# SPATIAL AUTOCORRELATION PREDICTION MODEL OF HOUSING MARKET IN SPRAWL AREA

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This thesis is dedicated to my parents,

MOHD SAIRI BIN JAMIL and NOR'AINI BINTI ABDUL MUTHALIB

For their endless love, prayers, support and encouragement

Thank you for believing in your daughter

To my siblings,

Thank you for being all ears to my problems, no matter how silly they were

To my close friends,

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## ABSTRACT

Urban sprawl is one of the most widely discussed urban issues as it leads to poorly planned patterns of development that result in negative consequences. In fact, research and modelling studies of urban sprawl are considered critical towards ensuring a sustainable urban growth. Therefore, this study aims to develop an urban sprawl model specifically for Johor Bahru by achieving four objectives: to investigate the clustering of housing location based on spatial proximity, to generate the urban sprawl characteristics based on the clustering characteristics of housing, to predict the future urban sprawl pattern based on spatial autocorrelation index and to develop urban sprawl models based on the spatial autocorrelation index. The land use and housing transaction data was acquired from the Department of Town and Country Planning Johor as well as Valuation and Property Services Department respectively. However, the use of spatial data prompted concerns about the possibility of spatial autocorrelation. Thus, to address the urban sprawl issue and methodological issues, this study conducted a series of analyses which included spatial autocorrelation analysis, principal component analysis, cluster analysis, kriging interpolation analysis and multiple regression analysis in developing the urban sprawl model. Through these analyses, it was discovered that the urban sprawl model in Johor Bahru is characterized by similar housing quality characteristics and dissimilar main infrastructure characteristics. Specifically, the housing developments in the city centre of Johor Bahru have similar housing quality characteristics. As the housing developments sprawled towards Kulai and Pasir Gudang respectively, it also demonstrated similar housing quality characteristics. Nevertheless, when the housing developments sprawled towards Iskandar Puteri, it is characterized by the dissimilar characteristics of main infrastructure. This urban sprawl model aids in describing the current and future urban sprawl phenomena in Johor Bahru. This research has contributed to the existing body of knowledge by generating a novel spatial autocorrelation index which consists of urban sprawl characteristics in Johor Bahru. The findings of this study will aid urban planners, developers and home buyers in gaining a deeper understanding of the characteristics of urban sprawl in Johor Bahru from the aspect of housing market.

## ABSTRAK

Rebakan bandar merupakan antara isu bandar yang paling banyak dibincangkan kerana ia membawa kepada corak pembangunan yang tidak dirancang serta mengakibatkan kesan negatif. Malah, kajian dan pemodelan rebakan bandar dianggap penting ke arah memastikan kelestarian pertumbuhan bandar. Maka, kajian ini bertujuan untuk membangunkan model rebakan bandar khususnya di kawasan Johor Bahru dengan mencapai empat objektif: untuk menyiasat pengelompokan lokasi perumahan berdasarkan kedekatan ruang, untuk menjana ciri-ciri rebakan bandar berdasarkan ciri-ciri kelompok perumahan, untuk meramal corak rebakan bandar berdasarkan indeks autokorelasi spatial dan untuk membangunkan model rebakan bandar berdasarkan indeks autokorelasi spatial. Data gunatanah dan data transaksi perumahan telah diperoleh daripada Jabatan Perancangan Bandar dan Desa Johor dan Jabatan Penilaian dan Perkhidmatan Harta. Namun, penggunaan data spatial telah menimbulkan kebimbangan tentang kemungkinan autokorelasi spatial. Maka, bagi menangani isu rebakan bandar serta isu metodologi, kajian ini telah menjalankan satu siri analisis bermula dengan analisis autokorelasi spatial, diikuti dengan analisis komponen utama, analisis kluster, analisis interpolasi kriging dan analisis regresi berganda untuk membangunkan model rebakan bandar. Melalui analisis ini, didapati model rebakan bandar di Johor Bahru dicirikan oleh ciri kualiti perumahan yang serupa dan ciri infrastruktur utama yang tidak serupa. Khususnya, pembangunan perumahan di kawasan pusat bandar Johor Bahru mempunyai ciri kualiti perumahan yang serupa. Rebakan pembangunan perumahan yang menghala ke kawasan Kulai dan Pasir Gudang juga menunjukkan ciri kualiti perumahan yang serupa. Namun begitu, apabila pembangunan perumahan merebak ke arah kawasan Iskandar Puteri, ia dicirikan oleh ciri-ciri infrastruktur utama yang tidak serupa. Model rebakan bandar ini membantu dalam menggambarkan fenomena rebakan bandar semasa dan akan datang di Johor Bahru. Penyelidikan ini telah menyumbang kepada badan pengetahuan sedia ada dengan menjana indeks autokorelasi spatial novel yang terdiri daripada ciri-ciri rebakan bandar khususnya di kawasan Johor Bahru. Hasil kajian ini akan membantu perancang bandar, pemaju dan pembeli rumah memahami dengan mendalam ciri-ciri rebakan bandar di Johor Bahru dari aspek pasaran perumahan.

