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ANALYZING LOCATIONS OF OUTDOOR ADVERTISEMENT DISPLAY BY USING FUZZY-AHP AND GIS

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Abstract

City councils generate revenue through fees for advertising display structures within their various council districts. However, there is yet a map that depicts the area where the advertisement display structure is permitted to be constructed. The city councils often need to refer to a manual book containing the guidelines in textual form, which may make it difficult to directly assess the location of the application to install an advertising display. Therefore, this study was conducted to spatialize the guidelines and analyse the suitable area for installing outdoor advertisement displays. Experts' choice was used to obtain the weightage for the main and sub-criteria, which was calculated using the Fuzzy-AHP method and then used to derive the GIS suitability index model indicating suitable and not suitable areas. Findings revealed that within the tested study area, 94% of the area is suitable, while 6% of it is not. Based on on-site verification, the model is proven to be reliable since the unsuitable area does not comply with the criteria. Hence, a visualization map was created to act as a spatialized guideline, which the experts also agree that the suitability map could help them make decisions efficiently, thus leading to smarter planning for the future.

Keywords: fuzzy-ahp, gis, mcda, index model, outdoor advertisement display

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INTRODUCTION

Advertising is a promotional tool used to introduce, encourage, or draw public attention to goods, services, persons, or entities. Companies or individuals must obtain approval from local authorities to establish an advertisement, as per the Outdoor Advertising Board Planning Guidelines Number 2 of 2009. Malaysia's Majlis Perbandaran Petaling Jaya and Majlis Perbandaran Kuantan have built a GIS system to display Outdoor Advertisement Display (OAD) locations. However, this system only displays the current position without further analysis.

It would be better if the City Council could swiftly approve an application by viewing the created map and identifying the area where an advertisement display structure is acceptable or permitted. Wakil et al. (2021) and Haidu et al. (2009) suggested that GIS could be an efficient method for determining the prospective placement of OAD based on preset criteria, making it easier to achieve order and harmony between OAD and the surrounding environment. GIS can help visualize customer locations by analyzing demographic information and psychographic, purchasing, and spending characteristics for accurate customer segmentation. It is also suggested that GIS and marketing can be integrated into market planning and decision-making, leading to the development of innovative marketing tactics.

OAD is a popular offline advertising method that targets the target market while they are not at home. The Town and Country Planning Department and the Malaysian Highways Authority have released guidelines for outdoor billboard placement in Malaysia. These guidelines address various types of displays, such as Free-Standing Billboards, Spectacular Gantry, Rooftop Advertisement, and Building Wrap. However, local governments generate revenue through fees and rental of advertising display structures. There is no map or inventory of suitable locations for advertising displays, making it difficult to recommend suitable sites and prevent unlawful displays that could be life-threatening and negatively impact drivers.

Thus, the aim of this study is to derive spatial-based guidelines, which are in the form of a map showing the suitability for installation of OAD. The study used Fuzzy-AHP to derive the weightage of the criteria for installation of OAD and GIS to develop a suitability index model for OAD, which actually depicts the manual guidelines by the city council.

LITERATURE REVIEW

Outdoor Advertisement Display

OAD aims to become a medium of communication for the advertising industry while also contributing to the development of a contemporary urban environment in addition to integrating with urban systems like transportation, architecture, and greening to create a space and improve the visual interface of a city (Molitor et al., 2020; Sadeghi et al., 2019; Tang et al., 2019).

As cities grow and the economy gets better, the advertisement industry grows rapidly. However, extreme urban visual pollution and deterioration of the socio-physical living environment have occurred due to the unmanaged placement, size, position, structure, and content of OAD in Malaysian metropolitan centers. This can be seen through an article published by the Majoriti, with the title of "Papan Iklan Usang, Tak Ikut Spesifikasi Bahayakan Pengguna Lebuh Raya" [Old Advertisement Board, Did Not Follow Specification Endangering Highway User], stated that a lot of unsupervised billboards were seen to be harmful towards the road users (Hussain, 2022). The Majoriti conducted a survey of the Klang Valley and discovered that there are numerous billboards that do not adhere to standards and have not been maintained for an extended period. Hence, it is necessary to follow the general guidelines for the advertisement display.

