Spatial Modeling of MSME Risk Based on Webgis with The Integration of Multidimensional Factor Analysis in Majene Regency

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Abstract

This research investigates and maps potential risks for Micro, Small, and Medium Enterprises (MSMEs) in Majene Regency, analyzing aspects of Human Resources (HR), capital, production, marketing, and law/legality. MSMEs are crucial to the regional economy , but they often face significant risks that hinder growth. This problem is worsened by a lack of spatial understanding of these vulnerabilities , which makes government interventions and development initiatives less effective. This study aims to spatially model and map MSME risks by integrating multidimensional factor analysis with WebGIS. The methodology involves four stages: (1) acquiring primary and secondary data related to the five risk dimensions; (2) using descriptive statistical and cluster analysis to categorize MSMEs; (3) applying risk factor scoring and weighting analysis to determine potential risk levels ; and (4) developing spatial modeling and GIS for risk visualization. The research results in a classification of MSMEs based on risk levels (high, medium, low), which is presented on a WebGIS platform to allow interactive spatial visualization. The findings are intended to provide a basis for more informed decision-making in the development of MSMEs in Majene Regency.

1. INTRODUCTION

Micro, Small, and Medium Enterprises (MSMEs) are a vital pillar of the Indonesian economy (contributing around 60.5% to the National GDP) (Aprilia et al., 2025; Irawan & Sukiyono, 2021; Juminawati et al., 2021), particularly in West Sulawesi Province. MSMEs play a major role in increasing income (Sirait et al., 2024) and absorbing 97% of the workforce (Salsabillah et al., 2023; Sinha et al., 2024). Based on the 2023 Economic Census data from the Central Statistics Agency, there were 61,507 businesses/companies in West Sulawesi, absorbing approximately 90,661 local workers (BPS, 2023). Specifically in Majene Regency, there are 9,848 SME actors spread across eight districts, with 85% of them located in the regency's government center (Bapenda, 2023).

However, MSMEs also frequently face various risks that can impede growth and potentially lead to bankruptcy (Obstáculos al Desarrollo de Las Pequeñas y Medianas Empresas En El Cantón La Concordia, 2023). A lack of spatial understanding of these vulnerabilities is exacerbated by limited digital infrastructure (Willem et al., 2024) and a lack of assistance for MSMEs (Evanita & Fahmi, 2023). In addition to policy-driven considerations, spatially explicit risk mapping constitutes an important scientific necessity in MSME studies. Non-spatial approaches to MSME risk assessment commonly based on aggregate statistics, survey averages, or sectoral classifications tend to obscure geographic heterogeneity and spatial interdependencies among risk factors. Such approaches implicitly assume homogeneity within administrative units, thereby limiting their explanatory power in capturing localized vulnerability patterns, spatial clustering of risks, and

neighborhood effects that influence MSME resilience (Ptak-Chmielewska & Chłoń-Domińczak, 2021; Supriyanto et al., 2017).

Spatial analysis enables the identification of place-based risk concentrations, spatial spillovers, and structural inequalities that cannot be detected through non-spatial descriptive or financial analyses alone. In the context of MSMEs, risk is not only a firm-level attribute but also a spatially embedded phenomenon influenced by access to infrastructure, markets, labor pools, and regulatory services (Wang, 2023). Therefore, the integration of GIS-based spatial modeling provides an analytical lens to advance MSME risk research beyond policy inventory toward scientific explanation. This research focuses on Majene Regency due to the urgent need to develop an adaptive and interactive risk mapping model (Kaluge, 2023), based on local characteristics, to support sustainable MSME development (Wang, 2023). This study formulates three main questions. (1) How can MSMEs in Majene Regency be classified based on business type and scale, as well as the risk profile inherent in each classification? (2) What multidimensional factors (HR, capital, production, marketing, legality) most significantly influence the risk level of MSMEs in Majene Regency, and how are they spatially related? (3) How can a webGIS model be designed to visualize and analyze the distribution of MSME risks interactively, as well as simulate the impact of intervention policies?

Research on MSME risks has been widely conducted, but most studies focus on financial or marketing aspects. This study broadens the scope by integrating relevant Human Resources (HR) (Nawangsari et al., 2023) and legality factors (Kwartati et al., 2024; Jikrillah et al., 2024) within the context of global competition and MSME protection. Furthermore, previous WebGIS-based MSME studies have primarily focused on location mapping, business distribution, or promotional functions, often treating risk dimensions independently and descriptively (Aini & Pribadi, 2021; Ayu & Novio, 2023). Methodologically, these studies rarely examine how human resources capacity, legal status, and market exposure interact simultaneously to shape MSME vulnerability patterns. Moreover, legality and human resource factors are frequently excluded or treated as binary attributes, resulting in limited theoretical insight into multidimensional risk dynamics.

This study addresses these limitations by integrating Human Resources (HR), legality, and other operational dimensions into a unified spatial risk framework. The novelty of this research lies in the development of an innovative webGIS model (Aziz et al., 2024; Prayuda et al., 2024) featuring a policy simulation feature, which has not been extensively explored in previous research. The theoretical implication of this integration lies in conceptualizing MSME risk as a multidimensional and spatially contingent system, rather than as isolated sectoral or financial weaknesses. This approach contributes to MSME risk theory by providing a comprehensive spatial-based decision support tool for the sustainable development of MSMEs (Nurlaili et al., 2024) in Majene Regency. .

2. METHODS

This research is positioned within a qualitative case study framework (Al Attqia et al., 2024; Roren et al., 2025), the analytical procedures combine qualitative field-based data collection with quantitative descriptive and classificatory techniques. Primary data were obtained through observation, interviews, and social mapping, which are characteristic of qualitative inquiry (Muhyi, 2018; Roren et al., 2025). These qualitative inputs were subsequently transformed into categorical and ordinal variables to enable descriptive statistical analysis, scoring, and cluster classification. Therefore, the methodological design can be more accurately described as a qualitative-dominant mixed-methods approach with quantitative descriptive analysis. Such integration is common in spatial socio-economic studies where qualitative understanding informs indicator construction, while quantitative techniques support pattern recognition and classification (Puntoriza & Fibriani, 2020; Atemoagbo et al., 2024). This location was chosen because it has the highest distribution of MSMEs. The research sample was determined using the purposive sampling method (Lenaini, 2021) in Banggae-Banggae Timur. The research process was divided into several main stages:

1. Social Mapping of MSME Actors

The initial step of this research focused on collecting and compiling field data through observation, interviews with stakeholders (Muhyi, 2018; Wulandari et al., 2023), and social mapping of MSMEs (Hadi et al., 2022). The main objective of this stage was to identify and obtain detailed information regarding the important characteristics of MSMEs that serve as research indicators, including business identity, type, class, activities (Sinha et al., 2024), capital and HR (Musthafa et al., 2024), as well as production processes (Wulandari et al., 2023). The final result of this stage was the creation of a database of MSME distribution based on their business type categories.
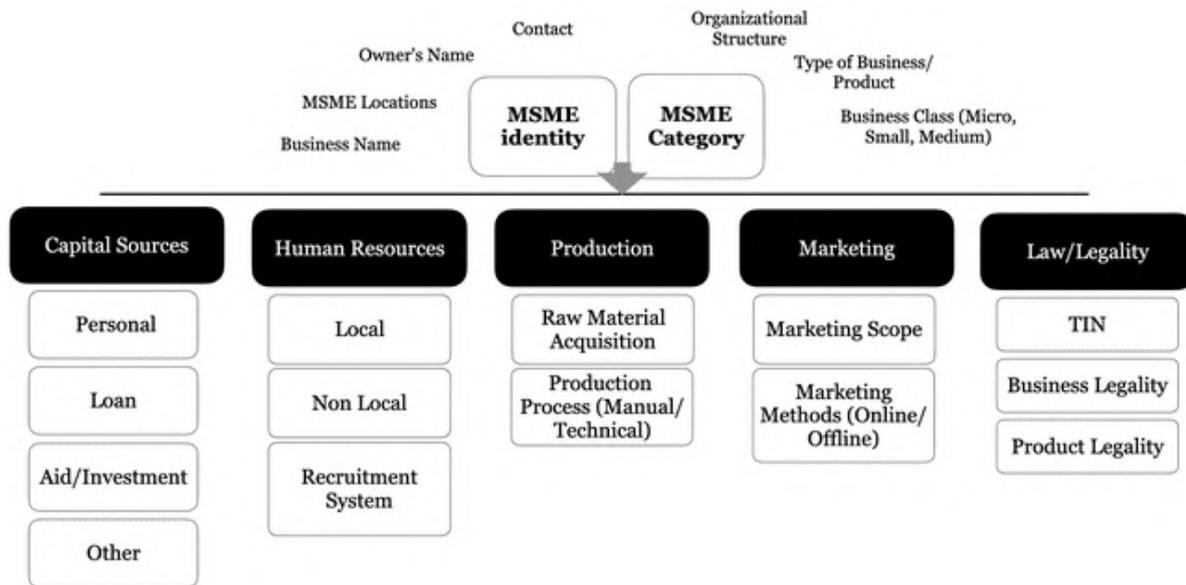

Figure 1. Conceptual Diagram of MSME Social Mapping Data Compilation

2. Analysis of MSME Characteristics

The collected data will be analyzed using the statistical cluster analysis method (Puntoriza & Fibriani, 2020; Saputra & Sahputra, 2023; Atemoagbo et al., 2024) with the SPSS v.26 application to group MSMEs that have similar characteristics. The results of this cluster analysis will be mapped geographically using GIS (Deril, 2023) with the Web Feature Service (WFS) feature (Ptak-Chmielewska & Chłoń-Domińczak, 2021; Aprudi & Murahman, 2022) to visualize the distribution of MSMEs based on their clusters.
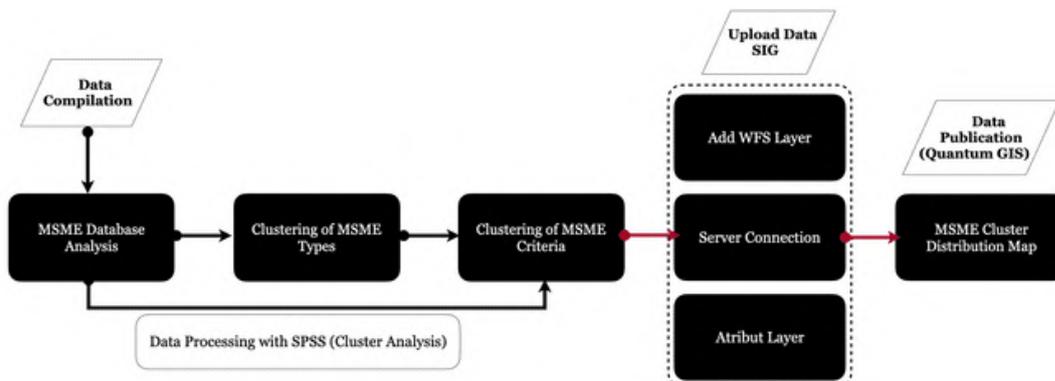

Figure 2. Conceptual Diagram of MSME Characteristics Analysis Based on WFS-QGIS

3. Analysis of MSME Potential Risk Indications

The identified MSME characteristic data will be analyzed using a risk factor ranking and predicate scoring method. This analysis will categorize MSMEs based on potential risks from the aspects of HR (Jikrillah et al., 2024), capital (Гельвих et al., 2020; Jikrillah et al., 2024), production (Fomichev, 2024), marketing (Deskys, 2023), and law/legality (Jikrillah et al., 2024). The output of this stage is the classification of MSMEs based
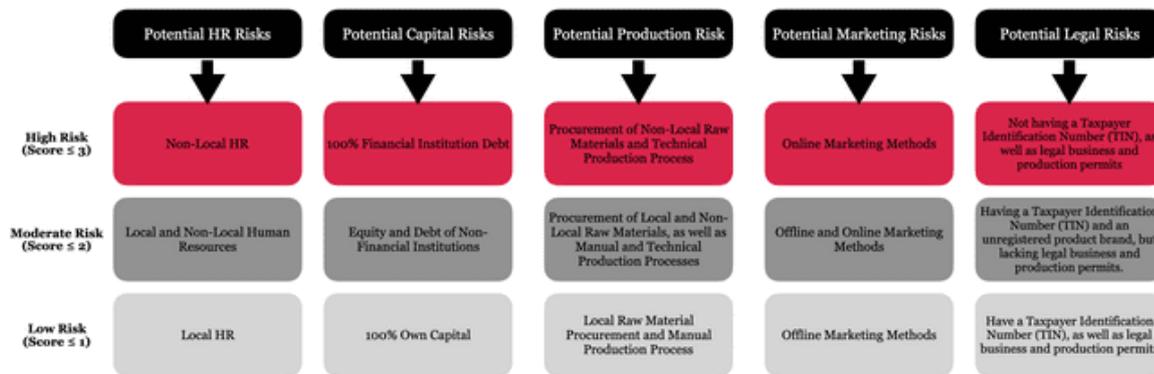
on potential risk indications.

Figure 3. Conceptual Diagram of Potential Risk Indication Analysis

The results from the scoring above will be followed up by the calculation of the total risk level score with the w (weight) component, which describes the influence of the HR dimension on the overall risk. The weight (w) is very important in multidimensional analysis because not all factors have the same impact. where: $\sum w=1$ or 100%.

The determination of weights (w) in this study was based on an empirical proportional approach derived from the observed distribution of high-risk occurrences across each risk dimension. Specifically, the weight assigned to each dimension reflects the percentage of MSMEs classified as high risk within that dimension. This data-driven weighting approach was adopted to reduce subjectivity and to ensure that the composite risk score reflects empirically dominant vulnerabilities in the study area. While expert judgment and analytic hierarchy processes (AHP) are commonly used in multidimensional risk assessment (Gelvikh et al., 2020), this study prioritizes internal consistency with observed field conditions rather than normative assumptions. Nevertheless, this approach also implies that the weighting results are context-specific and may vary across regions or samples, which constitutes a methodological limitation discussed further in the Discussion section.