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## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| CA | - | Cluster Analysis |
| GIS | - | Geographic Information System |
| HH | - | High-High |
| IRDA | - | Iskandar Regional Development Authority |
| JBCC | - | Johor Bahru City Centre |
| LISA | - | Local Indicator of Spatial Association |
| LL | - | Low-Low |
| LMiIndex | - | Local Moran's I Index |
| NAPIC | - | National Property Information Centre |
| PCA | - | Principal Component Analysis |
| QGIS | - | Quantum Geographic Information System |
| SAC | - | Spatial Autocorrelation |
| SPSS | - | Statistical Package for the Social Sciences |
| TFL | - | Tobler's First Law |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

Urbanisation will continue to occur throughout the world. Leeson (2018) reported that in 2014, North America had the highest percentage of its population living in urban areas (82%), followed by Latin America and the Caribbean (80%) and Europe (73%). In contrast, Africa and Asia were still primarily rural, with only 40% and 48% of their populations living in urban areas, respectively.The most rural parts of Africa and Asia will continue to urbanize more quickly than other parts of the world, with their urban populations reaching 56% and 64% of their total populations, respectively, by 2050 (Leeson, 2018).

According to Tze (2013) and Kok (2015), Malaysia is a developing country that is currently undergoing continuous development with numerous infrastructures which are constructed to suit urbanisation needs. In fact, Malaysia has grown rapidly since gaining independence in 1957 (Yasin et al., 2021). However, rapid urbanisation has resulted in an unfavourable phenomenon known as urban sprawl, which primarily affects suburban areas (Johnson, 2001). The emerging cities of the center and west of the United States were the first to experience urban sprawl, which quickly spread to Latin American and Asian cities before becoming a global problem (Morollon et al., 2015). According to Abdullah (2012)

and Jatmi (2022), the tendency of continuous urban sprawl is unlikely to slow down in the foreseeable future, especially for cities in Malaysia.

Additionally, urban sprawl is one of the most widely studied and contentious urban phenomena (Morollon et al., 2015). Urban sprawl has always piqued the interest of urban planners, geographers, urban economists and sociologists (Rubiera-Morollon, & Garrido-Yserte, 2020). As a matter of fact, urban sprawl research and modelling studies are critical in ensuring sustainable urban growth (Tewolde & Cabral, 2011). According to Johny and Mathews (2016), it is necessary to present urban sprawl in a spatial context in order to understand urban sprawl as a phenomenon.

In the context of urban analysis, urban sprawl is considered as one of the most relevant issues (Morollon et al., 2015). The sprawl phenomenon arose during the 1950s and 1960s in the development of North American cities where it was associated with the generalised use of automobile and the rapid growth of some cities. However, Latin-American and Asian cities are also undergoing the same processes of sprawl, since most old European cities were strongly concentrated around a tightly packed historical center and its commercial and business extensions, they typically followed a monocentric growth model with a strong center and hierarchical structure of sub-centres, which was different from the new cities of America or Asia (Morollon et al., 2015). As scholars are now viewing the concept of urban sprawl in a broader perspective, Zeng et al. (2015) highlighted the modeling of urban sprawl as an important research activity in recent years.

Abdullah (2003) identified three factors that would trigger suburbanisation, which are supply, demand and accessibility. The rise in human population and income has led to an increase in housing demand and land development. Moreover, developers of residential real estate have frequently been blamed for sprawl (Persky & Wiewel, 2012). In contrast to urban realities where population density is high and buildings accommodate multiple residences together, sprawl is connected with low density settlements that are made up of individual residences (Tombolini et al., 2015). A more precise source of housing demand stems from shifting housing preferences for low-density single-family houses in dispersed locations (Owusu-Ansah & O'Connor, 2010).