Road safety plays a major role in establishing OAD. Driver inattention and distraction are recognized as two of the most critical factors for road safety worldwide (Arevalo-Tamara et al., 2022; Oviedo-Trespalacios et al., 2019). Distracted driving includes dividing attention between the primary task, such as driving, and a non-driving-related secondary task, such as talking on a cell phone or reading roadside advertisements. A consistent finding in the literature is that the presence of roadside advertising seems to be correlated with road crashes (Hinton et al., 2022; Vrkljan & Jeleč, 2021; Wu et al., 2021; Brome et al., 2021). Uncontrolled advertisements are causing visual intrusion and block important traffic signs from motorists and pedestrians, thus causing unavoidable accidents. Hence, it is suggested that all commercial signs should be completely avoided at intersections or nearby. In conclusion, all advertising displays must be placed carefully inside the safe zone and must not obstruct the view of drivers.

GIS-MCDA in Site Suitability Analysis for Outdoor Advertisement Displays

Based on Belton and Stewart in 2002, MCDA can be defined as a method to explore decisions that take multiple factors into consideration. For approximately 20 years, MCDA methods have been used for spatial problems by coupling them with GIS (Malczewski & Rinner, 2015). MCDA emerged out of and as a response to single-criterion optimization approaches, namely linear programming. These were established during World War II and refined in the early days of the Operations Research discipline of corporate management in both contexts without addressing secondary effects that need numerous criteria.

MCDA contains multiple approaches. Analytical Hierarchical Process (AHP) and Analytical Network Process (ANP) are two common techniques used in MCDA (Elhosni & Faiz, 2021). AHP is one of the most comprehensive methods of multicriteria decision analysis (Saaty, 2008), while ANP is an extension and generalization of AHP. Both methods are based on the principles of decomposition, comparative judgment, and synthesis of priorities. The main

principle of comparative judgment requires assessment between elements in a given hierarchical structure with respect to their parent in the next-higher level (Malczewski & Rinner, 2015).

Site suitability modeling plays a crucial role in various fields, such as urban planning, environmental management, and resource allocation. GIS-MCDA methods are frequently used for analyzing and assessing potential site locations (Zaki et al., 2023; Mabahwi & Nakamura, 2024; Nor et al., 2024). Site suitability modeling involves combining various parameters using a weighted linear combination or other aggregation methods to create a composite index. Weigh is given to each criterion that reflects how important it is in the decision-making process. Index models allow for the analysis of many decision-making scenarios and offer a more thorough examination. However, the careful selection, weighting, and normalization of criteria necessary for index models can be very time-consuming.

GIS-MCDA integrates the spatial dimension into the decision-making process by considering the spatial relationships and interactions among criteria and site locations. It utilizes geospatial data and GIS to facilitate advanced spatial modeling and analysis. GIS-MCDA techniques, such as AHP, Fuzzy Logic, and OWA, enhance the accuracy and reliability of site suitability assessments. These techniques can help in decision-making that produces quality results.

RESEARCH METHODOLOGY

This study was conducted in five (5) stages: preliminary study, data acquisition, data processing, data analysis, and visualization, as depicted in Figure 1. The first stage, preliminary study, involved literature review and software training. The second stage involved data collection, which consisted of two (2) parts: Fuzzy-AHP and GIS. The Fuzzy-AHP part involved primary data collection to obtain experts' choice of criteria weightage, while the GIS part used secondary data collection to obtain spatial data representing the criteria from various sources. The third stage is data processing, which involves calculating the weightage using a Fuzzy-AHP pairwise comparison matrix and spatial data editing. Then, Weighted Overlay Analysis combined the weightage calculated and spatial data to derive site suitability indexes. Then, the next stage is analysis, where the locations were analyzed to determine high and low suitability areas. Site verification was conducted to verify the results. The final stage is visualization, where a map visualizing the suitability index was created to aid in planning new OAD locations that comply with guidelines.

