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GEOSPATIAL ANALYSIS OF SUSTAINABLE LIVING RESIDENTIAL SITE SUITABILITY USING ANALYTICAL HIERARCHY PROCESS

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Abstract

The demand for sustainable housing is rising because of the rapid increase in Malaysia's population. Housing areas with sufficient amenities, services, and accessibility contribute to people's having a higher quality of life since those amenities might satisfy their desire for a particular location. This study intends to identify significant parameters, weightage, and sustainable residential areas based on selected parameters. The Analytical Hierarchy Process (AHP) and the Geographical Information System (GIS) platform were used to assess the appropriate parameters and locations with adequate facility supply. To determine the suitability of residential areas in Ipoh, Perak, the weighted overlay approach was performed using the computed value and scale of the parameters. A site suitability map is created using three separate levels with low, medium, and high suitability areas. The most important parameters were found to be health and social care, while industrial areas, social amenities, and recreational places were found to be less important. With this outcome, purchasers could discover the most important regions that fulfil their demands by making the decision to invest in the right residential property.

***Keywords**:* Geospatial Analysis, Residential Site Suitability, AHP

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INTRODUCTION

The United Nations Sustainable Development Goals (SDGs) 11 defines sustainable residential as a high-quality housing development (cities and communities) with better dependability and impacts on nature and the environment (Chen, 2014). Sustainability provides a variety of approaches for balancing human needs and the protection of the environment to preserve future generations' rights and requirements for sustainable development (Mohamadzadeh et al., 2020). To ensure sustainable living and create safe cities, social and physical infrastructure, including accessibility, sewer efficiency, and green public areas potentially affect people's abilities and should be seriously considered in residential planning regulations (Abrabba et al., 2022). However, the process requires balancing among several criteria; thus, the analytical hierarchy process (AHP) with the GIS platform, a multi-criteria decision analysis (MCDA) technique is widely used to generate coefficients that provide the basis for real building valuation (Bunyan Unel & Yalpir, 2019). The AHP utilizes pairwise comparisons by analysing the opinions of experts about all the criteria that may affect the property's value. The outcome of the pairwise comparison is the weight assigned to each variable for the determination of the property's true value.

The hedonic pricing model and ordinary least squares (OLS) are also additional approaches to assist with better decision-making about house pricing (Aladwan & Ahamad, 2019; Maryam et al., 2022). To build a sustainable residential area, it is always essential to identify the adequacy of the parameters to be considered in the AHP process (Masri et al., 2016). This study will assist homebuyers in selecting residential real estate investments that fulfil their demands and everyday activities. Moreover, it is expected that the outcome of the research will provide information for urban planners and developers in deciding profitable locations for property development.

LITERATURE REVIEW

A sustainable community is described as a neighbourhood with satisfactory living conditions and sustainable housing indicators for a high-quality life (Qusen Zumaya & Baqir Motlak, 2021). Every sustainable community would provide social amenities, infrastructure, safety, and privacy to enhance the residents' quality of life that meet their needs and demands. The selection of location is vital to sustainable residential housing development because it affects human development and livability (Murseli & Isufi, 2014) since the location influences the sustainability of the residential and market price, social amenities, accessibility, and available services require more attention (Ahmad & Matori, 2016; Masri et al., 2016). The parameters of the built environment, specifically for the dwelling area, such as services offered, commercial areas, accessibility, and other amenities, have to be balanced in relation to the walking distance and travel durations from one location to another during the decision-making process (Chen, 2014; van Maarseveen et al., 2018). These are also inclusive of other amenities like retail centres, schools, green spaces, industrial facilities, and the recreational area that prospective users and investors desired (Aburas et al., 2017).