4. Spatial Modeling of MSME Potential Risk Based on webGIS

This stage implements the analysis results into webGIS-based modeling. This modeling will categorize MSMEs based on risk levels (high, medium, and low) for each category. The output of this stage is a spatial

map of MSME distribution that shows potential risks in the form of a digitized webGIS system (Ayu & Novio, 2023; Saputra et al., 2024).
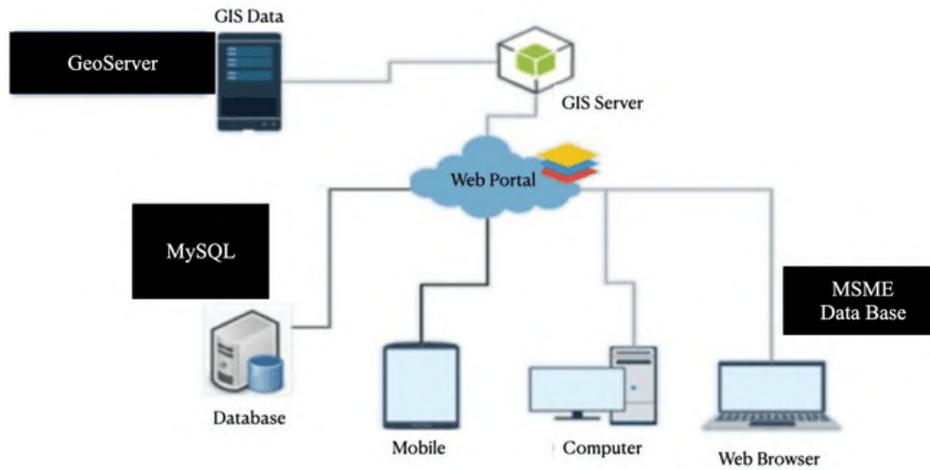

Figure 4. Conceptual Diagram of the webGIS System

3. RESULT AND DISCUSSION

This study employs a mixed-methods approach, integrating quantitative descriptive analysis and qualitative comparative evaluation to assess the potential for Transit-Oriented Development (TOD) implementation at Kiaracondong Station, Bandung Station, and Cikudapateuh Station. The methodology is structured into three phases: (1) data collection, (2) multi-criteria analysis, and (3) comparative benchmarking against global TOD standards. This approach ensures a comprehensive evaluation of land-use diversity, transport accessibility, and urban density, aligning with established TOD frameworks (Cervero & Kockelman, 1997; ITDP, 2017).

a. Characteristics and Categorization of MSMEs

MSME categorization was conducted based on characteristic similarities using K-means cluster analysis (grouping) with 4 main categories. This was done to understand the distribution characteristics of the MSME economic sectors in Majene Regency. The data shows a strong dominance from the food/culinary and retail trade sectors. Therefore, the analysis results can be detailed in the following table.

Table 1: Categorization of MSME Characteristics by Sector

Category Sector	Description of Business Type	Presentation	Information
A. Food and Beverages (Culinary/Food)	Snack Business (Crackers, Wet/Dry Cakes), Drinks (Ice Cubes), Food Stalls, Yellow Rice, Sambusa, Tempe.	Dominant (Around 60-70%)	This sector shows a high product diversity, from ready-to-eat foods to light processed foods.
B. Mixed Trading (Retail/General Trading)	Selling basic necessities, mixed (clothing, accessories), kiosks, or a mix of general merchandise.	High (Around 20-30%)	Reflecting the role of MSMEs as providers of daily needs at the local level.
C. Services	Tailor/Alterations, Haircut, Well Drilling Services.	Minority (Less than 10%)	The service sector is represented, but in smaller numbers than the production and trade sectors.

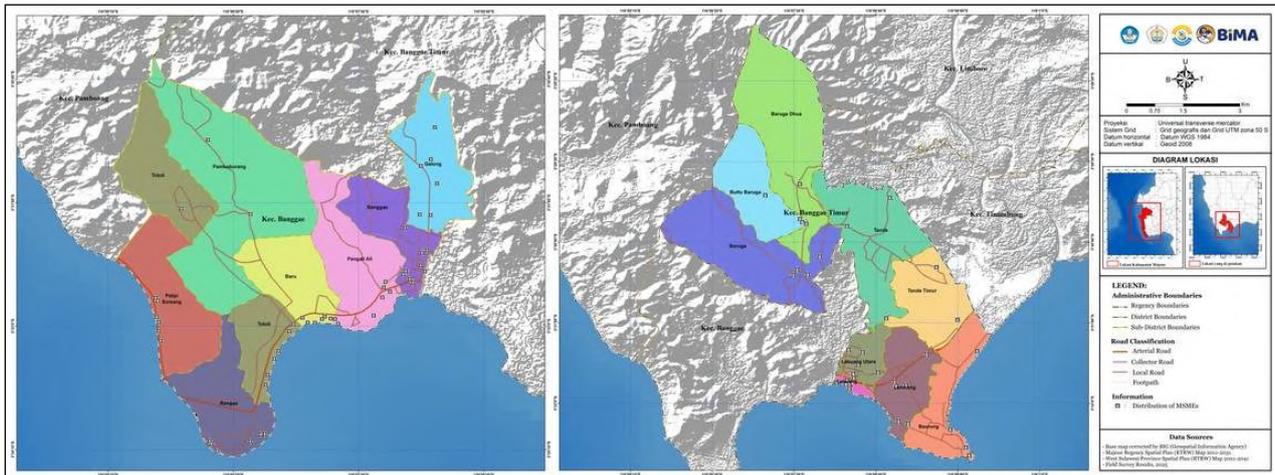| Category Sector	Description of Business Type	Presentation	Information
D. Manufacturing/Primary Production	Coconut oil, banana processing	Minority	Indicates production activities of raw materials or primary processed products that are specific to the region.

Figure 5. Spatial Distribution Map of Urban MSMEs in Majene: (a) Banggae District; and (b) Banggae Timur District

b. MSME Potential Risk Level

Risk management in Small and Medium Enterprises (SMEs) is an important process of identifying, assessing, managing, and mitigating risks that can affect business performance and continuity. SMEs often face unique challenges, including resource and liquidity limitations, making risk management crucial for maintaining the sustainability of the SME business (Crovini, 2019; Ahmad & Teo, 2024). Effective risk management helps SMEs reduce potential financial losses (Ciocoiu et al., 2024), increase business resilience, and enable them to run their operations (Gupta et al., 2024) more successfully in the face of uncertainty. It can also enhance the ability of SMEs to gain access to financing and compete in an increasingly complex market. As for some of the identification results of the MSME potential risk levels in Majene Regency, reviewed from several crucial aspects, they include:

1) Human Resources (HR) Risk

The human resources risk referred to that can pose a disaster risk is the origin of the HR, namely whether they come from the same local city as the MSME, from a non-local city different from the MSME's location, or a mixture of both local and non-local. This needs to be considered in relation to the amount of salary that must be paid and the level of HR turnover in supporting a business. Based on the results of the weighting analysis conducted, it was concluded that from a total of 88 MSME samples, 64.77% have a **High** HR risk level, with the percentage breakdown by business sector available in Table 2 below. Meanwhile, the spatial mapping of the MSME distribution resulting from the HR risk level analysis of the 100 samples conducted can be seen in Figure 6 below.

