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# MODELLING FACTOR OF BUILT-UP SATURATION IN THE CITY CENTRE OF KUALA LUMPUR AND PENANG

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## Abstract

In Kuala Lumpur and Penang City Centres, different built-up patterns have emerged based on the gazetted permitted development for the past few years. Since independence, Kuala Lumpur and Penang have experienced substantial growth and modernization throughout the years. Both cities have rapid growth despite the fact that the character of the cities has evolved in built-up patterns from bungalow and mansion settlements due to transporting tin from the mining area (Kuala Lumpur City Centre) into the golden triangle of Klang Valley; colonial areas and ancient shops due to resource transportation to the harbour (Georgetown) into UNESCO World Heritage Sites. There is development control, which is regulated to protect the distinctiveness of the city, including limiting its ability to grow and controlling the saturation of land. This demonstrates how these two city centres have largely concentrated buildings in Kuala Lumpur while Penang is maintaining its conservation plan. The research was conducted to observe the changes in development for both cities (1km radius) from 2015 until 2023 by using the method of overlay analysis between image processing and remote sensing data using the Geographic Information System (GIS) and the USGS Earth Explorer. This assessment is crucial in determining the saturated area, the pattern of built-up development, and the factor of development force.

***Keywords**:* Built-up pattern, Landsat Image, City Development, Urban Saturation

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## INTRODUCTION

The national capital and largest city of Malaysia is Kuala Lumpur, sometimes known as KL or the Federal Territory of Kuala Lumpur. Kuala Lumpur is one of Southeast Asia's rapidly growing cities in terms of both population and economic development. (Hua & Ping, 2018). Meanwhile, the city centre of Penang is Georgetown, which is Malaysia's second-largest city. It was the first British outpost in Southeast Asia when it was established in 1786 as an entrepôt (Yang, 2021). The process of creating models using spatial data and a Geographic Information System (GIS) is known as GIS modelling. It is a condensed portrayal of an event or complex system into a clear, straightforward idea of how the real world works. It is a representation of a notion, phenomenon, relationship, structure, system, or feature of the real world that is expressed visually, mathematically, physically, or verbally (Imam, 2019). The pattern of built-up areas has changed as a result of urbanisation's scope and expansion. Conditions related to socioeconomic status and the availability of natural resources may be adversely impacted by land use and cover patterns. (Nuissl & Siedentop, 2021). The most noticeable effect of modern development on the urban system is the irregular built-up pattern of urban growth brought on by the haphazard urbanisation process. Planning and managing urban growth effectively is essential to minimising the negative effects that result from the process of built-up expansion and its driving drivers (Liu, Cao, & Li, 2020). Urban sprawl is the term for the quick and unrestrained expansion of urban or metropolitan areas' boundaries in a way that is detrimental to their economic, social, and environmental well-being. (Amponsah, et al., 2022). The definition of spread, which is similar, is provided as a pattern of urban and regional development characterised by low density, automobile-dependent, exclusive new construction around the periphery of populous areas typically encircling a failing city." (Rubiera-Morollón & Garrido-Yserte, 2020).

## PROBLEM STATEMENT

The most prevalent forms of urban sprawl are based on the highest plot ratio, density, floor space, and linear development. Less than three different land uses may be found in most parts of Kuala Lumpur. This shows that urban sprawl is an issue in Kuala Lumpur, though not to a serious degree. Yet, if the existing issue is not addressed properly, Kuala Lumpur's future development may result in more sprawl. This results in an unbalanced allocation of land for usage (Rosni, Noor, & Abdullah, 2016). Due to mining operations in the 1850s, Kuala Lumpur's urbanisation process began in the City Centre (Bank, 2015). According to the Draft Kuala Lumpur Structure Plan 2040, public transportation utilisation is still low because of the last-mile problem, which implies connectivity is still not seamless, making it difficult to travel from one location to another using public

 

transportation. Poor design and planning are also to blame for any broken connections. This interaction of regulatory, spatial, and behavioural factors can make it difficult for Kuala Lumpur to implement its recently enacted sustainable transport strategy, and it also runs against Malaysia's increasing emphasis on sustainable development (National Transport Policy 2019-2030, 2019).