Because of the complexity and intricacies of the interdependency and interrelationship of these requirements, multi-criteria decision analysis (MCDA) is a suitable tool for property assessment. First, a site suitability study is required to provide benchmarks for planning and property evaluation (Ilayaraja et al., 2016). A number of studies have integrated MCDA and GIS to speed up the process of selecting suitable locations (Chen, 2014; Malczewski, 2006; Mokhtar et al., 2020) and as a basis to evaluate the value of the real estate (Bunyan Unel & Yalpir, 2019). In this respect, the process combines geographical data (GIS) and the value of judgments (factor weights) to aid decision-making (Malczewski, 2006; Mokhtar et al., 2020; Nur Ezra et al., 2018).

RESEARCH METHODOLOGY

The study area selected for this study is Ipoh, Perak, Malaysia. The location is selected because it is the third largest state in Malaysia which comprises both urban and suburban areas and has experienced rapid development in recent decades (Khahro et al., 2014). Figure 1 shows the detailed research methodology. The parameters used in this work were obtained from the study of Mokhtar et al. (2020) with the addition of two (2) new parameters, social amenities, and recreational areas, to test whether the parameters influence the result in comparison to the work of Yenisetty and Bahadure (2020). A good quality social amenity is known to create a good community and a recreational area with the presence of green space is positively correlated with the neighbourhood's air quality (van Maarseveen et al., 2018). The selection of the parameters is based on the availability of the parameters in the study area (Table 1).

Table 6: List of parameters used in Three (3) Different Studies

Authors & Year	Parameters
Mokhtar et al. (2020)	Health & Social Care, Available Service, School, Public Defense, Accessibility, Government Building, Place of Interest, Housing Area, Commercial Area, Industrial Area
Ahmad & Matori (2016)	Recreational area
Yenisetty & Bahadure (2020)	Social Amenities

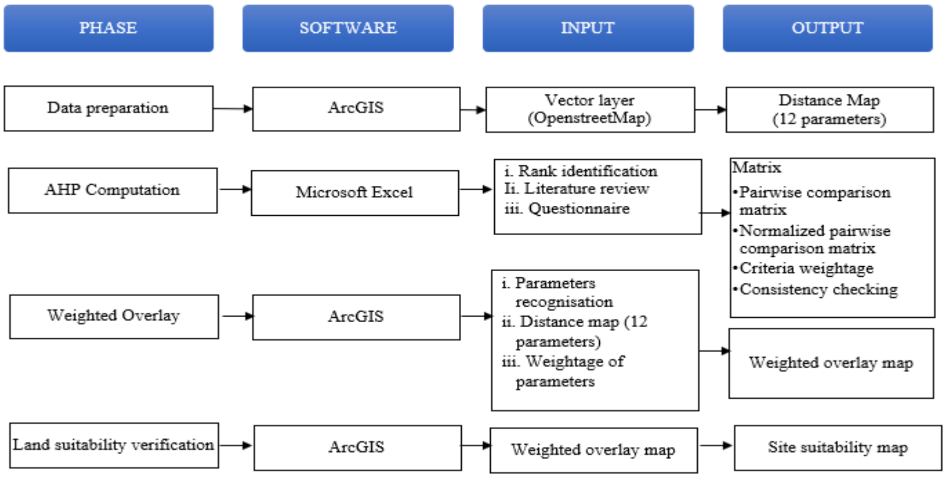

Figure 7: Overall Methodology

Data Used and Preparation

From OpenStreetMap (openstreetmap.org), the spatial dataset including accessibility features and other parameters used in the study was downloaded. OpenStreetMap is a platform for acquiring free vector data, which can be downloaded in OSM format for further processing in a GIS environment. The data obtained were converted into geodatabase files in ArcGIS 10.4. This study involves the classification of 12 variables (Table 2) projected to the Kertau RSO projection.

Table 2: Layer Classification of Twelve (12) Parameters.