Table 2: Composite HR Risk Level

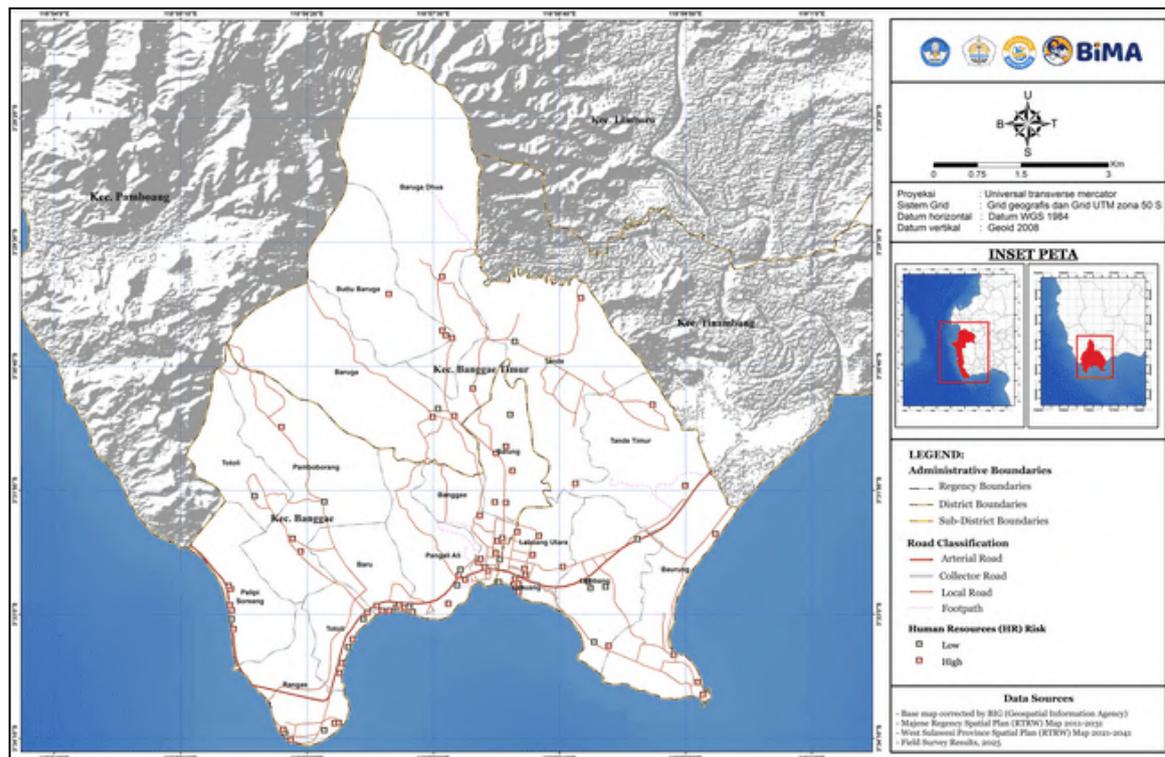| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	68.89%	24.44%	6.67%
B. Mixed Trading (Retail/General Trading)	25	56.00%	32.00%	12.00%
C. Services	6	66.67%	16.67%	16.67%
D. Manufacturing/Primary Production	12	66.67%	25.00%	8.33%
Total UMKM	**88**	**64.77%**	**26.14%**	**9.09%**

Figure 6. Distribution of MSME HR Potential Risk

The dominance of high human resource (HR) risk reflects structural labor constraints rather than individual managerial shortcomings. Most MSMEs in Majene Regency rely on informal labor arrangements, limited skill diversification, and owner-centered decision-making. The high HR risk is particularly pronounced in food, manufacturing, and service sectors, where operational continuity depends heavily on a small number of workers or even a single individual. Structurally, this condition indicates a weak local labor ecosystem characterized by limited access to vocational training, low labor mobility, and minimal institutional support for skill upgrading. In such a context, MSMEs are highly vulnerable to labor turnover, health-related disruptions, and productivity stagnation. The spatial clustering of HR risk further suggests that these vulnerabilities are embedded in specific urban areas with limited human capital circulation, reinforcing persistent risk patterns across neighboring MSMEs.

2) Capital Risk

Capital/financial risk is one of the potential risks faced by MSMEs. This risk has the potential to harm the entire business. This is inseparable from the fact that micro, small, and medium enterprises are classified based on their assets and generated profits. A lack of capital to develop the business can hinder the growth and

development rate of MSMEs. A stable and healthy financial condition is the key to MSME success. Based on the results of the weighting analysis conducted, it was concluded that from a total of 88 MSME samples, 64.77% have a **Medium** capital risk level, with the percentage breakdown by business sector available in Table 3 below. Meanwhile, the spatial mapping of the MSME distribution resulting from the Capital risk level analysis of the 100 samples conducted can be seen in Figure 7 below

Table 3: Composite Capital Risk Level

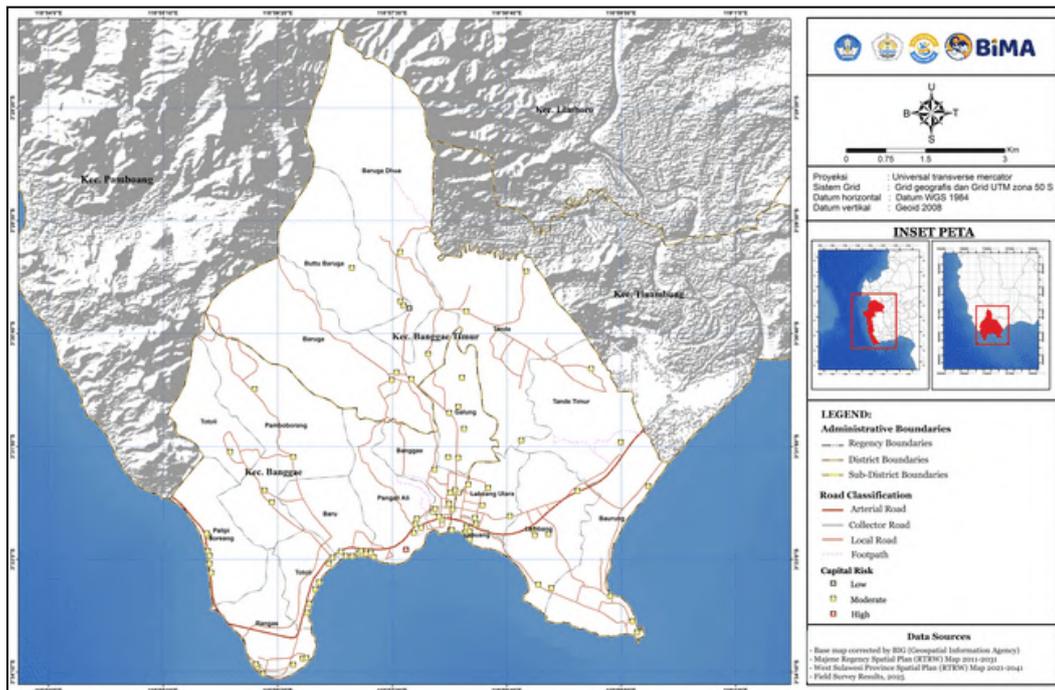| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	28.89%	66.67%	4.44%
B. Mixed Trading (Retail/General Trading)	25	28.00%	60.00%	12.00%
C. Services	6	16.67%	66.67%	16.67%
D. Manufacturing/Primary Production	12	25.00%	66.67%	8.33%
Total UMKM	**88**	**27.27%**	**64.77%**	**7.95%**

Figure 7. Distribution of MSME Potential Capital Risk

Although capital risk is predominantly categorized as moderate, the significant proportion of medium-risk MSMEs indicates persistent structural constraints in access to formal financing. Most MSMEs depend on personal savings or informal lending, which limits their ability to scale operations or absorb external shocks. From a structural standpoint, this reflects conditions of local financial exclusion, where MSMEs without adequate documentation, collateral, or legal recognition face barriers to accessing banking services and government credit schemes. Capital risk therefore acts as a reinforcing factor, amplifying vulnerabilities in production, marketing, and HR development by restricting investment capacity. Spatially, MSMEs with higher capital risk tend to be concentrated in areas with limited proximity to financial institutions and business support services.