Housing preferences as well as several economic factors such as the housing market have been identified as important drivers of urban sprawl in recent years

(Christiansen & Loftsgarden, 2011; Grigorescu et al., 2012). The theories of urban development in social sciences claimed that the spatial development of cities is the result of individual or collective appropriation of space (Dieleman & Wegener, 2004). Even though urban sprawl has an impact on various activities such as industry and transportation, it is particularly important in the housing sector because it involves individuals and families who change their living patterns and habits as well as those whose activities have a major impact on the area they move to (Garcia-Coll, 2011).

According to Dhaoui (2014), the phenomenon of urban sprawl is triggered by spatial proximity to resources and basic amenities. Besides, proximity is a critical basic foundation in spatial modeling (Osland, 2010). Moreover, the spatial autocorrelation concept aids in pattern analysis based on the similarity of values and their spatial proximity (Bandyopadhyay, Singh & Singh, 2012). In the context of this research, the proximity concept is used to motivate the use of a spatial autocorrelation analysis to model the urban sprawl phenomenon. Furthermore, housing preferences have been identified as important drivers of sprawl, thus garnering considerable attention from previous scholars.

The spatial and temporal dynamics of urban growth are critical considerations in modelling urban growth (Nole et al., 2014). According to Jat, Garg and Khare (2008), municipal authorities need to understand the urban sprawl phenomena and how it is expected to evolve in the years ahead in order to effectively plan future urban development and infrastructure. According to Gomes et al. (2018), analysing and comprehending the evolution of urban growth is a core principle of spatial planning. Thus, the development of urban sprawl model in Johor Bahru involves the prediction of future urban sprawl pattern that includes the temporal aspect.

According to Zhang et al. (2013), Geographic Information System (GIS) is capable of capturing, storing, analysing, managing and presenting data related to location. Aside from that, this software aids in the advancement of social science studies because almost all phenomena studied in social science occur in geographical space (Zhang et al., 2013). The combination of spatial analysis and GIS technology offers the greatest environment for real estate analysis because spatial analysis provides the necessary methods and GIS serves as a research platform for managing spatial data and implementing spatial methods (Can, 1998).

GIS is widely used for handling spatial data in urban developmental projects, decision making and policies (Pedro et al., 2019). Furthermore, using GIS technology, spatial statistics parameters and indices can be calculated from land use maps, which characterise landscape properties, spatial distribution, land use change, pattern and the extent of urban sprawl (Weijers, 2012). Shamsuddin and Yaakup (2007) proposed to explore and understand the spatial and temporal dimensions that contribute to land use changes and patterns that shape the urban landscape in order to reduce the negative effects of sprawling development through spatial modelling techniques that are combined with the use of GIS technology. Given the advancement of GIS technology in urban sprawl and spatial research, this study will combine both spatial analyses using GIS and statistical analysis to develop the urban sprawl model for Johor Bahru.

In conclusion, urban sprawl is a complex phenomenon and its explanation entails the use of multidisciplinary approaches, which should include geographical, cultural, sociological, economic, technological and political factors (Morollon et al., 2015). Additionally, it is necessary to study and quantify urban sprawl at local and regional scales in order to ensure that proper measures are taken to guarantee sustainability in urban planning (Ahmad & Goparaju, 2016). Furthermore, the remarkable advancement in GIS technology has enabled a much more detailed and concise analysis of urban sprawl modeling.

Hence, the purpose of this research is to model the phenomenon of urban sprawl in Johor Bahru by generating the urban sprawl characteristics and mapping the future urban sprawl pattern. The findings are expected to provide insights into the urban sprawl phenomenon in Johor Bahru, thereby assisting in better urban planning. This dissertation contains chapters that provide additional and detailed explanations of the theories, literatures, methodologies, analyses, results and discussions that are involved while conducting the research on urban sprawl.

## 1.2 Problem Statement

The physical expansion of dispersed urban areas, which is also known as urban sprawl, is a recent and concerning phenomenon (Alonso et al., 2017). Urban sprawl is one of the

most commonly discussed urban issues (Gandhi, Sharma & Vyas, 2016) and has been identified as a cause and a result of urban problems (Sinha & Griffith, 2019). Urban sprawl has become a major issue due to rapid changes related to the uncontrolled residential sprawl which prompt to negative social and environmental consequences (Grigorescu et al., 2012). Moreover, urban sprawl sparks a significant growth pattern in terms of land use and pushing a further outwards growth (Morollon et al., 2015).

