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Implementation of Hotspot Analysis Using the Kernel Density Estimation (KDE) Algorithm for WebGIS-Based Visualization of Culinary MSME Businesses: A Case Study of Makassar City

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Abstract

This study addresses the challenge of mapping the potential of culinary MSMEs (Micro, Small, and Medium Enterprises) in Makassar City by developing an interactive WebGIS-based visualization system. Using a Research and Development (R&D) approach, location data obtained from OpenStreetMap (OSM) were analyzed using the Kernel Density Estimation (KDE) algorithm to identify business hotspots. The findings reveal clear spatial concentration patterns, with the highest hotspot intensities located in the districts of Panakkukang, Rappocini, and Tamalate. A key contribution of this research is the identification of a substantial digital gap, as approximately 94% of officially registered MSMEs are not represented on digital map platforms. In response, the developed WebGIS system fulfills a dual role: it functions as an analytical tool for assessing business potential and as a strategic diagnostic instrument to support more targeted MSME digitalization initiatives.

Keywords: Hotspot; Analysis Kernel Density Estimation (KDE); Culinary MSMEs; WebGIS; Digital Gap.

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Abstrak

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Penelitian ini membahas tantangan dalam memetakan potensi UMKM (Usaha Mikro, Kecil, dan Menengah) kuliner di Kota Makassar melalui pengembangan sistem visualisasi interaktif berbasis WebGIS. Dengan menggunakan metode Research and Development (R&D), data lokasi dari OpenStreetMap (OSM) dianalisis menggunakan algoritma Kernel Density Estimation (KDE) untuk mengidentifikasi hotspot (titik panas) bisnis. Penelitian ini berhasil memetakan zona konsentrasi utama, dengan hotspot tertinggi berada di Kecamatan Panakkukang, Rappocini, dan Tamalate. Temuan krusial dari studi ini adalah terungkapnya kesenjangan digital yang masif, di mana sekitar 94% UMKM yang terdaftar secara resmi tidak memiliki visibilitas di peta digital. Oleh karena itu, platform WebGIS yang dikembangkan memiliki fungsi ganda: sebagai alat analisis potensi bisnis dan sebagai alat diagnostik strategis untuk mendorong program digitalisasi UMKM yang lebih tepat sasaran.

***Kata kunci**: Analisis Hotspot; Kernel Density Estimation (KDE); UMKM Kuliner; WebGIS; Kesenjangan Digital;*

INTRODUCTION

The rapid development of information and communication technology has significantly influenced the economic sector (Bambang & Abdur, 2019). Information systems have become the backbone of complex business data management processes. For Micro, Small, and Medium Enterprises (MSMEs), digital transformation plays a crucial role in ensuring business sustainability, particularly in the post-pandemic period (Widnyani et al., 2021). Makassar City is among the regions experiencing substantial growth in MSMEs; however, challenges related to data management and digital marketing remain major constraints (Ashdaq et al., 2025). According to recapitulation data from the Makassar City Office of Cooperatives and MSMEs, the number of active assisted MSMEs has consistently increased over the past five years, as presented in Table 1.

Table 1. Data on the Development of the Number of Fostered MSMEs in Makassar City by Sub-district (2019-2023)

NO	District	2019	2020	2021	2022	2023
1	Mariso	40	40	41	48	67
2	Mamajang	39	39	42	104	105
3	Tamalate	93	93	93	52	53
4	Rappocini	101	103	103	351	353
5	Makassar	47	48	48	117	116
6	Ujung Pandang	73	74	74	35	39
7	Wajo	36	37	38	22	22

8	Bontoala	33	33	33	15	15
9	Ujung Tanah	21	22	22	1	1
10	Kepulauan Sangkarrang	1	1	1	1	-
11	Tallo	35	35	35	39	42
12	Panakkukang	109	114	115	66	73
13	Manggala	40	40	40	39	44
14	Biringkanaya	71	73	73	54	54
15	Tamalanrea	52	54	54	51	52
Total	**Makassar**	**791**	**806**	**812**	**1.028**	**1.059**

Source: Makassar City Cooperatives and MSMEs Office, 2024

Based on recapitulation data from the Cooperative Office, the number of MSMEs has shown a significant increase. However, many MSME actors continue to rely on conventional practices and have not adopted systematic bookkeeping or location-based business mapping (Muttaqien et al., 2022). In fact, entrepreneurship in the digital era requires the integration of technology to expand market reach (Sudrartono et al., 2022). Digital marketing has also been demonstrated to exert a substantial influence on increasing sales volumes within home-based industries (Pradiani, 2018). Nevertheless, the absence of an interactive visualization system makes it difficult for business actors to identify high-potential market zones (blue ocean) as well as saturated areas.