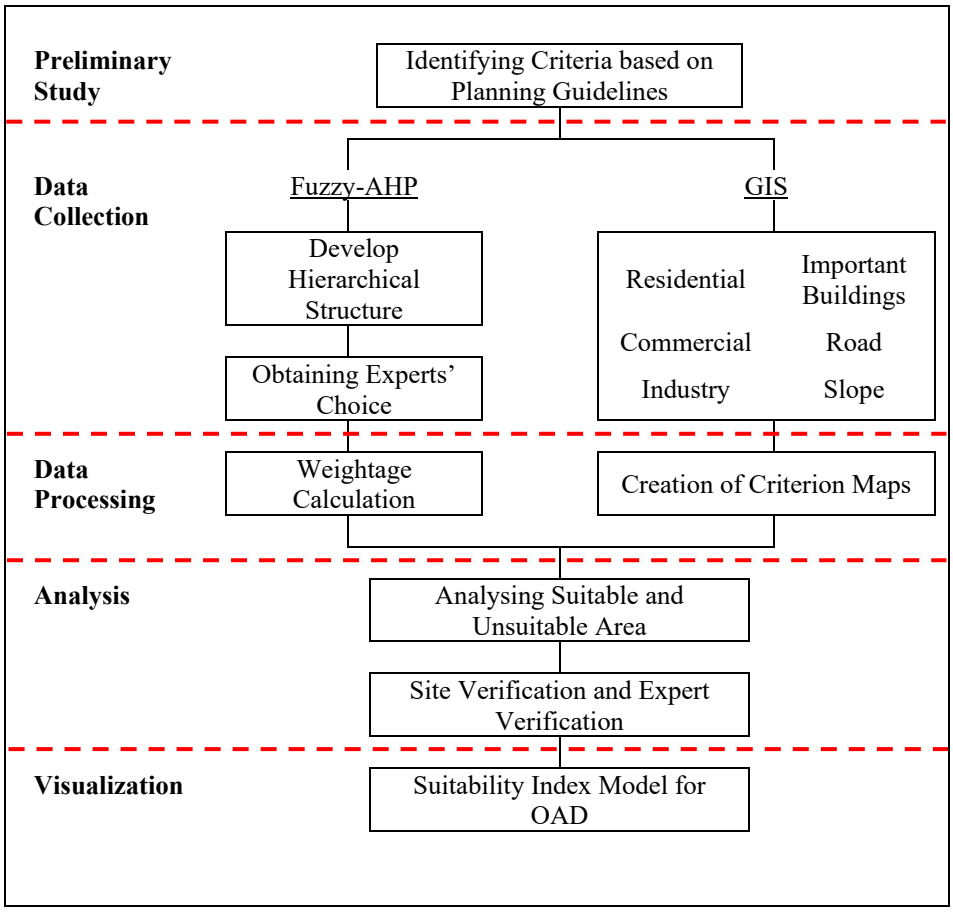


Figure 1: Methodology Framework

Selection of Criteria for Site Suitability Analysis of Outdoor Advertisement Display

This study used criteria based on the guidelines by MPSJ (2020), KKR (2020), and PLANMalaysia (2015) as the basis. There are many criteria to be considered when it comes to site suitability analysis, but for this study, three (3) main criteria are highlighted: public safety, public comfort, and environmental quality. Each of these criteria has a sub-criteria that represents them on the ground. These sub-criteria were identified as the geographic features that were suitable for representing the criteria. Table 1 depicts the selected criteria and sub-criteria for the Site Suitability Analysis of OAD that is adapted from the guidelines mentioned earlier.

Table 1: Main Criteria and Sub-Criteria

Criteria	Sub-Criteria
Public Safety	Road Distance Road User's Driving Visibility Emergency Road Accessibility
Public Comfort	Pedestrian Walk Residential Area Distance From Each OAD
Environment Quality	Intersection Important Buildings Heritage Buildings

Calculating Weightage Using Fuzzy-AHP

After obtaining the Expert's Choice through a pairwise comparison matrix, the weightage for each criterion and their sub-criteria were computed. As this study uses Fuzzy-AHP, the pairwise comparison is in the form of linguistic variables. After the calculation is completed, the weightage of the criteria has been determined. Each criterion will be assigned to a weightage of normalized weights. Then, all the values that have been calculated will be inserted in GIS software to do a Site Suitability Analysis. Each criterion will also be assigned to each layer.

Suitability Index Modelling for Outdoor Advertisement Display

The Suitability Index Model is a method for creating an integrated analysis by applying a single scale of values to varied and distinct sources. Suitability index modeling determines the optimal or most ideal locations for a particular phenomenon. Hence, the suitability index modeling was chosen to determine the site's suitability for OAD. Figure 2 shows the steps to perform the suitability index modeling, which integrates Fuzzy-AHP.