Despite the fact that urban growth is seen as an important element for a sustainable economy, unregulated or sprawling urban growth can result in a variety of issues (Nole et al., 2014). The general issue is that urban sprawl patterns are poorly planned patterns of development (Brian, 2016) that result in negative consequences such as increased congestion and air pollution from increased vehicle travel, reduced ecosystem services from deforestation and loss of local farmland (Magliocca et al., 2015). Urban sprawl is considered as an unsustainable form of urban development (Sinha, 2018; Alonso et al., 2017).

According to Wen and Chu (2018), the planning and construction of new urban areas not only open up new space for urban economy, but also shape a new pattern of urban space. However, the trend of urban development generates a concerning problem as it can lead to settlement patterns which are environmentally inefficient and give negative impacts to the surrounding such as air pollution, heat waves and flash flood (Rimba et al., 2017; Rosni et al., 2016; Pauleit, Ennos & Golding, 2005). Since urban sprawl is a specific urban built environment that is related to the requirements of sustainable development goals, progress towards sustainability necessitates a better understanding of urban sprawl (Mehriar, Masoumi & Mohino, 2020). Thus, issues raised by the urban sprawl phenomenon have piqued interest of researchers in assessing the pattern and characteristics of urban sprawl in the research area through the housing perspective.

Specifically, this study involves the use of housing location data. However, spatial data has a high degree of self-correlation (Shekhar et al., 2011) which ignites the issue known as spatial autocorrelation or spatial association (Mazzulla & Forciniti, 2012). In fact, when working with spatial data, Zhang et al. (2010) stressed that spatial association is deeply ingrained in geographic data and analyses based on regular statistics are very

likely to be inaccurate. The problem of spatial association refers to situations in which observations are spatially dependent, causing nearby spatial units to be associated in some way (Fischer, 2001). When spatial dependence emerges, different values of a spatially-located variable associated to a phenomenon are not independent of one another, suggesting that two close values are more likely to resemble each other than two distant values (Souris & Demoraes, 2019).

In urban studies, this spatial autocorrelation issue frequently means that data from nearby locations are usually more similar than those from distant areas (Mazzulla & Forciniti, 2012). Additionally, Curto and Rolando (2018) had also highlighted the issue of spatial autocorrelation in real estate data. Therefore, since this study of urban sprawl includes the usage of real estate data, it is important to highlight the issue of spatial autocorrelation in this study through identifying the existence of spatial dependence or clusters within the housing location data.

Clusters form in a geographic distribution when features are found in close proximity to one another or when groups of features with similarly high or low values are discovered together (Aghajani et al., 2017). Moreover, spatial proximity to resources and basic facilities has been recognized as a contributing factor to sprawl (Dhaoui, 2014; Caruso et al., 2017). The spatial autocorrelation perspective emphasises the clustering of similar or dissimilar phenomena in geographic space rather than random mixtures of phenomena to form map patterns (Griffith, 2018).

Urban sprawl is also described as the rapid expansion of residential development in a relatively undeveloped environment (Bagheri and Tousi, 2017). Since a sprawling pattern usually shows a highly irregular form, Ma et al. (2008) emphasised that it is necessary to find some suitable approaches to describe the pattern while suggesting the spatial autocorrelation approach. Moreover, spatial patterns emerge as a result of spatial processes where they can be visualised through maps (Klippel et al., 2011). According to Aithal (2017), since sprawl occurs in space, geography and time, it is vital to comprehend sprawl across time in order to plan and implement policy. Hence, it is necessary to develop a prediction model of spatial autocorrelation index on housing distribution in urban sprawl areas.

Based on past studies, urban sprawl is characterised by either the element of population, types of development, effect of sprawl, unplanned and uneven growth, urban density and urban form (Aithal, 2017; Sinha, 2018; Weijers, 2012; Galster et al., 2001; Gandhi et al., 2016). Nonetheless, no previous study was found to characterise urban sprawl through housing characteristics. Moreover, many past studies such as Salvati and Carlucci (2014), Nole et al. (2014), Musakwa and Niekerk (2014) and Qian and Wu (2019) utilized spatial autocorrelation analysis to predict the urban sprawl pattern. However, no previous study was found to have developed a spatial autocorrelation index model nor predict the future urban sprawl pattern based on the spatial autocorrelation index through the housing characteristics.