To address this issue, the Hotspot analysis method, which utilizes spatial data, offers a relevant and effective solution. Data clustering techniques enable more accurate mapping of distribution patterns across different areas (Simanjuntak & Khaira, 2021). Among these techniques, Kernel Density Estimation (KDE) is particularly effective. KDE transforms discrete data points into continuous and smooth density surfaces, a capability that has been widely applied in disaster-prone area assessment and various forms of big data analysis (Radhi et al., 2022); (Lidrawati et al., 2022).

The results of the KDE analysis ideally require visualization through a WebGIS platform. Numerous previous studies have demonstrated the effectiveness of WebGIS. For example, (Rokhman et al., 2021) successfully mapped the distribution of MSMEs in Sidoarjo, while (Prayogo & Basith, 2020) developed a visualization system for Batik MSMEs in Yogyakarta. Similar studies were also conducted in Malang (Sulaksono, 2019) and in Semarang for mapping health facilities (Alifian et al., 2023). Additionally,

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location-based methods (Location Based Service) have been utilized as MSME promotional media in Kudus (Sholikhan et al., 2018).
Despite the growing number of WebGIS-related studies, only a limited body of research integrates WebGIS with advanced density analysis specifically for the culinary sector in Makassar. Therefore, this study aims to implement the KDE algorithm to visualize business hotspots, aligning with the concept of MSME cluster development as a strategy to enhance competitiveness (Sumaryana, 2018).

The rapid development of information and communication technology (ICT) has significantly transformed economic activities by enabling businesses to manage information more efficiently, improve operational performance, and expand market reach (Bambang & Abdur, 2019). Information systems have become fundamental infrastructures for managing increasingly complex business data and supporting evidence-based decision-making. For Micro, Small, and Medium Enterprises (MSMEs), digital transformation has emerged as a critical factor for improving business resilience, particularly in the post-pandemic era where digital technologies have become essential for sustaining competitiveness and business continuity (Widnyani et al., 2021). In Indonesia, government initiatives promoting digital entrepreneurship have accelerated the adoption of digital platforms among MSMEs, although implementation remains uneven across regions.

Makassar City represents one of the regions experiencing substantial growth in MSMEs. However, challenges related to business data management, digital marketing, and spatial information utilization continue to hinder the optimization of business development (Ashdaq et al., 2025). According to the Makassar City Office of Cooperatives and MSMEs, the number of active assisted MSMEs increased from 791 businesses in 2019 to 1,059 businesses in 2023, indicating continuous entrepreneurial growth. Despite this increase, many MSMEs continue to rely on conventional business practices and have not adopted systematic bookkeeping, digital information systems, or location-based business mapping (Muttaqien et al., 2022). Consequently, business owners experience difficulties in identifying potential market locations, evaluating competition intensity, and making strategic expansion decisions. In today's digital economy, entrepreneurship requires not only digital marketing

capabilities but also data-driven spatial intelligence to support business planning and sustainable growth (Sudrartono et al., 2022). Previous studies have also demonstrated that digital marketing significantly contributes to increased sales performance among MSMEs (Pradiani, 2018). Nevertheless, without an interactive spatial visualization system, entrepreneurs face considerable challenges in distinguishing high-potential business zones (blue oceans) from highly competitive market areas.

Several studies have attempted to address MSME information management through Geographic Information Systems (GIS) and WebGIS technologies. Rokhman et al. (2021) developed a WebGIS application to map MSME distribution in Sidoarjo, while Prayogo and Basith (2020) designed a spatial information system for Batik MSMEs in Yogyakarta. Similar applications were developed by Sulaksono (2019) for MSME mapping in Malang and Alifian et al. (2023) for visualizing healthcare facilities in Semarang. Furthermore, Sholikhan et al. (2018) implemented a Location-Based Service (LBS) application as a promotional medium for MSMEs in Kudus. These studies demonstrate the effectiveness of WebGIS in providing location-based business information and improving accessibility to spatial data.

In parallel, spatial statistical methods have increasingly been employed to analyze geographic patterns and support decision-making. Among these methods, Kernel Density Estimation (KDE) has proven particularly effective in transforming discrete spatial observations into continuous density surfaces, thereby enabling the identification of hotspot areas. Previous studies have successfully applied KDE in disaster risk assessment, crime analysis, public health surveillance, and big data analytics (Radhi et al., 2022; Lidrawati et al., 2022). Simanjuntak and Khaira (2021) further highlighted that spatial clustering techniques improve the accuracy of identifying regional concentration patterns compared with conventional descriptive mapping.