3) Production Risk

Essentially, production risk is closely related to operational risk, but it is distinguished by its focus on the output quality, which serves as the direct interface with customers. Because every business inevitably has risks, MSME actors are required to continuously anticipate and manage this vulnerability. This risk management and evaluation step must be applied consistently to ensure its impact can be minimized and does not cause significant losses to business continuity. Based on the results of the weighting analysis conducted, it was concluded that from a total of 88 MSME samples, 64.05% have a **High** production risk level, with the percentage breakdown by business sector available in Table 4 below. Meanwhile, the spatial mapping of the MSME distribution resulting from the Production risk level analysis of the 100 samples conducted can be seen in Figure 8 below.

Table 4: Composite Production Risk Level

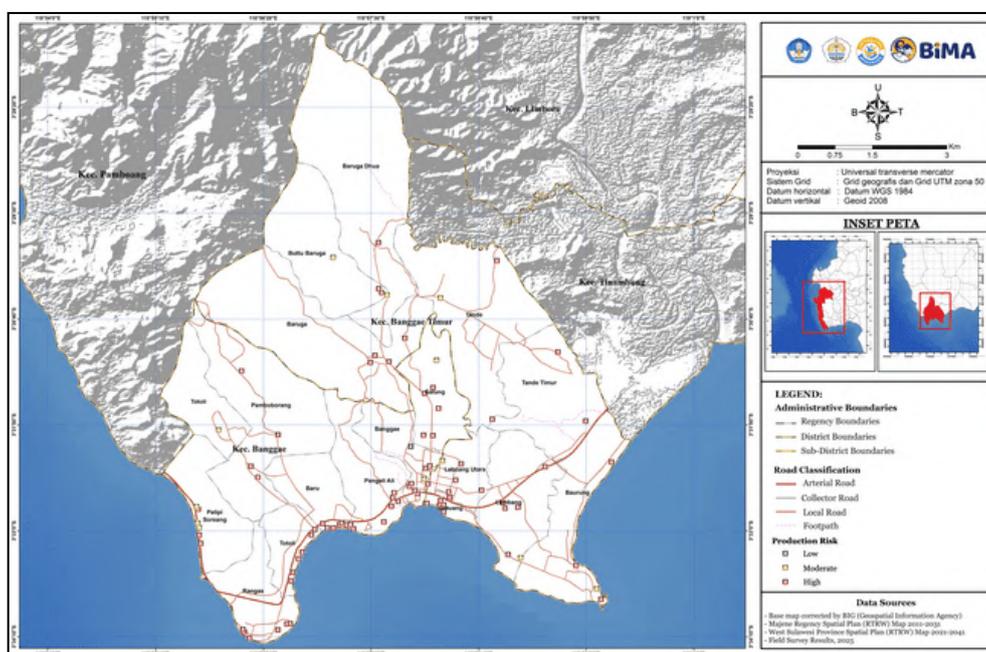| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	73.33%	22.22%	4.44%
B. Mixed Trading (Retail/General	25	52.00%	40.00%	8.00%
C. Services	6	66.67%	33.33%	0.00
D. Manufacturing/Primary Production	12	75.00%	25.00%	0.00%
Total UMKM	88	67.05%	28.41%	4.55%

Figure 8. Distribution of MSME Potential Production Risk

The prevalence of high production risk indicates that MSME production processes remain largely traditional, non-standardized, and highly dependent on individual skills. Limited access to modern equipment, technology, and quality control systems results in unstable output levels and inconsistent product quality, particularly in food processing and small-scale manufacturing sectors. The structural implication of this condition is that MSMEs operate within a high-risk production regime that restricts productivity growth and business upgrading. Production risk is spatially clustered in areas dominated by micro-scale enterprises, where technological diffusion is limited. The frequent co-occurrence of production risk with HR risk highlights the

systemic interaction between skill limitations and operational vulnerability, rather than isolated operational failures.

4) Marketing Risk

Marketing risk is the risk that arises when market prices move in an unfavorable direction, which will be detrimental to MSMEs. Generally, market risk consists of interest rate risk, commodity risk, equity risk, basis risk, and other risks. Based on the results of the weighting analysis conducted, it was concluded that from a total of 88 MSME samples, 72.73% have a **High** marketing risk level, with the percentage breakdown by business sector available in Table 5 below. Meanwhile, the spatial mapping of the MSME distribution resulting from the Marketing risk level analysis of the 100 samples conducted can be seen in Figure 9 below.

Table 5: Composite Marketing Risk Level

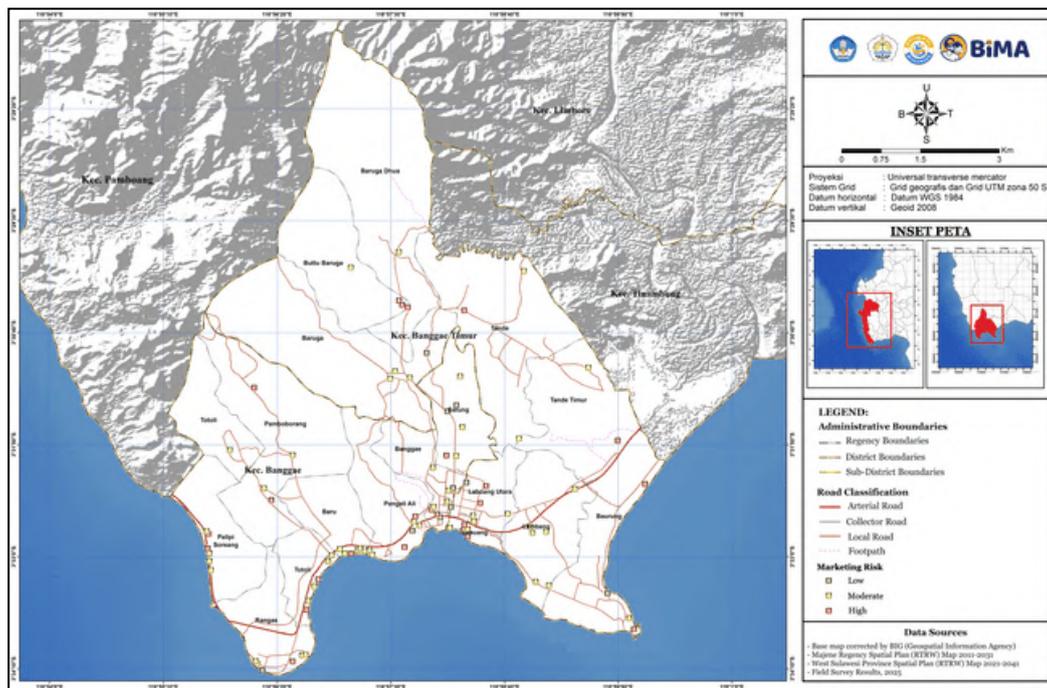| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	73.33%	22.22%	4.44%
B. Mixed Trading (Retail/General Trading)	25	72.00%	24.00%	4.00%
C. Services	6	66.67%	33.33%	0.00
D. Manufacturing/Primary Production	12	75.00%	25.00%	0.00%
Total UMKM	88	72.73%	23.86%	3.41%