Based on the foregoing, this study aims to fill the identified research gap by developing a spatial autocorrelation model of housing distribution in the Johor Bahru sprawl areas through utilising the spatial autocorrelation index. The developed spatial autocorrelation index in this study characterised urban sprawl through the housing characteristics.

Additionally, this study attempts to address the urban sprawl issue and the following methodological issues encountered while conducting the analyses in order to develop an urban sprawl model in Johor Bahru.

i. This study begins by highlighting the issue of urban sprawl. However, further literature review has suggested the existence of spatial dependence or clusters in spatial data. Moreover, the essence of spatial proximity detected from both the urban sprawl phenomenon and spatial autocorrelation analysis leads to the use of spatial autocorrelation approach in identifying housing location clustering based on spatial proximity.

ii. The local spatial autocorrelation analysis of the housing data resulted in a LISA cluster map with two distinct clustering characteristics. However, the particular housing characteristics that induce the clustering are unclear, thus necessitating further research into those characteristics. The spatial autocorrelation or clusters in housing data have been confirmed; thus, correlated housing characteristics can be reduced to a few factors while retaining as much information as possible. The

grouping of these factors contributes to the identification of the characteristics of clusters (urban sprawl characteristics).

iii. A spatial autocorrelation index, which is in line with urban sprawl characteristics, provides insight into the current spatial structure in Johor Bahru. Furthermore, the prediction of urban sprawl characteristics can yield the future urban sprawl pattern. This analysis tends to address the urban sprawl issues through mapping the future urban sprawl pattern in the study area. Moreover, the spatial autocorrelation issue was considered through the kriging analysis which was conducted to predict the future urban sprawl pattern.

iv. The use of a spatial autocorrelation index to forecast future urban sprawl patterns attracted not only particular attention about the relationship between the index and housing attributes, but also the goodness of fit for the urban sprawl model.

According to Tong et al. (2017), the identified urban development and sprawl patterns have the potential to motivate the government to implement integrative urban planning strategies. In fact, understanding the patterns of urban sprawl can help city planners to plan for better future developments such as infrastructure facilities (Sudhira et al., 2004). Furthermore, understanding dispersed patterns of urban development is critical for mitigating the environmental and other negative effects of urban sprawl (Magliocca, McConnell & Walls, 2015). Additionally, the detection of expansion patterns aids in characterising urban sprawl (Weijers, 2012). In order to incorporate necessary measures to control urban sprawl, it is necessary to understand the current dynamics and future potential of sprawl in a certain area (Johny & Mathews, 2016).

As a result, addressing the urban sprawl issues in Johor Bahru contributes to a better knowledge of this phenomenon, thus leading to a more effective urban planning. Furthermore, addressing the methodological issues that have arisen contributes to the value of this study.

## 1.3 Research Questions

With reference to the problem statement, this study aims to address the following research questions:

1. Does the housing location cluster based on spatial proximity?
2. What are the urban sprawl characteristics based on the clustering characteristics of housing?
3. What is the future urban sprawl pattern based on spatial autocorrelation index?
4. What are the urban sprawl models based on the spatial autocorrelation index?

## 1.4 Research Objectives

This study aims to develop an urban sprawl model specifically for the area of Johor Bahru. Hence, based on the research questions stated above, the objectives of this study are as follows:

1. To investigate the clustering of housing location based on spatial proximity.
2. To generate the urban sprawl characteristics based on the clustering characteristics of housing.
3. To predict the future urban sprawl pattern based on spatial autocorrelation index.
4. To develop urban sprawl models based on the spatial autocorrelation index.

## 1.5 Scope of Study

Regardless of the fact that urban growth is an important component of a sustainable economy, a sprawling urban growth can become one of the primary concerns to sustainable development in a city. In light of this problem, the present study aims to develop an urban sprawl model in Johor Bahru in order to better understand the characteristics of urban sprawl as well as to provide a better knowledge of the phenomenon for future planning.

According to Wang et al. (2015), urbanisation and economic growth are two of the most important factors that drives up housing demand. In fact, the rapid growth of urban population has resulted in a significant demand for housing (Tze, 2013). Nechyba and Walsh (2004) highlighted that urban sprawl has created opportunities for most households to demand more housing and land. Furthermore, Brody (2013) remarked that the consumption of residential housing development has taken a substantial part of vacant

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