Although previous studies have demonstrated the usefulness of WebGIS and KDE independently, several important research gaps remain. First, most WebGIS-based MSME studies focus primarily on visualizing business locations without incorporating advanced spatial statistical analysis capable of identifying business density patterns and hotspot areas. Second, studies employing KDE have predominantly been conducted in disaster management, public health, and environmental monitoring, while its application to MSME spatial analysis remains relatively limited. Third,

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previous research generally emphasizes descriptive mapping rather than providing analytical decision-support tools that can assist entrepreneurs and policymakers in identifying potential business clusters, market saturation, and opportunities for business expansion. Finally, studies specifically integrating WebGIS and Kernel Density Estimation for culinary MSME mapping in Makassar City are still scarce, despite the city's rapid MSME growth and strategic role as an economic hub in Eastern Indonesia. Therefore, this study addresses these gaps by integrating Kernel Density Estimation (KDE) with a WebGIS-based visualization platform to analyze and visualize the spatial distribution of culinary MSMEs in Makassar City. Unlike previous studies that merely present business locations, the proposed system generates hotspot density maps capable of identifying areas with high and low business concentrations, thereby providing more meaningful spatial insights for strategic business planning. The novelty of this research lies in (1) integrating KDE with an interactive WebGIS platform specifically for culinary MSMEs, (2) developing a spatial decision-support system that facilitates the identification of potential business hotspots and market saturation zones, and (3) providing empirical evidence on how density-based spatial analytics can support MSME cluster development and regional competitiveness. Accordingly, this study is expected to contribute both theoretically by extending the application of spatial analytics in MSME research and practically by providing policymakers and business actors with a data-driven tool for business development and location-based decision-making.

METHODS

This study employs a Research and Development (R&D) approach. Spatial data were collected through OpenStreetMap (OSM) scraping. The use of big data in this research requires appropriate preprocessing techniques to ensure that the data become well-structured (Radhi et al., 2022). First, the authors should provide a more comprehensive explanation of the Research and Development (R&D) stages. Although the manuscript mentions the use of an R&D framework, the implementation of each stage is not adequately described. It is recommended that the authors clearly explain the sequence of activities, such as needs analysis, system design, prototype development, implementation, testing, validation, revision, and final deployment. Presenting

these stages in a flowchart or process diagram would further improve the clarity of the research methodology.

Second, the data collection procedures require greater transparency. The manuscript states that OpenStreetMap (OSM) was used as the primary spatial data source; however, it does not explain how the data were obtained, filtered, or verified. The authors should specify the methods used to extract OSM data (e.g., Overpass API, Geofabrik, or QGIS plugins), the criteria for selecting culinary MSMEs, the period during which the data were collected, and the attributes included in the analysis. In addition, the procedures for cleaning duplicate records, correcting incomplete coordinates, and validating geographic locations should be described to enhance data reliability.

Third, the validation process should be elaborated. It remains unclear whether the spatial data obtained from OpenStreetMap were validated through field observations, comparisons with official government databases, or expert verification. Since the completeness and positional accuracy of crowdsourced geographic data may vary, the manuscript should explain the validation strategy adopted to ensure the reliability of the dataset before conducting spatial analysis.

Fourth, the technical implementation of Kernel Density Estimation (KDE) requires a much more detailed description. The manuscript should specify the KDE equation, kernel function (e.g., Gaussian or Quartic), bandwidth selection method, search radius, cell size or raster resolution, coordinate reference system (CRS), and software or programming environment used for the analysis (e.g., ArcGIS Pro, QGIS, Python, or R). These parameters substantially influence hotspot detection and are essential for enabling other researchers to replicate the analysis. Furthermore, the rationale for selecting these parameter values should be supported by relevant literature.

Finally, the manuscript should describe the WebGIS development process in greater detail. Information regarding the system architecture, software stack, database management system, web mapping libraries (e.g., Leaflet or OpenLayers), server configuration, and integration between the KDE output and the WebGIS platform would substantially improve the technical contribution of the study. If the proposed system is intended as a decision-support tool, additional information regarding usability testing, system performance evaluation, or user acceptance assessment would further strengthen the methodological rigor.