Figure 9. Distribution of MSME Potential Marketing Risk

Marketing risk emerges as one of the most dominant dimensions across all MSME sectors. This indicates that MSMEs in Majene Regency predominantly operate within narrow, highly competitive local markets with low product differentiation. Limited use of digital marketing platforms, weak branding strategies, and dependence on traditional distribution channels increase exposure to demand volatility and price competition. Structurally, high marketing risk reflects unequal access to market networks, digital infrastructure, and

commercial information. MSMEs lacking legal status are often excluded from formal supply chains, e-commerce platforms, and institutional procurement systems, further constraining market expansion. The spatial overlap between high marketing risk and high legality risk suggests a reinforcing vulnerability loop, where institutional exclusion directly limits economic opportunities and increases exposure to market uncertainty.

5) Law/Legality Risk

Legal risk (or Law/Legality Risk) for MSMEs broadly covers compliance with taxation and business operational regulations, as well as having a significant impact on formal aspects such as possessing a Taxpayer Identification Number (NPWP) and the legality of the business entity or product. Although often overlooked, compliance with these regulations is crucial; if consumers feel harmed by the product or service they received, they can use that legal basis to demand accountability from the business owner as the producer. Based on the results of the weighting analysis conducted, it was concluded that from a total of 88 MSME samples, 68.18% have a High law/legality risk level, with the percentage breakdown by business sector available in Table 6 below. Meanwhile, the spatial mapping of the MSME distribution resulting from the law/legality risk level analysis of the 100 samples conducted can be seen in Figure 10 below.

Table 6: Composite Law/Legality Risk Level

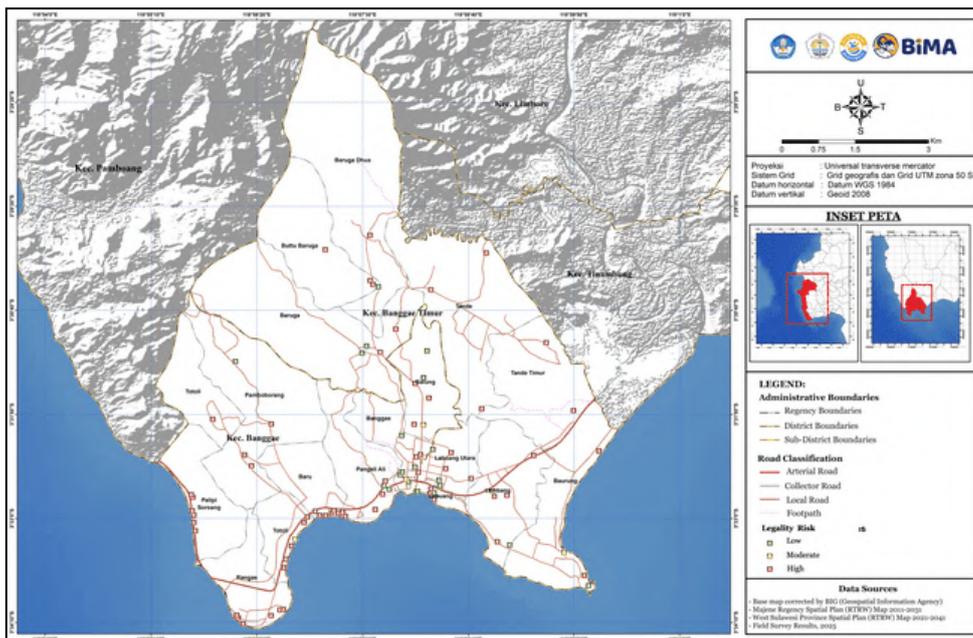| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	68.89%	22.22%	8.89%
B. Mixed Trading (Retail/General Trading)	25	68.00%	28.00%	4.00%
C. Services	6	66.67%	33.33%	0.00
D. Manufacturing/Primary Production	12	66.67%	25.00%	8.33%
Total UMKM	88	68.18%	25.00%	6.82%

Figure 10. Distribution of MSME Potential Law/Legality Risk

The dominance of high risk in the law/legality dimension represents a critical structural vulnerability. A substantial proportion of MSMEs lack basic legal documents such as business licenses, tax identification numbers, or product certifications. This condition is not merely an individual compliance issue, but reflects institutional barriers, including procedural complexity, compliance costs, and limited legal literacy among MSME actors. Structurally, high legality risk has far-reaching implications. Informal MSMEs are systematically excluded from formal markets, financial services, and government support programs, thereby intensifying vulnerabilities in other dimensions such as marketing and capital access. Spatially, the concentration of legality risk suggests that informality is territorially embedded and systemic, rather than a series of isolated firm-level decisions.

Based on the description above, MSMEs can be further classified into general risk level clusters (High, Medium, Low) by integrating the scores from the five risk dimensions (HR, Capital, Production, Marketing, and Law) using clustering principles. Where:

$$R_{Tot} = W_{HR}.R_{HR} + W_{Capital}.R_{Capital} + W_{Production}.R_{Production} + W_{Marketing}.R_{Marketing} + W_{Legality}.R_{Legality}$$

Where:

R: Risk Score or Vulnerability Level (Where: High=3, Medium=2, Low=1).; and

W: The weight given to each risk dimension. The weight (w) is very important in multidimensional analysis because not all factors have the same impact. The results of the weight calculation are based on the high-risk analysis results for each variable and can be detailed as follows.

Table 7: MSME Risk Weight based on Main Variables

Variable	Description	Score
wHR	Influence of the HR dimension on the overall risk	64.77%
wCapital	Influence of the Capital dimension on the overall risk	27.27%
wProduction	Influence of the Production dimension on the overall risk	67.05%
wMarketing	Influence of the Marketing dimension on the overall risk	72.73%
wLegalityt	Influence of the Law dimension on the overall risk	68.18%

Based on the calculation results above, a recapitulation of the overall MSME risk level is obtained, based on the 5 variables which can be detailed in Table 8 and Figure 11 below.