The areas affected by urban sprawl in Georgetown are described as having lost their rural qualities but still fall outside the urban category. These regions are particularly ambiguous, which presents a number of problems like unchecked urban growth and other uses besides agriculture. Therefore, urban sprawl can be viewed as a border between rural and urban areas. The specific findings of this study indicate that rapid growth in cities, uneven expansion, reasonably priced housing, income and employment opportunities, insufficient facilities, unplanned or poorly executed urban expansion, and poor implementation of development strategies are the main causes of urban sprawl in developing countries. Due to restrictions brought on by growing urbanisation, the procedure for planning is confined to fundamental crisis management because it is unable to forecast the future. In short, government regulation is the primary cause of the emergence of urban sprawl. Errors in planning and policy orientation in development strategies may have a big impact on the issue of urban sprawl as we approach industrialization and sustainable development. (Asli, Rahman, & Salib, 2022).

## RESEARCH QUESTIONS

i. What are the factors of development intensity that affect the saturation of land in Georgetown and Kuala Lumpur City Centre from the year 2015 to 2023?
ii. What is the comparison of the built-up pattern in Georgetown and Kuala Lumpur City Centre from 2015 to 2023?
iii. How can the distribution of saturation development be defined by built-up analysis?

## PURPOSE OF THE STUDY

This study aims to identify the saturation of built-up areas by evaluating the development control methods employed in Georgetown and Kuala Lumpur City Centre. The following describes the objectives of this study:

i. To determine the factor of intensity development built-up pattern by assessing remote sensing, image processing, and tools of development control approach for Georgetown and Kuala Lumpur City Centre.
ii. To comprehend the different built-up patterns that changed between 2015 and 2023.

iii. To examine the distribution of saturation development defined in the built-up analysis.

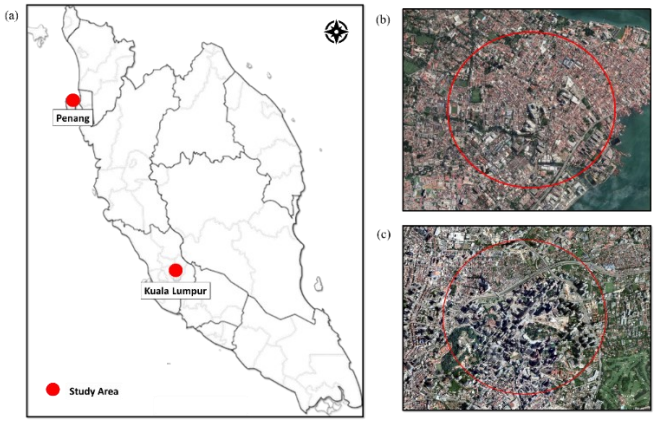


**Figure 1.** Kuala Lumpur and Georgetown Site Area

Two different cities were selected based on the rapid growth of urban areas (Figure 1): - which is Kuala Lumpur City Centre and Georgetown. Map (a) points out the location of cities in Peninsula Malaysia, while map (b) shows the location of Georgetown, and map (c) Kuala Lumpur City Centre. The red circle on maps (b) and (c) shows the radius of 1 km from the centre of the city and demonstrates how most of the land use area in Kuala Lumpur has commercial as the primary activity in contrast to Penang's area, which focuses on residential land uses while having sporadic commercial activities because the majority of the lands serve as protective buffers around UNESCO heritage building areas.

## RESEARCH METHODS

Various observations were made in qualitative research while assessing the designated development control criteria in planning policies as well as the Landsat image using remote sensing techniques. The specified plot ratio and actual floor space are determined through field observation. Site data is utilised for intensity development to establish the overall floor area and built-up size. The total built-up area for each development was then calculated by adding the total land area for both city centres. The Landsat image was produced based on a satellite image by distinguishing between built-up and non-built-up areas using remote sensing technology. The built-up area is used to compute the urban expansion component. A comparison analysis was carried out to estimate the physical growth of both cities by superimposing GIS data and Landsat photos. Secondary data was provided by the local governments of Penang Island City

Council (MBPP) and Kuala Lumpur City Hall (DBKL). Relevant information was gathered to compile statistics on the maximum plinth area, plot ratio, and distribution of land use in 2023, all of which were implemented to control development in the city area by the local government. To calculate the floor area, plinth, the built-up for each building, and the height of the buildings above the surface of the land, observational methods were used within a 1 km radius. The analysis of the data, which was then entered in the GIS, will be used to map each variable over the area of both cities that is currently built-up.