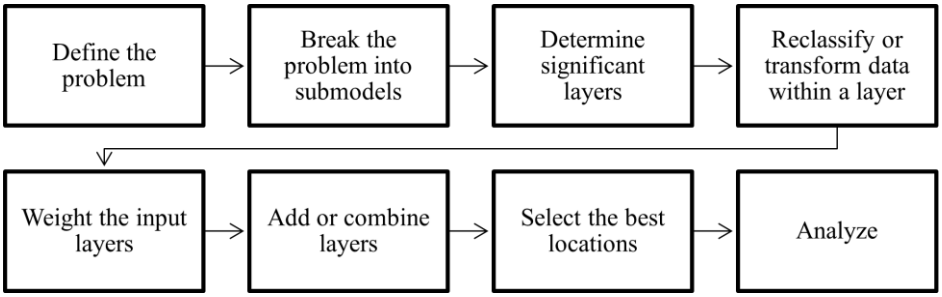


Figure 2: Steps to Perform Suitability Indec Modelling

The first step for suitability index modeling was to define the problems. The problem that occurred in this study was to determine the suitable area for outdoor advertisement display according to the existing guidelines. All the main and sub-criteria were determined by analyzing the past guidelines.

The second step was to break the problem into sub-models. This was because most suitability modeling problems were mostly complex. It is better to break them down to achieve clear and organized methods for solving the problems. The sub-models can be divided according to the criteria.

Next, the significant layers were determined. The attributes or layers that affect each layer need to be identified. Each factor captures and describes a component of the phenomenon being defined by the sub-model. Each factor contributes to the objectives of the sub-model, and each sub-model contributes to the objectives of the overall model. As a result, the index model should incorporate all factors that contribute to defining the phenomena. For example, since the Outdoor Advertisement Display needs to be 50m away from a major road a certain distance, the buffer was run to create the distance of the buffer.

Reclassification or transformation of data within the layer is important because different numbers of systems cannot be directly combined effectively. Before the layers can be added to the model, they must be reclassified or changed to a common ratio scale due to the potentially diverse ranges of values and different types of numbering systems that each input layer may possess. Hence, all the sub-criteria were reclassified into two (2) classes: one (1) was not suitable, and two (2) was suitable.

The next stage was assigning weight to the input layer. Some factors may be more crucial to the overall objective than others. If this is the case, the factors can be weighted according to their significance before being combined. These weights were obtained through the Fuzzy-AHP method. In the suitability index model, it is desirable to establish the link between all input factors to discover areas that satisfy the model's objectives. Figure 3.6 and Figure 3.7 show how the weightage was incorporated into the index model for this study to derive the suitability index model for OAD.

ANALYSIS AND DISCUSSION

This section discusses the results of the site suitability modeling for the OAD. This section includes an evaluation of the weightage of the main criteria and sub-criteria used in the analysis, as well as the results on the site suitability modeling for the OAD, which is divided into two (2) categories of Suitable and Unsuitable. The location of existing OAD was analyzed based on the suitability map.

Weightage of Criteria and Subcriteria

This section summarizes the weightage for each criterion and sub-criteria by using Fuzzy-AHP techniques. The final weightage for each criterion was

determined by experts who are academic and industry experts. A total of five (5) experts answered the pairwise comparison given. Then, all the calculations were done to compute the final weightage. Table 2 depicts the weightage for criteria and sub-criteria.

Table 2: Weightage for Sub-Criteria

Main Criteria	Weightage	Sub-Criteria	Weightage	Priorities	Rank
Public Safety	0.606	Road Distance	0.116	0.070	6
		Road User's Driving Visibility	0.644	0.390	1
		Emergency Road Accessibility	0.240	0.145	2
Public Comfort	0.166	Pedestrian Walk	0.288	0.048	8
		Residential Area	0.484	0.080	4
		Distance From Each OAD	0.228	0.038	9
Environment Quality	0.228	Intersection	0.246	0.056	7
		Heritage Building	0.427	0.097	3
		Important Building	0.327	0.075	5

In finding site suitability for OAD, public safety should be prioritized as the most important criterion, followed by environmental quality and public comfort as secondary and tertiary factors, respectively. Public safety is vital, as OAD should not endanger the public's safety. A thorough examination of the environment's quality is also required to verify that the display has no negative impact on its surroundings. Finally, public comfort should be considered to ensure that the display does not cause inconvenience or discomfort to the public. By prioritizing these criteria in the site, the suitability study, OAD may be placed in suitable locations that serve their purpose while also protecting the safety and well-being of the public.