Parameters/Ranking	**1**	**2**	**3**
	Distance Classification (m)		
Distance to Health and Social Care	0 – 2478	2478 – 4924	4924 – 9446
Distance to Available Service	0 – 1856	1856 – 3902	3902 – 7607
Distance to School	0 – 1793	1793 – 3958	3958 – 7643
Distance to Public Defense	0 – 2865	2865 – 5297	5297 – 9395
Distance to Accessibility	0 – 2747	2747 – 5021	5021 – 8956
Distance to Government Building	0 – 1867	1867 – 3767	3767 – 6938
Distance to Place of Interest	0 – 1217	1217 – 2493	2493 – 5350
Distance to Housing Area	0 – 134	134 – 385	385 - 1193
Distance to Commercial Area	0 – 650	650 – 1521	1521 - 3259
Distance to Industrial Area	3294 - 6698	1768 – 3294	0 – 1768
Distance to Social Amenities	0 – 1302	1302 – 2666	2666 - 5354
Distance to Recreational Area	0 – 1221	1221 – 2382	2382 - 5106

The Euclidean Distance Tool in the ArcGIS spatial analyst is used to determine the distance to a location of the sample data since it is an effective method for evaluating environmental exposure distance (Aburas et al., 2017). It is utilised to extract the distance class for each parameter in this study. It computed the distance between the feature or point's centre and the centres of the surrounding cells. The range of distance classification layer represents the indices to the amenities that were produced by natural breaks classification (Aburas et al., 2017) and have been reclassified into three new classes consisting of low suitability (3), medium suitability (2), and high suitability (1) (Kamalov, 2020), resulting in a raster remap. If the distance to the point or feature is less, the scale indicating the level of difficulty to reach the facilities will also be reduced. The 12 data layers and their categorization are presented in Table 2.

AHP and GIS based for Site Suitability Analysis and Mapping

Using the AHP, the pairwise comparison was conducted which provided the weighting values that reflect the significance of each parameter (Malczewski, 2006). The scale was set from one (1), which indicates equal value, to nine (9), which represents the most significant aspect (Santosh et al., 2018). The upper diagonal of the pairwise comparison matrices was allocated a numeric rank, whereas the bottom diagonal was awarded a reciprocal value. Each variable's criterion weight was computed by dividing the value assigned in the matrices by the total value of the variables. Based on the normalised pairwise comparison matrices, the weighted sum value matrix was produced by multiplying the matrix value by the obtained criteria weight. The value of the weighted sum was divided according to the variable weighted values. The final output is utilised to estimate the consistency ratio (CR) which indicates whether consistent judgements are made between the parameters. When the CR number surpasses 0.1, it indicates that the judgement is unacceptable and has to be repeated (Bunyan Unel & Yalpir, 2019) but when the CR value is less than 0.1, the AHP process is acceptable. The ratio of the weighted sum value, the highest eigenvalue (λ_max) of the matrix, the consistency index (CI), and lastly the consistency ratio (CR) are essential judgements for the computation (Bozdağ et al., 2016). The consistency ratio (CR) is determined based on the random index (RI) value (Malczewski, 2006).

Once the result of the AHP process is satisfactory, the site suitability mapping is performed using the overlay method in ArcGIS using the reclassified layers and the AHP-calculated weights. The weighted overlay integrates raster data and weights and converts them into a raster map that depicts specific land suitability classes (low, medium, and high suitability) based on the relationship between the parameters (Roslee et al., 2017). Finally, the suitability map was exported and generated into a Google Earth image for validation.

RESULT AND DISCUSSION

According to Aburas et al. (2017), CR > 0.10 indicates inconsistent judgements, whilst CR < 0.10 indicates an acceptable ratio value for the judgement. The weights of the 10 and 12 parameter categories are shown in Table 3. The CI, RI, and CR values demonstrate significantly superior outcomes than Ilayaraja et al. (2016) which is 0.15. To maintain the uniformity of every parameter, the AHP ranking of certain parameters was revised. Table 4 shows the greatest eigenvalue (13.741) which resulted in the calculated CI and CR values being 0.16 and 0.10, respectively, showing that the evaluation had near-inconsistent judgements but was still rated as acceptable. Weighted overlay analysis was used to generate a map of residential land suitability (Figure 2), which reveals that the city's centre is the most attractive location for homebuyers because it encompasses all twelve (12) parameters. It is due to providing convenient access to a wide variety of services and facilities that residents need and use on a regular basis. Most of the conveniences are concentrated in the central business district (CBD) (Figure 2). The central part of the map is more suitable than the outlying areas because it is closer to the central business district (CBD), which is where the mapped region is located.

