most populous, with a population of 5,791,184 people, with a total landmass of 153,148km2 and a population density of 45/km² (Central Department of Statistics & Information, Saudi Arabia, 2021). Hajj and Umrah are the two most important functions of the city, which attract people from all over the world. The high population in the city is a reflection of rural-urban migration, coupled with pilgrims staying back after performing their religious obligation. These have led to the evolution and proliferation of informal settlements in and around the city boundary.

Fig. 1: Map of Saudi Arabia Showing Makkah
(Source: Majrashi, 2017)

6.0 METHODOLOGY

This study adopts a case study design to assess the impacts of development-induced displacement on the residents of Jabal Al-Sherasheef in Makkah, Kingdom of Saudi Arabia, who were displaced due to the expansion of the Haram. The design employed both quantitative and qualitative techniques for a better understanding of development-induced displacement in the study area. A questionnaire and semi-structured interview were employed to collect quantifiable data on the socio-economic well-being of the residents before and after displacement, while the semi-structured interview offered in-depth insights into the lived experiences and perceptions of the residents. The design allows cross-verification of data for a better and in-depth understanding.

Target respondents are people displaced from Jabal Al-Sherasheef in Makkah. The fact that the population of the study is unknown, 415 displaced people were traced to respond to the questionnaire. Samples were drawn using the snowballing sampling technique. Ten (10) participants were selected for an interview using a purposive sampling technique. The questionnaire was developed based on the review of the literature on informal settlements and development-induced displacement. It was reviewed for clarity and pre-tested with 50 respondents to identify areas needing further amendment. After this, the instrument was administered by the

researcher and four assistants from Jabal Al-Sherasheef. Similarly, an interview guide was developed to explore key social, cultural and economic themes. The time and venue for the interview were arranged by the respondents based on their convenience. During the interview, they were allowed to adequately express their experiences. Both quantitative and qualitative data were analysed concurrently.

Quantitative data were analysed descriptively using frequencies and percentages. An inferential test, specifically a paired sample t-test, was conducted to examine disparities in the socio-cultural and economic well-being of the displaced people before and after displacement. Qualitative data from the interview were transcribed and analysed. The analysis allows integration of data and findings, where quantitative results offered generalizability, and qualitative results offered contextual explanations. Ethical considerations were carefully taken care of throughout the study. Participation was voluntary, and respondents were assured of confidentiality and anonymity, especially with the sensitivity of displacement experiences. Challenges encountered include, but are not limited to, access to the displaced population and potential recall bias.

7.0 RESULTS AND DISCUSSION

Analysis of the spatial extent of the study areas was initially conducted. Figure 2 shows the planned built-up areas of Makkah in blue, and the informal settlements in brown. The informal settlements in Makkah covered an area of 6,102.98 hectares. The informal settlements are subdivided into 65 patches located across the city (Otsuki, 2019). Article (5) of Central Department of Statistics & Information, Saudi Arabia (2021) categorised informal settlements into three: those that arose due to individual development of house units with or without permit; semi-organised informal settlements with building permits and where structures are in the form of semi-geometric form; and historical areas/towns, where part of the old city forms part of it.

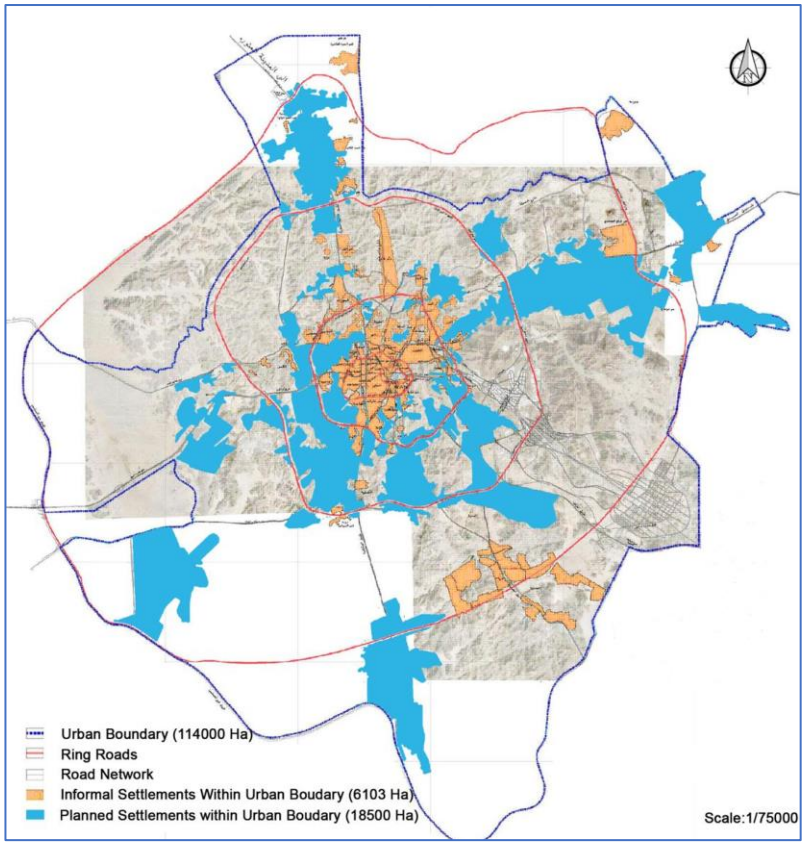

Fig. 2: Distribution of Planned and Informal Settlements in Makkah
(Source: Majrashi, 2017)

The findings of the research are presented and discussed in this section. Both descriptive and inferential statistical techniques were employed to analyse the data collected. Furthermore, qualitative insights from interviews were used to complement the qualitative findings. Table 1 presents the demographic profile of the respondents.

Table 1: Demographic Profile of the Respondents

Variable	Response	Frequency (f)	Percentage (%)
Gender	Male	396	95.4
	Female	19	4.6
Nationality	Saudi	298	71.8
	Others	117	28.2
Country of birth	Saudi	372	89.6
	Country of origin	43	10.4
Age group	21-30	108	26.0
	31-40	161	38.8
	41-50	66	15.9
	51-60	48	11.6
	61 and above	32	7.7
Level of education	Informal	73	17.6
	Primary	88	21.2
	Secondary	71	17.1
	Diploma	103	24.8
	Degree	70	16.9
	Post graduate	10	2.4
Employment	Self-employed	52	12.5
	Public	172	41.4
	Private	158	38.1
	Unskilled labour	33	8.0
Duration of stay	0-5	3	0.7
	6-10	9	2.2
	11-15	49	11.8
	16 and above	354	85.3

The result reveals a pronounced gender imbalance, as the male respondents constitute an overwhelming majority (95.4%), while the females constitute a marginal proportion of 4.6%. The skewed nature of the findings may be connected to the socio-cultural and religious background of the people, which limits the participation of females with non-relatives and or activities outside the home environment.

With respect to the nationality of the respondents, Saudi citizens dominate the sample with 71.8% representation, although the non-Saudi citizens represent a substantial proportion (28.2). Notably, despite the composition of the respondents, 89.6% were born in the Kingdom of Saudi Arabia, suggesting a high level of socio-spatial integration with migrants. This implies that both the citizens and non-citizens have long-standing attachments to Jabal Al-Sherasheef.

The age distribution of the respondents demonstrates that more than 50% of the respondents fall within the age bracket of 31-50 years of age. This can have substantial implications for the socio-cultural well-being and economic stability.

Educational attainment among the displaced population is relatively low, with more than half of the respondents having attended secondary, primary or informal education. This reaffirms what the literature characterises as informal settlements, linking it to limited access to educational facilities and services. Even though there is representation of diploma and degree holders, indicating that those respondents did not allow the environment to influence them.

Employment status of the respondents from Jabal Al-Sherasheef illustrates a complex situation. Despite their low level of education, a significant proportion of the respondents work with either the public or private sector, while a notable segment is engaged with the informal sector. This demonstrates the coexistence of both formal and informal sectors within Jabal Al-Sherasheef. This implies that, on average, people who attended secondary level of education can be employed to work in either the public or private sector.

With respect to the duration of stay, the overwhelming majority (85.3%) of the respondents lived in Jabal Al-

Sherasheef for over 15 years. The long-term occupancy highlights the deep-rooted social and economic ties in the area, and explains why some of the foreign settlers were born in Saudi Arabia.

An assessment of the displaced family structure before and after displacement (Figure 3) reveals a significant transformation from a predominantly extended family to a nuclear family. Before the displacement, extended families dominated the composition of households, thereby reflecting strong social ties and networks. However, after displacement, nuclear family structure dominates, thereby implying the breakdown of the extended family system and social networks. The shift from extended to nucleated family structure suggests a fragmentation of traditional social structures.

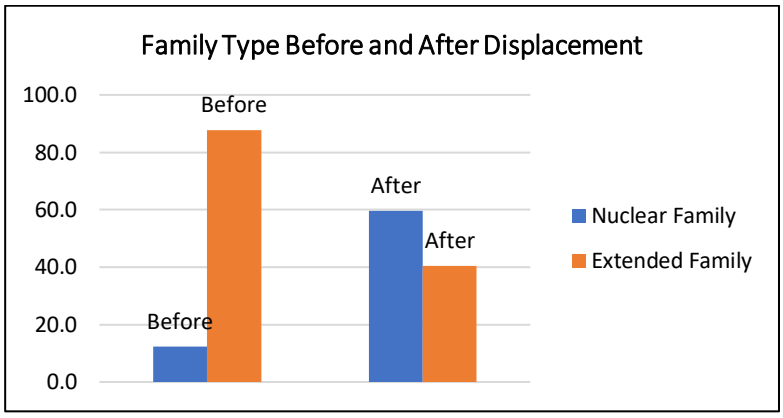

Fig. 3: Family Type Before and After Displacement
(Source: Authors' Analysis)

Concerning tenure type, the findings reveal a substantial shift in tenure after the residents were displaced from Jabal Al-Sherasheef (Figure 4). Before the residents were displaced, a dominant proportion of them possessed land, indicating a relatively stable tenure structure. However, the post-displacement results suggest that more than half of the residents shifted to tenancy status, as only 30% of the respondents retained their status as owners.

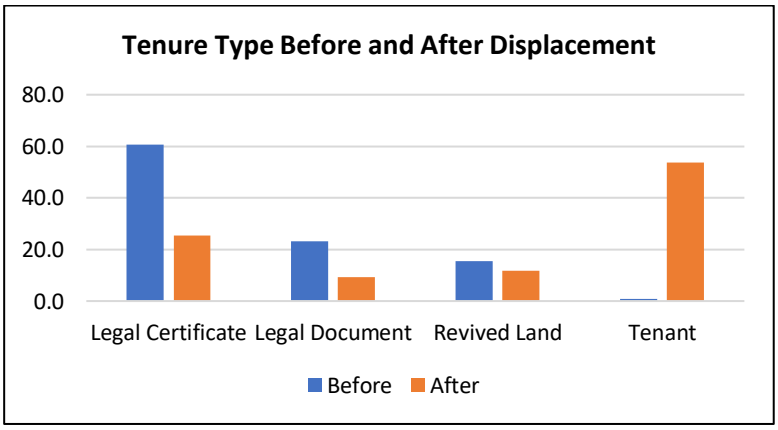

Fig. 4: Tenure Status of the Respondents
(Source: Authors' Analysis)

To achieve the aim of the research, which is to assess the impact of development-induced displacement on the affected people, a paired sample t-test was employed to determine the difference between the condition of the displaced before and after displacement. The findings reveal that there is a statistically significant decrease in household size before displacement (M=2.21, SD=.949) to (M=2.07, SD=.886) after displacement, t=3.206 (414), p<.005 as in Table 2. The decrease in house hold size may be due to the nature houses before displacement which can be expanded to suit the need of the households and accommodate all members of the extended

family, and even newly married couples because the house is owned by the households; while after displacement, they move into apartments that cannot be expanded, and accommodates limited number of people (mostly nuclear family only). This is a reflection of physical constraints and social restructuring.

Table 2: Paired Sample t-test Results

	Before Displacement		After Displacement		t-value	df	Sig. (2-tailed)
	Mean	SD	Mean	SD			
Household size	2.21	.949	2.07	.886	3.206	414	.001
Monthly income	2.35	1.025	2.24	.982	2.568	414	.011
Monthly expenditure	3.14	1.139	3.69	1.286	-10.458	414	.000
Location of shopping centres	1.66	.989	2.15	1.113	-7.289	414	.000

Similarly, there is statistically significant decrease in the income of the displaced after displacement, with a mean value of 2.35, SD = 1.025 before displacement, to mean of 2.24 and SD of .982 after displacement with a t value of 2.568 at 414 degree of freedom and $p<.05$. On the other hand, there is statistically significant increase in their monthly expenditure after displacement, with a mean of 3.14, SD=1.139 before displacement and mean of 3.69 and SD=1.286 after displacement with t value of 10.548 at 414 degree of freedom and $p<.001$. This implies that those who were self-employed and those who are unskilled labourers may have lost their jobs/means of income as a result of the displacement. This is one of the risks highlighted by Cernea (1990) in his Impoverishment Risk and Reconstruction Model (IRR). This issue can be addressed through employment generation in the displaced new locations. Despite a decrease in the monthly earnings of the people, their expenditure, on the other hand, increased. This may be attributed to a change of status of housing ownership from personal to rental, coupled with expensive services in the new location, since it is planned, unlike in the informal settlement, where services are informal and at the same time cheap.

The responses reveal that there is a statistically significant increase in the distance to shopping areas, with a mean value of 1.66, SD=.989 before displacement to a mean of 2.15, SD=1.113 after displacement, with a t value of 7.289 at 414 degrees of freedom and $p<.001$. This implies that the displaced now stay in planned areas with specific land uses located in specific areas. Unlike in the informal settlement, where everything is informal, such as rooms or sections of houses that are informally converted to shops. This can allow residents of the area to shop without going a long distance, while in a planned area, people have to go to commercial areas for shopping.

The qualitative findings offer in-depth insight into development-induced displacement. Ownership and family ties are the primary motives behind staying in Jabal Al-Sherasheef. This reinforces the significance of extended family structure. The majority of them indicated “the area/house belongs to my family; I have a section in the house and stay with them”. This implies that those whose immediate family owns a house do not need to suffer looking for accommodation elsewhere, as some indicated that “my extended family cannot allow me and my family to stay elsewhere”. The house, therefore, continues to undergo modification to meet the needs of the extended family. Some argue that proximity to religious infrastructure is an influential factor for staying in the area. The respondents cite the reason that “the area is close to the city centre and also Masjid Al-Haram”. This implies that the people stay in the area because of its proximity to the city centre and their business activities or working place, as they can reach those places easily and within a short period of time. Very few respondents indicated that “it is cheaper to stay in the area than other apartments elsewhere”. Since they cannot afford to rent a luxurious apartment due to their status as low-income earners, they go for the cheaper option. Cumulative loss of these can contribute to economic and social dislocation.

8.0 DISCUSSION

This study empirically operationalised Cernea’s Impoverishment Risk and Reconstruction (IRR) model. The findings demonstrate interaction between the key concepts of the model and development-induced displacement in Jabal Al-Sherasheef, thereby producing socio-economic vulnerability as conceptualised by the model. It demonstrates a direct link between empirical findings and the key concepts of the IRR model as

presented in Figure 5. The displacement systematically and measurably re-imaged IRR risks. This highlights the significance of employing a holistic approach to resettlement studies, exploring the material and non-material impacts of displacement, and providing empirical evidence within an urban context.

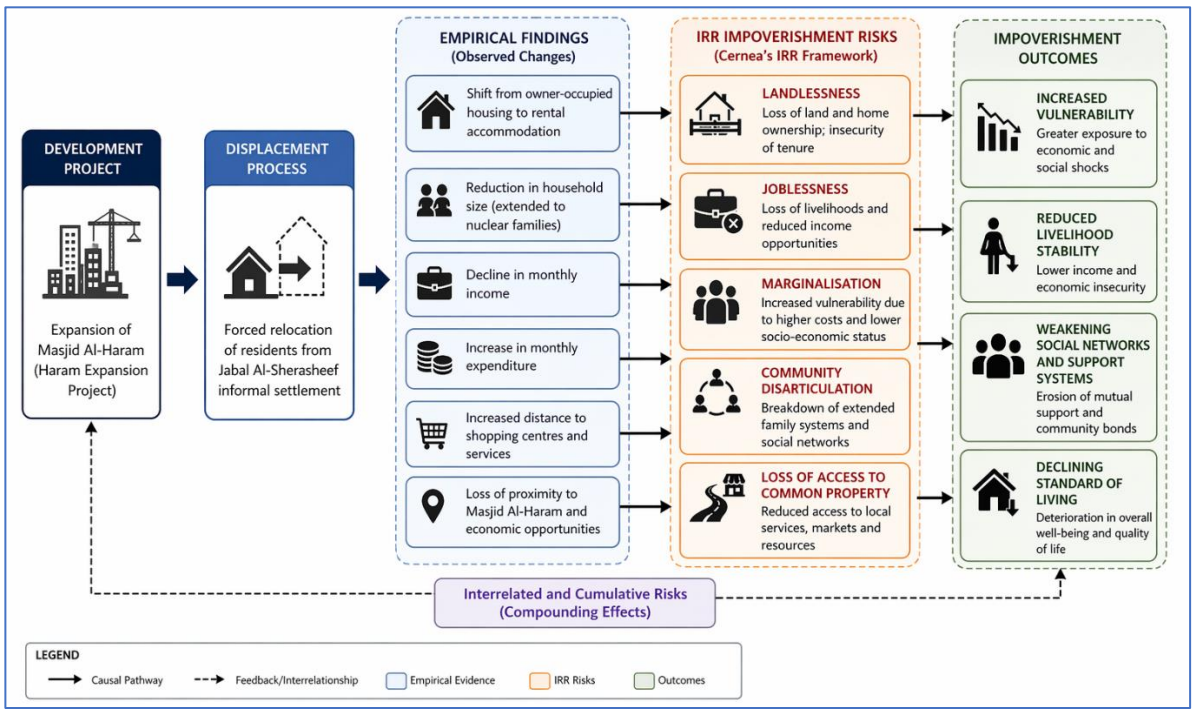

Fig. 5: Conceptual Framework Linking Development-Induced Displacement, Empirical Findings and IRR Impoverishment Risks
(Source: Authors' Conceptualisation based on Cernea's IRR model (1990, 1997) and Empirical Data from the Field)

Empirical evidence from the study in Al-Sherasheef, Makkah demonstrate shift in family structure from extended to nuclear family size due to displacement induced by development, signifying fundamental disruption of social systems. Relating this to Cernea's Impoverishment Risk and Reconstruction (IRR) model, this shift conforms to community disarticulation, as displacement breaks down long-standing kinship networks and wears away social bonds. Family structure, particularly extended serve as a critical support system for economic and social stability. Their breakdown led to non-material loss, which is mainly underestimated in conventional resettlement studies. The dynamics of family structure are reflected in the dynamics of household size, as the study reveals a significant reduction in household size, which is mainly influenced by formal housing arrangements in the new location. This demonstrates fragmentation of social network/ties, thereby underpinning community disarticulation of the IRR model.

The study has presented an evidence-based study of tenurial insecurity and manifestation of landlessness by the displaced people of Jabal Al-Sherasheef due to a shift in tenure type, as many of the owner-occupiers before displacement have become tenants in rented accommodation. The shift aligns with Cernea's concept of landlessness and signifies physical loss of property, posing a threat to long-term economic security and exposing the displaced to vulnerable economic and social conditions, thereby subjecting the displaced to long-term economic insecurity.

Income and employment status of the displaced demonstrate a significant decrease after displacement, thereby pushing them towards joblessness, in line with the conceptualisation of the IRR framework by Cernea. This provided evidence that family and neighbourhood structure are critical support systems for economic and social stability, signifying informality. Therefore, when it is ripped to pieces, it affects individuals whose livelihoods were connected to the spatial and economic setting of the original settlement.

The study provides empirical evidence of increased expenditure, suggesting economic marginalisation and deterioration of economic well-being. This underscores a shift from an informal and low-cost living environment

to a formal setting, characterised by a higher cost of living. This subjects the less advantaged households to a series of living challenges and places them at risk of impoverishment, as pointed out by the IRR model. This can be challenging for the disadvantaged population, as the study provided evidence of increased household expenditure, leading to reduced socio-economic well-being, presenting substantial evidence of marginalisation.

Access to shopping facilities becomes a challenge in the new location. Proximity to goods and services in the new area is influenced by the extent of formality in the area, unlike in the old settlement, where mixed land uses facilitated access to the facilities. This signifies that the new area is planned, and therefore functional zoning exists, which subsequently increases travel time and cost for goods and services. The increased distance to facilities and services according to the IRR model signifies a loss of access to common property resources. This can influence the socio-economic well-being of the displaced people.

9.0 CONCLUSION

The study explored the socio-economic and cultural impacts of development-induced displacement on the affected population who lived in Jabal Al-Sherasheef due to the expansion of Masjid Al-Haram and supporting infrastructure. A case study design combining both quantitative and qualitative approaches was employed to provide an in-depth understanding of pre- and post-displacement conditions of the people, by measuring outcomes and lived experiences. Findings reveal that displaced persons experience notable socio-economic disruptions. This is despite being relocated to planned areas. This includes a shift from house/land owners to tenancy status, breakdown of socio-cultural network/ties, declining income, increased expenditure and reduced access to basic services. Practically, living in a planned environment, zoning determines where each activity or service is located, which increases the distance to access these services, implying high expenditure. These lead to deterioration of the socio-economic well-being of the affected population, particularly as they were used to life in an informal setting, where mixed-use operations operate with no regulation. Viewing the scenario through the lens of the Impoverishment Risk and Reconstruction Framework by Cernea, empirical findings demonstrate the interconnection between the concepts of the model and the outcome of the study. Instead of experiencing a better well-being after displacement, the affected households experience intensified vulnerability. The empirical evidence of the study highlights the inadequacy of resettlement in improving the well-being of people, despite the fact that the resettled area is a planned one. In reality, development-induced displacement can play a vital role in uplifting a city's image in terms of infrastructure; however, it can influence economic and social disruptions, specifically for low-income and informally employed individuals. The study contributes to the body of knowledge by empirically operationalising the Impoverishment Risk and Reconstruction Framework within the context of Makkah, Saudi Arabia, which undergoes rapid urban development and redevelopment. It revealed that development-induced displacement is a serious challenge in urban Makkah, no matter how formally planned an area is. The outcome highlights the need for integration of livelihood restoration and support, social network preservation and improved access to services into resettlement planning policies and strategies to overcome the long-term impact of development-induced displacement.

10.0 POLICY RECOMMENDATIONS

Improper management of development-induced displacement can reproduce multiple material and non-material losses that can further impact the socio-economic well-being of the affected persons. Since development-induced displacement is inevitable, the impacts can be mitigated through the following policy recommendations:

i. The need to prioritise livelihood restoration and improvement
ii. Consideration of secure tenure arrangements and provision of multiple options of affordable housing
iii. Consideration of the social fabric of the affected communities in displacement and resettlement policies
iv. The need to strengthen institutional and legal frameworks and produce a clear guideline and legal framework for displacing people from their origin.
v. Adopt participatory planning where the displaced can be encouraged to participate in planning, implementation, resettlement and post-resettlement phases to ensure sustainable resettlement
vi. Ensure effective monitoring across all the phases that can guide post-resettlement support where necessary.

REFERENCES

Abbott, J. (2002). An Analysis of Informal Settlement Upgrading and Critique of Existing Methodological Approaches. *Habitat International*, *26*(3), 303-315.

Adam, A. G. (2014). Informal Settlements in the Peri-Urban Areas of Bahir Dar, Ethiopia: An Institutional Analysis. *Habitat International*, 43, 90-97.

Alene, E. T. (2022). Determinant Factors for the Expansion of Informal Settlement in Gondar City, Northwest Ethiopia. *Journal of Urban Management*, *11*(3), 321-337.