Table 8: Composite Percentage of MSME Risk Level

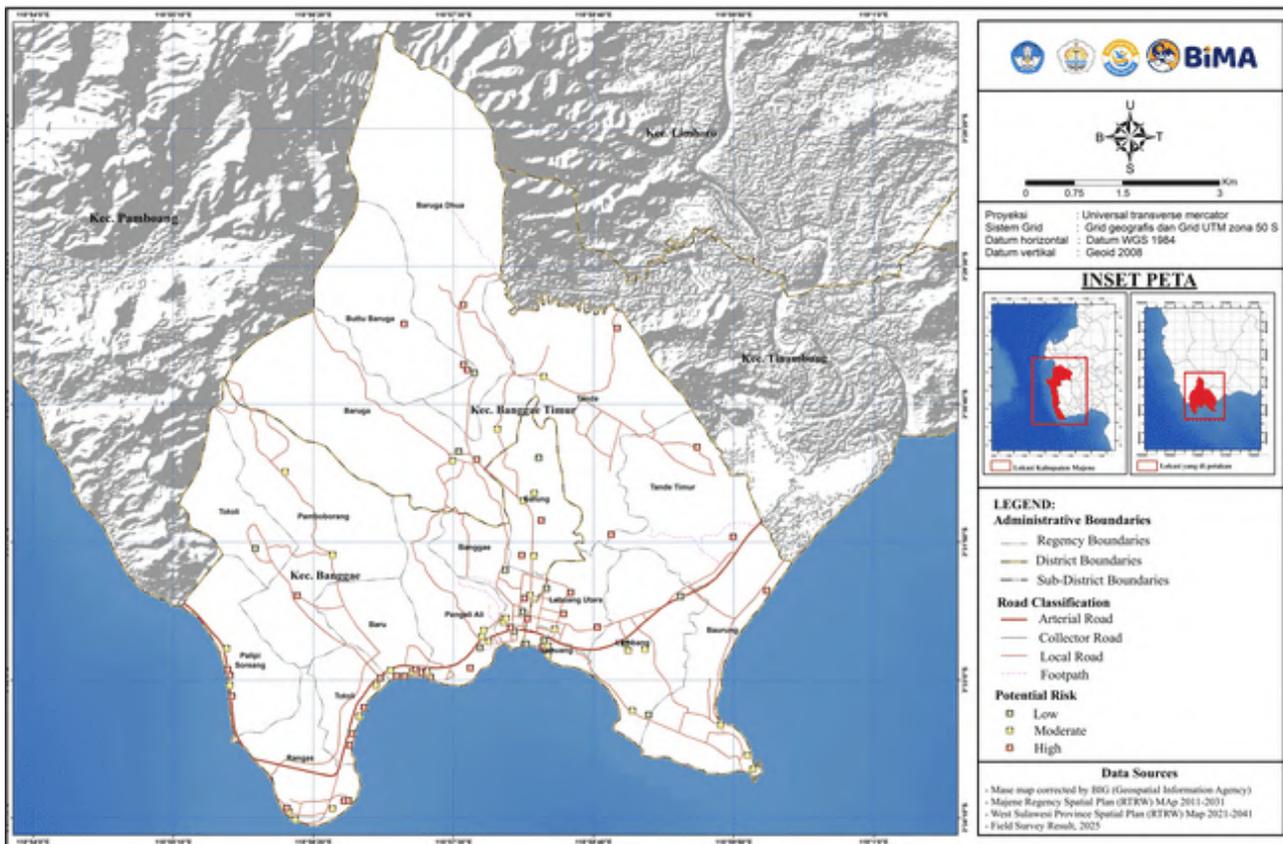| Category Sector	MSME	risk level percentage		
		High	Moderate	Low
A. Food and Beverages (Culinary/Food)	45	40.00%	40.00%	20.00%
B. Mixed Trading (Retail/General Trading)	25	51.72%	41.38%	6.90%
C. Services	6	60.00%	20.00%	20.00%
D. Manufacturing/Primary Production	12	77.78%	0.00%	22.22%
Total UMKM	88	50.00%	34.09%	15.91%

Figure 11. Distribution of MSME Potential Risk

The analysis results above illustrate that although the vulnerability of MSMEs in Majene varies greatly by sector, in general, it is still dominated by an aggregate high risk of around 50%, with the following conclusions: The Manufacturing/Primary Production sector shows the most extreme composite vulnerability, with 77.78% of MSMEs falling into the High Risk category. This indicates that processing or goods production businesses (such as coconut oil, machetes/knives, or coconut shells) simultaneously face serious challenges in HR, Production, Marketing, and Legality. The Services sector shows 60.00% of MSMEs are in the High Risk category. The measured service businesses (such as tailors, barbershops, or well drilling services) are considered highly vulnerable, most likely due to factors of dependence on a single skill and legality. The Mixed Trade sector is percentage-wise slightly lower than Services and Manufacturing, but this sector has more than half of its MSMEs at High Risk (51.72%), which is generally driven by high Marketing (competition) and Legality risks; and The Food & Beverage sector shows the most even risk distribution, with equally strong percentages of High and Medium Risk (40.00%). This indicates a polarization, where some culinary MSMEs

have achieved moderate stability, while a large portion of others are still struggling with vulnerabilities across various dimensions.

The dominance of high-risk categories across multiple dimensions suggests the presence of systemic and structural vulnerabilities rather than isolated firm-level weaknesses. The prevalence of high HR, marketing, and legality risks indicates limited access to skilled labor, formal regulatory systems, and competitive market networks, particularly in urban MSME clusters dominated by micro-scale enterprises. The spatial concentration of high-risk MSMEs reflects cumulative disadvantage effects, where multiple risk dimensions overlap within the same geographic areas. For example, areas with high marketing risk also tend to exhibit legality and HR constraints, suggesting interdependence among risk dimensions rather than independent occurrence (Ciocoiu et al., 2024; Gupta et al., 2024). The interaction between legality and marketing risks highlights a structural issue: informal MSMEs face restricted market expansion opportunities due to limited legal recognition, which in turn reinforces their vulnerability. Similarly, high production risk in manufacturing and food sectors is closely associated with HR limitations and lack of standardized processes.

The consistently high-risk levels observed across most dimensions suggest that MSME vulnerability in Majene Regency is structurally embedded rather than episodic. This challenges conventional MSME risk models that emphasize managerial or financial deficiencies alone. From a theoretical perspective, the findings support the argument that MSME risk should be conceptualized as a spatially mediated, multidimensional phenomenon shaped by institutional access, labor structure, and market geography. The scoring–clustering approach used in this study, while effective for classification, may oversimplify dynamic risk interactions and should be complemented by longitudinal or relational analyses in future research.

c. Spatial Modeling of MSME Risk Distribution Based on webGIS

In this digital era, the mapping of MSME units can now be done online through a website-based Geographic Information System (GIS). This WebGIS implementation provides users with easy access to obtain information and find the location of MSMEs anytime and from anywhere (Aini & Pribadi, 2021; Achmad et al., 2022). Furthermore, this mapping not only facilitates easier planning and decision-making but also expands the reach of MSME mapping data. Specifically, the use of WebGIS is also effective as a promotional and marketing tool for MSMEs (Ayu & Novio, 2023; Huda et al., 2024). In this system, essential MSME data such as location, business type, products, and related details are collected, managed, and visualized through interactive maps available on the website (Satria et al., 2021).