Table 3: The computed value of weightage, CI, RI, and CR of previous work.

SET	Parameters	CW	CI	RI	CR
1 (Mokhtar et al., 2020)	Health and Social Care	0.30	0.23	1.49	0.15
	Available Service	0.22			
	School	0.13			
	Public Defense	0.10			
	Accessibility	0.08			
	Government Building	0.04			
	Place of Interest	0.04			
	Housing Area	0.04			
	Commercial Area	0.03			
	Industrial Area	0.02			
2 (Revised Weightage and Parameters)	Health and Social Care	0.28	0.16	1.54	0.10
	Available Service	0.21			
	School	0.13			
	Public Defense	0.10			
	Accessibility	0.09			
	Government Building	0.04			
	Place of Interest	0.04			
	Housing Area	0.04			
	Commercial Area	0.03			
	Industrial Area	0.02			
	Social Amenities	0.02			
	Recreational Area	0.02			

Table 5 shows a list of available parameters at the chosen location for each suitability level of a sustainable residential living area. The residential area was identified as the selected area, which was mapped using the Google Earth platform (Figure 3). In Ipoh, Perak, most of the residential areas are found in the high- and medium-suitability regions, which are filled with amenities and accessibility. Most amenities were concentrated in the CBD region, which indicated that it offered more sustainable living than neighbourhoods away from the CBD. In areas with scarce facilities, such as Bandar Lahat Baru (Figure 2), there are fewer amenities and unfavourable parameters, such as an industrial area that is regarded as a dangerous facility. A study by van Maarseveen et al. (2018) found that potential purchasers' willingness to purchase a residential property was influenced by the distance between housing and the industrial sector. Due to its ability to shorten travel times, people prefer to invest in residential real estate that meets the most sustainable residential criteria.

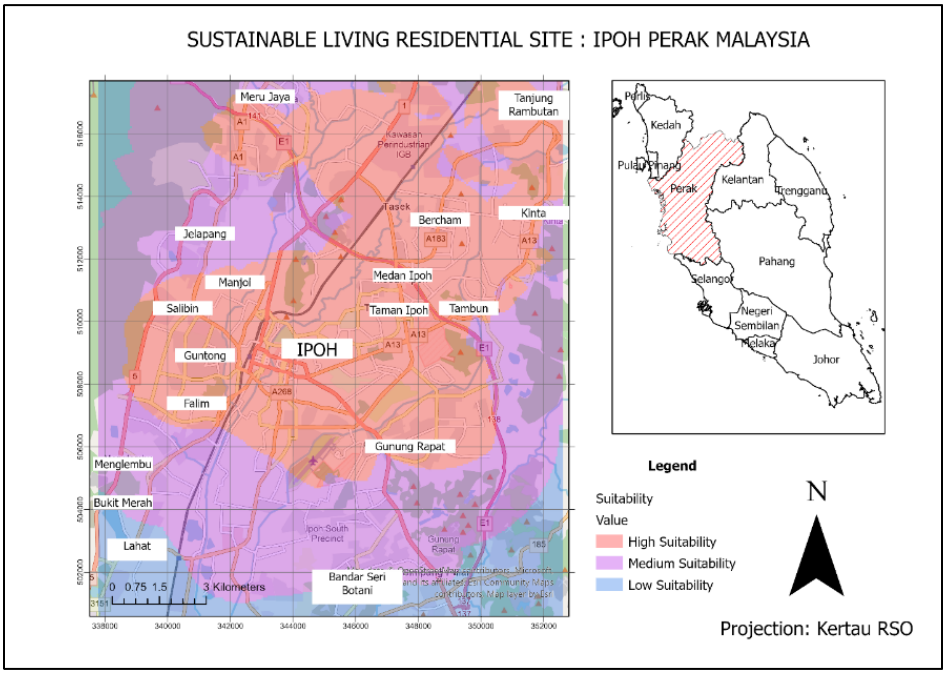

Figure 2: Suitability Residential Living Area Map

Table 4: The consistency ratio of twelve (12) parameters.