Al-Khudairi, A., (2012). "*Friday Meeting with Dr. Abdulaziz Al-Khudairi*", Khalejia TV.Saudi Arabia. http://www.youtube.com/watch?v=SZ91QScu1zs. Accessed 10/9/2012.

Alrasheedi, K. G., Dewan, A., & El-Mowafy, A. (2023). Using local knowledge and remote sensing in the identification of informal settlements in Riyadh City, Saudi Arabia. *Remote Sensing*, *15*(15), 3895.

Al-Shareef, M. (2002). The Problem Changing Urban Cities of Saudi Arabia: The National and Regional Perspective. *Journal of Building Technology, Saudi Arabia*. Issue 1.

Al-Shareef, M. 2003.The Squatting Development in Makkah AL-Mukkaramah Characteristics, Problems and Solutions. *Scientific Journal of King Faisal University, Saudi Arabia*, 4(1).

Al-Shareef, M. and Seraj, M. (1992). *A Field Study of Informal Endemicity Areas in Makkah*.

Al-Sobhi, H. (2014). *Towards Comprehensive Strategy of Future Treatments of Informal Areas in Makkah*. Master's Degree in Architecture, Department Islamic Architecture Umm al-Qura University.

Al-Zahrani, K. (2014). *Slum Areas in Makkah Between Hope and Reality" Toward a Safe Environment and Sustainable*. Master's Degree in Architecture, Department Islamic Architecture Umm al-Qura University.

Bandara, J. (2025). Development-Induced Displacement and Resettlement, Women, and Social Security. Journal of Social Sciences-NISD, 3(2).

Bikis, A., & Pandey, D. (2023). Squatter Settlement and Informal Urbanization: Causes and Consequences. *Environmental Science and Pollution Research*, *30*(9), 23276-23294.

Cahliková, Z., & Stojanov, R. (2013). Development-Induced Displacement and Sustainable Development: The Case Study of Slezská Harta Dam in the Czech Republic. *Problemy Ekorozwoju*, 8(2), 75-84.

Central Department of Statistics & Information Saudi Arabia (CDSI) (2021). Saudi Arabia.

Cernea, M. (2000a). *Risks, Safeguards, and Reconstruction: A Model for Population Displacement and Resettlement*. In M. Cernea and C. McDowell (eds.), Risk and Reconstruction. Experiences of Resettlers and Refugees, Washington, The World Bank, pp. 11-55.

Cernea, M. and C. McDowell. (2000b). *Risks and Reconstruction: Experiences of Resettlers and Refugees*. Washington, DC: The World Bank.

Cernea, M. M. (1990). `Poverty Risks from Population Displacement in Water Resources Development', Development Discussion Paper No 355. Cambridge, MA: Harvard Institute for International Development.

Cernea, M. M. (1996). *Impoverishment Risks and Livelihood Reconstruction: A Model for Resettling Displaced Populations*. Washington, DC: The World Bank, Environment Department (mimeo).

Cernea, M. M. (1997). The Risks and Reconstruction Model for Resettling Displaced Populations.

Cernea, M. M. (2000c). Risks, Safeguards and Reconstruction: A Model for Population Displacement and Resettlement. Economic and Political Weekly, 3659-3678.

Cernea, M. M., and Mathur, H. M. (2007). *Can Compensation Prevent Impoverishment?: Reforming Resettlement Through Investments*. Oxford University Press.

Cheau, V. (2026). Socio-Cultural and Economic Impact of Development-Induced Displacement: A Comparative Study of Affected Families Before and After Resettlement. Available at SSRN 6302578.

Choguill, C. L. (1999). Community Infrastructure for Low-Income Cities: The Potential for Progressive Improvement. *Habitat International*, *23*(2), 289-301.

Choguill, C. L., Franceys, R., & Cotton, A. (1993). Building Community Infrastructure in the 1990s: Progressive Improvement. *Habitat International*, *17*(4), 1-12.

Davis, M. (2006). *Planet of Slum*. Verso: London.

Development Commission of Makkah Al-Mukarramah and Mashaaer (DCOMM) (2008). Project of the List of Informal Settlement Development in Makkah Region.

Dodman, D., B. Hayward, M. Pelling, V. Castan Broto, W. Chow, E. Chu, R. Dawson, L. Khirfan, T. McPhearson, A. Prakash, Y. Zheng, and G. Ziervogel (2022). *Cities, Settlements and Key Infrastructure*. In: Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem, B. Rama

(eds.). Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 907–1040, doi:10.1017/9781009325844.008.

Dovey, K. (2015). Sustainable Informal Settlements? *Procedia-Social and Behavioral Sciences*, 179, 5-13.

FIG. (2008). *Informal Settlements: The Road Towards More Sustainable Places*. FIG Report no. 42. Copenhagen: International Federation of Surveyors (FIG).

Hoshour, K. and Kalafut, J. (2007). *Development-Induced Displacement & Resettlement*. Issue Paper, (International Accountability Project: February 2007). "Development-Induced and Conflict-Induced IDPs: Bridging the Research Divide" Available at: http://www.fmreview.org/FMRpdfs/BrookingsSpecial/15.pdf, Accessed 15/09/14.

Internal Displacement Monitoring Centre (IDMC) of the Norwegian Refugee Council (NRC) (2008). *Submission to the Committee on Economic, Social and Cultural Rights: 40th Session*. Economic, Social and Cultural Rights of Internally Displaced Persons (IDPs) in India April 2008.

Kaida, N., and Miah, T. M. (2015). Rural-Urban Perspectives on Impoverishment Risks in Development-Induced Involuntary Resettlement in Bangladesh. *Habitat International*, 50, 73-79.

Karimi. K and Parham E. (2012). *An Evidence-Informed Approach to Developing an Adaptable Regeneration Programme for Declining Informal Settlements*. Proceedings: Eighth International Space Syntax Symposium Edited by M. Greene, J. Reyes and A. Castro. Santiago de Chile: PUC, 2012.

Majrashi, A. (2017). *Development-induced displacement of informal settlements in Makkah, Saudi Arabia*. *Disserttation, Teknologi Malaysia University* (2017).

Mbatta, I. P. (2025). Pre-displacement Psychosocial Well-being Among Planned Displacement: The Perspectives of Msimbazi Basin Residents in Dar es Salaam, Tanzania. Tanzania Journal for Population studies and Development, 32(1), 34-56.

Municipality of Jeddah. (2009). Jeddah Strategic Plan, Building Our Future, Preserving Our Heritage and Values.

Otsuki, K. (2019). Who is in 'the public'? Infrastructure of displacement and urban resettlement in Mozambique. *Built Environment*, *44*(4), 493-508.

Robinson, W.C (2003). Risks and Rights: The Causes, Consequences, and Challenges of Development-Induced Displacement. *Occasional Paper,* Vol. 18. Washington, DC: Brookings Institution.

Simon, O., & Ngereja, Z. (2025). Spatial Determinants of Informal Settlement Expansion in Dar es Salaam Metropolitan City, Tanzania: A Geographically Weighted Regression Approach. *Geo Journal*, *90*(3), 100.

Singh, I., & Muhuri, S. (2024). Essential livelihood recovery interventions (LRIs) for urban development-induced rural displacement and resettlement in India: a Delphi technique. Environment, Development and Sustainability, 1-28.

Srinivas, K. R. (1994). Power without Accountability: Draft Bill on Plant Breeders' Rights. *Economic and Political Weekly*. 729-730.

Srinivas, S. (2005). *Technical Standards and Economic Development: Meeting the most Common Denominator*. Prepared for the United Nations Industrial Development Organization (UNIDO), Vienna.

Terminski, B. (2013). Development-induced Displacement and Resettlement: Theoretical Frameworks and Current Challenges. *Development*, 10, 101.

UN-HABITAT (2022). *World Cities Report 2022: Envisaging the Future of Cities*. United Nations Human Settlements Programme (UN-Habitat); P.O. Box 30030, Nairobi, Kenya

UN-Habitat. (2003). *The Challenges of Slums: Global Report on Human Settlements 2003*. London: Earthscan Publication Ltd.

UN-Habitat. (2005). *Bringing Down the Cost: Realistic Standards for Shelter*. Available at http://www.unhabitat.org.

United Nations Economic Commission for Europe Secretariat. (2009). *Globally Harmonized System of Classification and Labelling of Chemicals (GHS)*. United Nations Publications.

Vesalon, L., and Creţan, R. (2012). Development-Induced Displacement in Romania: The Case of Roşia Montană Mining Project. *Journal of Urban and Regional Analysis*, 4(1), 63-75.

Wekesa, B. W., Steyn, G. S., and Otieno, F. F. (2011). A Review of Physical and Socio-Economic Characteristics and Intervention Approaches of Informal Settlements. *Habitat International*, 35(2), 238-245.

Willis, K. D. (2009). Squatter Settlements. *World*, 47, 31-6.

World Bank (2001). *Operational Policy 4.12 on Involuntary Resettlement*. Social Development Department. Washington D.C., World Bank.

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EXPLORING SPACE ADAPTABILITY AND MULTI-FUNCTIONALITY IN THE DESIGN AND CONSTRUCTION OF AN INTERNATIONAL TRADE FAIR COMPLEX FOR TARABA STATE

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ABSTRACT

This research focuses on the design and construction of a multi-functional international trade fair complex for Taraba State, Nigeria, with an emphasis on spatial adaptability. This research focuses on the design and construction of a multi-functional international trade fair complex for Taraba State, Nigeria, with an emphasis on spatial adaptability. The existing state-owned trade fair facility in Jalingo lacks the necessary infrastructure to support multiple functions year-round effectively. The study aims to propose a design solution for a versatile trade fair complex capable of accommodating diverse activities and responding to changing space requirements. A mixed-method research design approach was adopted, employing case studies, structured observation checklists, and architectural design tools, including AutoCAD, as instruments for data collection. Results are presented using tables, plates, frequency distributions, percentages, and architectural design drawings to illustrate spatial allocation, functional relationships, and design outcomes. Findings revealed that 50% of the facilities at the current state-owned Jalingo trade fair complex were either unavailable or inadequate. The proposed Jalingo International Trade Fair Complex was designed to incorporate 18 key functional components, totaling 47 usable facilities, including exhibition halls, open fairgrounds, parking lots, cultural pavilions, offices, and service areas. The results further indicate that the most extensively used spaces are the parking area (44,400m²), exhibition halls (40,950m²), and open fairground (14,250m²), while the eatery service unit, internet cafe, and information desk areas occupied the least spatial allocation with 39m², 40.56m², and 59.40m² respectively. In conclusion, the proposed design offers a sustainable framework for improving facility utilization and enhancing the socio-economic value of trade fair infrastructures in the State of Taraba. Therefore, it is recommended that implementing this project, either through state initiatives or public-private partnerships, will create direct and indirect employment opportunities and enhance Taraba State's internally generated revenue base.

Keywords: Architectural design, Facility management, Flexibility, Multi-functionality, Spatial adaptability, Trade fair complex

1.0 INTRODUCTION

The increasing global demand for multi-functional spaces presents a critical sustainability challenge, as it requires the effective adaptation of built environments to accommodate diverse human activities to ensure

sustainable and efficient space usage. This adaptability reflects the evolving relationship between space utilization and sustainable development. Pius (2016) emphasizes that the effectiveness of a trade fair complex largely depends on its physical characteristics, spatial organization, and geographical location, which collectively influence its capacity to serve as a platform for commercial interaction, innovation display, product marketing, investment promotion, and public awareness.

Trade fairs, as defined by the International Chamber of Commerce [ICC] (2020), are periodic events that bring together commercial and allied activities. These events provide opportunities for companies operating within specific industries to present their products and services, interact with clients and business partners, observe competitive practices, and evaluate emerging market dynamics and opportunities (Shehu et al., 2019; Kodei, 2024). The long-term sustainability of trade fair complexes, therefore, lies in extending the functional use of such facilities beyond occasional exhibitions. A defining feature of sustainable fairground and event venues is the integration of flexible, multi-purpose spaces capable of supporting varied functions throughout the year. The State of Taraba in Nigeria is notably endowed with rich natural resources and remarkable cultural diversity, comprising numerous ethnic groups including Jenjo, Kuteb, Chamba, Kodei, Mumuyes, Mambila, Wurkum, Fulani, Jukun, Ichen, Tiv, Hausa, Karinjo, Bandawa, Munga, Lol, Zoh, and Ndoro. As a result of this diversity and economic potential, trade fairs in the state have evolved into major events that attract significant participation from both national and international audiences.

1.1 Statement of the Problem

Trade fairs are recognized as significant revenue-generating ventures, contributing financially through ticket sales, exhibition booth rentals, gate fees, and advertising opportunities. These income streams have the potential to strengthen the internally generated revenue for both state governments and organizing bodies in most developing countries. Nevertheless, reliance on trade fairs alone is insufficient, as the high operational and maintenance costs of such facilities necessitate the integration of additional revenue-producing activities within the same site. Public facilities such as trade fair complexes are by nature spaces that operates intermittently rather than continuously (Kodei et al., 2023). Since trade fairs are seasonal events, their venues often remain unused for an extended period, thereby resulting in idle infrastructure and underperforming assets. Oguejiofor (2011) asserts that the full potential of a trade fair complex can only be realized through intelligent and flexible design solutions that accommodate evolving spatial demands. Despite its vast land area of approximately 764,687m², the existing state-owned Jalingo Trade Fair Complex in Taraba State, Nigeria, established in the year 2000, has hosted only two major and two minor trade fairs to date (Kodei et al., 2023). This limited level of activity highlights a significant pattern of underutilization, which may be attributed to the absence of multi-use and multi-functional design strategies within the expansive facility. Furthermore, although Pius (2016) conducted a study titled “Review of Planning and Design Characteristics of Trade Fair Complex in Jalingo,” the research focused primarily on the urban site planning and did not address the architectural design considerations necessary for achieving functional flexibility of facilities.

Consequently, this study is motivated by the need to develop an innovative architectural design response which could promote a multi-functional trade fair complex capable of accommodating a wide range of activities, including exhibitions, fairs, performances, meetings, and conferences. By enhancing spatial adaptability and functional flexibility, such a design approach aims to support sustainable space utilization and improve the economic viability of the facility. The provision of a trade fair complex that can efficiently respond to changing spatial requirements is therefore critical to maximizing its long-term relevance and productivity.

1.2 Purpose of the Study

The purpose of this study is to propose a new design and construction of Jalingo international trade fair complex for the State of Taraba in Nigeria by exploring the concept of space adaptability and multi-functionalities in Architectural design, and the objectives of the study are:

i. To assess the availability and adequacy of facilities at the existing state-owned Jalingo Trade Fair Complex.
ii. To design an adaptable and multi-functional Jalingo International Trade Fair Complex for multi-purpose activities.

1.3 Research Questions

i. What facilities are available and their level of adequacy at the existing Jalingo Trade Fair Complex? How can an adaptable and multi-functional Jalingo International Trade Fair Complex be designed?

1.4 Motivation of this study

This study was motivated by its architectural relevance and the pressing need to develop a multi-functional trade fair complex in Jalingo city, as a catalyst for socio-economic advancement in Taraba State and Nigeria at large. Within architectural practice, exhibitions have historically played a vital role in driving innovation and socio-economic growth, often serving as experimental platforms for emerging materials, construction techniques, and spatial concepts. Notably, exhibition architecture pioneered the large-scale application of materials such as steel and glass, which later became integral to modern building design. Built environments do remain effective only when they satisfy the evolving needs of their users. When functional requirements change, buildings must adapt accordingly to achieve flexibility using minimal resources and intervention. This principle underscores the importance of adaptable architectural solutions in contemporary design practice.

Consequently, this research seeks to transform the existing Taraba State Trade Fair Complex in Jalingo into a multi-functional international trade fair facility or construction of new one as the case may be. The proposed development aims to serve as a strategic investment for the State Chamber of Commerce and Industry, with the capacity to enhance revenue generation, improve facility utilization, and position the complex as a year-round economic and social hub. Through this transformation, the study aspires to contribute to sustainable architectural development and long-term economic viability for the state.

2.0 LITERATURE REVIEW

2.1 The Concept of Trade Fair

The concept of a trade fair has evolved over time as a structured platform for commercial interaction and exchange. According to Kodei (2024), the Oxford Dictionary defines a fair as a periodic event organized at a fixed location and time for the sale of goods, often accompanied by exhibitions, entertainment, and cultural displays. Trade fairs function as commercial showcases where numerous firms from different regions and countries present their products and services to potential buyers. Fairs also serve as dynamic marketplaces that facilitate direct interaction between buyers and sellers, offering exporters access to foreign markets and providing efficient opportunities to establish business networks and assess market conditions. Oguejiofor (2011) observes that various terms such as trade fairs, trade exhibitions, and trade shows are commonly used interchangeably to describe events designed primarily to stimulate trade and commercial engagement. Trade fairs play a particularly significant role in markets where traditional advertising methods are less effective or where direct product demonstration is essential. Naveh (2001) highlights their importance in underdeveloped or politically restrictive economies, where access to international markets may be limited and face-to-face interaction becomes a critical marketing tool. Trade fairs can be categorized into several types based on scale, purpose, and target audience (Oguejiofor, 2011), as follows:

a) *World Fairs/International Exhibitions*: These are large-scale, non-periodic global events where nations exhibit technological innovation, cultural identity, and development achievements. They are largely symbolic and political in nature, rotate between host countries, and occur at irregular intervals. Examples include the 1967 Montreal Expo in Canada and the 1970 Osaka Expo in Japan.
b) *General Trade Fairs (Horizontal Exhibitions)*: This category includes exhibitors from multiple sectors of the economy and targets a broad client base. Such fairs are typically organized to address specific industrial or marketing objectives and are often held annually at fixed venues.
c) *Simple Fairs*: These fairs focused on product display and promotion rather than immediate sales. Transactions usually involve placing orders for future delivery, and the events tend to be moderately specialized.
d) *Specialized Trade Fairs (Vertical Fairs)*: Emerging from industrial diversification, these fairs concentrate on specific industries or product categories. They are usually held at regular intervals in the same location and are primarily open to industry professionals. They are also referred to as “industry fairs,” in contrast to consumer fairs, which are open to the general public. Participation may be international, national, regional, or local.
e) *Semi-Private Exhibitions*: These exhibitions involve a single manufacturer presenting products to a selected few audiences. A common example is the launch of a new automobile model exclusively for dealers or industry stakeholders.
f) *Trade Marts*: A trade mart is a permanent commercial complex consisting of multiple showrooms designed for the continuous promotion and sale of products and services from one or more industries.
g) *Conference Fairs*: These consist of relatively small exhibitions that accompany conferences, seminars, or professional meetings, typically showcasing specialized products related to the theme of the event.

2.2 Space Adaptability in Architectural Design

Space adaptability is a fundamental consideration in contemporary architectural design, as buildings are expected to respond effectively to any changing functional, social, and environmental demands. Mabadeje et al. (2022) argued that buildings should be conceived with the capacity to adjust or be modified in response to evolving conditions. Since change is an inherent aspect of the built environment, architectural design must incorporate elements that enable transformation over time. Acharya (2013) emphasizes that although a building may be designed for a specific purpose, it should possess the flexibility to accommodate multiple uses throughout its lifespan. On their part, Schneider and Till (2007) describe adaptability as the condition that allows users to modify and personalize spaces within defined limits to suit their preferences. In architectural discourse, adaptability extends beyond the provision of shelter or the simple definition of space; it reflects the capacity of architecture to support long-term usability and relevance. Mabadeje et al. (2022) further outlined several strategic approaches through which adaptability can be achieved in building design, as follows:

1) Durability: the selection of materials, construction systems, and assemblies that minimize maintenance, repairs, and replacement, thereby extending the building's lifespan and supporting adaptability.

2) Convertibility: the ability of a building to accommodate changes in functions without major structural alteration.

3) Flexibility: the provision for minor modifications in spatial arrangement to support varying activities.

4) Expandability: the capacity to increase or reduce building space in response to changing needs.

5) Design for disassembly: designing components and assemblies so that they can be easily dismantled, reused, or recycled thereby promoting sustainability and long-term adaptability.

2.3 Approaches to Improve Space Adaptability and Functionalities

The pursuit of sustainable economic development and social inclusion has encouraged the continuous use of fairgrounds and event facilities beyond their primary functions. Year-round utilization through off-season programs such as community gatherings, civic events, religious activities, political gatherings, hobby exhibitions, and traveling shows could enhances its revenue generation and social value. Till and Schneider (2005) identify two dominant approaches to achieving adaptability in architectural design: with one focusing on spatial planning and functional organization, while the other relies on technological interventions. In some design strategies, adaptability is achieved primarily through advanced building technologies rather than spatial configuration. A multi-functional space is characterized by its ability to support multiple activities without rigid zoning, thereby allowing diverse uses to co-exist within the same environment. Such spaces may evolve organically or be intentionally designed to accommodate various functions over different periods of the day or year, and their inherent flexibility allows them to be continuously exploited over time. Ryan (2009) categorizes building layout spaces into five thematic groups: cultural spaces, 24-hour spaces, recreational or "fun" spaces, associated spaces, and healthy spaces. Furthermore, he highlights the importance of integrating both interior and exterior multi-functional areas to accommodate diverse users and activities. As cities continuously evolve, the functions and programs of buildings must also adapt. To remain relevant, buildings should be capable of hosting varied activities throughout their lifespan. Consequently, architectural design must prioritize versatility, ensuring that buildings can fulfill multiple purposes simultaneously and respond effectively to temporal changes.

2.4 Case studies: Multi-functionalities of trade fair centres

This study reviewed multi-functionalities of trade fair centres across the globe. The case studies trade fair centres are four internationals: Melaka International Trade Centre (MITC), Malaysia; Shanghai New International Expo Center (SNIEC), China; Cairo International Convention Centre (CICC), Egypt and Codissia Trade Fair Complex, India were considered. While two local case studies: Kaduna international Trade and investment Centre, KITIC, Kaduna State and Lagos International Trade Fair Complex, LITFC, Lagos State all situated in Nigeria are reviewed for their multi-functionalities as summarized in Table 1.

Table 1: A review of trade fair complexes across the globe

Location	Name/ Spatial Size	Functional facilities
Nigeria	Kaduna International Trade and Investment Centre	Information Bureau; Courier Services; Police Post/Security Services; Car hire and Car Park; Fire Prevention Post; Custom and Excise Post; Reception podiums for special day activities; Postal Services; Business Centres; Medical/Health Centre; Permanent Shopping Arcade; Toilets; Festival Ground; warehouses, Exhibition halls; Water facilities; Conference Centre; Catering Services; Technical Services; Electricity power house
Nigeria	Lagos International Trade Fair Complex • It has a landed area of 3.22 Acre which comprises Parcel A and B. • It has the largest trade exhibition arena in Nigeria	12 exhibition Halls, of an average of 1,050m^2 each; An office/administration complex with Banking halls, auditorium; Reception halls; A Motel Complex with 100 chalets; A luxurious park restaurant with artificial lake; A mini stadium; A warehouse complex; Standard lawn tennis courts and football pitches; Staff quarters complex with airstrip; Open Land spaces for further development. **Others:** 5,570 seating capacity; 821, 872m^2 open space for hire.
Malaysia	Melaka International Trade Centre • It has 3.1 acre of land	Exhibition Hall, Grand Ballroom, Auditorium, Board Room, VIP Room, Business Centre, Surau, Dining Hall, Hotels and Apartments, Bus Terminals and Taxicab service and Sports Complex amongst others etc.
China	Shanghai New International Expo Center. • It has an estimated area of 300,000m^2.	17 exhibitions halls; 3 entrance halls of flexible space for visitor registration, information kiosks, opening ceremonies, business centers, coffee and tea zones, specialized food and dining events, cloak room, etc; 20 loading bays located between halls with direct drive-in access to the exhibition floors in the exhibition halls. Superior loading capability: 3 tons/m2 of indoor, 5 tons/m2 of outdoor and 20 tons/m2 of outdoor heavy areas; 51 meeting rooms with different sizes and styles for organizing meetings, seminars, conferences, cocktails, etc; Spacious parking for 4730 cars and others; and over 40 Food & Beverages outlets and restaurants
Egypt	Cairo International Convention and Exhibition Centre. • It is built over an area of 300,000 sq m and 30,000m^2 of it are given over for conference and exhibition facilities.	Convention Centre; Cafeteria; Banquet Halls; Exhibition Halls. Other facilities: The Gallery, The commercial center, Open space, Event garden

Location	Name/ Spatial Size	Functional facilities
India	Codissia Intec Technology Center (CODISSIA TRADE FAIR COMPLEX). • The complex covers a total of ground area of 160,000m^2.	Exhibition halls; Open Air Theater; Seminar Halls; Pantry and Restaurant service core; Telephone &Internet Kiosk; 8. Open ground space; Car Park; Power: Generator set to provide alternative electricity; Fire Safety facilities; Water supply for general purposes; An International Standard Food court; Head Rooms; Hall entry for vehicles; Wide Service trenches for power, water supply and drain line, Telephones and compressed air; Heavy duty flooring; Toilet facilities for Gents & Ladies; Exclusive service entry and exit; Ambulance and First Aid Service on request; Large paved area and lovely landscape for visitors to relax; Other Services at request: Courier service though outsourced courier agents. Free shuttle service for visitors from the entrance road to complex on demand.