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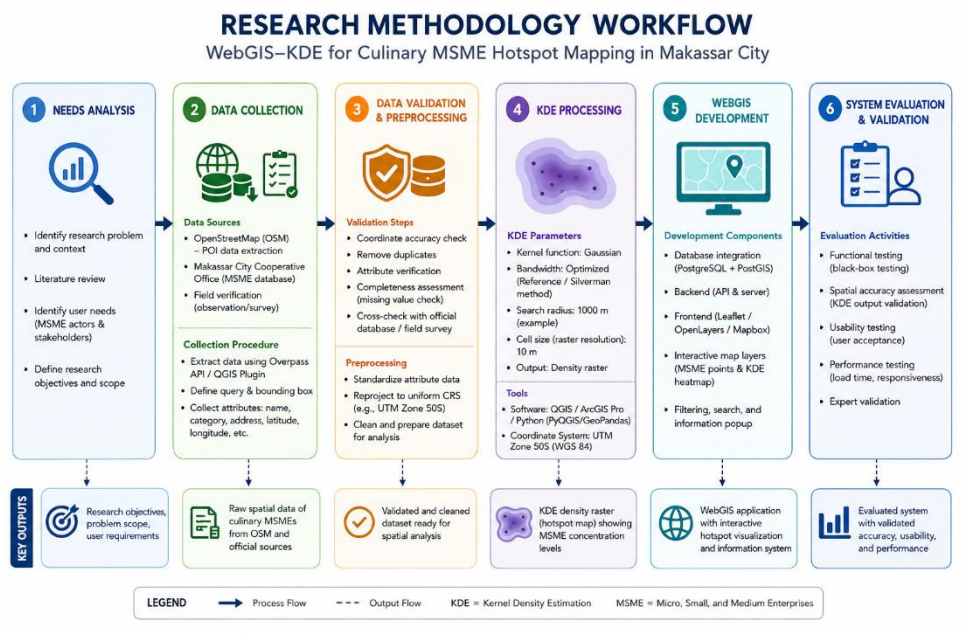
Overall, expanding the methodological description would significantly improve the transparency, reproducibility, and scientific robustness of the study, allowing readers to better understand, evaluate, and replicate the proposed WebGIS–KDE framework for spatial analysis of culinary MSMEs. The Kernel Density Estimation (KDE) algorithm was utilized due to its capability to analyze non-parametric probability densities, a technique widely applied in both energy-related and spatial analyses (Qin et al., 2016). Moreover, the KDE principle in identifying area concentrations closely aligns with machine learning–based approaches used to assess regional vulnerabilities (Song et al., 2023).

Figure 1. Research Methodology Workflow



Source: Visualized by authors (2026)

The visualization component was developed as a web-based platform designed to be interactive, following the principles of multimedia-based expert systems that enhance user accessibility (Hayadi, 2017) and support interactive learning environments (Muftizar et al., 2020).

RESULT AND DISCUSSION

Results of Spatial Data Processing

The spatial data obtained through the OSMnx acquisition process initially consist of raw, unstructured data that must undergo a cleaning phase. The final preprocessing stage produced 753 valid culinary MSME

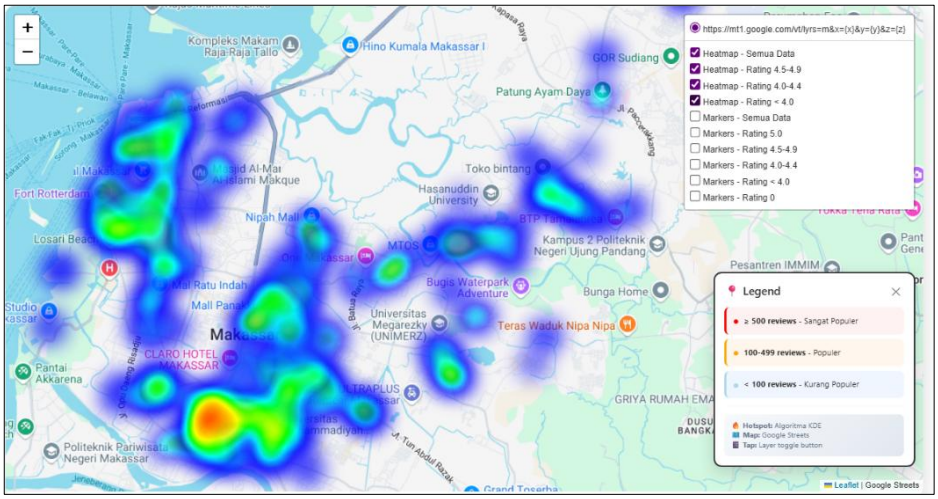
data points with complete attributes required for KDE analysis. These data points serve as the basis for generating heatmaps in the WebGIS platform. The developed system incorporates several interactive features, including dynamic maps, rating-based filters, and informative pop-up windows.

