The Eastasouth Management and Business
Vol. 4, No. 02, January 2026, pp. 367 – 388
ISSN: 2985-7120, DOI: 10.58812/esmb.v4i02

Optimizing Food Distribution Facility Inspections in the Archipelagic Working Area of Loka Pom Tanimbar Through Geographic Information Systems and Social Network Analysis

Anton Dwi Nurcahyo[1], Sri Widiyanesti[2]
[1,2] Distance Learning Master of Management Study Program, School of Economics and Business, Telkom University, Indonesia

Article Info

Article history:

Received Dec, 2025
Revised Jan, 2026
Accepted Jan, 2026

Keywords:

Archipelago Region;
Food Distribution Facilities;
Geographic Information System;
Inspection Optimization;
Social Network Analysis

ABSTRACT

The geographic conditions of the archipelagic region within the working area of Loka POM Tanimbar, combined with limited access to transportation and infrastructure, have led to uneven coverage in food distribution facility inspections. Data from these inspections reveal that the risk to food safety remains relatively high, as supervision has not been fully risk-based or regionally targeted. As such, optimizing inspections is crucial for improving business compliance with regulations and enhancing public protection. This study aims to identify the vulnerability profile of non-compliant food distribution facilities at the sub-district level, analyze the characteristics of the inspection network, and provide actionable recommendations for optimizing food distribution facility inspections through spatial and social network analysis. Using a descriptive quantitative method and Geographic Information System (GIS) approach with QGIS, along with the SIPT database from BPOM, spatial analysis through Hot Spot Analysis (Getis-Ord Gi*) and Global Moran's I in ArcGIS identified patterns of vulnerability in food distribution. Social Network Analysis with Gephi assessed the inspection network structure. The results showed that inspections were focused in administrative and economic centers like Tanimbar Selatan and Moa Lakor, with 13 sub-districts remaining unreached, creating blind spots for non-compliant food circulation. Expired products were the predominant issue, indicating poor stock management and internal control among business operators. Spatial analysis pinpointed Tanimbar Selatan as a high-risk hotspot, while network analysis revealed a centralized inspection structure lacking horizontal connectivity between regions. The study's main contribution is recommending a spatial- and risk-based inspection strategy that is adaptive to the unique geographical challenges of archipelagic regions, emphasizing horizontal connectivity, sub-district clustering, and integrating GIS and social network analysis for adaptive, data-driven, and sustainable supervision.

Corresponding Author:

Name: Anton Dwi Nurcahyo
Institution: Distance Learning Master of Management Study Program, School of Economics and Business, Telkom University, Indonesia
Emai: antondwi@student.telkomuniversity.ac.id

1. INTRODUCTION

Industries globally and in Indonesia face the reality of the free trade era. On the other hand, the Food and Drug industry is one of the significant contributors to Gross Domestic Product (GDP), specifically at 34.33%, with the food and beverage industry having growth at 9.23% within 2017, which is the highest compared to other non-oil and gas industries and grew from 8.46% within the previous year with the chemical, pharmaceuticals, and traditional medicines industries having growth at 4.53% [1]. As such, the supervision of food distribution is one of the critical aspects within the context of the aftermarket surveillance system aiming at allowing products on the market to meet specific criteria on safety and quality and efficiency parameters. As such, the Food and Drug Supervisory Agency (BPOM) deals with the supervision of products from production to the consumption stage through supervisory activities within the premarket and aftermarket stages aiming at securing the public from the threat posed by illegal and harmful products [2]. In reference to Presidential Regulation Number 80 within the year 2017, the Food and Drug Supervisory Agency (BPOM) is a non-ministerial state agency entrusted with handling government business within the field of supervising drugs and foods with administrative responsibilities deriving from the president through the ministrer handling government business within the field of health [3].

BPOM is responsible for controlling drugs and food products in accordance with laws and bylaws: drugs and active pharmaceutical ingredients; narcotics; psychotropic substances; precursors; addictive substances; traditional medicines; health supplements; cosmetics; and processed foods and through several strategic processes such as standardization; product registration; inspection of facilities and products; laboratory testing; and law enforcement for products either prior to obtaining a Distribution Permit Number (NIE) and after obtaining the permit [1]. In this context, "Loka POM Tanimbar is a Technical Implementation Unit (UPT) at the National Agency of Drug and Food Control (BPOM), established under the terms and conditions outlined by the BPOM Regulation Number 22 of 2020 on Organization and Work Procedures for all UPT under and responsible to the Head of the Agency; and with strategic and technical supervision from the Deputy within the scope of duties and administrative supervision by Principal Secretary." Loka POM Tanimbar was established on September 16th, 2018 and is stationed at Saumlaki with a supervisory domain that embraces Tanimbar Islands and Southwest Maluku Regency [1].