Parameters		**(A)**	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**	**(G)**	**(H)**	**(I)**	**(J)**	**(K)**	**(L)**	**Weighted Sum Value**	**Criteria Weight**	**Ratio**
Health and Social care	**(A)**	0.28	0.41	0.50	0.49	0.52	0.31	0.30	0.33	0.28	0.20	0.14	0.17	3.93	0.28	14.282
Available Service	**(B)**	0.14	0.21	0.25	0.39	0.43	0.26	0.26	0.29	0.25	0.17	0.14	0.17	2.98	0.21	14.481
School	**(C)**	0.07	0.10	0.13	0.20	0.34	0.22	0.23	0.11	0.13	0.15	0.13	0.06	1.85	0.13	14.739
Public Defense	**(D)**	0.06	0.05	0.06	0.10	0.17	0.18	0.19	0.11	0.16	0.12	0.10	0.11	1.40	0.10	14.236
Accessibility	**(E)**	0.05	0.04	0.03	0.05	0.09	0.09	0.15	0.18	0.25	0.10	0.10	0.09	1.22	0.09	14.135
Government Building	**(F)**	0.04	0.03	0.03	0.02	0.04	0.04	0.08	0.07	0.06	0.07	0.05	0.06	0.60	0.04	13.667
Place of Interest	**(G)**	0.04	0.03	0.02	0.02	0.02	0.02	0.04	0.07	0.09	0.10	0.03	0.04	0.52	0.04	13.860
Housing Area	**(H)**	0.03	0.03	0.04	0.03	0.02	0.02	0.02	0.04	0.06	0.12	0.05	0.04	0.50	0.04	13.554
Commercial Area	**(I)**	0.03	0.03	0.03	0.02	0.01	0.02	0.01	0.02	0.03	0.15	0.03	0.04	0.42	0.03	13.394
Industrial Area	**(J)**	0.05	0.05	0.04	0.01	0.02	0.01	0.01	0.01	0.01	0.02	0.03	0.04	0.31	0.02	12.252
Social Amenities	**(K)**	0.03	0.02	0.02	0.02	0.01	0.01	0.02	0.01	0.02	0.01	0.02	0.02	0.21	0.02	13.032
Recreational	**(L)**	0.03	0.02	0.04	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.24	0.02	13.265

Table 5: Availability Facilities at the Selected Location with Different Levels of Sustainability Residential Area

Level Suitability	Location	Parameters Available
High	Falim	Health & Social Care, Public Defence, School, Place of Interest, Commercial Area, Social Amenities, Government Building, Industrial Area, Available Service, Housing Area, Recreational Area, Accessibility
Medium	Taman Taufik	Commercial Area, School, Industrial Area, Accessibility, Social Amenities, Available Service, Recreational Area, Housing Area
Low	Bandar Lahat Baru	Industrial Area, Commercial Area, Housing Area, Accessibility

CONCLUSION

The purpose of the study was to determine the suitability of residential property sites in Ipoh and to produce the site suitability map. The distance from each relevant metric was analysed and categorised into high (1), medium (2), and low (3) suitability. The inconsistency in the previous study which employed 10 parameters has been verified. Even though the value was nearly discordant with the evaluations, the CR value of 0.10 indicates that the parameter evaluations were acceptable and reliable. Most of the residential areas in Ipoh, Perak are detected within high and medium suitability zones, compared to the low suitability area, which occurs mostly in the less developed area with population and limited infrastructure. The result also revealed that the most significant parameters are health and social care while industrial areas, social facilities, and recreational places have little significance. It can be inferred that since most of the parameters are not available at remote locations far away from the central business district, they are found unsuitable for a sustainable residential neighbourhood. The addition of two other factors affects the area occupied by the various classes compared to the previous study (Ahmad & Matori, 2016).

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