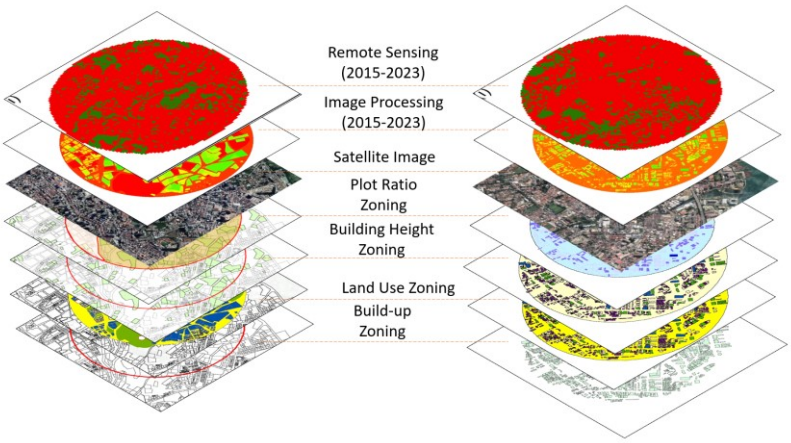


**Figure 2.** Overlay Built-Up Analysis Kuala Lumpur City Centre (left) and Georgetown (right)

Processing the Landsat image is the second technique applied in this investigation. Using the USGS Earth Explorer to obtain data from different Landsat sensor categories, this inquiry uses four main processes of Landsat image processing (Yin, et al., 2022). The Landsat image was first retrieved from the USGS Earth Explorer. The second step in the image's pre-processing includes subsetting the image, extracting the research region from satellite photographs, calibrating radiometric sensors, and restoring the atmospheric image. The next step is picking an area of interest and producing a ground truth image for classification and precision testing using 50 randomly selected photographs from Google Earth. The classification of the image was done using the maximum probability method. In the following step, picture differentiation is used to identify the expanded urban region. To acquire the most precise shape, it was also necessary to use the sharpest and most steady digital image. Clicking the Create Imagery Layer button in ArcGIS is the first step in producing image processing. Next, the type of layer to create is selected, the layer's attributes are set, the necessary data is input, and the layer is uploaded. The data is now ready for

analysis and visualisation after this is finished. Raster analytics and picture analysis are used at the site, regional, national, and international levels to profit from a user-friendly web experience that gives users the freedom to create unique raster functionalities. Image services are created using the imagery and analysis findings. It is simple to update and interface with the rest of ArcGIS thanks to these services. In this study, these procedures are applied to create an extended urban area for KL and Penang City Centre, which spans the years 2015 until 2023.

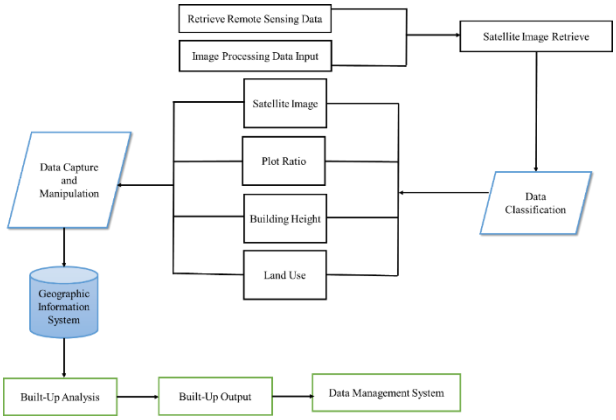


**Figure 3.** Built-up Saturation Model Development

Figure 3 shows the group of methods in general as well as the system development methodology used for this study. Satellite image retrieval is described in the initial development phase for the data classification, which is retrieving remote sensing data and image processing data input. To get the data ready for analysis, each of these levels must be appropriately identified because they overlap. The preparation of the data capture and manipulation, which consists of the following data satellite image, plot ratio, building height and land use is the next process stage to determine the built-up pattern. After combining spatial and non-spatial data, distribution management may be done with the use of GIS application, to produce built-up analysis on which output will be produced.

## BUILT-UP PATTERN ANALYSIS

Residential and commercial land uses appear to be the most significant factors determining built-up and non-built-up patterns after analysing the data employing statistical techniques, conducting the regression model, and calculating the results. This study's emphasis is on residential and commercial regions.