Suitability Index for Outdoor Advertisement Display

The Suitability Map classifies the suitable sites for OAD into two (2) categories: Suitable and Not Suitable area. As can be seen from Figure 3, the suitable areas are mostly away from the city and located around village areas. The areas that were suitable were around Kampung Endah, Kampung Sungai Lang Tengah, and Kampung Sungai Kelambu. This can happen because the area might have a flatland area. On the other hand, the unsuitable areas are mostly near the city.

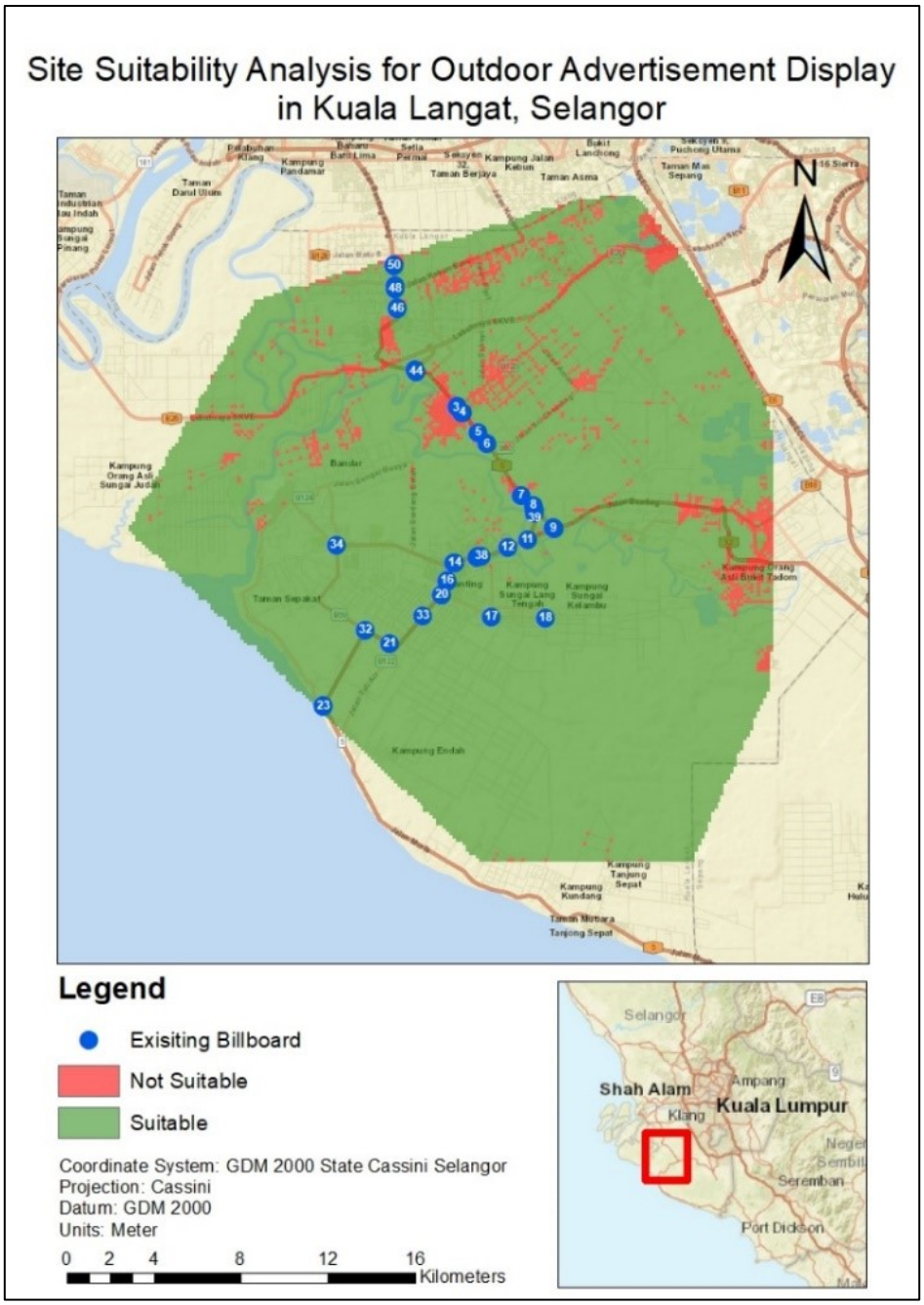
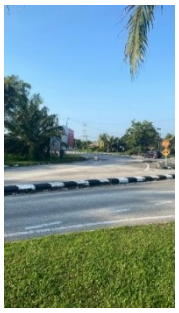