Source: KADCCIMA (2021), Kodei et al. (2023)

3.0 METHODOLOGY

The selection of an appropriate research methodology requires careful consideration of the study's aim, objectives, hypotheses, and research questions (Shehu & Shehu, 2022; Shehu et al., 2023; Shehu & Shehu, 2023a; Shehu, 2024; Kodei, 2024; Saidu et al., 2025). In response, this study proposes a new design and construction of Jalingo international trade fair complex for the State of Taraba in Nigeria by exploring the concept of space adaptability and multi-functionalities in Architectural design. A mixed-method research design approach was adopted, employing reviewing of case studies, structured observation checklist of facilities at the existing state-owned trade complex, and architectural tools including AutoCAD (used for designing or drawings) as the main instruments for data collection. In this research four international and two national case study trade fair centers in Malaysia, China, Egypt, India as well as Lagos and Kaduna state trade fair complex were reviewed for their multi-functionalities as highlighted in Table 1. Qualitative research design, particularly content analysis, is well suited to studies that explore conceptual, spatial, and social dimensions of architecture. This method has been successfully applied in related architectural and environmental studies (Shehu, 2021; Shehu, 2025; Shehu, Zakariyau, Yusuf, Aliyu, Kodei, Saidu & Shehu, 2025). Content analysis involves the systematic examination of documentary sources including books, journals, technical reports, interviews, and observational records to identify recurring themes and patterns relevant to the research focus (Shehu, 2021; Umar et al., 2025). It is also regarded as a highly replicable method for tracking trends over a period of time and analyzing the underlying meanings of documented materials (Shehu, 2025). In addition to document analysis, qualitative research commonly employs observational techniques, interviews, and case studies (Kodei, 2024; Mohammed et al., 2025; Umar et al., 2025; Shehu et al., 2025a). Data for this study were obtained through inference-based case studies and a structured observational checklist. The checklist was developed using an "Availability and Adequacy" rating system to generate data aligned with research objective one i.e., a physical observation of availability and the level of adequacy of facilities at the existing state-owned Jalingo Trade Fair Complex. Jalingo, the capital of Taraba State, is located within the Guinea Savannah zone of northeastern Nigeria, lying approximately between latitude 8°54′ North and longitude 11°21′ East. It is bordered by Lau Local Government Area to the north, Yorro Local Government Area to the east, and Ardo Kola Local Government Area to the south and west, all in Taraba State. Figure 1 illustrates the location of Jalingo town and the proposed International Trade Fair Complex within Taraba State. The proposed design was developed in compliance with the Nigerian Building Code and relevant architectural standards.

Fig. 1: Map of Taraba State, showing the location of the study
Source: National Population Commission (2010)

The variables or multi-functional facilities considered for the design and construction of the newly improved Jalingo International trade fair complex comprises the following: walkways, ramps, stairways, signage, pavilion, electric power generating house, entrance gate, ticket room, perimeter fence, public conveniences, security area, administrative unit, exhibition buildings, courtyard and fair grounds, service facilities, parking facilities (covered and outdoor), accommodation, eatery service unit, conference halls, gym halls, Archi-build exhibition centre, pavilion for cultural activities and warehouses. Data obtained were analyzed and presented in tables, frequencies, percentages, plates, and in architectural figures respectively. Figure 2 shows the summary of the research methodology adapted for this study.

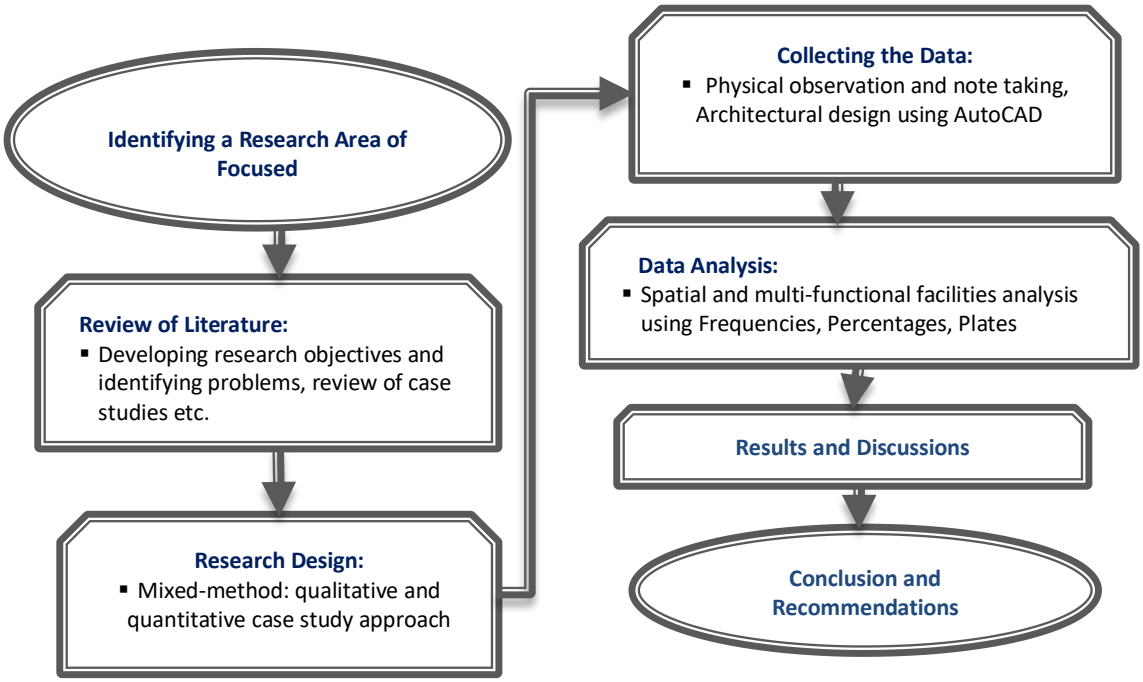

Fig. 2: Research methodology flow chart
Adapted: Shehu (2024); Shehu and Shehu (2023b), Shehu et al. (2025b)

4.0 RESULTS AND DISCUSSIONS

4.1 Availability and Adequacy of Facilities at the Existing Jalingo Trade Fair Complex

The assessment of facilities at the existing Jalingo Trade Fair Complex, as presented in Table 2, revealed substantial infrastructural deficiencies that limit its functional performance. Fourteen (14) essential facilities expected in a standard public building were evaluated using a structured observational checklist based on availability and level of adequacy criteria. The findings indicate that 50% of the required facilities were not available, while 50% were available in some form. However, among the available facilities, only 14.29% were adequate (entrance gates and perimeter fencing), whereas 35.71% were inadequate in terms of size, quality, and functionality. Critical deficiencies include the absence of ramps, walkways, landscaping, parking lots, water supply systems, lighting infrastructure, and a functional powerhouse. The only pavilion (6 m × 20 m), with a seating capacity of approximately 250, is insufficient for large-scale exhibitions and public gatherings. Public conveniences are limited to three toilets serving the entire complex. The fairground remains unpaved and prone to erosion during the rainy season.

Table 2: Availability and Adequacy of Facilities at Existing Jalingo Trade Fair

S/N	Facilities/items	Availability		Adequacy	
		Available	*Not Available*	*Adequate*	*Not-adequate*
1	Pavilion	✓			×
2	Seating arrangement		×		
3	Public conveniences	✓			×
4	Ramps		×		
5	Walkways		×		
6	Perimeter fencing	✓		✓	
7	Power house		×		
8	Security room	✓			×
9	Ticketing room	✓			×
10	Fair ground	✓			×
11	Entrance gate	✓		✓	
12	Landscaping/parking space		×		
13	Lighting system		×		
14	Water facility system		×		
	Total = 14	7 (50%)	7 (50%)	2 (14.29%)	5 (35.71%)

Figure 3 depicts the floor plan of the existing Jalingo Trade Fair complex, visually highlighting the non-existence and inadequacy of essential structural facilities as presented in Table 2, as well as the lack of multi-functional facilities to support multi-purpose activities.

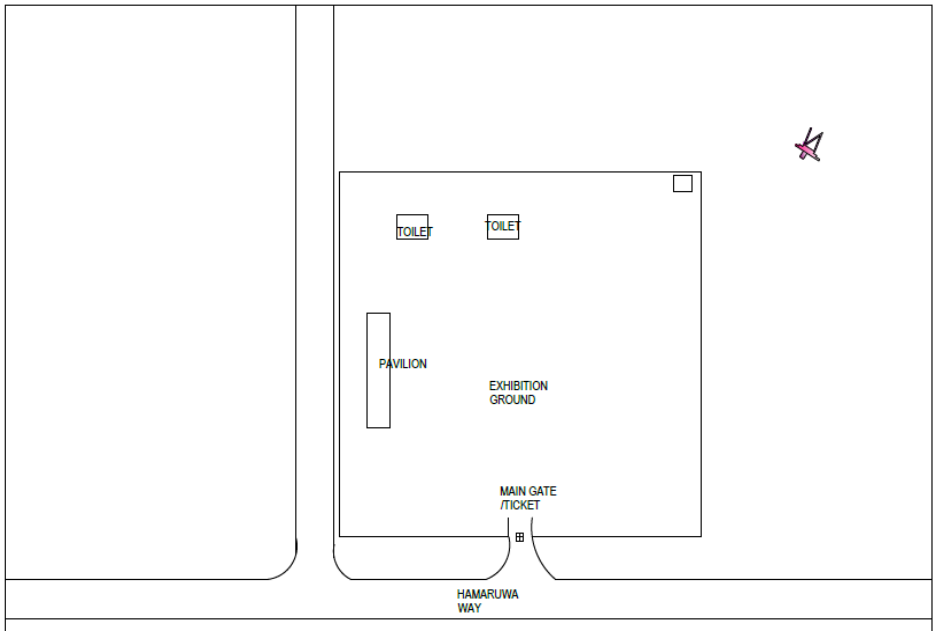

Fig. 3: Floor Plan of the Existing Jalingo Trade Fair Complex

Meanwhile, Plates I-V depict the present state of facilities available at the existing Jalingo Trade Fair Complex. Except for the perimeter fencing and entrance gate, basically all other essential facilities are not available, while the few available ones, including pavilion, toilets, security and ticketing rooms, and fairgrounds, are inadequate.

Plate I: The Existing Security House/Ticket Room and Entrance Gate at JTFC
Source: Authors Field Survey (2025)

Plate II: The only Pavilion at the present Jalingo Trade fair complex (JTFC)
Source: Authors Field Survey (2025)

Plate III: Jalingo trade fair complex depicting temporary shanties
Source: Authors Field Survey (2025)

Plate IV: The Existing Public Toilets at the Present Jalingo Trade fair complex
Source: Authors Field Survey (2025)

Plate V: Current state of fair ground and perimeter fencing at Jalingo trade fair complex
Source: Authors Field Survey (2025)

4.2 Proposed Design and Spatial Configuration of the New International Trade Fair Complex

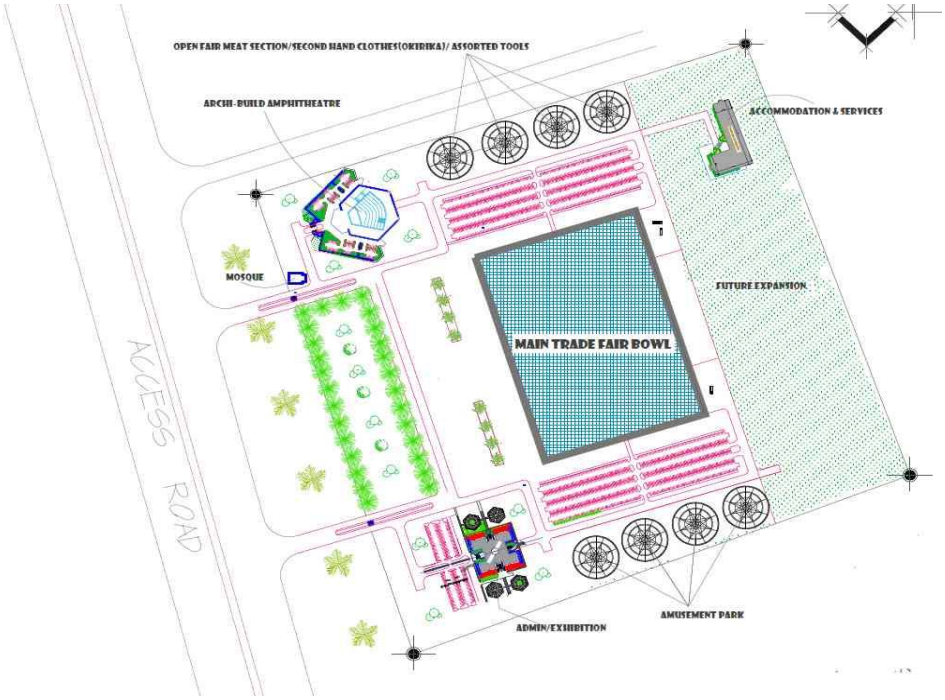

Fig. 4: Site layout plan for the proposed Jalingo International Trade Fair Complex

Figure 4 shows the proposed site layout plan for the proposed Jalingo International Trade Fair complex. The design revealed that it has both open space and built-up functional facilities. The total plot area is 940,000m^{2,} equivalent to 94.00 hectares. The built-up area covers 115,638.20m^2, representing 12.30% of the site, while 87.70% remains open for circulation, landscaping, and future expansion.

4.3 Proposed Construction Site for the International Trade Fair Complex

The site layout plan for the existing state-owned Jalingo trade fair complex is presented in Figure 5. Meanwhile, in this research, four sites were proposed for the construction of the new multi- functional Jalingo International Trade Fair Complex, as thus:

- The first proposed site: the present Jalingo Trade fair complex located opposite legislative quarters along Hammanruwa way, Jalingo. The site is made up of single large commercial plots that make up its roughly rectangular form with a total area of about 761,000m^2. The site has a northeast - southwest orientation. The trade fair complex is accessible with good roads, some are dual carriageway with drainage, sidewalk ways, and verges. Almost all the roads surrounding the area are in good condition. All the other roads leading to Jalingo trade fair complex are also in good condition and well-constructed with streetlights. Developments and construction work carried out on the site include an exhibition pavilion, a security house, a gate house/ticketing room, a perimeter fence, shanties, public toilets, and space for a cultural show.

- The second proposed site is 1,750,030m^2 situated along Kona Road in Gulum, about 6km on the outskirts of Jalingo city.

- The third proposed site with a dimension of 1,902,500m^2 is situated at mile 6 Bye-Pass about 13km away from Jalingo town.

- The fourth site with a dimension 3,805,000m^2 is situated at Lakaviri kilometer 20 along Yorro road.

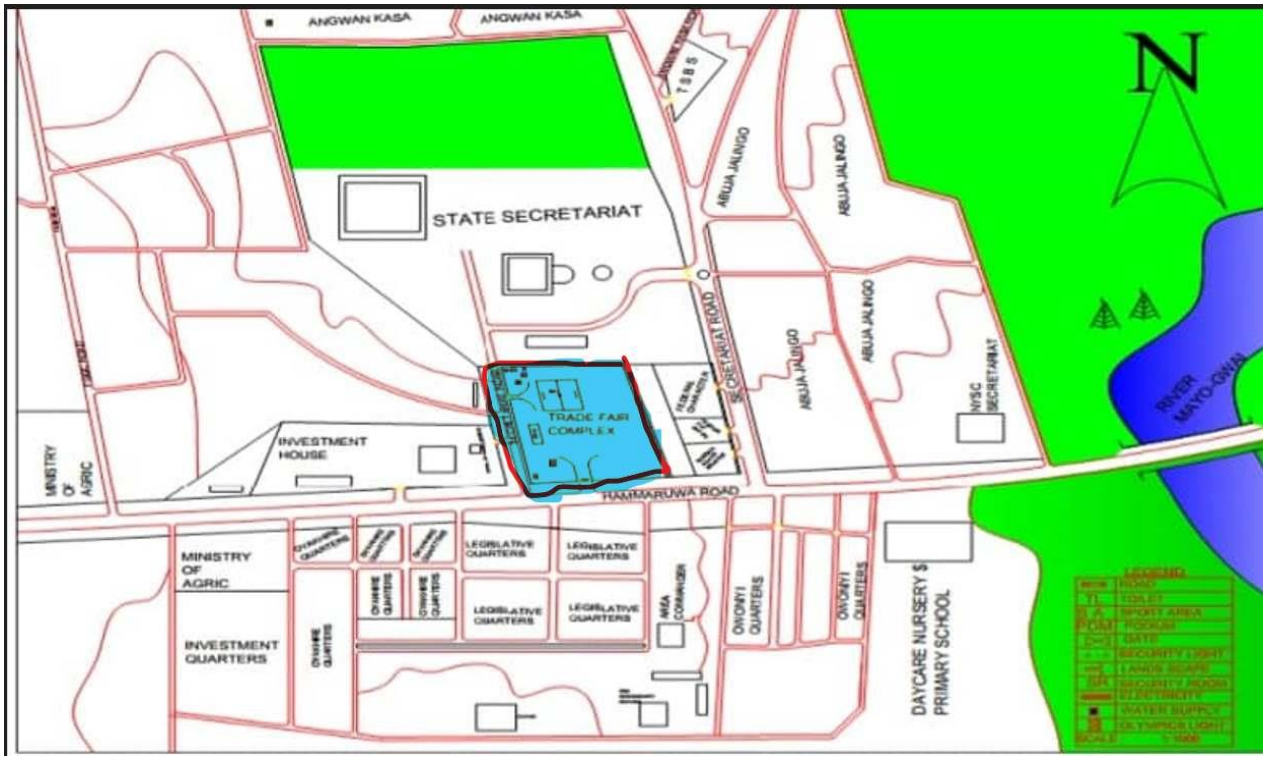

Fig. 5: Site Layout plan of the existing Jalingo Trade Fair complex

4.4 Functional Flow of Facilities

Figure 6 reveals that all facilities are interconnected through internal access roads and pedestrian walkways to enhance mobility, accessibility, and crowd management. Each facility is well equipped with public conveniences. The total built-up areas occupied 115,638.21m^2. The spatial hierarchy reflects functional prioritization, with emphasis on high-demand areas such as exhibition and parking facilities.

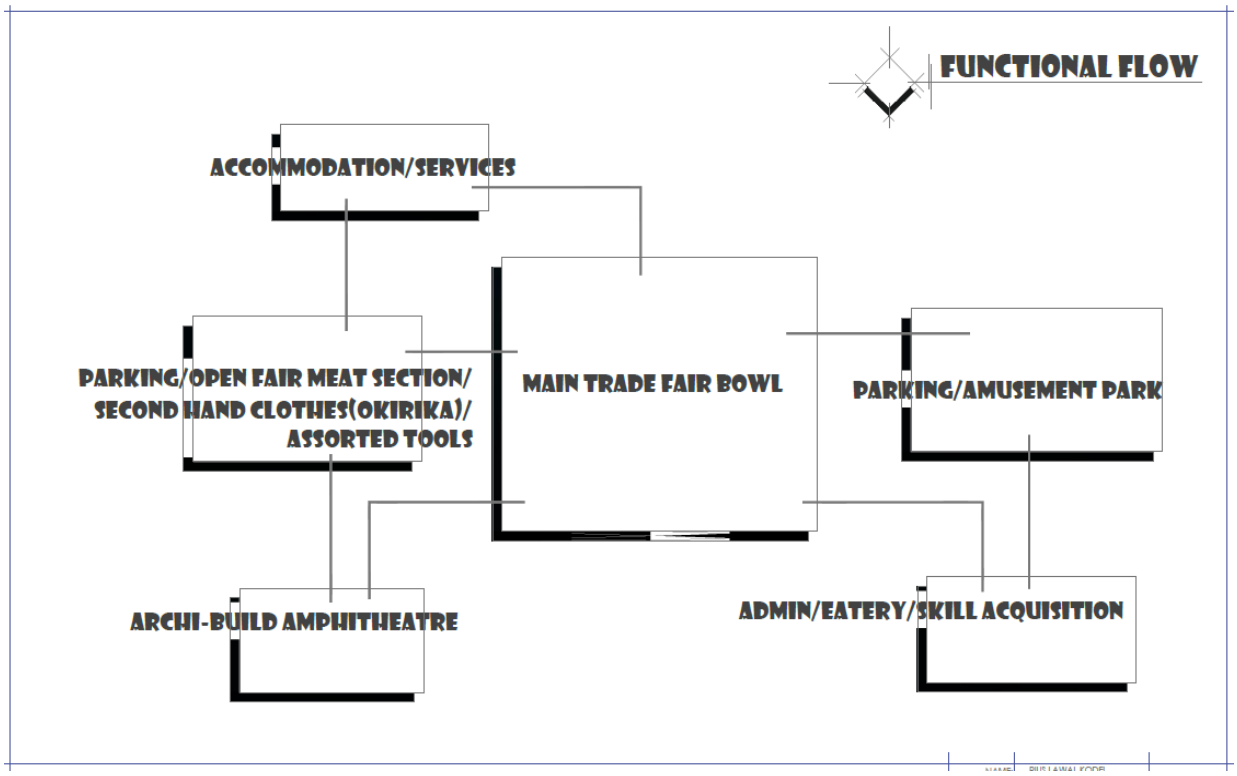

Fig. 6: Functional flow relationship of facilities

Table 3 presents the results for functional facilities and spatial allocation for the proposed Jalingo International Trade Fair Complex. Findings revealed that the design integrates 18 key functional components comprising 47 usable facilities. Major spatial allocations include: Parking facilities: 44,400m² (38.39%); Exhibition halls: 40,950m² (35.40%); Open fairground: 14,250m² (12.32%). Other facilities include administrative units, service areas, accommodation blocks, conference halls, a gym hall, cultural pavilions, Archi-build exhibition centres, warehouses, youth skill acquisition centres, mini-event halls, an internet café, and an eatery unit. Meanwhile, the eatery service unit, internet cafe, and information desk areas occupied the least spatial allocation with 39m², 40.56m^2, and 59.40m^2 respectively.