## Overlay Built-Up Analysis

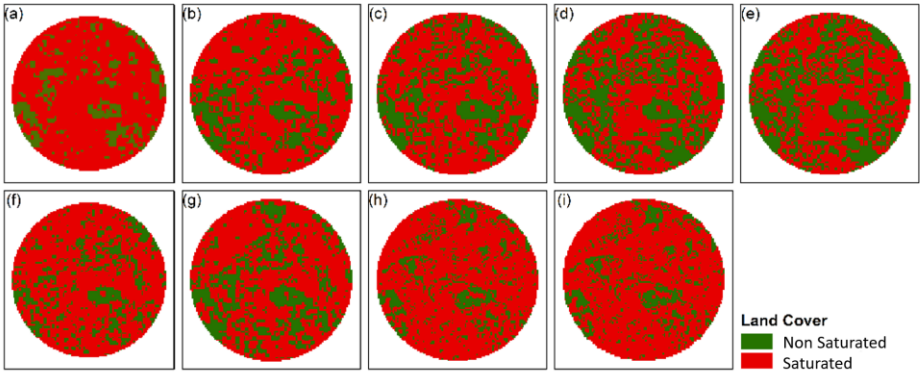


**Figure 4.** Built-Up Pattern of Kuala Lumpur City Centre from Year 2015 until 2023 by Remote Sensing

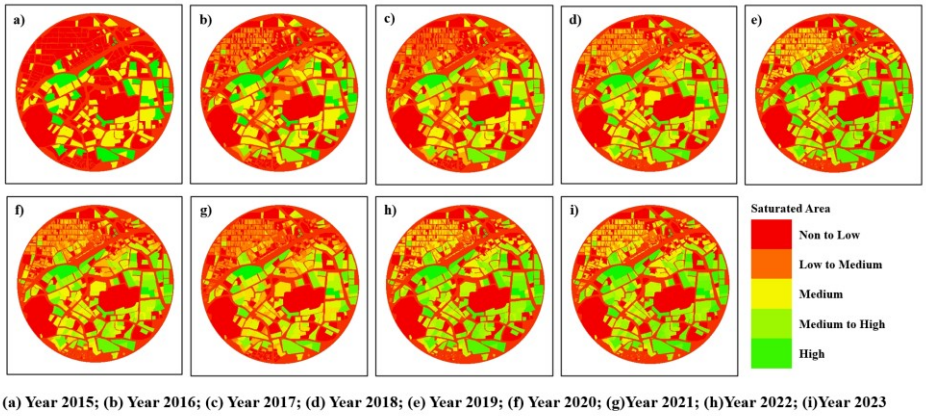


**Figure 5.** Built-Up Pattern of Kuala Lumpur City Centre from Year 2015 until 2023 by Image Processing

**Table 1:** Comparison built-up pattern between remote sensing and image processing of KL City Centre (1 km) from 2015-2023

| Analysis | 2015 (%) | | 2016 (%) | | 2017 (%) | | 2018 (%) | | 2019 (%) | | 2020 (%) | | 2021 (%) | | 2022 (%) | | 2023 (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated |
| **Remote Sensing** | 81.03 | 18.97 | 72.25 | 27.75 | 67.22 | 32.78 | 56.52 | 43.48 | 56.52 | 43.48 | 76.14 | 23.86 | 67.92 | 32.08 | 80.50 | 19.50 | 80.50 | 19.50 |
| **Image Processing** | 63.20 | 36.80 | 76.22 | 23.78 | 65.78 | 34.22 | 78.69 | 21.31 | 80.45 | 19.55 | 77.41 | 22.59 | 74.55 | 25.45 | 80.59 | 19.41 | 81.65 | 18.35 |
| **Different** | 17.83 | -17.83 | -3.97 | 3.97 | 1.44 | -1.44 | -22.17 | 22.17 | -23.93 | 23.93 | -1.27 | 1.27 | -6.63 | 6.63 | -0.09 | 0.09 | -1.15 | 1.15 |
| **Changes** | | | 21.8 | -21.8 | -5.41 | 5.41 | -20.73 | 20.73 | 1.76 | -1.76 | -22.68 | 22.68 | 5.36 | -5.36 | -6.54 | 6.54 | -1.06 | 1.06 |