Functionality testing carried out using the Black Box Testing approach yielded valid results for all primary features. The test scenarios included verifying heatmap layer activation, pop-up marker interactions displaying business names and address details, as well as interface responsiveness on mobile devices. All system components operated according to the design specifications without any functional issues.

Hotspot Visualization Analysis

Figure 1 presents the visualization of the KDE algorithm implemented within the WebGIS environment. The red color gradation represents areas with a very high concentration of culinary businesses (hotspots), while the yellow and green gradations indicate medium-density zones. Meanwhile, blue areas reflect regions with relatively low business density.

Figure 2. Visualization of Culinary MSMEs Heatmap Distribution



Source: Data Processed, 2025

Based on the KDE visualization, a pattern of grouping (agglomeration) of the culinary business was identified. Details of hotspot zones are presented in Table 1.

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Table 1. Distribution of Main Hotspot Zones

Density Zone	District	Number of MSMEs (Sample)	Regional Characteristics
High	Panakukang	110	Modern business centers, malls and offices
High	Rappocini	106	Higher education areas and dense settlements.
High	Tamalate	94	A combination of commercial and residential areas.
High	Makassar	61	Old town centre & offices.
Middle	Biringkanaya	31	Areas near the airport & trans-Sulawesi
Middle	Manggala	30	Residential areas are growing.
Low	Wajo	8	Port area & wholesale trade.
Low	Bontoala	2	Port area (north).

Source: Data Processed 2025

The analysis indicates that the Panakkukang, Rappocini, and Tamalate Districts function as the primary centers of gravity for Makassar's culinary economy. This aligns with the theory of economic agglomeration, which posits that businesses tend to cluster in densely populated areas supported by key infrastructures such as universities and office complexes. These findings are also consistent with the theory of regional clustering as a strategy for regional economic development, wherein business

agglomeration commonly occurs in core economic activity zones (Supriyanto et al., 2017).

The mapping approach applied in this study successfully transforms previously scattered distributions into structured and interpretable clusters, similar to the use of the K-Means method in microenterprise mapping (Remawati et al., 2021).

Key Findings: Digital Gap

A major finding of this research is the substantial disparity between MSME data available in digital platforms (Online Map/OSM) and the administrative data recorded by the government.

Table 2. Comparison of Mapped Data (OSM) vs Official Data

District	Number of Mapped MSMEs (OSM)	Number of Official MSMEs (Cooperative Office 2025)	Gap
Panakukang	111	2.065	-1.954
Rappocini	55	3.107	-3.052
Tamalate	67	1.902	-1.835
Makassar	117	4.553	-4.436
Biringkanaya	70	4.280	-4.210
Manggala	108	3.981	-3.873
TOTAL	**1.883**	**33.529**	**~31.646**

Source: Data Processed 2025

The data presented in Table 2 indicate that of the 33,529 MSMEs officially registered, only 1,883 are identifiable on OpenStreetMap. This means that approximately 94.4% of MSMEs in Makassar City lack sufficient digital visibility on open mapping platforms. These findings suggest that the developed WebGIS has two strategic functions. First, it serves as a business analysis tool that enables investors to identify both highly saturated zones (red ocean) and less competitive areas (blue ocean).

Second, it acts as a diagnostic instrument for the government to assess sub-districts with low levels of MSME digital literacy.

This situation reinforces the notion that visualization for strategic planning is crucial for city-level decision-makers (Sundary et al., 2016), yet field-level data remain limited. The WebGIS system can assist the government in mitigating regional economic disparities, similar to the use of scoring and weighting approaches for prioritizing disaster-prone area management (Sholikhan et al., 2019).

CONCLUSION

This study successfully developed a WebGIS system using an R&D approach to visualize the distribution of culinary MSMEs in Makassar City. The implementation of the Kernel Density Estimation (KDE) algorithm proved effective in identifying business concentration zones, with the main hotspots located in Panakkukang, Rappocini, and Tamalate Districts. The system passed all functionality tests with valid results. However, the primary contribution of this research lies in its empirical revelation of a significant "digital divide," where approximately 94% of officially registered MSMEs in Makassar remain invisible on digital mapping platforms.

It is recommended that the City Government utilize these findings as a foundation for a structured MSME digitization program, prioritizing the registration of MSMEs on digital platforms. For MSME actors, proactive registration is encouraged to enhance business visibility. A limitation of this study is the reliance on secondary OSM data, which is heavily dependent on user-generated contributions. Therefore, future research is advised to incorporate field validation through primary surveys to enrich data attributes.

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