Table 3: Functional facilities and space analysis

S/N	Facilities	Frequency	Area (m^2)	Space (%)
a)	Administrative Unit	1	795.15	0.69
b)	Exhibition Area	18	40950.00	35.41
c)	Service Facilities	4	1840.37	1.59
d)	Accommodation	5	2664.50	2.30
e)	Reception/Security Area	2	510.00	0.44
f)	Information Desk	1	59.40	0.05
g)	Tech/Maintenance Division	1	118.32	0.10
h)	Conference Hall	2	272.50	0.24
i)	Gym Hall	1	293.88	0.25

S/N	Facilities	Frequency	Area (m^2)	Space (%)
j)	Archi-build Exhibition Centre	2	6203.70	5.36
k)	Warehouses	1	746.70	0.65
l)	Pavilion (Cultural Activities)	2	1458.00	1.26
m)	Eatery Service Unit	1	39.00	0.03
n)	Open Fair Ground	1	14250.00	12.32
o)	Mini-Event Hall	1	293.88	0.25
p)	Internet-Café	1	40.56	0.04
q)	Youth Skill Acquisition	1	702.25	0.61
r)	Parking Facilities	2	44400.00	38.40
	Total	47	115,638.21	100.00

5.0 DISCUSSIONS

This study highlights a clear relationship between infrastructural adequacy and facility utilization. The existing state-owned trade fair complex lacks essential components required for operational efficiency and adaptability as highlighted in Table 2, Fig. 3 and Plates I-V which directly contributes to its low usage rate. The absence of multi-functional design strategies has resulted in a rigid spatial configuration that cannot accommodate diverse activities beyond seasonal trade events. The findings revealed that the state of facilities at the present Jalingo Trade Fair Complex are not in line with both the Nigerian building code, international building code and Architectural design standards in terms of types, minimum sizes and other requirements of a building and support facilities expected at a private, public and social buildings such as: convention centres, trade and exhibition centres among others (National Building Code [NBC], 2006; Shehu et al., 2020; Federal Housing Authority, 2021; Shehu & Shehu, 2022).

Consequently, the proposed design addresses these shortcomings through the integration of adaptability and multi-functional principles as shown in Table 1 reviewed of six case studies trade fair complex. Flexibility is achieved through large-span exhibition halls and open fairgrounds capable of accommodating exhibitions, conferences, cultural festivals, and recreational events. Convertibility is incorporated through multi-purpose halls that can serve varying functions without major structural alteration. Expandability is ensured by maintaining a low site coverage ratio, allowing phased development in response to future demands. The total plot area and the built-up area is higher than most similar studies, for instance Oguejiofor (2011).

Basically, the dominance of parking and exhibition spaces in the spatial allocation is strategically justified. Trade fair complexes typically experience high visitor volumes; therefore, adequate parking and expansive exhibition halls are essential for operational functionality and revenue generation. Smaller allocations for eatery and internet services reflect their supportive role within the broader facility framework. Meanwhile, the inclusion of youth skill acquisition centres, cultural pavilions, conference facilities, and accommodation units in the design transforms the complex into a year-round socio-economic hub rather than a seasonal event facility. This diversification enhances the long-term viability of the project and aligns with sustainable infrastructure models that emphasize continuous utilization.

5.1 Implication of the Findings

The practical implication of the findings of the study are outline as follows:

- *Architectural Implications:* The study underscores the necessity of integrating adaptability and multi-functionality at the conceptual design stage. Public infrastructure should be conceived as a dynamic system capable of responding to changing functional requirements. The proposed model provides a replicable framework for similar trade fair developments in Nigeria and other developing regions.
- *Economic Implications:* The proposed complex has substantial revenue-generating potential through exhibition rentals, conference hosting, parking fees, accommodation services, and year-round programming. By supporting diverse activities beyond periodic trade fairs, the facility can significantly enhance Taraba State's internally generated revenue. Additionally, the project is expected to generate direct employment during construction and operation, as well as indirect employment in hospitality,

transport, retail, and service sectors. The multiplier effect of such infrastructure can stimulate regional economic growth and reduce dependency on federal government allocations which is a norm by most states of the federation of Nigeria.

- *Urban and Regional Development Implications:* The development of a multi-functional international trade fair complex can stimulate urban expansion, attracts private investment, improve surrounding infrastructure, and increase land values. It positions Jalingo as a strategic commercial and cultural hub within North-Eastern Nigeria, thereby enhancing regional competitiveness.
- *Social and Sustainability Implications:* The inclusion of cultural pavilions promotes heritage preservation and tourism development. Youth skill acquisition facilities support entrepreneurship and workforce development. The low built-up ratio enhances environmental sustainability by preserving open space for landscaping, stormwater management, and for future expansion.
- Overall, multi-functionality could also optimize land use efficiency by reducing the need for separate single-purpose facilities, thereby promoting resource conservation and long-term sustainability.

6.0 CONCLUSION

This study presents the architectural design proposal for a new Jalingo International Trade Fair Complex in state of Taraba in Nigeria, based on the principle of multi-functional space utilization. Prior to this study, the existing state-owned trade fair complex exhibited significant deficiencies in infrastructure and functional facilities, limiting its capacity to support diverse activities and year-round use unlike the six case studies trade fair centres reviewed across the globe. The proposed design addresses these shortcomings by introducing a flexible and adaptable spatial framework capable of supporting multiple functions within a single integrated complex.

The proposed Jalingo International Trade Fair Complex incorporates eighteen key functional components, with a total of forty-seven usable facilities including: the administrative unit, exhibition spaces, service facilities, accommodation units, reception and security areas, information desks, technical and maintenance divisions, conference halls, gymnasium, architectural and building exhibition centre, warehouses, cultural activity pavilions, food service areas, open fairgrounds, mini event halls, internet cafés, youth skill acquisition centres, and comprehensive parking facilities. Among these, the facilities occupying the largest land areas are the parking spaces (44,400m²), exhibition halls (40,950m²), and open fairgrounds (14,250m²), while the eatery service unit, internet cafe, and information desk areas occupied the smallest spatial allocation at 39m², 40.56m^2, and 59.40m^2 respectively.

This research reinforces the argument that architectural design could significantly influence economic performance. Space adaptability emerges as a critical determinant of infrastructural sustainability, particularly in public facilities intended to serve evolving community needs.

It is therefore recommended that the implementation of this proposed developmental project, either through direct government funding or via public-private partnership arrangements, would significantly enhance economic activity within the state. The project has the potential to generate substantial direct and indirect employment opportunities, capable of promoting continuous utilization of the facility, and strengthening Taraba State's internally generated revenue base. Ultimately, the realization of this multi-functional international trade fair complex would contribute to sustainable architectural development and long-term socio-economic growth in the North-Eastern region of Nigeria.

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REFERENCES

Acharya, L. (2013). *Flexible Architecture for Dynamic Societies, Reflection on a Journey from the 20th Century into the Future,* Faculty of Humanities, Social Sciences and Education, University of Tromso.

Federal Housing Authority (2021). *Architectural design plan*. www.fha.gov.ng

ICC (2020). International Chamber of Commerce. www.icc.com

KADCCIMA (2021). Kaduna Chamber of Commerce, Industry, Mines and Agriculture. www.kadccima.org.ng

Kodei, P. L. (2024). *Design of A Multi-Functional Jalingo International Trade Fair Complex: Exploring Space Adaptability.* A published Master's Thesis, Department of Architecture. Abubakar Tafawa Balewa University, Bauchi.

Kodei, P. L., Bashir, M. U., Jalam, U. A., Pius, D., & Shehu, S. (2023). Review of the regional trade fair complex Jalingo: Exploring multi-functional Facilities. *International Journal of Multidisciplinary Research and Growth Evaluation,* 4(5), 14-35.

Mabadeje, J. A., Banji, S. A., & Bello, K. (2022). Review of Performance and Adaptable of Demountable Exposition Centre towards Sustainability Development. *African Scholar Journal of African Innovation & Advanced Studies*, VOL. 26 NO. 2.

Mohammed, U., Aliyu, M., & Ati, B. N. (2025). Assessment of Landscape Elements in Public Buildings in Tertiary Institutions in Nigeria: A Case Study of Federal Polytechnic Mubi, Adamawa State. *Journal of African Advancement & Sustainability Studies,* 9 (2), 58-65. https://doi.org/10.70382/sjaass.v9i2.038

National Building Code [NBC] (2006*). Federal Republic of Nigeria-National Building Code.* Federal ministry of Housing and Urban Development. Abuja.

National Population Commission [NPC] (2010). Federal Republic of Nigeria 2006 National Population and Housing Census: Priority Table, Volume 3. www.npc.gov.ng

Naveh, Z. (2001). Ten Major Premises for a Holistic Conception of Multi-Functional Landscape. *Landscape Urban Planning,* 57(3-4): 269-284.

Oguejiofor, H. K. (2011). *Trade Fair Complex, Benin City*. A published Masters' Thesis, University of Nigeria Nsukka.

Pius, D. (2016). *A Review of the Planning and Design Characteristics of Trade Fair Complex in Jalingo.* A published Bachelor of Technology, Federal University of Technology Yola, Nigeria.

Ryan, Z. (2009). The Good Life: New Multi-Functional Spaces for Recreation. Building Space Institute.

Saidu, S., Waziri, A.Y., Ishaku, B., & Shehu, S. (2025). The Use of Social Media Tools for Effective Communication in Construction Project Delivery in Maiduguri Metropolis, Borno State. *Bima Journal of Science and Technology (BJST),* 8 (4B), 173-181. https://doi.org/10.56892/bima.v8i4B.1194

Schneider, T. & Till, J. (2007). *Flexible Housing.* Oxford United Kingdom: Architectural press.

Shehu, S. & Shehu, R. (2022). A Principle Framework for Determining Timely Completion of Building Projects in Public Tertiary Institutions in Bauchi and Gombe State, Nigeria. *Borneo Journal of Sciences & Technology,* 4(1), 80-90. http://doi.org/10.35370/bjost.2022.4.1-12

Shehu, S. & Shehu, R. (2023a). The Impact Quality Management Success Factors on the Quality Performance of Construction Projects in The Lake Chad Basin. *Construction,* 3(2), 172-182. https://doi.org/10.15282/construction.v3i2.9599

Shehu, S. & Shehu, R. (2023b). Quality Performance Indicators of Building Construction Projects in Nigeria. *Borneo Journal of Social Science & Humanities,* 5 (2), 24-42. https://doi.org/10.35370/bjssh.2023.5.2-03

Shehu, S. (2021). A Review of Time Management Factors in Construction Project Delivery. *Journal of Project Management and Practice,* 1(2): 34-45. https://doi.org/10.22452/jpmp.vol1no2.3

Shehu, S. (2024). Perceptions of Stakeholders on the Impacts of Cost Management Success Factors on The Performance of Public Building Construction Projects in The Sahel Region: Evidence from Yobe State. *Journal of Civil Engineering, Science and Technology*, 15(2), 188-206 https://doi.org/10.33736/jcest.6791.2024

Shehu, S. (2025). Financing and Practices Inducing Compliance with Due Processes in the Procurement of Public Construction Projects in Nigeria's Local Government Area: A Case Study of Misau Council, Bauchi State. *Proceedings of International Conference for Institute of Administration (ICIA)* 6th – 9th July 2025 at Ahmadu Bello University Zaria, Nigeria.

Shehu, S., Ali, Z. A., Shehu, R., Aliyu, U., Muhammad, A., & Saidu, S. (2025b). Practices Influencing Programme Abandonment, Time and Cost Overrun of Postgraduate Studies in The Built Environment in A Developing Economy. *Proceedings of the Faculty of Management Science University of Maiduguri 2nd International Conference* 11th -13th February, 2025, Maiduguri, Nigeria.

Shehu, S., Shehu, R., & Aliyu, U. (2023). Sustainable Practices Influencing Timely Delivery of Building Construction Project. *Journal of project management practice (JPMP),* 3(1), 1-22. https://doi.org/10.22452/jpmp.vol3no1.1

Shehu, S., Zadawa, A. N., Waziri, A. Y., & Shehu, R. (2020). Adherence with the Processes of Time Management in Construction Project Delivery in Nigeria. *Borneo Journal of Social Science & Humanities.* https://doi.org/10.35370/bjssh.2.1-08

Shehu, S., Zadawa, A. N., Waziri, A.Y., & Shehu, R. (2019). Principles Influencing Adherence to Time Management

in Construction Project in Gombe State, North Eastern Nigeria. International Journal of Engineering Applied Sciences and Technology, 4(5), 349-353.

Shehu, S., Zakariyau, A., Yusuf, H. Y., Aliyu, U., Kodei, P. L., Saidu, S., & Shehu, R. (2025a). Compliance with Public Procurement Act Methodologies in Public Construction Projects in Nigeria's Local Government Area: Evidence from Misau Council, Bauchi State. *Proceedings of International Conference for Institute of Administration (ICIA)* 6th -9th July 2025 at Ahmadu Bello University Zaria, Nigeria.

Till, J. & Schneider, T. (2005). Flexible Housing: The Means to the End. Oxford United Kingdom: Architectural Press.

Umar, R. A., Zadawa, A. N., Shehu, S., Shehu, A. S., & Yakubu, Y. (2025). Construction Procurement Processes in Public Tertiary Institutions: A Case Study of Gombe State, Nigeria. *Dutse Journal of Pure and Applied Sciences,* 11 (3b): 144-151. https://dx.doi.org/10.4314/dujopas.v11i3b.16

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SOCIO-TECHNOLOGICAL PATHWAYS TO SUSTAINABLE SMART CITIES: A DEMATEL ANALYSIS OF IoT CHALLENGES AND STRATEGIC RESPONSES

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ABSTRACT

Smart cities are widely promoted as a response to urbanisation pressures, with the Internet of Things (IoT) providing the core enabling technology. IoT adoption at the city scale involves coupled technical, organisational, and financial challenges that are rarely studied as a connected system. This study applies the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, grounded in a socio-technical systems perspective, to model the perceived causal relationships among five recurring IoT challenges (interoperability, scalability, data analytics, data security and privacy, and financial constraints) and five widely proposed strategic responses (standardisation of IoT protocols, microservices-oriented architecture, edge computing, data-protection regulation, and public–private partnerships). Twenty-five purposively selected experts engaged in IoT-enabled smart city projects in Malaysia provided the influence judgments analysed here. The analysis identifies data security and privacy as the dominant perceived causal driver among the challenges, financial constraints as the most prominent receiving challenge, and the standardisation of IoT protocols as the strategy with the strongest net influence and the broadest perceived reach across the challenges. Rather than asserting universal causal claims, the study provides a context-specific, expert-based prioritisation framework for Malaysian smart city implementation, with implications for how policymakers, urban planners, and technology providers sequence interventions in resource-constrained settings.

Keywords: Decision Making and Trial Evaluation (DEMATEL), Internet of Things (IoT), IoT Challenges, Smart Cities, Urban Sustainability, Socio-Technical Systems

1.0 INTRODUCTION

Cities face mounting pressure from rapid urbanisation, including congestion, environmental degradation, and infrastructural strain. The United Nations (2022) projects that about 68 per cent of the world's population will live in urban areas by 2050, with the Asia-Pacific region taking a substantial share of this growth (Ismagilova et al., 2019). The search for technology-enabled approaches to urban management has intensified in response.

The smart city concept has emerged as one such approach. It combines digital infrastructure, data analytics, and connected devices to deliver public services more efficiently (Kim et al., 2021). The Internet of Things (IoT) is the data-generating layer that underpins this approach, connecting sensors, actuators, and platforms to support real-time monitoring and decision-making in traffic, utilities, public safety, and waste management (Alavi et al., 2018; Al-Obaidi et al., 2022; Hoang, 2024).
IoT deployment at the city scale is not a purely technical exercise. It involves coordination among public agencies, private operators, infrastructure providers, and end-users (Bibri et al., 2023; Hussain, 2024). Documented obstacles include weak system interoperability, scaling problems, gaps in data analytics capacity,

persistent data security and privacy risks, and recurring financial constraints (Rejeb et al., 2022; Singh et al., 2024). Prior studies have examined these obstacles individually (Bhardwaj et al., 2024; Hassan et al., 2021; Rafiq et al., 2023; Ratnakar et al., 2020), but few have analysed how they interact as a connected system. Weak data protection can amplify financial exposure, and interoperability gaps can raise integration costs and constrain scalability. Treating these obstacles in isolation risks misallocating limited resources and overlooking the points where intervention would yield the greatest effect.

A second weakness in the existing literature is methodological. Most prior work is descriptive or single-issue, with limited use of analytical techniques that can map mutual influence among multiple factors (Janssen et al., 2019). This study addresses both gaps by applying the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method to model perceived causal relationships among IoT challenges and strategic responses. DEMATEL is particularly suited to problems characterised by interconnected qualitative factors and limited large-sample data, as it derives an influence structure from structured expert judgments and visualises it through cause–and–effect diagrams (Chen et al., 2023; Makki & Alqahtani, 2024).
The study is situated in Malaysia, where smart city initiatives have advanced under the Malaysia Smart City Framework but remain unevenly distributed across states and sectors. This context offers a useful test bed: ambitions are high, expertise is concentrated within an identifiable group of professionals, and implementation outcomes vary, making the setting suitable for expert-based causal mapping. Twenty-five purposively selected experts engaged in IoT-enabled smart city projects in Malaysia evaluated the perceived influence of five widely cited challenges and five corresponding strategies.

Two research questions guide the study:

> **RQ1**: How do the major challenges of IoT implementation in Malaysian smart cities perceptually influence one another?
>
> **RQ2**: Which strategic responses exert the strongest perceived influence on these challenges, and how should they be prioritised?

The study makes two contributions, both framed conservatively to reflect what DEMATEL can support. First, it offers a Malaysia-focused, expert-based causal mapping of IoT barriers and responses, situating findings within a specific socio-technical environment rather than claiming universal causal truth. Second, it provides a DEMATEL-based prioritisation framework that policymakers, planners, and technology providers can adapt when sequencing interventions under resource constraints. The study draws on a socio-technical systems perspective in which effective IoT adoption depends on the coordinated treatment of technical, organisational, and financial factors rather than the improvement of any one dimension in isolation.

2.0 LITERATURE REVIEW

2.1 *Smart City and the Role of IoT*

Smart cities have been widely studied as urban configurations that combine information and communication technologies (ICT), physical infrastructure, and citizen participation to deliver services more efficiently (Bellini et al., 2022; Syed et al., 2021). Early scholarship emphasised technology-centric definitions, but more recent work positions smart cities as socio-technical systems in which technical, organisational, and human dimensions are tightly coupled (Bibri et al., 2023; Hussain, 2024). The implication is that gains in one dimension, such as sensor coverage, cannot be sustained without parallel progress in others, such as governance, data ethics, and financing.

IoT is the principal data-generating layer of this system. It comprises sensing devices, communication networks, computing resources, and analytics platforms that together enable real-time decision-making (Ali et al., 2023; Whaiduzzaman et al., 2022). Documented application domains include energy management, mobility, e-governance, health, and environmental monitoring (Bauer et al., 2021; Houssein et al., 2024; Zaman et al., 2024). Several reviews argue that IoT delivers value only when paired with appropriate governance, standardisation, and investment frameworks (Alam, 2024; Gade & Aithal, 2022).

2.2 *Critical Review of IoT Implementation Challenges*

Prior studies identify a wide range of obstacles to IoT-enabled smart city implementation. Synthesising and comparing this work reveals that five challenges appear consistently across reviews and case studies, regardless of geography.
(i) Interoperability. Whaiduzzaman et al. (2022) and Ali et al. (2023) note that heterogeneous protocols and

proprietary platforms continue to fragment IoT ecosystems, while Saidala et al. (2024) argue that the absence of harmonised standards is the principal source of integration cost.
(ii) Scalability. Gade and Aithal (2022) and EI et al. (2023) document difficulties in extending pilot projects to city-wide deployments, particularly when architectures are not modular.
(iii) Data analytics capacity. James et al. (2022) and Zaman et al. (2024) point to bandwidth limits, processing constraints, and data-quality issues as recurring bottlenecks.
(iv) Data security and privacy. Al-Turjman et al. (2022) and Hussain (2024) document the expanded attack surface of dense IoT deployments and emphasise that public trust hinges on credible data governance.
(v) Financial constraints. Popova (2020) and Gyimah et al. (2021) show that capital intensity, uncertain returns, and procurement complexity persistently limit municipal investment.

These five challenges are retained as the analytical variables in this study because (a) they recur across the reviewed literature, (b) they span the technical–organisational–financial dimensions of the socio-technical framework adopted here, and (c) they were validated through an initial consultation with three senior smart-city experts in Malaysia, whose responses were not retained in the final dataset, who confirmed their salience for the local context. Other plausible factors, such as workforce skill gaps and political continuity, were considered but excluded to keep the DEMATEL matrix tractable. This is consistent with prior work that has applied DEMATEL with five to eight factors (Khan et al., 2022; Yadav et al., 2020).

2.3 *Critical Review of Strategic Responses*

A parallel literature has examined strategies to address these challenges, although most studies discuss strategies in isolation rather than as a coordinated portfolio. Five responses recur most frequently: (i) standardisation of IoT protocols, which reduces fragmentation and supports interoperability (Amjad et al., 2021; Saidala et al., 2024; Shahbazian, 2023); (ii) microservices-oriented architecture (MSA), which enables independent scaling of services and decouples failure domains (Ali et al., 2023); (iii) edge computing, which mitigates latency and bandwidth constraints by performing analytics close to data sources (Alam, 2024); (iv) regulatory frameworks for data protection, which strengthen public trust and provide a legal basis for data governance (Hussain, 2024); and (v) public–private partnerships (PPPs), which mobilise capital and operational expertise that municipalities frequently lack (Bauer et al., 2021; Chang et al., 2023).

The selection of these five strategies follows the same logic applied to the challenges: they appear consistently in the literature, span the same socio-technical dimensions, and represent levers that policymakers in Malaysia can plausibly influence in the medium term.

2.4 *Research Gap and the Case for DEMATEL*

Three observations together justify the present study. First, prior work generally treats challenges and strategies as separable lists rather than as a coupled system. Second, where causal modelling has been attempted, it has usually relied on interpretive structural modelling (ISM), the analytic network process (ANP), or structural equation modelling (SEM), each of which has limitations for the present problem. ISM produces hierarchies but cannot quantify the strength of influence (Janssen et al., 2019). ANP captures dependencies but requires consistent pairwise comparisons that involve many factors. SEM requires large samples and an a priori measurement model. DEMATEL, by contrast, is well-suited to small expert panels, quantifies both prominence and net influence, and visualises causal structure through influence diagrams (Chen et al., 2023; Makki & Alqahtani, 2024). It does not establish empirical causality in the experimental sense; it yields a structured map of perceived influence among factors, which is the appropriate inferential target for the questions posed here.

Third, country-specific evidence is limited. Despite Malaysia's active smart city agenda, no published study has applied DEMATEL to map the relationships among IoT challenges and strategies in this context. The present study addresses this gap by combining a socio-technical conceptual lens with a DEMATEL analysis of expert judgments from Malaysian practitioners.

3.0 CONCEPTUAL FRAMEWORK

The study adopts a socio-technical systems perspective on smart city IoT implementation. This perspective holds that technological subsystems and social subsystems are mutually constitutive: outcomes depend on the joint optimisation of technical, organisational, and human components rather than on any one component in isolation (Bibri et al., 2023; Hussain, 2024).

Under this lens, IoT-enabled smart cities can be conceptualised as a system with three interacting subsystems. The technical subsystem comprises devices, networks, protocols, and analytics platforms; the organisational subsystem comprises governance arrangements, regulations, partnerships, and operational practices; and the financial subsystem comprises investment models, cost structures, and value flows. The five challenges identified above map directly onto these subsystems: interoperability, scalability, and data analytics are primarily technical; data security and privacy span technical and organisational domains; and financial constraints are primarily financial but also reflect organisational decisions about procurement and risk-sharing. The five strategies span the same subsystems: standardisation and edge computing are technical interventions; regulation and PPPs are organisational and financial interventions; and MSA is technical, with organisational implications for service ownership.

This mapping yields two analytical expectations that the DEMATEL analysis can examine. First, because socio-technical subsystems are coupled, the perceived causal structure among the five challenges should not be flat; some challenges should serve as drivers, while others serve as receivers. Second, strategies that touch multiple subsystems simultaneously, such as standardisation, which has both technical and governance implications, should be perceived as having broader influence on challenges than strategies operating within a single subsystem.