Figure 4 illustrates the use of Landsat image data for remote sensing both saturated and non-saturated areas, while Figure 5 shows the image processing of available built-up patterns using the Geographic Information System (GIS) for the past seven years, which is from 2015 until 2023 in Kuala Lumpur City Centre. Their built-up pattern improved throughout the year, especially in the commercial and residential land uses of their location near the Kuala Lumpur Twin Towers and Kampung Baru. This is due to conversion being updated by the local authorities. Between 2015 and 2016, there were significant changes in saturated areas (21.8%) and non-saturated areas (-21.8%) especially in commercial (31.48%) and residential (20.69%) land uses. This is because in the Jalan Tun Razak area are several condominiums, such as Expressionz Professional Suites, Three28 (643-1,625 sq ft), and KL Trillion, which is a commercial building (1,076-22,562 sq ft). The year of completion of these condominiums was 2018 while KL Trillion was completed in 2015. The changes of the year 2016-2017 in saturated areas were -5.41%, whereas non-saturated areas were 5.41%, especially in open space (0.18%) land uses. Between 2017 and 2018, the changes in saturated area were -20.73% and non-saturated area were 20.73%, which affected more open spaces (0.23%) land uses that led more towards the development of pocket parks. Between 2019 and 2020, the pandemic of COVID-19 happened, and many owners decided to close their businesses, and the buildings became abandoned, especially around commercial (43.01%) land uses in the city centre. Therefore, the buildup pattern fluctuated in the saturated area at -22.68% and non-saturated area at 22.68%, and it rose again from the year 2021-2022 onwards in the saturated area at -6.54% and the non-saturated area at 6.54% since there was new development construction, especially in the residential (33.65%) land uses, which are Sunway Belfield Residence (788-1,337 sq ft), which is 4.4 km, and The Atrium (556-1,227 sq ft), which is 5 km from KLCC. Between 2020 and 2021, the changes in saturated area were 5.36%, and non-saturated area were -5.36% in commercial (35.36%) land uses. In 2022-2023, the changes in saturated area were -1.06%, and non-saturated area were 1.06% in

open space (0.19%) land uses, which shows the least development changes throughout the seven years.