LensaUMKM WebGIS is built on the Laravel code framework, a PHP framework chosen because it provides efficient and expressive syntax to accelerate web application development. For geographic visualization, this application relies on Leaflet.js as the main mapping library. The main map page displays online Google Maps and various interactive features. The main interface is designed simply, displaying three separate icons representing MSME risk categories (high, medium, and low). The high-risk icon is shown with a red point, medium risk with an orange point, and low risk is shown with a green point. The assistance feature provided is a search for multidimensional risk variables (HR, capital, production, marketing, and business law/legality) which is equipped with detailed MSME information to describe their characteristics. In addition, there is supplementary information in the form of a "View on Google Maps" link in the info marker, which functions to direct visitors to a direct Google Maps display with the coordinates of the MSME location in a satellite imagery view. An overview of the webGIS compiled based on the analysis of characteristics and potential risk indications of MSMEs in Majene Regency can be seen in the following figure:
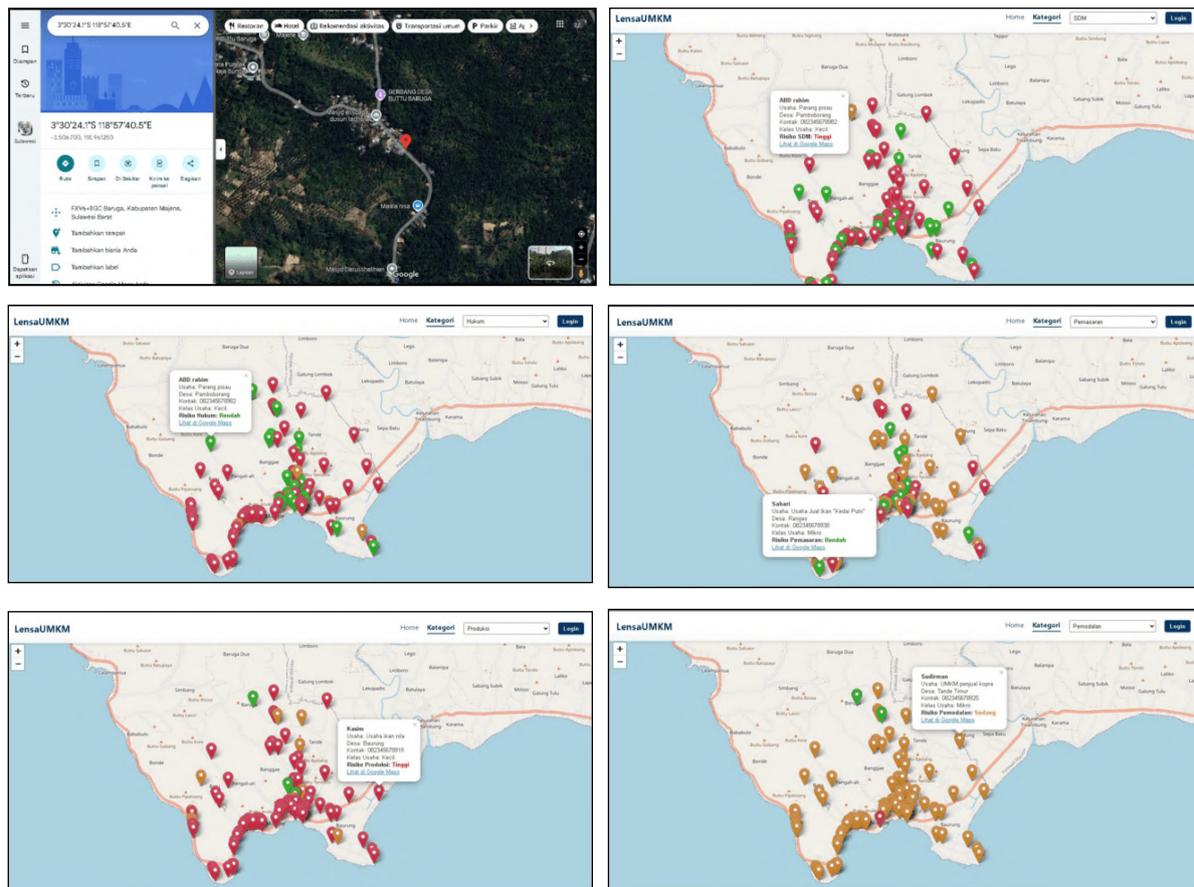
Figure 12. Interface Design of the LensaUMKM webGIS Spatial Modeling for Majene
Regency Based on MSME Risk Level

This study contributes to MSME risk theory by integrating spatial planning perspectives into risk assessment, emphasizing that vulnerability is not only firm-specific but also place-dependent. For spatial planning, the WebGIS-based risk model provides an analytical bridge between MSME development strategies and territorial planning, enabling targeted, location-specific interventions..

4. CONCLUSIONS

This section will present the analysis results based on the previously determined methods. The results section comprises six subsections: mixed land use, density analysis, public transport services, design (accessibility), building intensity analysis, and a comparative analysis of the three stations.

In general, based on the analysis of MSME characteristics in Majene Regency, they are divided into 4 business sector groups (clusters), namely: food and beverage, mixed trade, the services sector, and manufacturing/primary production, dominated by micro and small enterprises. This indicates that the local economy in Majene Regency is fundamentally still very limited and has not contributed much to the regency's regional economy. This may be caused by the lack of relevant, well-targeted government assistance/MSME development programs. Thus, as a form of further analysis, an identification of MSME risk vulnerability was carried out based on multidimensional factors, referring to the 5 main variables (HR, capital, production, marketing, and law/legality).

Based on the analysis of vulnerability and risk levels for each of these variables, they can be grouped into 3 risk clusters, including:

- Cluster I: High-Risk Cluster, with the general characteristic that the majority of risk scores are high (3 out of 5 dimensions or more), making this group highly vulnerable and requiring immediate intervention. Almost all MSMEs in this cluster have a High Law/Legality Risk score (due to "No legality documents") and are often accompanied by High HR Risk or High Production Risk (e.g., Selling Food/Bura, Selling Ice Cubes, "Anugrah" Ketupat Business).

- Cluster II: Medium-Risk Cluster, with the general characteristic that risk scores are dominated by a combination of Medium and High, with the number of high-risk dimensions being less than 3, and having the potential for increased risk if unsupported. Preventive interventions and capacity building are greatly needed. In this cluster, this generally occurs in the Capital and Marketing dimensions, while Law Risk remains High.

- Cluster III: Low-Risk Cluster, with the general characteristic that the majority of risk scores (3 out of 5 dimensions or more) are Low, making the business relatively stable and able to serve as a best practice model. This minority group of MSMEs is in the cluster that has better legality and more structured management.

Initial observations indicate that the majority of MSMEs in Majene Regency fall into the High-Risk Cluster (Cluster I), driven by universal vulnerability in the Law/Legality dimension and high risks in the HR and Production dimensions, especially in the Food/Beverage sector. This categorization will be a key input in the Spatial Modeling phase to visualize the distribution of risk clusters in the Majene region. Overall, the dominance of high risk across multiple dimensions indicates that MSME vulnerability in Majene Regency is multidimensional, interdependent, and structurally embedded within local spatial and institutional contexts. Risks do not occur independently, but accumulate through interacting mechanisms involving human capital, production capacity, market access, financial inclusion, and regulatory statusThese findings support the argument that spatially enabled risk analysis using WebGIS functions not only as a visualization tool, but as an analytical framework for understanding cumulative and place-based MSME vulnerability. Consequently, the contribution of this study extends beyond descriptive mapping, offering insights into the structural dynamics of MSME risk that are relevant for spatial planning, targeted policy intervention, and theoretical development in MSME risk studies.

Furthermore, this study does not include sensitivity testing of the weighting scheme or comparative statistical testing across sectors or subregions. As a result, the findings primarily function as a spatially informed risk diagnosis rather than a causal model. However, the analytical framework developed has strong potential for further advancement. Future studies may incorporate sensitivity analysis, scenario simulation, or inferential spatial statistics (e.g., spatial autocorrelation or regression) to strengthen explanatory power and theoretical contribution.

5. ACKNOWLEDGMENTS

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