The framework also informs interpretation. Because socio-technical influence operates partly through human and organisational judgment, expert-based causal mapping is an appropriate, theoretically motivated method for surfacing influence structures in this domain. At the same time, the framework cautions that DEMATEL outputs reflect modelled perceptions of how the system works rather than empirical measurements of how it actually does; this caution shapes the interpretation of results in Section 6.

4.0 RESEARCH METHODOLOGY

4.1 Method Selection and Justification

The study applies the DEMATEL method to model perceived causal relationships among IoT challenges and strategies. As outlined in Section 2.4, DEMATEL was selected over alternative multi-criteria methods because: (i) it accommodates small expert panels, which is the standard data condition for technology-adoption studies in emerging implementation contexts; (ii) it quantifies both prominence (R + C) and net causal direction (R − C), allowing the analysis to distinguish prominent factors from causally dominant ones, an important distinction in this study; and (iii) it produces visual influence diagrams that communicate findings to non-specialist policymakers (Khan et al., 2022; Pinto et al., 2022; Yadav et al., 2020).

4.2 Expert Selection

DEMATEL is an expert-judgment method; the quality of its outputs depends on the panel's relevance and consistency rather than on a large random sample. Published DEMATEL applications in technology and urban systems research typically involve between 5 and 30 experts (Khan et al., 2022; Makki & Alqahtani, 2024; Wang et al., 2021). The present study used a panel of 25 experts, which sits comfortably within this range.

Recruitment followed a purposive sampling strategy, supplemented by limited snowball sampling. The inclusion criteria required that each participant: (a) had at least five years of professional experience in IoT, ICT, or smart city projects; (b) had direct involvement in at least one operational or pilot IoT-enabled smart city initiative in Malaysia; and (c) held a technical, managerial, or strategic role with sufficient breadth to evaluate cross-cutting influences among the factors. Candidates were initially identified through professional registries, conference participant lists, and project documentation. Each candidate was then contacted individually, and those who consented were invited to nominate one additional qualified colleague. Participation was voluntary, and responses were anonymised.

To mitigate bias arising from a relatively homogeneous sample, three procedural measures were used: (i) participants were drawn from multiple project sites across Malaysia rather than from a single municipality; (ii) the questionnaire was piloted with three senior experts, whose responses were not retained in the final dataset, to allow item refinement; and (iii) participants were instructed to evaluate influence in general project conditions rather than relative to a single project.

The resulting panel nonetheless skews male, private-sector, and concentrated in Pulau Pinang, Kuala Lumpur, and Cyberjaya. These features are discussed as limitations in Section 7.

4.3 Data Collection

Each expert completed a structured questionnaire in which they evaluated the direct perceived influence of each factor on every other factor using a five-point scale: 0 = no influence, 1 = low, 2 = moderate, 3 = high, 4 = very high. Three matrices were elicited from each respondent: (a) challenges × challenges (5 × 5), (b) strategies × strategies (5 × 5), and (c) strategies × challenges (combined 10 × 10). Diagonal cells were fixed at zero.

4.4 DEMATEL Analytical Procedure

The DEMATEL procedure was applied identically to each of the three matrices.

Step 1: Collect Expert Opinions and Compute the Average Matrix (Z)

Experts assessed the pairwise relationships among the factors, producing a set of direct influence matrices. For each expert k, a non-negative $n \times n$ matrix $X_k = [x_{ij}^k]$was created, where x_{ij}^k denotes the influence of factor i on factor j. These matrices were then averaged across all m experts to obtain the overall average matrix $Z = [z_{ij}]$as follows:

$$Z_{ij} = \frac{1}{m}\sum_{i=1}^{m} X_{ij}^k \qquad \ldots\ldots Equation\ 1$$

This aggregation captures the collective perception of the expert group.

Step 2: Calculate the Normalised Initial Direct-Relation Matrix (D)

To normalise the matrix Z, all elements were divided by the maximum row sum, ensuring that every , d_{ij} element lies between 0 and 1. The normalised direct-relation matrix $D$is expressed as:

$$D = A \times S,$$
$$S = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}} \qquad \ldots\ldots Equation\ 2$$

This step adjusts the values to maintain consistency and comparability across factors.

Step 3: Derive the Total Relation Matrix T

Using the normalised matrix *D*, a total influence matrix *T* was calculated to account for the direct and indirect effects of all variables. The mathematical formula is provided as:

$$T = D(I - D)^{-1} \qquad \ldots\ldots Equation\ 3$$

where I represents the identity matrix. The total influence t_{ij} represents the combined impact of one factor i on another j. This matrix summarises all interdependencies within the system.

Step 4: Calculate the Sum of Rows and Columns (R and C)

To determine the overall influence and dependence of each factor, the sum of rows (R_i) and the sum of columns (C_j) in the matrix T was computed as:

$$R_i = [r_i]_{n \times 1} = \left(\sum_{j=1}^{n} t_{ij}\right)_{n \times 1} \qquad \ldots\ldots Equation\ 4$$
$$C_j = [c_j]'_{1 \times n} = \left(\sum_{j=1}^{n} t_{ij}\right)'_{1 \times n} \qquad \ldots\ldots Equation\ 5$$

Here, R_i represents the total influence that factor i exerts on others, while C_j reflects the total influence received by factor j. The values of $(R_i + C_j)$ indicate the importance or prominence of a factor within the system, whereas $(R_i - C_j)$identifies whether the factor acts as a cause (positive value) or an effect (negative value).

Step 5: Determine the Threshold Value (α)

The threshold is computed as the mean of all elements in T:

$$\alpha = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n}[t_{ij}]}{N} \qquad \ldots\ldots Equation\ 6$$

where $N = n^2$ is the total number of elements in the matrix T. Only entries $t_{ij} > \alpha$ are retained when drawing the influence digraph; smaller entries are treated as negligible (Ahmad et al., 2021; Boutkhoum et al., 2021; Lin, 2022).

Step 6: Construct the Cause-and-Effect Diagram
Each factor is plotted on a two-dimensional plane with prominence ($R_i + C_j$) on the horizontal axis and net relation ($R_i - C_j$) on the vertical axis. Factors with $R_i - C_j > 0$ are perceived causes; those with $R_i - C_j < 0$ are perceived effects (Khan et al., 2022; Pinto et al., 2022; Xu et al., 2023).

4.5 Reliability and Consensus Assessment

Two reliability considerations apply to DEMATEL data. The first is internal consistency of the expert ratings, which was assessed using Cronbach's alpha:

$$\alpha = \frac{K}{K-1}\left(1 - \frac{\sum i\sigma_i^2}{\sigma_t^2}\right) \qquad \text{……Equation 7}$$

where K is the number of items, σ_i^2 is the variance of item i, and σ_T^2 is the variance of total scores (Tavakol & Dennick, 2011). Cronbach's alpha is not a DEMATEL-specific statistic, and its limitations for influence data are acknowledged: it indicates the consistency with which respondents rated related items, not the convergence of their causal judgments. It is reported here as a supplementary check rather than as a definitive consensus measure, and the values obtained, all exceeding 0.90 in this study, are interpreted accordingly. Specialist DEMATEL consensus indices, such as Kendall's coefficient of concordance and the average gap between successive elicitation rounds, were considered; the present design used a single round, and these alternative measures are noted as appropriate extensions for future work.

4.6 Application Context and Variable Coding

Three DEMATEL analyses were conducted:

(i) challenges × challenges
(ii) strategies × strategies
(iii) strategies × challenges.

The variables were coded as follows.

Challenges:

A – Interoperability issue
B – Scalability issue
C – Data analytics issue
D – Data security and privacy issues
E – Financial issue

Strategies:

F – Standardisation of IoT protocols
G – Microservices-oriented architecture (MSA)
H – Edge computing for IoT data analytics
I – Data protection regulations and standards
J – Public–private partnerships (PPP)

5.0 RESULTS

5.1 Respondent Profile

Table 1 summarises the demographic profile of the 25 respondents. The panel was 84 per cent male and predominantly aged 36–45 years. Educational attainment was high, with 96 per cent holding at least a bachelor's degree. Most respondents had 6–10 years of relevant experience (56 per cent), with a further 32 per cent reporting 11–15 years. Engineering (56 per cent) and information technology (20 per cent) were the dominant fields of expertise. Twenty-two respondents (88 per cent) worked in the private sector, and 60 per cent were employed in large organisations. Project sites were concentrated in Pulau Pinang (44 per cent), Kuala Lumpur (16 per cent), and Cyberjaya (16 per cent). Smart industry and production (32 per cent), smart living (20 per cent), and smart mobility (16 per cent) were the most common project categories.

Table 1: Demographic Profile of Respondents (n=25)

Background Information	Characteristic	Frequency	Percentage (%)
Gender	Male	21	84.00
	Female	4	16.00
Age	26 - 30 years old	1	4.00
	31 - 35 years old	3	12.00
	36 - 40 years old	8	32.00
	41 - 45 years old	6	24.00
	46 - 50 years old	1	4.00
	51-55 years old	5	24.00
	Above 55 years old	1	4.00
Education Level	Bachelor's degree	16	64.00
	Master's degree	8	32.00
	PhD's degree	1	4.00
Years of Experience	1-5 years	3	12.00
	6-10 years	14	56.00
	11-15 years	8	32.00
Nature of organization	Developer	1	4.00
	Private Company	18	72.00
	Government Agency	3	12.00
	Government-Linked Company (GLC)	3	12.00
Field of expertise	Information Technology	5	20.00
	Engineering (e.g., Electrical etc..)	13	56.00
	Project Management	2	8.00
	Internet of Things	3	12.00
	Strategy and Business Development	1	4.00
	Mixed ofmechanical engineering and internet technology	1	4.00
Role in the company	Director	8	32.00
	Project Manager	5	20.00
	Executive	1	4.00
	Quantity Surveyor	1	4.00
	Electrical Engineer	2	8.00
	Network Engineer	2	8.00
	Embedded System Engineer	2	8.00
	Cloud Infrastructure Engineer	1	4.00
	IoT Architect	1	4.00
	Senior Manager	1	4.00
	Head Data Analytic	1	4.00
Organization type	Government	3	12.00
	Private Sector	22	88.00
Company Size	Small (1-50 employees)	7	28.00
	Medium (51-250 employees)	3	12.00
	Large (251+ employees)	15	60.00
Familiarity with IoT technologies	Moderately familiar	6	24.00
	Very familiar	19	76.00
Level of involvement in Smart City project	Occasional Involvement	1	4.00
	Moderate Involvement	8	32.00
	Significant Involvement	11	44.00
	Extensive Involvement	5	20.00
Project Location	Kuala Lumpur	4	16.00
	Putrajaya	2	8.00
	Cyberjaya	4	16.00

Background Information	Characteristic	Frequency	Percentage (%)
	Selangor	3	12.00
	Pulau Pinang	11	44.00
	Pahang	1	4.00
Type of Smart City project involved in	Smart governance	2	8.00
	Smart industry and production	8	32.00
	Smart economy	2	8.00
	Smart energy	2	8.00
	Smart health	1	4.00
	Smart environment	1	4.00
	Smart mobility and transportation	4	16.00
	Smart living	5	20.00
Smart City Project Sum	RM 1,000,001 – RM 5,000,000	11	44.00
	RM 5,000,001 – RM 10,000,000	4	16.00
	RM 10,000,001 – RM 15,000,000	1	4.00
	RM 15,000,001 – RM 20,000,000	2	8.00
	More than RM 20,000,000	3	12.00
Biggest Perceived Challenge in IoT for Smart Cities	Interoperability issue	7	28.00
	Scalability issue	2	8.00
	Data security and private issue	1	4.00
	Data analytic issue	2	8.00
	Financial issue	13	52.00

When asked to identify the single biggest perceived challenge in their projects, 52 per cent of respondents named financial issues, followed by interoperability (28 per cent). This descriptive ranking should not be confused with the DEMATEL analysis that follows, which models perceived influence relationships rather than self-reported importance.

5.2 DEMATEL Analysis I: Challenges versus Challenges

The 25 expert matrices were averaged using Equation 1 (Table 2), normalised using Equation 2 (Table 3), and used to compute the total-relation matrix T via Equation 3 (Table 4). Row and column sums (Equations 4–5) yielded the prominence and net-relation values shown in Table 5. The threshold α computed from Equation 6 was 1.424. Table 6 shows the entries of T exceeding this threshold.

Table 2. Average direct-relation matrix Z (Challenges vs Challenges)

Factors	A	B	C	D	E	Sum
A	0.000	2.480	2.480	2.600	3.080	10.640
B	2.280	0.000	1.680	2.160	3.080	9.200
C	2.480	2.040	0.000	2.400	2.760	9.680
D	2.760	2.360	2.480	0.000	3.000	10.600
E	3.000	3.200	2.800	2.920	0.000	11.920
SUM	10.520	10.080	9.440	10.080	11.920	-

Table 3. Normalised direct-relation matrix D (Challenges vs Challenges)

Factors	A	B	C	D	E
A	0.000	0.208	0.208	0.218	0.258
B	0.191	0.000	0.141	0.181	0.258
C	0.208	0.171	0.000	0.201	0.232
D	0.232	0.198	0.208	0.000	0.252
E	0.252	0.268	0.235	0.245	0.000

Table 4. Total relation matrix T (Challenges vs Challenges)

Factors	A	B	C	D	E
A	1.318	1.451	1.379	1.453	1.659
B	1.335	1.141	1.200	1.288	1.500
C	1.392	1.330	1.117	1.346	1.533
D	1.503	1.441	1.376	1.270	1.650
E	1.637	1.605	1.503	1.584	1.584

Table 5. Sum of Rows and Columns of Matrix T (Challenges vs Challenges)

Factors	Sum R_i	Sum C_j	$R_i + C_j$	$R_i - C_j$
A	7.259	7.185	14.445	0.074
B	6.464	6.968	13.432	-0.504
C	6.719	6.575	13.294	0.144
D	7.240	6.941	14.181	0.298
E	7.914	7.926	15.840	-0.012

Table 6. Inner-dependency matrix above threshold α = 1.424 (Challenges × Challenges)

Factors	A	B	C	D	E
A	-	1.451	-	1.453	1.659
B	-	-	-	-	1.500
C	-	-	-	-	1.533
D	1.503	1.441	-	-	1.650
E	1.637	1.605	1.503	1.584	1.584

Table 7. Cronbach's alpha (Challenges vs Challenges)

Items/Questions/Components, K	20
Sum of Item Variances, i	22.166
Variances of Total Scores, t	176.998
Cronbach's alpha	0.921

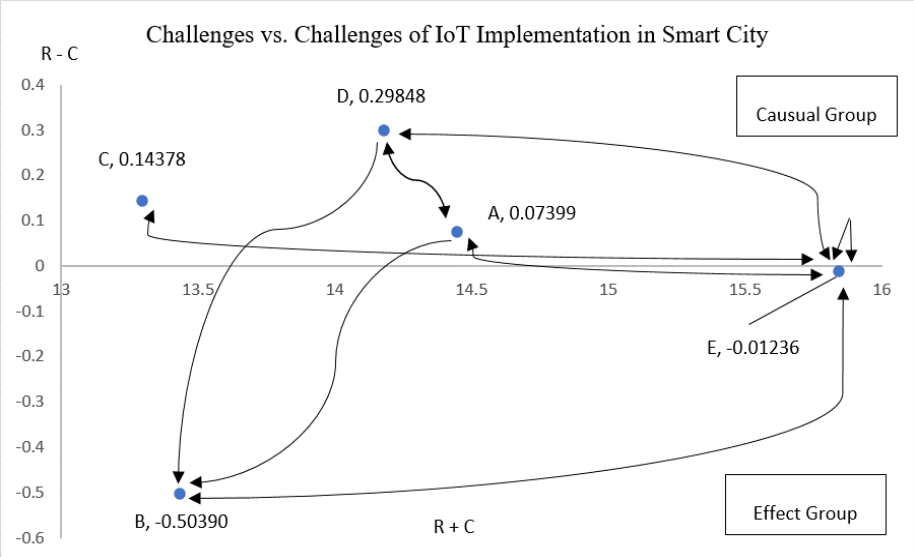

Fig. 1: Impact-direction diagram of Challenges vs Challenges of IoT Implementation in Smart City

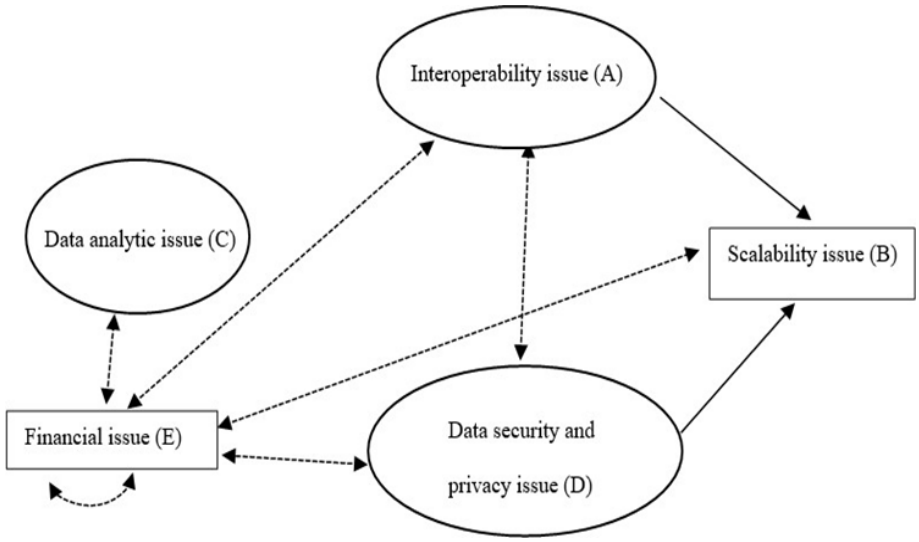

Fig. 2: Relationship Diagram of Challenges vs Challenges of IoT Implementation in Smart City

The Cronbach's alpha for this matrix was 0.921 (Table 7), indicating high internal consistency in expert ratings. As noted in Section 4.5, this is reported as a supplementary check rather than a substitute for DEMATEL-specific consensus measures. Reading Table 5, financial issues (E) recorded the highest prominence ($R_i + C_j = 15.840$), meaning that experts perceived this factor as the most active participant in the influence network. However, its net-relation value ($R_i - C_j = -0.012$) is close to zero and marginally negative, indicating that financial constraints are perceived as roughly as influential as they are influenced, with a slight tilt toward being an effect rather than a cause. A factor can therefore be highly prominent without being a strong perceived driver, a distinction frequently underused in DEMATEL applications. Financial constraints are pervasive across the system but are perceived as substantially shaped by other factors, an interpretation consistent with Popova (2020) and Gyimah et al. (2021), who argue that financial pressure in technology projects is partly downstream of technical and governance choices.

Data security and privacy (D) recorded the largest positive net-relation value ($R_i - C_j = 0.298$), making it the strongest perceived causal driver among the five challenges. Interoperability (A) and data analytics (C) also fall on the cause side, with small positive net values (0.074 and 0.144, respectively). Scalability (B) is the clearest perceived effect ($R_i - C_j = -0.504$). Table 6 shows above-threshold influence flowing from D and E to multiple other factors, and from A to D and E, suggesting reciprocal links between security, interoperability, and financial pressure.

These findings should be read as expert perceptions of causal structure rather than as objective causal facts. In the Malaysian panel's collective judgment, weaknesses in data security and privacy are seen as triggering downstream costs and integration difficulties, an interpretation consistent with prior arguments by Al-Turjman et al. (2022) and Liu et al. (2024).

5.3 DEMATEL Analysis II: Strategies versus Strategies

The same procedure was applied to the strategies. Tables 8 to 11 report the average, normalised, total-relation, and prominence and net-relation matrices, respectively. The threshold α was 2.336; Table 12 shows entries exceeding it; Cronbach's alpha was 0.901 (Table 13).

Table 8. Average direct-relation matrix Z (Strategies × Strategies)

Factors	F	G	H	I	J	SUM
F	0.000	2.520	2.480	3.320	3.080	11.400
G	2.160	0.000	2.240	2.240	2.640	9.280
H	2.520	2.360	0.000	2.720	2.440	10.040
I	2.960	2.160	2.840	0.000	2.680	10.640
J	3.080	2.360	2.680	2. 88	0.000	11.000
SUM	10.720	9.400	10.240	11.160	10.840	-

Table 9. Normalised direct-relation matrix D (Strategies × Strategies)

Factors	F	G	H	I	J
F	0.000	0.221	0.218	0.291	0.270
G	0.189	0.000	0.196	0.196	0.232
H	0.221	0.207	0.000	0.239	0.214
I	0.260	0.189	0.249	0.000	0.235
J	0.270	0.207	0.235	0.253	0.000

Table 10. Total relation matrix T (Strategies vs Strategies)

Factors	F	G	H	I	J
F	2.399	2.320	2.485	2.701	2.622
G	2.179	1.802	2.106	2.248	2.217
H	2.338	2.096	2.074	2.418	2.343
I	2.476	2.185	2.382	2.343	2.471
J	2.544	2.252	2.432	2.608	2.342

Table 11. Sum of Rows and Columns of Matrix T (Strategies vs Strategies)

Factors	Sum R_i	Sum C_j	$R_i + C_j$	$R_i - C_j$
F	12.527	11.936	24.463	0.591
G	10.552	10.656	21.208	-0.104
H	11.270	11.477	22.747	-0.208
I	11.856	12.318	24.174	-0.462
J	12.178	11.996	24.174	0.183

Table 12. Inner-dependency matrix above threshold α = 2.336 (Strategies × Strategies)

Factors	F	G	H	I	J
F	2.399	-	2.485	2.701	2.622
G	-	-	-	-	-
H	2.338	-	-	2.418	2.343
I	2.476	-	2.382	2.343	2.471
J	2.544	-	2.432	2.608	2.342

Table 13. Cronbach's alpha of Strategies vs Strategies

Items/Questions/Components, K	20
Sum of Item Variances, i	22.480
Variances of Total Scores, t	155.830
Cronbach's alpha	0.901

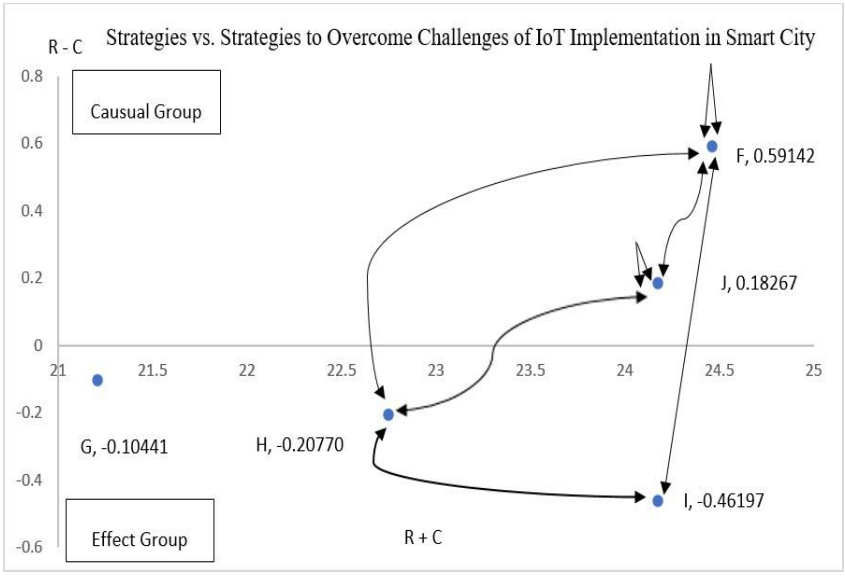

Fig. 3: Impact-direction Diagram of Strategies vs Strategies to Overcome the Challenge of IoT Implementation in Smart City

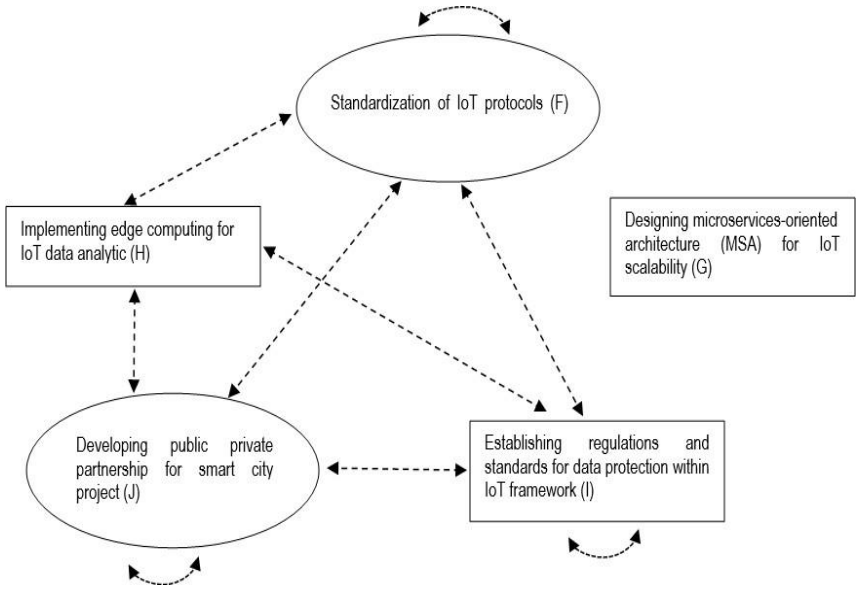

Fig. 4: Relationship Diagram of Strategies vs Strategies to Overcome the Challenge of IoT Implementation in Smart City

Standardisation of IoT protocols (F) recorded both the highest prominence ($R_i + C_j = 24.463$) and the largest positive net relation ($R_i - C_j = 0.591$), identifying it as the strongest perceived causal strategy among the five. Public–private partnerships (J) recorded a positive net relation (0.182) and high prominence (24.174), placing it as a secondary perceived driver. Microservices-oriented architecture (G), edge computing (H), and regulatory frameworks (I) fell on the effect side, indicating that they are perceived as shaped by other strategic choices, plausibly because their effectiveness depends on prior agreement on protocols and partnership arrangements.