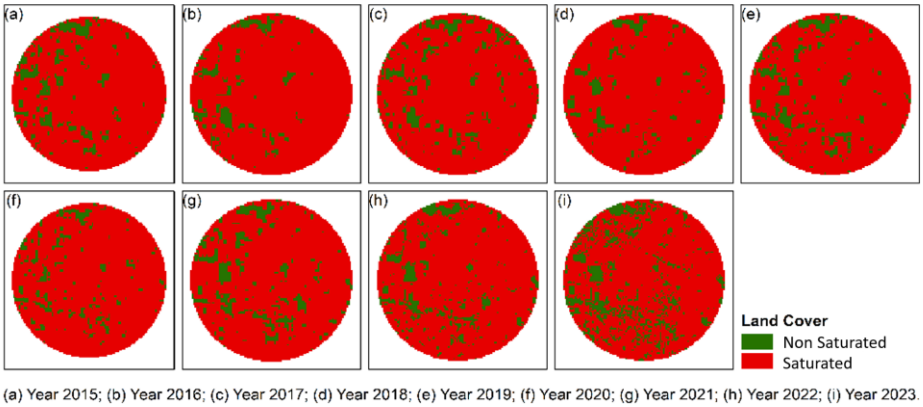


**Figure 6.** Built-Up Pattern of Georgetown from Year 2015 until 2023 by Remote Sensing

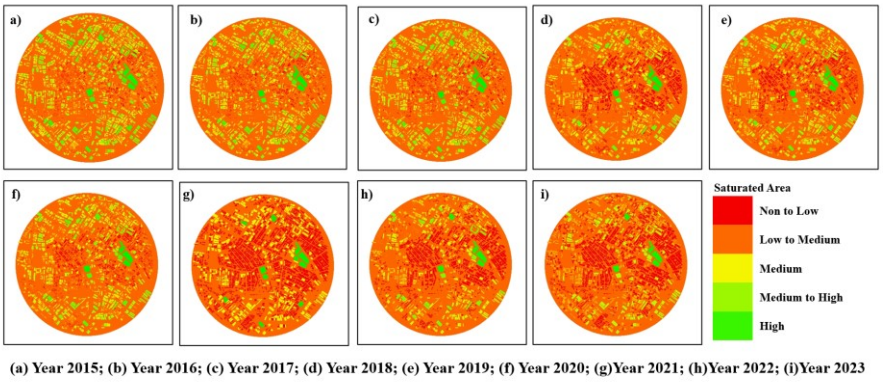


**Figure 7.** Built-Up Pattern of Georgetown from Year 2015 until 2023 by Image Processing

**Table 2:** Comparison built-up pattern between remote sensing and image processing of Georgetown (1 km) from 2015-2023

| Analysis | 2015 (%) | | 2016 (%) | | 2017 (%) | | 2018 (%) | | 2019 (%) | | 2020 (%) | | 2021 (%) | | 2022 (%) | | 2023 (%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated | Saturated | Non Saturated |
| **Remote Sensing** | 81.03 | 18.97 | 72.25 | 27.75 | 67.22 | 32.78 | 56.52 | 43.48 | 56.52 | 43.48 | 76.14 | 23.86 | 67.92 | 32.08 | 80.50 | 19.50 | 80.50 | 19.50 |
| **Image Processing** | 75.89 | 24.11 | 63.54 | 36.46 | 63.54 | 36.46 | 73.65 | 26.35 | 72.11 | 27.89 | 71.03 | 28.97 | 65.36 | 34.64 | 68.44 | 31.56 | 68.56 | 31.44 |
| **Different** | 5.14 | -5.14 | 8.71 | -8.71 | 3.68 | -3.68 | -17.13 | 17.13 | -15.49 | 15.49 | 5.37 | -5.37 | 14.56 | -14.56 | 12.06 | -12.06 | 11.94 | -11.94 |
| **Changes** | | | -3.57 | 3.57 | 5.03 | -5.03 | 20.81 | -20.81 | -1.64 | 1.64 | -20.86 | 20.86 | -9.19 | 9.19 | 2.50 | -2.50 | 0.12 | -0.12 |

Figure 6 illustrates the use of Landsat image data for remote sensing both non-saturated and saturated areas while Figure 7 shows the image processing of available built-up patterns using the Geographic Information System (GIS) for the past seven years which is from 2015 until 2023 in Penang City Centre. Their built-up pattern did not improve much compared to KL City Centre, especially in the Kompleks Tun Abdul Razak (KOMTAR) area since the city centre is protected by UNESCO. This is because the height of each building is restricted. In 2015-2016, the changes in saturated areas were -3.57%, and the non-saturated areas were 3.57%, which affected open space (0.26%) land uses. In 2016-2017, the changes in saturated area were 5.03%, and non-saturated area were -5.03%, which affected residential (13.78%) land uses. In 2017-2018, there were significant changes in saturated area, which was 20.81%, and non-saturated area was -20.81%. This is because new developments have occurred in commercial (36.36%) and residential (19.54%) land uses around Jalan Ceah Choo Yoo, Showtow Land, Jalan Sultan Ahmad Shah, Lintang Macallum and Gurney Drive, which forced development into the city centre. The total build-up area of these developments is 15,721 sq ft, and the year of completion is around 2020-2026. In 2018-2019, the changes in saturated area were -1.67% and non-saturated area were 1.67%, which affected open space (0.23%) land uses. In 2019-2020, there were also significant changes in saturated areas, which are -20.86% and non-saturated areas, which are 20.86%, especially in commercial (34.42%) and open space (0.25%) land uses. This is because several historical buildings have been demolished because they cannot be maintained and a new Light Rail Transit Project will be completed in 2030. One of the locations that has been demolished has been turned into an archaeological park that will be one of the LRT stations, which is Sia Boey Urban Archaeological Park which was completed in 2019. In 2020-2021, the changes in saturated area were -9.19% and non-saturated area were 9.19%, which affected open space (0.26%) land uses. In 2021-2022, the changes in saturated area were 2.50%, and non saturated area were -2.50%, which affected commercial (33.23%) land uses. In 2022-2023, the changes in saturated area were 0.12% and non-saturated area were -0.12% which affected residential (12.88%) land uses.