Figure 3: Site Suitability Map for OAD

The site's suitability has been verified in two (2) different methods. First, the referenced locations of the existing OADs were determined. This aids in determining the validity of the proposed Fuzzy-AHP and GIS-based site selection methodology. The Kuala Langat, Selangor region was examined for site validity. The analysis was conducted using the established guidelines. Second, it is also possible to account for the justification of an expert. The verification was performed via an interview. The expert was from the city council. Table 3 shows the Unsuitable OAD in the research area. A total of seven (7) out of 41 OADs had been identified in unsuitable areas and not adhering to the guidelines.

Table 3: Site Verification for Unsuitable OADs

Characteristics	Areas
OAD was too close to the main road	 Jalan Kampung Jenjarom
OAD was close to the residential area	 Jalan Klang Banting
OAD was close to the main road	 Jalan Klang Banting

Comparison of GIS-based Suitability Map of OAD with Existing Manual or Guidelines based on Verification by Interview with Expert

An expert from the city council was interviewed regarding this comparison. The Suitability Map of OAD was shown to the expert so that he could make a comparison with the existing manual or guidelines. Several questions were asked, such as whether the suitable locations comply with the guidelines and whether having the map would help them. In addition, other questions were asked about whether it is possible to replace the traditional manual book with spatialized guidelines.

Based on the interview, the expert agreed that a GIS-based Suitability Map provides a lot of advantages over the existing manual or guidelines. When having a map of site suitability will make the process of evaluating site suitability easier compared to solely relying on guidelines. While guidelines provide general recommendations and criteria for site suitability, a map can visually represent the distribution of different criteria spatially and help identify areas that meet specific criteria more efficiently.

A map gives a visual picture of the physical environment as well as the distribution of significant factors that affect a site's suitability. It is a visual representation of various elements, such as roads, buildings, pedestrian walks, and many others. For instance, since the OAD must be established within 30m of the residential area, the map can show where it is located.

A suitability map can also provide simplicity and clarity. Maps are an easy-to-understand and visually appealing representation of complex data. Rather than going through the long guidelines, users can quickly comprehend the suitability map. It facilitates effective communication among project team members and simplifies the decision-making process.

Site suitability analysis often involves considering multiple criteria simultaneously. By overlaying different data layers on a map, various factors can be assessed by interacting spatially. For example, the layers of roads, contours, important buildings, and residential areas can be combined to create a suitability map. Plus, the criteria can be adjusted and modified easily. By changing the weighting of the different criteria, the impact on site suitability can immediately be visualized. This flexibility enables the exploration of different scenarios and the comparison of alternative options efficiently.

In conclusion, based on the interview with an expert from the city council, having a site suitability map would be helpful to them. Nonetheless, it is essential to note that guidelines continue to play an important part in the site suitability analysis. This is because authorities still use the guidelines as references as the guidelines contain more details in terms of the regulations that need to be followed. Maps are useful instruments for visualizing and analyzing data, but guidelines provide the knowledge and expertise required for correctly interpreting the data. The development of the suitability map should be guided by

guidelines that specify the requirements, criteria, and standard procedures. Therefore, a combination of both guidelines and a map-based analysis approach can be the most effective way to evaluate site suitability.

CONCLUSION

In conclusion, the results of this study have determined and analyzed the site suitability index for OAD using Fuzzy-AHP and GIS in Kuala Langat, Selangor area. The Fuzzy-AHP allowed for incorporating subjective judgments and uncertainty in the decision-making process, while GIS provided the necessary spatial data analysis capabilities. A final map was created that depicts the area where the OAD is suitable and not suitable to be established. The development of the suitability index model for OAD successfully proved the potential of GIS in spatializing the traditional manual or guidelines that are written in a book. Hopefully, the map can aid the city council in decision-making for new OADs, collecting revenue from the OAD, and monitoring illegal OADs.

Future studies should expand the study area to other local authorities in Selangor to support the state's Smart State vision. This would automatically enable the legal and ethical placement of OAD, saving time and energy. Local authorities can identify and rank suitable locations for OAD, track their effectiveness, and make necessary amendments. Regularly updating spatial and attribute data and conducting field or on-site surveys are essential for accurate representation of visibility and accessibility.

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