Above-threshold linkages in Table 12 indicate that standardisation extends to edge computing, regulation, and PPPs, supporting the interpretation that standardisation serves as connective tissue across the strategy set. This pattern is consistent with arguments by Adepoju et al. (2025), Amjad et al. (2021), and Shahbazian (2023) that standardisation underpins both technical interoperability and policy convergence.

5.4 DEMATEL Analysis III: Strategies versus Challenges

The combined strategy–challenge analysis examined how each of the five strategies is perceived to influence each of the five challenges. Tables 14 to 18 report the corresponding matrices; the threshold α was 0.133; Cronbach's alpha was 0.964 (Table 19).

Table 14. Average direct-relation matrix Z (Strategies × Challenges)

Factors	F	G	H	I	J	A	B	C	D	E	SUM
F	0.000	2.520	2.480	3.320	3.080	3.320	2.880	2.800	2.720	2.760	25.880
G	2.160	0.000	2.240	2.240	2.640	2.320	2.480	2.000	2.240	2.800	21.120
H	2.520	2.360	0.000	2.720	2.440	2.640	2.240	2.560	2.880	3.160	23.520
I	2.960	2.160	2.840	0.000	2.680	3.000	2.440	2.520	3.080	2.800	24.480
J	3.080	2.360	2.680	2.880	0.000	2.800	2.840	2.680	2.800	3.320	25.440
A	0.000	0.000	0.000	0.000	0.000	0.000	2.480	2.480	2.600	3.080	10.640
B	0.000	0.000	0.000	0.000	0.000	2.280	0.000	1.680	2.160	3.080	9.200
C	0.000	0.000	0.000	0.000	0.000	2.480	2.040	0.000	2.400	2.760	9.680
D	0.000	0.000	0.000	0.000	0.000	2.760	2.360	2.480	0.000	3.000	10.600
E	0.000	0.000	0.000	0.000	0.000	3.000	3.200	2.800	2.920	0.000	11.920
SUM	10.720	9.400	10.240	11.160	10.840	24.600	22.960	22.000	23.800	26.760	-

Table 15. Normalised direct-relation matrix D (Strategies × Challenges)

Factors	F	G	H	I	J	A	B	C	D	E
F	0.000	0.094	0.093	0.124	0.115	0.124	0.108	0.105	0.102	0.103
G	0.081	0.000	0.084	0.084	0.099	0.087	0.093	0.075	0.084	0.105
H	0.094	0.088	0.000	0.102	0.091	0.099	0.084	0.096	0.108	0.118
I	0.111	0.081	0.106	0.000	0.100	0.112	0.091	0.094	0.115	0.105
J	0.115	0.088	0.100	0.108	0.000	0.105	0.106	0.100	0.105	0.124
A	0.000	0.000	0.000	0.000	0.000	0.000	0.093	0.093	0.097	0.115
B	0.000	0.000	0.000	0.000	0.000	0.085	0.000	0.063	0.081	0.115
C	0.000	0.000	0.000	0.000	0.000	0.093	0.076	0.000	0.090	0.103
D	0.000	0.000	0.000	0.000	0.000	0.103	0.088	0.093	0.000	0.112
E	0.000	0.000	0.000	0.000	0.000	0.112	0.120	0.105	0.109	0.000

Table 16. Total relation matrix T (Strategies vs Challenges)

Factors	F	G	H	I	J	A	B	C	D	E
F	0.064	0.142	0.146	0.177	0.168	0.310	0.286	0.275	0.285	0.310
G	0.128	0.046	0.128	0.132	0.143	0.245	0.242	0.219	0.237	0.274
H	0.143	0.131	0.054	0.151	0.141	0.271	0.249	0.252	0.273	0.303
I	0.160	0.128	0.153	0.062	0.151	0.290	0.263	0.258	0.287	0.300
J	0.165	0.136	0.150	0.161	0.062	0.291	0.281	0.268	0.284	0.323
A	0.000	0.000	0.000	0.000	0.000	0.059	0.142	0.138	0.145	0.169
B	0.000	0.000	0.000	0.000	0.000	0.130	0.050	0.106	0.125	0.161
C	0.000	0.000	0.000	0.000	0.000	0.139	0.123	0.049	0.134	0.153
D	0.000	0.000	0.000	0.000	0.000	0.152	0.138	0.138	0.056	0.166
E	0.000	0.000	0.000	0.000	0.000	0.165	0.169	0.153	0.160	0.072

Table 17. Sum of Rows and Columns of Matrix T (Strategies vs Challenges)

Factors	Sum R_i	Sum C_j	$R_i + C_j$	$R_i - C_j$
F	2.163	0.659	2.822	1.504
G	1.794	0.583	2.377	1.211
H	1.967	0.632	2.599	1.336
I	2.052	0.683	2.735	1.369
J	2.122	0.664	2.786	1.458
A	0.652	2.053	2.705	-1.400
B	0.572	1.942	2.515	-1.370
C	0.598	1.856	2.454	-1.257
D	0.650	1.988	2.638	-1.337
E	0.721	2.232	2.952	-1.511

Table 18. Inner-dependency matrix above threshold α = 0.133 (Strategies × Challenges)

Factors	F	G	H	I	J	A	B	C	D	E
F	-	0.142	0.146	0.177	0.168	0.310	0.286	0.275	0.285	0.310
G	-	-	-	-	0.143	0.245	0.242	0.219	0.237	0.274
H	0.143	-	-	0.151	0.141	0.271	0.249	0.252	0.273	0.303
I	0.160	-	0.153	-	0.151	0.290	0.263	0.258	0.287	0.300
J	0.165	0.136	0.150	0.161	-	0.291	0.281	0.268	0.284	0.323
A	-	-	-	-	-	-	0.142	0.138	0.145	0.169
B	-	-	-	-	-	-	-	-	-	0.161
C	-	-	-	-	-	0.139	-	-	0.134	0.153
D	-	-	-	-	-	0.152	0.138	0.138	-	0.166
E	-	-	-	-	-	0.165	0.169	0.153	0.160	-

Table 19. Cronbach's alpha of Strategies vs Challenges

Items/Questions/Components, K	65
Sum of Item Variances, i	69.962
Variances of Total Scores, t	1383.210
Cronbach's alpha	0.964

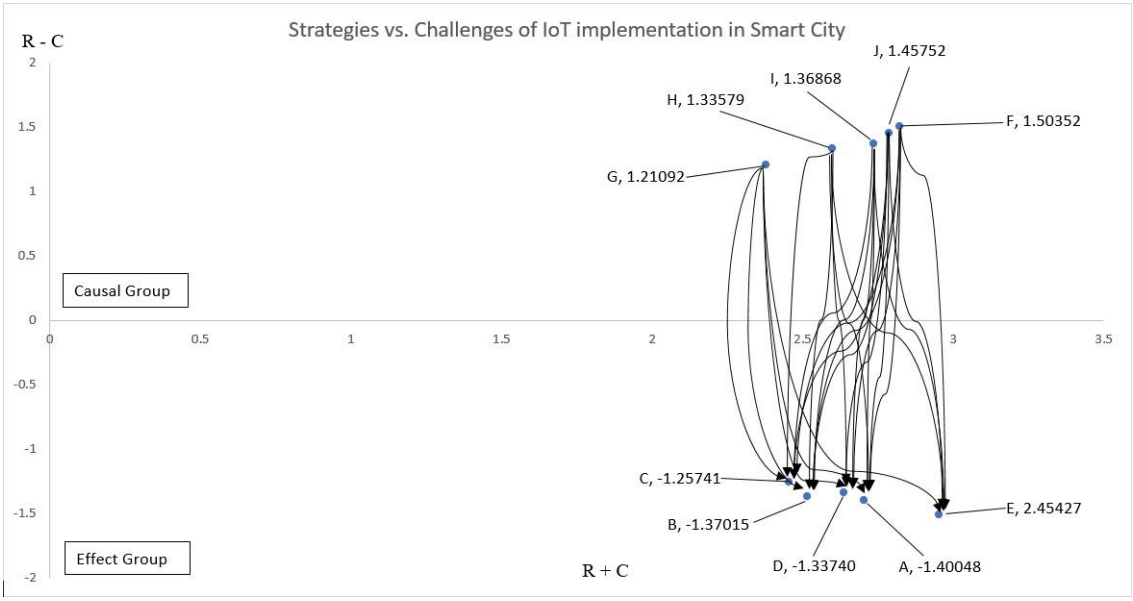

Fig. 5: Impact-direction diagram of Strategies versus Challenges of IoT implementation in a smart city

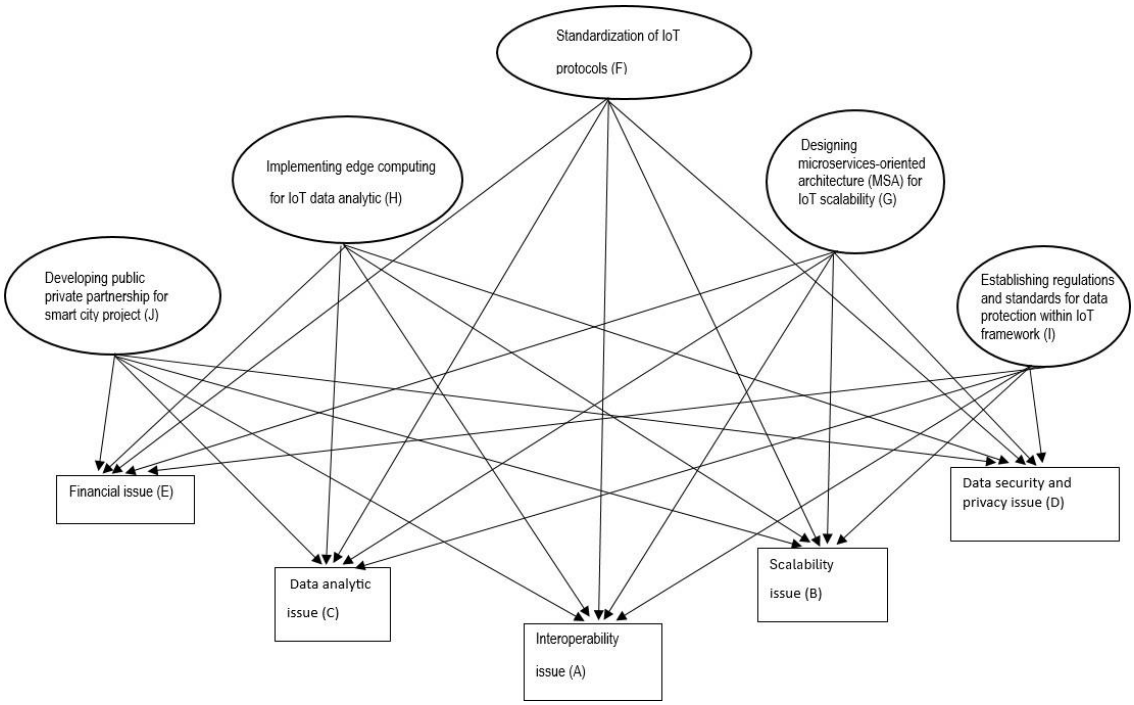

Fig. 6: Relationship diagram of Strategies vs Challenges of IoT Implementation in a smart city

Two patterns are evident. First, all five strategies recorded positive net-relation values, and all five challenges recorded negative net-relation values, confirming that the strategies are perceived collectively to act on the challenges rather than the reverse. Second, standardisation of IoT protocols (F) again recorded the strongest net influence ($R_i - C_j$ = +1.504), followed by PPPs (J, +1.458), regulatory frameworks (I, +1.369), edge computing (H, +1.336), and MSA (G, +1.211).

Tracing the above-threshold paths, standardisation exerts direct perceived influence on all five challenges, with the largest entries flowing to interoperability (A) and financial constraints (E). PPPs likewise reach all five challenges and have the largest perceived effect on financial constraints. Edge computing is most strongly

perceived to affect data analytics and data security. Regulatory frameworks are perceived to have the greatest influence on data security and privacy. Across the three analyses, standardisation and PPPs are perceived within this panel as the strategies with the broadest influence, while data security and privacy are perceived as the most influential challenge to address first.

6.0 DISCUSSION

The DEMATEL analyses produced three findings that warrant careful interpretation.

6.1 Prominence versus Net Causality: The Financial-Constraint Paradox

An important feature of DEMATEL is the distinction between prominence ($R_i + C_j$) and net causality ($R_i - C_j$). Financial constraints recorded the highest prominence among challenges, but a near-zero, marginally negative net-relation value. In substantive terms, experts perceive financial pressure as ubiquitous in the system, touching and being touched by every other challenge, yet not as an independent root cause. Financial constraints appear to absorb pressure from upstream issues: weak data security inflates cost through risk management and trust-building, and poor interoperability inflates integration costs. The practical implication is that direct financial interventions, such as budget increases, may yield smaller systemic returns than upstream interventions in security and standardisation, because the financial problem partly reflects costs imposed by those upstream weaknesses. This interpretation is consistent with Popova (2020) and contrasts with simpler accounts that treat finance as a primary independent barrier.

6.2 Data Security and Privacy as a Perceived Driver

Among the five challenges, data security and privacy showed the strongest positive net relation, making it the strongest perceived causal driver in the panel's judgment. This is consistent with the broader literature on socio-technical IoT systems, which argues that trust and risk management shape the conditions under which other components can operate (Al-Turjman et al., 2022; Hussain, 2024; Liu et al., 2024). The result should be read as a recommendation grounded in expert-based DEMATEL findings rather than as an empirical causal law. The panel believes that addressing security and privacy first would relieve pressure elsewhere in the system, and this view is plausible in light of prior work; empirical validation using longitudinal project data would be needed to establish the corresponding causal claim.

6.3 Standardisation and PPPs as Cross-Cutting Strategies

The strategy analyses converge on standardisation of IoT protocols as the strongest perceived driver and PPPs as a strong secondary driver. The convergence is consistent with the socio-technical framework. Standardisation is a technical intervention with organisational consequences: it lowers integration costs (technical), enables shared procurement (financial), and provides a common reference for regulation (organisational). PPPs are an organisational intervention with technical and financial consequences. Both strategies span subsystems, in line with the framework's expectation that cross-cutting interventions exert broader influence. Strategies confined to a single subsystem, such as MSA and edge computing, appear as perceived effects rather than perceived causes.

6.4 Implication for Policy and Practice

The findings imply a sequence rather than a portfolio of equal-weight interventions: standardisation and data-protection regulation should be established early; PPP structures layered next to mobilise capital; and technical strategies such as edge computing and MSA deployed within this stabilised environment. National alignment with international IoT standards, such as ISO/IEC 30141, would support this sequence by reducing fragmentation, and embedding this alignment within Malaysia's existing smart city policy infrastructure would lower the cost of subsequent municipal-level deployments. These implications should be applied with caution outside the Malaysian context: features such as the concentration of expertise, the active role of GLCs, and an established yet still-evolving regulatory base shape the observed influence structure, and other institutional configurations may exhibit different patterns.

6.5 Interpretive Cautions

Three cautions discipline the interpretation. First, DEMATEL outputs are perceived influence structures derived from expert judgment; they are not measured causal effects. Second, the panel is small, predominantly male, and geographically concentrated, so the influence structure should be read as representing the views of senior IoT professionals operating in major Malaysian smart-city hubs rather than the views of all stakeholders. Third, the threshold α is computed as the mean of T; alternative threshold choices would produce slightly different digraphs without changing the prominence or net-relation rankings.

7.0 CONCLUSION, LIMITATIONS, AND FUTURE RESEARCH

This study used DEMATEL to model the perceived causal structure linking five IoT implementation challenges and five strategic responses in Malaysian smart cities, drawing on the judgments of 25 practitioners and a socio-technical conceptual framework. Two patterns stand out. Among challenges, data security and privacy were the strongest perceived causal drivers. At the same time, financial constraints were the most prominent but largely receiving factor, a distinction with direct implications for how interventions are sequenced. Among strategies, standardisation of IoT protocols was the strongest perceived driver, with public–private partnerships acting as a strong secondary lever. Both span technical, organisational, and financial subsystems, consistent with the framework's expectation that cross-cutting interventions have the broadest perceived influence.

The study makes two conservative and specific contributions. First, it provides a Malaysia-focused, expert-based causal mapping of IoT challenges and strategies, a context-specific addition to a literature that has so far treated these factors largely in isolation. Second, it offers a DEMATEL-based prioritisation framework that policymakers, urban planners, and technology providers in similar settings can adapt when allocating limited resources. The framework supports sequencing rather than a uniform portfolio of interventions.

7.1 Limitations

Several limitations qualify the findings. The expert panel is relatively small (n = 25), is skewed toward male respondents from the private sector, and is geographically concentrated in Pulau Pinang, Kuala Lumpur, and Cyberjaya. Although the sample size is consistent with established DEMATEL practice, the demographic and geographic skew constrains generalisation to other

Malaysian states and to other countries. DEMATEL itself produces perceived influence structures rather than empirically tested causal effects, and is sensitive to threshold choice. Cronbach's alpha was used as a supplementary internal-consistency check; it is not a DEMATEL-specific consensus measure. The study analyses five challenges and five strategies; other plausible factors, such as skill shortages, political continuity, and cybersecurity workforce capacity, were excluded to keep the matrices tractable.

7.2 Future Research

Four extensions would strengthen the evidence base. First, the study could be replicated with larger and more demographically balanced expert panels, including public-sector and civil-society representatives, to test the robustness of the influence structure. Second, comparative DEMATEL studies in other countries, such as Indonesia, Vietnam, and the United Arab Emirates, would identify which features of the influence structure are common across contexts and which are Malaysia-specific. Third, fuzzy DEMATEL or grey DEMATEL variants could relax the assumption of crisp expert ratings and accommodate uncertainty in expert judgment. Fourth, mixed-method follow-up studies that combine DEMATEL with longitudinal case studies of specific projects would help distinguish perceived causal structures from empirically observable causal effects.

In sum, the study offers a careful, expert-grounded basis for sequencing IoT interventions in Malaysian smart cities. The findings are not claims about how IoT systems must work everywhere; they are a structured representation of how a panel of experienced Malaysian practitioners currently judges the relationships among the principal challenges and strategies they face.

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CONFLICTS OF INTEREST AND INFORMED CONSENT DECLARATIONS

The authors certify that they have no affiliations with, or involvement in, any organisation or entity with any financial or non-financial interest in the subject matter or materials discussed in this manuscript. Informed consent was obtained from all participating experts, and responses were anonymised.

DATA AVAILABILITY STATEMENT

The data supporting the findings of this study are available from the corresponding author on reasonable request.