**Built-up & Saturation Findings**

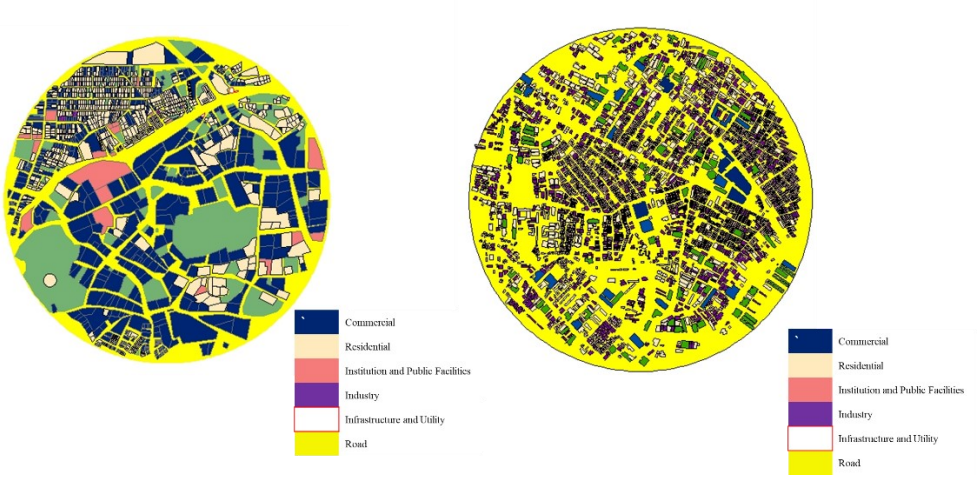


**Figure 8.** Result from land use observation for Kuala Lumpur City Centre (left) and Georgetown (right) in 2023

**Table 3** Comparison tools of development control between KL and Georgetown (1 km) by 2023

| Urban Centre | Ikm Radius of Land Use | | | Average Plinth Area | Average Building Floor | Total Built-Up Area (Sqm) | Average Plot Ratio | Gross Floor Area | Non-Built-Up Area (Sqm) |
|---|---|---|---|---|---|---|---|---|---|
| | Area (Acre) | Lowest Build-Up | Highest Built-Up | | | | | | |
| KL City Centre | 247.1 | Industry (0.25%) | Commercial (38.5%) | 40% | 18 | 151,564 | 1:8 | 17,778,760 | 854,522 |
| Penang City Centre | 247.0 | Industry (0.068%) | Residential (12.88%) | 60% | 14 | 235,510 | 1:5 | 11,755,060 | 766,185 |
| *Comparison* | | 0.189% | 25.62% | 20% | 4 | 83,946 | 0:2 | 6,023,700 | 88,337 |

Table 3 shows the comparison tools of development control within a 1km radius for the two cities and demonstrates that due to the fact that the majority of the areas are buffer zones for UNESCO heritage building areas, in contrast to Penang's area, Kuala Lumpur's area regulates built-up areas, with commercial being the primary development activity, whose emphasis is on residential land uses while having sporadic commercial activities. In Georgetown, residential zoning is the major land use, which is found at Kampung Makam and Sungai Pinang, while in Kuala Lumpur City Centre, commercial is the highest built-up area, which is located around the Kuala Lumpur Twin Tower

area. The lowest land use built-up area in both cities is industrial, which is near Chulia Street (Penang City Centre) and Kampung Baru (Kuala Lumpur City Centre). Therefore, the comparison of the lowest build-up area is 0.189%, and the highest build-up area is 32.32%. Both regions demonstrate how the plinth area influences the built-up area's size, per the GIS study. By utilising 60% of the average allowable plinth size, Penang has 22.6% of the actual building space, compared to Kuala Lumpur, where the average plinth area is 40% and only 17.5% of the built-up space can be used for structures or buildings. In both cities, the non-built-up area contains a sizable portion of open space and transportation, which are classified as non-structure buildings, at 82.5% and 77.5% for the KL and Penang City Centres, respectively. Development limitations implemented have led to a concentration of buildings in Penang City Centre and growth from the southern to the northern part of the peninsula, especially in coastal regions with historic buildings, which have limited development. Due to the higher densities that the local authorities have permitted in this area, urban areas have now reached Kuala Lumpur City Centre's eastern region.

## CONCLUSION

The advantage of this study is that it focused on using spatial data to develop visualisation results through creating multiple types of maps and analysing the outcomes. The built-up area between the two city centres shows different patterns over the past seven years. Kuala Lumpur City Centre shows rapid changes over the years, while Penang City Centre only shows slight but significant changes over the years, especially in commercial, residential, and open space land uses. There were new developments that occurred in saturated areas, mainly commercial and residential land uses, while abolishment buildings happened to build up pocket parks in non-saturated areas, which are open space land uses.

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