REFERENCES

Adepoju, P. A., Ige, A. B., Akinade, A. O., & Afolabi, A. I. (2025). Smart cities and Internet of Things (IoT): A review of emerging technologies and challenges. *International Journal of Research and Innovation in Social Science*, *9*(1), 1536–1549. doi:10.47772/IJRISS.2025.9010127

Ahmad, S., Miskon, S., Alabdan, R., & Tlili, I. (2021). Statistical assessment of business intelligence system adoption model for sustainable textile and apparel industry. *IEEE Access*, *9*, 106560–106574. doi:10.1109/ACCESS.2021.3100410

Alam, T. (2024). Metaverse of Things (MoT) applications for revolutionising urban living in smart cities. *Smart Cities*, *7*(5), 2466–2494. doi:10.3390/smartcities7050096

Alavi, A. H., Jiao, P., Buttlar, W. G., & Lajnef, N. (2018). Internet of Things-enabled smart cities: State-of-the-art and future trends. *Measurement*, *129*, 589–606. doi:10.1016/j.measurement.2018.07.067

Ali, Z., Mahmood, A., Khatoon, S., Alhakami, W., Ullah, S. S., Iqbal, J., & Hussain, S. (2023). A generic Internet of

Things (IoT) middleware for smart city applications. *Sustainability*, *15*(1), 743. doi:10.3390/su15010743
Al-Obaidi, K. M., Hossain, M., Alduais, N. A. M., Al-Duais, H. S., Omrany, H., & Ghaffarianhoseini, A. (2022). A review of using IoT for energy-efficient buildings and cities: A built-environment perspective. *Energies*, *15*(16), 5991. doi:10.3390/en15165991
Al-Turjman, F., Zahmatkesh, H., & Shahroze, R. (2022). An overview of security and privacy in smart cities' IoT communications. *Transactions on Emerging Telecommunications Technologies*, *33*(6), e3677. doi:10.1002/ett.3677
Amjad, A., Azam, F., Anwar, M. W., & Butt, W. H. (2021). A systematic review on the data interoperability of application-layer protocols in industrial IoT. *IEEE Access*, *9*, 96528–96545. doi:10.1109/ACCESS.2021.3094763
Bauer, M., Sanchez, L., & Song, J. (2021). IoT-enabled smart cities: Evolution and outlook. *Sensors*, *21*(13), 4511. doi:10.3390/s21134511
Bellini, P., Nesi, P., & Pantaleo, G. (2022). IoT-enabled smart cities: A review of concepts, frameworks and key technologies. *Applied Sciences*, *12*(3), 1607. doi:10.3390/app12031607
Bhardwaj, V., Anooja, A., Vermani, L. S., Sunita, & Dhaliwal, B. K. (2024). Smart cities and the IoT: An in-depth analysis of global research trends and future directions. *Discover Internet of Things*, *4*(1), 19. doi:10.1007/s43926-024-00076-3
Bibri, S. E., Krogstie, J., Kaboli, A., & Alahi, A. (2023). Smarter eco-cities and their leading-edge artificial intelligence of things solutions for environmental sustainability: A comprehensive systematic review. *Environmental Science and Ecotechnology*, *19*, 100330. doi:10.1016/j.ese.2023.100330
Boutkhoum, O., Hanine, M., Nabil, M., El Barakaz, F., Lee, E., Rustam, F., & Ashraf, I. (2021). Analysis and evaluation of barriers influencing blockchain implementation in Moroccan sustainable supply chain management: An integrated IFAHP-DEMATEL framework. *Mathematics*, *9*(14), 1601. doi:10.3390/math9141601
Chang, C. M., Salinas, G. T., Gamero, T. S., Schroeder, S., Vélez Canchanya, M. A., & Mahnaz, S. L. (2023). An infrastructure-management humanistic approach for smart cities development, evolution, and sustainability. *Infrastructures*, *8*(9), 127. doi:10.3390/infrastructures8090127
Chen, W., Li, W., Shao, L., Zhang, T., & Wang, X. (2023). Large-scale group-hierarchical DEMATEL method for complex systems. *PLOS One*, *18*(12), e0288326. doi:10.1371/journal.pone.0288326
EI, I., MI, A., Edith, O., & Deborah, O. (2023). A framework for smart city model enabled by Internet of Things (IoT). *International Journal of Computer Applications*, *185*(6), 6–11. doi:10.5120/ijca2023922685
Gade, D. S., & Aithal, P. S. (2022). ICT and digital technology-based solutions for smart city challenges and opportunities. *International Journal of Applied Engineering and Management Letters*, *6*(1), 1–21. doi:10.5281/zenodo.5860810
Gyimah, D., Siganos, A., & Veld, C. (2021). Effects of financial constraints and product market competition on share repurchases. *Journal of International Financial Markets, Institutions and Money*, *74*, 101392. doi:10.1016/j.intfin.2021.101392
Hassan, R. J., Zeebaree, S. R. M., Ameen, S. Y., Kak, S. F., Sadeeq, M. A. M., Ageed, Z. S., Al-Zebari, A., & Salih, A. M. (2021). State-of-the-art survey for IoT effects on smart city technology: Challenges, opportunities, and solutions. *Asian Journal of Research in Computer Science*, *8*(3), 32–48. doi:10.9734/ajrcos/2021/v8i330202
Hoang, T. V. (2024). Impact of the integration of artificial intelligence and Internet of Things technologies on smart city transformation. *Journal of Technical Education Science*, *19*(1), 64–73. doi:10.54644/jte. 2024.1532
Houssein, E. H., Othman, M. A., Mohamed, W. M., & Younan, M. (2024). Internet of Things in smart cities: Comprehensive review, open issues and challenges. *IEEE Internet of Things Journal*, *11*(21), 34941–34952. doi:10.1109/JIOT.2024.3449753
Hussain, I. (2024). Secure, sustainable smart cities and the Internet of Things: Perspectives, challenges, and future directions. *Sustainability*, *16*(4), 1390. doi:10.3390/su16041390
Ismagilova, E., Hughes, L., Dwivedi, Y. K., & Raman, K. R. (2019). Smart cities: Advances in research—An information systems perspective. *International Journal of Information Management*, *47*, 88–100. doi:10.1016/j.ijinfomgt.2019.01.004
James, P., Jonczyk, J., Smith, L., Harris, N., Komar, T., Bell, D., & Ranjan, R. (2022). Realising smart city infrastructure at scale, in the wild: A case study. *Frontiers in Sustainable Cities*, *4*, 767942. doi:10.3389/frsc.2022.767942
Janssen, M., Luthra, S., Mangla, S., Rana, N. P., & Dwivedi, Y. K. (2019). Challenges for adopting and implementing IoT in smart cities: An integrated MICMAC-ISM approach. *Internet Research*, *29*(6), 1589–

1616. doi:10.1108/INTR-06-2018-0252
Khan, S., Singh, R., Haleem, A., Dsilva, J., & Ali, S. S. (2022). Exploration of critical success factors of Logistics 4.0: A DEMATEL approach. *Logistics*, *6*(1), 13. doi:10.3390/logistics6010013
Kim, H., Choi, H., Kang, H., An, J., Yeom, S., & Hong, T. (2021). A systematic review of the smart energy conservation system: From smart homes to sustainable smart cities. *Renewable and Sustainable Energy Reviews*, *140*, 110755. doi:10.1016/j.rser.2021.110755
Lin, W. C. (2022). Maritime environment assessment and management using the balanced scorecard through DEMATEL and ANP techniques. *International Journal of Environmental Research and Public Health*, *19*(5), 2873. doi:10.3390/ijerph19052873
Liu, J., Hu, H., Xu, W., & Luo, D. (2024). Internet of Things challenges and future scope for enhanced living environments. In A. R. Hurson (Ed.), Advances in computers (Vol. 133). Amsterdam, Netherlands: Elsevier.
Makki, A. A., & Alqahtani, A. Y. (2024). Analysis of the barriers to smart city development using DEMATEL. *Urban Science*, *8*(1), 10. doi:10.3390/urbansci8010010
Pinto, B. M. B., Ferreira, F. A. F., Spahr, R. W., Sunderman, M. A., & Pereira, L. F. (2022). Analysing causes of urban blight using cognitive mapping and DEMATEL. *Annals of Operations Research*, *325*(2), 1083–1110. doi:10.1007/s10479-022-04614-6
Popova, Y. (2020). Economic or financial substantiation for smart city solutions: A literature study. *Economic Annals-XXI*, *183*(5-6), 125–133. doi:10.21003/ea.V183-12
Rafiq, I., Mahmood, A., Razzaq, S., Jafri, S. H. M., & Aziz, I. (2023). IoT applications and challenges in smart cities and services. *The Journal of Engineering*, *2023*(4), e12262. doi:10.1049/tje2.12262
Ratnakar, S. S., Vidyavathi, D. P., & Shyamala. (2020). The role of IoT in smart cities: Opportunities and challenges. *International Research Journal of Modernisation in Engineering Technology and Science*, *2*(2). Retrieved from https://www.irjmets.com
Rejeb, A., Rejeb, K., Simske, S., Treiblmaier, H., & Zailani, S. (2022). The big picture on the Internet of Things and the smart city: A review of what we know and what we need to know. *Internet of Things*, *19*, 100565. doi:10.1016/j.iot.2022.100565
Saidala, R. K., V H. V., Padmapriya, G., S J., Priya, V. K., & Shaikh, A. A. (2024). Interoperability and standardisation in the Internet of Things. In Proceedings of the Ninth International Conference on Science, Technology, Engineering and Mathematics (ICONSTEM). doi:10.1109/ICONSTEM60960.2024.10568856
Shahbazian, R. (2023). Enhancing IoT security through standardisation: A review. *Advances in the Standards & Applied Sciences*, *1*(4), e181024. doi:10.22034/asas.2023.411968.1032
Singh, C., Chadha, S., Bathrinath, S., Dixit, I., P, S., & Sathish, T. (2024). IoT-based smart cities: Challenges and future perspectives. In Proceedings of the Ninth International Conference on Science, Technology, Engineering and Mathematics (ICONSTEM) (pp. 1–6). New York, NY: IEEE. doi:10.1109/ICONSTEM60960.2024.10568658
Syed, A. S., Sierra-Sosa, D., Kumar, A., & Elmaghraby, A. (2021). IoT in smart cities: A survey of technologies, practices and challenges. *Smart Cities*, *4*(2), 429–475. doi:10.3390/smartcities4020024
Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International Journal of Medical Education*, *2*, 53–55. doi:10.5116/ijme.4dfb.8dfd
United Nations. (2022). World urbanisation prospects: The 2022 revision. New York, NY: Department of Economic and Social Affairs, Population Division. Retrieved from https://population.un.org/wup/
Wang, K., Zhao, Y., Gangadhari, R. K., & Li, Z. (2021). Analysing the adoption challenges of the Internet of Things (IoT) and artificial intelligence (AI) for smart cities in China. *Sustainability*, *13*(19), 10983. doi:10.3390/su131910983
Whaiduzzaman, M., Barros, A., Chanda, M., Barman, S., Sultana, T., Rahman, M. S., Roy, S., & Fidge, C. J. (2022). A review of emerging technologies for IoT-based smart cities. *Sensors*, *22*(23), 9271. doi:10.3390/s22239271
Xu, W., Xie, Y., Yu, Q., & Proverbs, D. (2023). An evaluation of factors influencing the resilience of flood-affected communities in China. *Hydrology*, *10*(2), 35. doi:10.3390/hydrology10020035
Yadav, S., Luthra, S., & Garg, D. (2020). Internet of Things (IoT)-based coordination system in agri-food supply chain: Development of an efficient framework using DEMATEL-ISM. *Operations Management Research*, *15*(1-2), 1–27. doi:10.1007/s12063-020-00164-x
Zaman, M., Puryear, N., Abdelwahed, S., & Zohrabi, N. (2024). A review of IoT-based smart city development and management. *Smart Cities*, *7*(3), 1462–1501. doi:10.3390/smartcities7030061

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ALIGNING CURATORIAL INTENT WITH PERCEPTION-BASED NAVIGATION: SOM AND ISOVIST APPROACHES IN EXHIBITION DESIGN

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ABSTRACT

Designing intuitive indoor exhibition spaces requires aligning the intended narrative sequence with visitors' spontaneous movement. Evaluating this alignment before construction remains a challenge in architectural planning. This research presents a computational framework to assess spatial layouts by comparing planned exhibition routes with simulated visitor behaviour. The study employs two complementary computational approaches within a temporary indoor exhibition context: the Self-Organising Map (SOM) and Isovist-based agent simulation. The SOM algorithm generates an optimised sequence of exhibit nodes, representing the intended visitor route, while the Isovist simulation predicts movement based on spatial geometry, visibility, and obstacle avoidance. An image-based, pixel-level comparison using OpenCV quantifies the overlap between SOM-generated paths and Isovist trajectories, revealing areas of alignment and divergence. Results show partial overlap, indicating that while SOM captures structured circulation, natural visitor movement is more adaptive and variable. The methodology highlights spatial inefficiencies and navigational bottlenecks, providing architects and planners with a diagnostic tool to optimise exhibition layouts, enhance circulation, and ensure key points of interest are naturally discoverable.

Keywords: Visitor movement, Isovist simulation, SOM algorithm, indoor navigation

1.0 INTRODUCTION

Indoor navigation within exhibition spaces is a critical field of study for understanding how spatial configurations influence visitor movement. Historically, research has focused on tracking exhibit engagement time (Melton, 1935; Serrell, 1998) and analysing how display layouts impact visitor pathways (Bourdeau and Chebat, 2001). While traditional studies relied on observational methods or questionnaires, advancements in computational algorithms now enable the simulation of movement patterns to model and predict complex spatial behaviours. Algorithms such as random walk, A*, and ant-colony optimisation have been employed to model movement (Yoshimura et al. 2019; Pasandi et al. 2021), while others investigate shortest-path solutions for emergency planning (Marzouk and Hassan, 2022). Despite the importance of navigation in both urban and indoor contexts, a gap remains in evaluating the alignment between design intent and algorithmic predictions in complex temporary environments.

This research proposes a comparative framework between two computational algorithms—SOM and Isovist-based simulation—to evaluate the intuitive nature of exhibition layouts. These algorithms represent fundamentally different models of navigation: global sequence optimisation versus locally informed, perception-driven movement. In this study, the SOM algorithm generates an optimised intended path, with major exhibits

serving as sequential nodes (Kohonen, 1990), while the Isovist simulation operates as an independent predictive agent, navigating the space based on visibility, geometry, and obstacle avoidance (Benedikt, 1979). By comparing these two distinct approaches, the study assesses whether the physical arrangement of a space naturally supports the curator's intended visitor experience.
The simulated paths are analysed using an image-based, pixel-level comparison in OpenCV to quantify spatial overlaps and divergences. This method provides an objective measure of alignment between the intended sequence and predicted movement patterns, enabling systematic evaluation without relying on observational data. To guide the investigation, the study poses the following research question:

To what extent does simulated visitor movement (Isovist) correspond with the optimised and intended exhibition sequence (SOM)?

By bridging the gap between design intent and algorithmic prediction, this research offers a comprehensive understanding of visitor navigation in indoor spaces. The study introduces a computational method for evaluating navigational intuitiveness prior to construction. It provides insights for optimising space design and improving navigation systems in exhibition contexts, ensuring that critical points of interest are naturally accessible within the spatial flow.

2.0 LITERATURE REVIEW

Research on pedestrian movement has traditionally focused on indoor navigation and wayfinding within the context of evacuation planning, navigation systems, and agent-based simulations. Indoor navigation involves spatial perception, decision-making, and movement within enclosed environments, shaped by spatial configuration, environmental constraints, and user behaviour rather than purely shortest-path logic (Jayakanth et al., 2020; Marzouk and Hassan, 2022). The increasing complexity of indoor environments, such as museums and commercial spaces, has driven the development of computational models capable of predicting movement patterns (Yan et al., 2021).
Agent-Based Modelling (ABM) has been widely used to analyse visitor interaction with exhibition layouts. It also helps evaluate experiential discrepancies between intended and actual spatial use (Liu et al., 2024). In evacuation contexts, simulations often combine behavioural models with Computational Fluid Dynamics to represent environmental hazards (Kasereka et al., 2018; Luh et al., 2012). Cellular automata, social force models, and floor-field approaches represent pedestrians as agents influenced by attraction, repulsion, and spatial constraints (Burstedde et al., 2001; Helbing et al., 2000; Tan et al., 2015). These approaches, while effective for modelling crowd dynamics, primarily address efficiency and safety rather than the exploratory movement characteristic of exhibition environments.
Pathfinding algorithms, such as A* and its variants, are used in indoor navigation, especially in obstacle-dense environments (Pasandi et al., 2021). Studies show that spatial geometry and obstacle configuration shape route selection (Ni et al., 2020; Cui et al., 2023). However, shortest-path optimisation misses experiential navigation, where visitors may deviate to explore visually accessible points of interest.
Visibility-based spatial analysis offers an alternative, perception-based framework. The Isovist (Benedikt, 1979) describes the visible spatial field from one location and strongly influences navigation and exploration (Wiener et al., 2007). Isovist simulations model navigation as a process shaped by geometry, visibility, and obstacles, not predetermined paths.
In contrast, machine-learning approaches such as the Self-Organising Map (SOM) provide global optimisation capabilities. Originally developed as a neural network clustering and ordering algorithm (Kohonen, 1990), SOM has been adapted to travelling-salesman-type routing problems, generating optimised visitation sequences when multiple destinations must be visited in a structured order (Yan et al., 2021). In exhibition design, this capability enables SOM to represent an intended narrative sequence defined by relationships among exhibit nodes.
Despite significant advances, existing research rarely compares optimised routing structures with visibility-driven movement predictions within a single analytical framework. Most studies treat navigation either as behavioural simulation or route optimisation independently, leaving unresolved whether architectural layouts inherently support intended visitor sequences. This limitation is particularly critical in temporary exhibition environments, where the spatial configuration must intuitively guide visitors without relying on signage or post-occupancy corrections.
This research addresses this gap by comparing SOM-optimised routes, which represent design intent, with Isovist-based simulations that predict geometry-driven visitor pathways. Using an image-based, pixel-level

comparison in OpenCV, the study quantifies the overlap and divergence between these models to evaluate the navigational intuitiveness of exhibition layouts. By reframing navigation as a measurable relationship between intended sequencing and spatial perception, the framework provides a proactive computational tool for assessing exhibition design prior to construction.
The following table summarises key studies reviewed in this research, highlighting the computational algorithms employed and the specific navigation or movement-related challenges each study addresses.

Table 1: Summary of Reviewed Studies: Algorithms Applied and Navigation Issues Addressed

Author(s)	Algorithm / Method Used	Issues Tackled
Jayakanth et al. (2020)	Indoor navigation modelling	Influence of spatial configuration and pedestrian characteristics on navigation decisions
Marzouk & Hassan (2022)	Shortest path / evacuation modelling	Route optimization and emergency navigation efficiency
Yan et al. (2021)	Indoor navigation systems; SOM-based routing	Limitations of shortest-path logic; multi-destination navigation behaviour
Liu et al. (2024)	Agent-Based Modelling (ABM)	Gap between exhibition layout design and visitor experience
Kasereka et al. (2018); Luh et al. (2012)	CFD + behavioral simulation	Evacuation dynamics under environmental hazards
Burstedde et al. (2001)	Cellular Automata (CA), Floor-field model	Crowd movement and interaction dynamics
Helbing et al. (2000)	Social force / multi-grid models	Emergent pedestrian behaviour through force-based interactions
Tan et al. (2015)	Force-based agent simulation	Context-driven collective movement patterns
Pasandi et al. (2021)	Modified A* (MASA)	Navigation in obstacle-rich environments
Said et al. (2012)	Geometric path analysis	Relationship between building geometry and route selection
Ni et al. (2020)	Multi-navigation simulation	Movement in multi-obstacle environments
Cui et al. (2023)	Newtonian motion-based algorithm	Dynamic obstacle avoidance
Formolo & van der Wal (2017)	Behavioral/social modelling	Psychological factors in navigation (limited spatial modelling)
Benedikt (1979)	Isovist analysis	Visibility-driven spatial perception
Wiener et al. (2007)	Visibility-based navigation studies	Influence of visual fields on route choice
Kohonen (1990)	Self-Organizing Map (SOM)	Neural-network ordering and sequence optimization

2.2 Research Gap and Contribution

Existing studies on indoor navigation predominantly examine either behavioural simulation models that predict pedestrian movement based on spatial perception and environmental interaction, or optimisation algorithms that generate efficient routing sequences between destinations. Visibility-based approaches, such as Isovist analysis, effectively explain locally driven navigation decisions influenced by geometry and visual access, while optimisation methods, including SOM, generate globally ordered visitation sequences. However, these paradigms have largely been investigated in isolation, leaving a limited understanding of whether architectural layouts inherently support a designer's intended experiential sequence. Moreover, prior research often relies on post-occupancy observation or evacuation-driven scenarios, offering limited applicability to temporary exhibition environments where intuitive navigation must emerge directly from spatial configuration.

This research addresses this gap by introducing a comparative computational framework that evaluates the alignment between SOM-optimised exhibition routes and Isovist-simulated visitor pathways. Using an image-based, pixel-level comparison in OpenCV, the study quantifies spatial overlap and divergence between the two models, providing an objective measure of navigational alignment. This approach offers a proactive diagnostic tool for designers, enabling the assessment of route intuitiveness and identification of spatial inefficiencies during early-stage design, prior to physical implementation or observational data collection.

3.0 METHODOLOGY

This research employs a computational framework comprising SOM simulation**,** Isovist-based movement simulation, and comparative analysis to evaluate indoor exhibition navigation. SOM represents *top-down curatorial cognition*, while Isovist represents *bottom-up embodied perception*. The methodology is designed to examine how the spatial arrangement of exhibits aligns with both the intended visitor sequence and natural, perception-driven movement patterns.

1. **SOM Simulation**

The SOM algorithm provides a global optimisation approach, generating an intended visitation sequence that reflects the designer's narrative plan for the exhibition (Kohonen, 1990). SOM adapts a neural-network clustering framework to sequence multiple exhibit nodes, producing an optimised. The algorithm identifies the Best Matching Unit (BMU) for each exhibit node and iteratively updates node weights to refine the sequence. A one-dimensional circular SOM with a ring topology is employed, where node proximity is defined by index distance rather than Cartesian spatial coordinates.

The SOM algorithm is used to generate an optimised visitor route through an exhibition that reflects the designer's intended narrative sequence. The algorithm clusters and sequences exhibit nodes iteratively, producing a path that aligns design intent with potential visitor movement. The pseudocode is as follows.

1. Initialization:
    - Collect all exhibit locations as input points.
    - Initialise a set of SOM nodes with random positions (weights).
    - Set initial learning rate, neighbourhood radius, and iteration counter.
2. Best Matching Unit (BMU) Identification:
    - For each input exhibit point, find the SOM node whose position is closest to the point (Euclidean distance in weight space).
    - This node is designated as the BMU for that point.
3. Node Weight Update:
    - Update the BMU and its neighbouring nodes to move slightly toward the input point.
    - The amount of adjustment decreases with distance from the BMU (Gaussian neighbourhood influence).
    - The learning rate and neighbourhood size decrease gradually over iterations to facilitate convergence.
4. Iteration:
    - Repeat BMU identification and weight update for all input points over multiple iterations until the map stabilises.
5. Route Construction (Visualisation):
    - Arrange SOM nodes along a circular 1D topology (ring).
    - Define proximity between nodes based on their positions along the ring, ensuring that the first and last nodes are neighbours.
    - Connect nodes sequentially to form a closed polyline representing the optimised visitor path through the exhibition.

1. **Isovist Simulation**

Isovist simulation models, locally informed and visibility-driven, predict how visitors might navigate an exhibition based on spatial geometry and visibility polygons (Benedikt, 1979). Unlike SOM, this approach does not impose a global path but allows agents to make incremental movement decisions influenced by field of view, obstacles, and spatial configuration (Turner et al. 2001; Ha & Lykotrafitis, 2012).

Isovist simulation models how visitors might move through an exhibition based on visibility and spatial geometry. Unlike SOM, which produces a global route, this approach allows agents to make incremental movement decisions influenced by their field of view, obstacles, and surrounding space. The pseudocode is as follows.

1. Initialization:
    - Place an agent at a starting location with an initial viewing direction.
    - Define agent parameters: field-of-view angle, sensing range, and movement detail (number of rays).

2. Observation Step:
    - Generate a set of rays within the agent's vision cone to simulate the visible area (Isovist).
    - For each ray:
        a. Detect intersections with nearby walls, obstacles, or exhibit features.
        b. Identify the closest intersection point along the ray.
3. Decision Step:
    - From all rays, select the direction corresponding to the maximum visible distance (the most open path).
    - Update the agent's direction by slightly adjusting toward this maximum visibility vector.
    - Normalise the direction to ensure consistent movement.
4. Movement Step:
    - Move the agent forward by a fixed step size along the updated direction.
    - Record the new position to build the agent's movement trail.
5. Iteration:
    - Repeat the observation, decision, and movement steps for the desired number of iterations or until the agent reaches a boundary.
6. Data Output:
    - Collect the agent's path (trail) for visualisation.
    - Record intermediate data such as ray intersections and visibility distances for analysis.

1. **Alignment Analysis**

To evaluate navigational alignment, the SOM-optimised path is compared with the Isovist-simulated pathways using an image-based spatial framework. By combining SOM and Isovist data with an image-based comparison using the OpenCV library, NumPy for mathematical calculations, and matplotlib for graph visualisation. This methodology provides a proactive framework to evaluate exhibition navigation before construction or observational data collection. SOM represents the designer's intended path, Isovist simulates perception-driven visitor movement, and the comparison quantifies alignment, providing insights into the intuitiveness and efficiency of the layout.

Method: Quantifying Overlap Between SOM and Isovist Areas

To measure the degree of spatial overlap between SOM-optimised visitor routes and Isovist-simulated movement pathways in a plan or diagram, providing an objective assessment of how well the designed sequence aligns with simulated human behaviour. The pseudocode is as follows.

1. Image Preparation

The diagram is loaded as an image and converted to a standard RGB colour space, allowing accurate identification of the SOM and ISO areas.

2. Feature Identification

For each feature (SOM and ISO), a mask is created to visually isolate it. Each pixel is examined: if its colour closely matches the target colour for the feature, it is marked as part of that area; otherwise, it is treated as background.

3. Mask Refinement

To remove small gaps and inconsistencies, a morphological dilation is applied to both masks. This slightly expands the identified regions to ensure a continuous and robust representation of each area.

4. Overlap Analysis

The overlap between the SOM and ISO areas is determined by identifying the regions where the two masks coincide using a logical intersection.

5. Quantification

The proportion of the SOM area that overlaps with the ISO area is calculated, providing a clear metric of alignment between the design intent and simulated visitor movement.

6. Spatial Distribution Visualisation

The 2D masks are processed into 1D density profiles by summing pixel frequencies. These are plotted on a line chart, with the intersection area highlighted to visually demonstrate the spatial overlap.

7. Interpretation

The resulting percentage and distribution graph indicates how much of the intended route corresponds to naturally visible and accessible pathways, allowing designers to assess and refine exhibition layouts before construction.

1. **Selection of Context**

The context for this research was chosen based on visitor accessibility. A portion of a temporary indoor exhibition, located on the second floor of the Bartlett School of Architecture at UCL during its Summer Show 2023 in London, UK, was selected. This exhibition displayed student architectural projects, attracting both students and the public interested in architecture. A smaller section of the exhibition was chosen to ensure efficiency and maintain control over the algorithmic simulations.

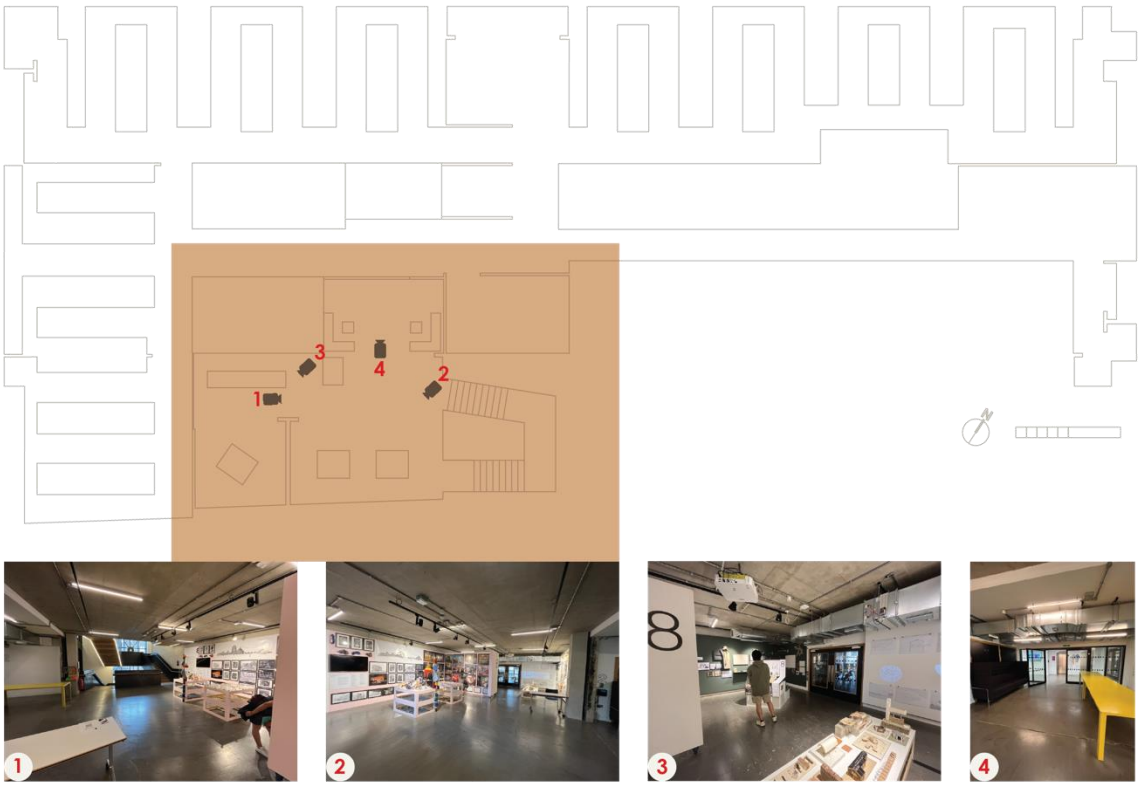

Fig. 1: Context of the research space, with photos captured from multiple perspectives.

4.0 RESULTS

The research is conducted using computational tools such as Grasshopper3D within Rhino3D for algorithm development in C#, while graphical presentations were prepared using Adobe Illustrator. For the comparative alignment phase, the OpenCV library was employed within VS Code. The result section consists of three parts: SOM simulation, Isovist simulations, and a simulation alignment analysis. The key steps and findings are as follows:

1. **SOM Simulation**

For the SOM simulation, several points were defined to act as nodes through which the path would be generated. The starting point was set near the staircase, with most nodes placed along the walls near the exhibits. A total of nine points were positioned, and the SOM algorithm progressively developed a path that gradually connected all the nodes. The final output ensured that every defined node was included in the generated route.

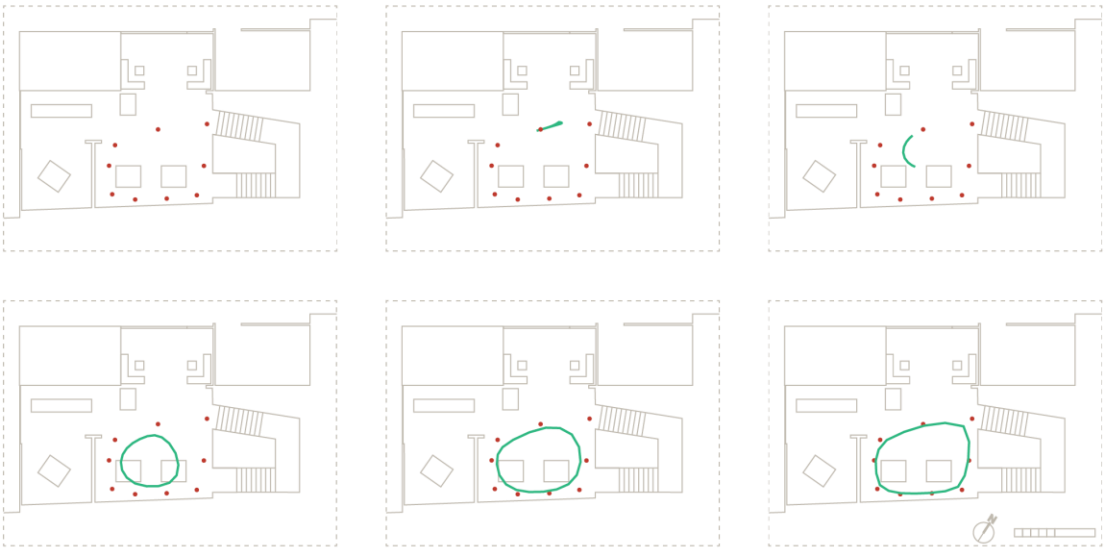

Fig. 2: SOM simulation development

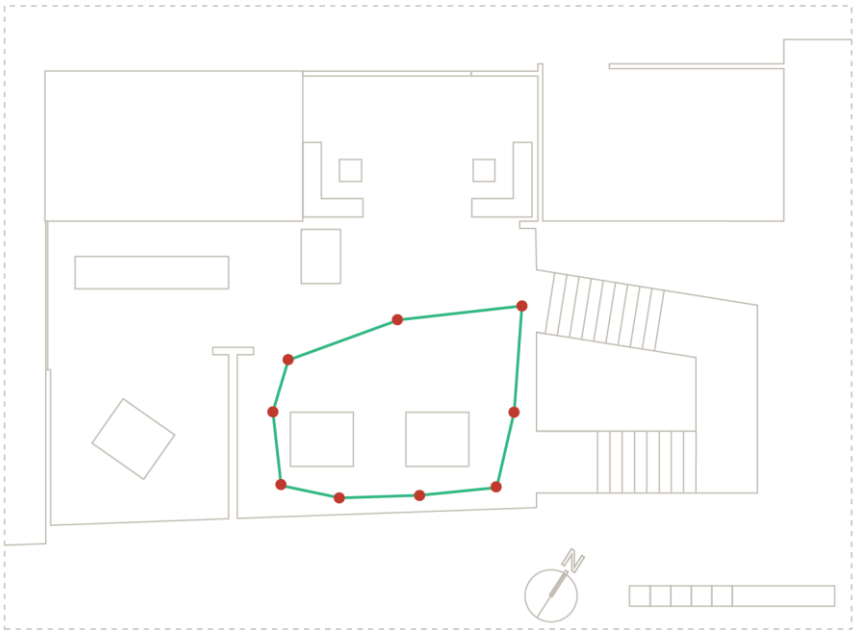

Fig. 3: SOM simulation output

4.2 Isovist Simulation

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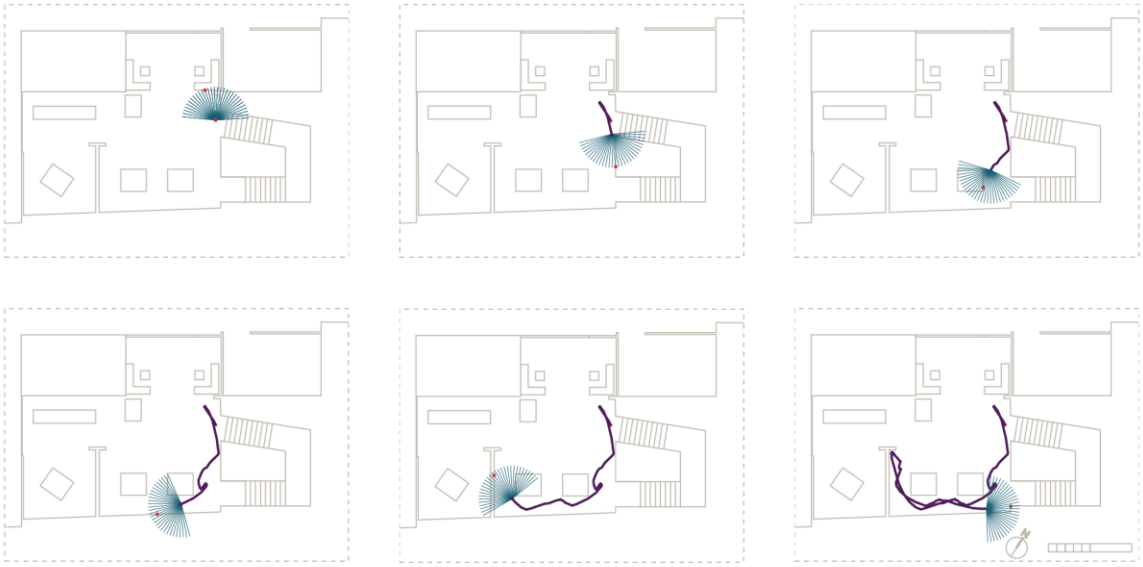

Fig. 4: Isovist simulation development

Fig. 5: A collection of 30 isovist simulation

4.3 Simulation Alignment

The results show that about 40.52% of the 30 Isovist rays overlap with the SOM simulation, reflecting the variability in visitor movement patterns. This partial overlap suggests that while SOM captures a general navigational trend, the Isovist simulations reveal the unpredictability and flexibility of actual visitor pathways within the space.

Fig. 6: Parallel Simulation Results: SOM and Isovist

With the help of the 'matplotlib' library, the following graph represents the horizontal spatial distribution of the SOM and ISO features by summing masked pixels along with the vertical axis to generate a 1D profile. The ISO density is notably higher due to the greater number of samples than in the SOM samples. By mapping this distribution simultaneously, a clear column-by-column cross-section is provided showing overlaps between the two distinctive datasets.

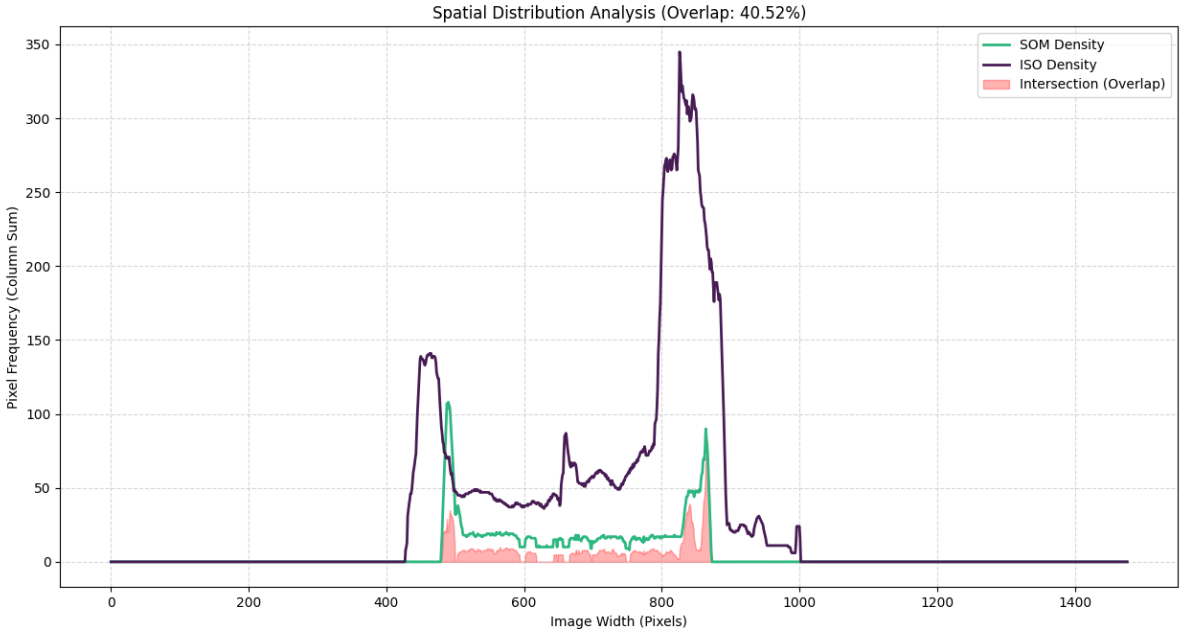

Fig. 7: Spatial Distribution Analysis of Intersection

5.0 DISCUSSIONS

The study shows that while the SOM-generated paths provide a structured, optimised route through the exhibition, the Isovist simulations capture the more unpredictable, free-flowing nature of visitor movement. The alignment between the two is partial, reflecting that simulated visibility-based navigation aligns with the intended exhibition sequence only to a limited extent. This indicates that while SOM can guide the overall flow, real or simulated visitor behaviour—modelled through Isovist—tends to deviate from the model due to the agent's tendency to follow edges, avoid repetition, and respond dynamically to spatial constraints. The

framework's novelty lies in treating optimisation and visibility-driven models as measurable, complementary perspectives rather than isolated methods, enabling designers to test route intuitiveness before construction.

In practice, several limitations influenced the findings. Isovist simulations were stopped when paths began to loop or when agents approached the staircase, reflecting natural exit behaviour. Unlike SOM, Isovist paths are not closed loops and are influenced by randomness, environmental cues, and changes in mathematical values, making direct path-to-path comparisons challenging. Additionally, the SOM paths are biased by the predefined node placement, which controls the trajectory and may not fully represent spontaneous movement patterns. Finally, comparing the two simulations using alignment metrics provides a useful but partial perspective, as it does not capture differences in movement dynamics, attention, or dwell time.

Future work could address these limitations by incorporating additional behavioural parameters into the Isovist simulation, such as varying attention, preferred walking speed, or dwell times at exhibits. Adaptive SOM methods could also be explored to allow dynamic node placement based on visitor behaviour. Furthermore, integrating real-world tracking data could validate the simulations and align the designed routes with actual visitor movement. These extensions would provide a more comprehensive framework for evaluating the interaction between spatial design intent and emergent visitor behaviour.

6.0 CONCLUSION

This research investigated the extent to which simulated visitor movement, modelled through Isovist, aligns with an optimised exhibition sequence generated by SOM within an indoor exhibition context. By applying SOM to define structured paths through key nodes and Isovist to simulate visibility-driven, adaptive navigation, the study provided insights into the interplay between designed spatial intent and emergent movement patterns.

The findings indicate that while SOM produces predictable, node-connected routes that ensure coverage of all key exhibits, Isovist captures the more spontaneous, free-flowing behaviour of visitors. Approximately 40% of the Isovist paths aligned with SOM-generated routes, reflecting partial alignment between planned and emergent navigation. This demonstrates that while designed circulation can guide visitor flow, natural movement is influenced by visibility, spatial configuration, and dynamic environmental cues, which SOM alone cannot fully capture.

The study also highlighted several limitations. Isovist simulations were sensitive to parameters such as movement step size, steering responsiveness, and visibility range, which affect path variability. The SOM paths, constrained by predefined nodes, may introduce biases that do not fully reflect real-world movement. Comparing the two simulations through overlap metrics provides a useful but partial assessment of alignment.

Despite these limitations, the research establishes a computational framework for evaluating indoor exhibition navigation. Isovist simulations offer potential for applications requiring adaptability, such as visibility-driven analysis or emergency evacuation modelling, while SOM can inform route optimisation, exhibit placement, and targeted circulation planning. Future work could integrate real visitor tracking, adaptive node placement, dynamic environmental factors, and richer behavioural parameters to enhance predictive accuracy and applicability.

Overall, the study demonstrates that combining structured optimisation (SOM) with visibility-based simulation (Isovist) provides complementary perspectives for understanding, predicting, and designing visitor movement, offering valuable insights for exhibition layout, spatial planning, and the design of engaging indoor environments.

REFERENCES

Benedikt, M. L. (1979). To Take Hold of Space: Isovists and Isovist Fields. *Environment and Planning B*, 6, 47–65.

Bourdeau, L., & Chebat, J. C. (2001). An empirical study of the effects of the design of the display galleries of an art gallery on the movement of visitors. *Museum Management and Curatorship*, 19, 63–73.

Burstedde, C., Klauck, K., Schadschneider, A., & Zittartz, J. (2001). Simulation of pedestrian dynamics using a two-dimensional cellular automaton. *Physica A: Statistical Mechanics and its Applications*, 295(3–4), 507–525. https://doi.org/10.1016/s0378-4371(01)00141-8

Chun, J., Schieck, A. F., Psarras, S., & Koutsolampros, P. (2019). Agent-based simulation for "Choice of Seats": A study on the human space usage pattern. In *Proc. 12th International Space Syntax Symposium*, Beijing, China.

Cui, Z., Cai, M., Xiao, Y., Zhu, Z., & Chen, G. (2023). Influences of obstacle factors on the transmission trends of respiratory infectious diseases in indoor public places. *Journal of Building Engineering*, 64, 105706. https://doi.org/10.1016/j.jobe.2022.105706

Formolo, D., & van der Wal, C. N. (2017). Simulating collective evacuations with social elements. In *Computational Collective Intelligence* (pp. 160–171). https://doi.org/10.1007/978-3-319-67074-4_16

Gjestland, R. (2020). *How to Design a Cinema Auditorium*. Brussels, Belgium: International Union of Cinemas (UNIC). Available: https://unic-cinemas.org/fileadmin/CinemaAuditoriumDesign_v1.0.pdf

Grajewski, T., & Vaughan, L. (2001). *Space Syntax Observation Manual*. London, UK: UCL Bartlett and Space Syntax Ltd.

Ha, V., & Lykotrafitis, G. (2012). Agent-based modelling of a multi-room multi-floor building emergency evacuation. *Physica A: Statistical Mechanics and its Applications*, 391(8), 2740–2751. https://doi.org/10.1016/j.physa.2011.12.034

Helbing, D., Farkas, I. J., & Vicsek, T. (2000). Simulating dynamical features of escape panic. *Nature*, 407, 487–490. https://doi.org/10.1038/35035023

Jayakanth, K., AbdelGhani, K., Somaya, A., & Abdulla, A. (2020). Indoor positioning and wayfinding systems: A survey. *Human-centric Computing and Information Sciences*, 10(18), 26. https://doi.org/10.1186/s13673-020-00222-0

Kasereka, S., Kasoro, N., Kyamakya, K., Goufo, E. F. D., Chokki, A. P., & Yengo, M. V. (2018). Agent-based modelling and simulation for evacuation of people from a building in case of fire. *Procedia Computer Science*, 130, 10–17. https://doi.org/10.1016/j.procs.2018.04.006

Khotbehsara, E. M., Askarizad, R., Mehrinejad, M., Nasab, S. N., & Somasundaraswaran, K. (2023). The impact of COVID-19 on visitors' wayfinding within healthcare centers. *Ain Shams Engineering Journal*, 14(5), 101957. https://doi.org/10.1016/j.asej.2022.101957

Kohonen, T. (1990). The self-organizing map. *Proceedings of the IEEE*, 78(9), 1464–1480. https://doi.org/10.1109/5.58325

Liu, Y., Chen, L., Xu, Y., & Yang, J. (2024). Exhibition space circulation in museums from the perspective of pedestrian simulation. *Buildings*, 14(3), 847. https://doi.org/10.3390/buildings14030847

Luh, P. B., Wilkie, C., Chang, S.-C., & Marsh, K. L. (2012). Modeling and optimization of building emergency evacuation considering blocking effects on crowd movement. *IEEE Transactions on Automation Science and Engineering*, 9(4), 687–700. https://doi.org/10.1109/tase.2012.2200039

Lyu, K., Globa, A., Brambilla, A., & de Dear, R. (2023). An immersive multisensory virtual reality approach to the study of human-built environment interactions: Technical workflows. https://doi.org/10.2139/ssrn.4439246

Marzouk, M., & Hassan, F. (2022). Modeling evacuation and visitation proximity in museums using agent-based simulation. *Journal of Building Engineering*, 56, 104794. https://doi.org/10.1016/j.jobe.2022.104794

Melton, A. W. (1935). *Problems of Installation in Museums of Art*. Washington, DC: American Association of Museums Monograph New Series No. 14.

Ni, Z., Liu, Z., Liu, T., Chai, Y., & Liu, C. (2020). Simulation model of crowd evacuation navigation in a multi-obstacle environment. *Transportation Research Record: Journal of the Transportation Research Board*, 2675(4), 90–104. https://doi.org/10.1177/0361198120971264

Pasandi, L., Hooshmand, M., & Rahbar, M. (2021). Modified A* algorithm integrated with ant colony optimization for multi-objective route-finding; case study: Yazd. *Applied Soft Computing*, 113, 107877. https://doi.org/10.1016/j.asoc.2021.107877

Said, H., Kandil, A., & Cai, H. (2012). Agent-based simulation of labour emergency evacuation in high-rise building construction sites. In *Proc. Construction Research Congress 2012: Construction Challenges in a Flat World*. https://doi.org/10.1061/9780784412329.111

Serrell, B. (1998). *Paying Attention: Visitors and Museum Exhibitions*. Washington, DC: American Association of Museums.

Song, W., Xu, X., Wang, B.-H., & Ni, S. (2006). Simulation of evacuation processes using a multi-grid model for pedestrian dynamics. *Physica A: Statistical Mechanics and its Applications*, 363(2), 492–500. https://doi.org/10.1016/j.physa.2005.08.036

Tan, L., Hu, M., & Lin, H. (2015). Agent-based simulation of building evacuation: Combining human behavior with predictable spatial accessibility in a fire emergency. *Information Sciences*, 295, 53–66. https://doi.org/10.1016/j.ins.2014.09.029

Turner, A., Doxa, M., O'Sullivan, D., & Penn, A. (2001). From isovists to visibility graphs: A methodology for the analysis of architectural space. *Environment and Planning B*, 28(1), 103–121.

Was, J., & Kułakowski, K. (2010). Agent-based approach in evacuation modeling. In *Proc. Agent and Multi-Agent Systems: Technology and Applications* (pp. 325–330). https://doi.org/10.1007/978-3-642-13480-7_34

Wiener, J. M., Franz, G., Rossmanith, N., Reichelt, A., Mallot, H. A., & Bülthoff, H. H. (2007). Isovist analysis captures properties of space relevant for locomotion and experience. *Perception*, 36(7), 1066–1083. https://doi.org/10.1068/p5587

Yan, J., Zlatanova, S., Lee, J. (B.), & Liu, Q. (2021). Indoor traveling salesman problem (ITSP) path planning. *ISPRS International Journal of Geo-Information*, 10(9), 616. https://doi.org/10.3390/ijgi10090616

Yoshimura, Y., Sintara, R., Krebs, A., & Ratti, C. (2019). Analysis of visitors' mobility patterns through random walk in the Louvre Museum. *Journal of Ambient Intelligence and Humanized Computing*, 15(2), 1643–1658. https://doi.org/10.1007/s12652-019-01428-6