As the Technical Implementation Unit, Loka POM Tanimbar bears the responsibility for carrying drug and food control policies into action. That is, inspecting distribution centers and pharmaceutical services, serving as the frontline for consumer protection. Oversight gradually unfolds, from premarket to postmarket, guided at the level of business actors, with good distribution practices enforced, facility inspections for drugs, traditional medicines, cosmetics, health supplements, and food, plus sampling, lab testing, and enforcing administrative sanctions. Those sanctions can include a distribution ban, product recall, revocation of permit, confiscation, and destruction.

Business actors are central in ensuring that products are safe, effective, or beneficial and of a high quality through compliance with standards and ongoing guidance. BPOM's food supervision primarily targets processed foods, defined as items produced through a process with or without additives, under technical regulations that cover safe and hygienic distribution, storage, transportation, and display. In this framework, the jurisdiction of Loka POM Tanimbar-including the Tanimbar Islands Regency and Southwest Maluku Regency-presents particular challenges. That area is dominated by water, including a lot of inhabited and uninhabited isles; villages spread across many subdistricts pose a challenge in terms of access, connectivity, and comprehensive territorial coverage.

For planning, the Tanimbar Loka POM monitoring framework was developed in line with the 2020-2024 RPJMN to guide the 2020-2024 Renstra Badan POM. It was then adopted as the 2021-2024 Renstra Loka POM Tanimbar, RKT, and the 2024 Performance Agreement (PK), listing a vision, mission, strategic objectives, strategies, policies, programs, activities, and performance indicators [4]. Performance is measured annually through a Performance Report (Lapkin) as accountability. In 2024, Loka POM Tanimbar set nine targets for activities and 25 performance indicators, including one strategic objective, which is to "improve effectiveness in inspections of drug and food facilities, along with public service". Indicators are on the percentage of implemented and followed-up inspection decisions/recommendations and the percentage of distribution facilities that meet the requirements (MK) [4]. Yet, island logistics pose real obstacles in terms of transport, weather, and geographic scope, all complicating food distribution supervision in an archipelago. As a consequence, the 2024 inspection coverage analysis may not fully reflect facility distribution across all subdistricts, risking uneven supervision in remote zones. In 2024, out of 776 food distribution facilities, only 300 were subjected to inspection, which was approximately 38.86%. This shows that the strategy for monitoring needs to be more geographically responsive to ensure fewer blind spots around high-risk facilities because of limited oversight.

Figure 1. Results of Food Distribution Facility Inspections by the Tanimbar Local POM in 2024
Source: [5]

The data in Figure 1 shows that most food distribution facilities were not inspected in 2024; of 776 food distribution facilities, only 300 facilities (38.86%) were successfully inspected, with 73% of the inspected facilities complying with distribution regulations and 27% not complying with regulations (TMK), meaning that nearly 1 in 4 inspected facilities still violated regulations, highlighting the need for risk-based supervision [5]. In the context of small and medium-scale food industries, inconsistent quality is often influenced by low quality awareness, technological limitations, and a weak quality culture in the upstream-downstream supply chain controlled by MSMEs. while in the agribusiness of island nations, supply chain risk management faces the complexities of distribution, infrastructure limitations, and potential internal and external disruptions, requiring adaptive risk management strategies to maintain food distribution resilience [6]. The geographical conditions and transportation infrastructure in the Tanimbar Loka POM working area—with offices located in Saumlaki, supervision travel time within the district is around 12 hours, to Southwest Maluku and remote villages up to

72 hours, with the main modes of transportation being ships and planes with limited schedules that are highly affected by weather, and ship waiting times that can reach two weeks to one month—make the cost and efficiency of supervision highly influenced by extreme weather, infrastructure limitations, and difficult access to remote islands [5].

[7] explains that imbalances in the distribution structure and limited connectivity between units in a supply chain system lead to concentration of activities, operational bottlenecks, and low monitoring effectiveness. This necessitates a data-driven approach, mapping, and network strengthening to improve the efficiency and performance of the system.

The working area of Loka POM Tanimbar faces challenges typical of 3T areas, particularly limitations in information technology infrastructure that impact reporting, coordination, real-time monitoring of product distribution, and public education, as uneven internet access makes the use of applications such as BPOM Mobile and online communication less than optimal. so that education must be conducted more face-to-face, with the consequences of greater time, cost, and resource requirements [4], [5]. Research in the Maluku islands shows that the geographical conditions of the islands pose serious challenges in accessing public services, making a spatial approach important for identifying service gaps and formulating data-based policies [8]. In this context, the complexity of the food distribution chain in Tanimbar, which has many distribution points, limited infrastructure, and accessibility, requires a monitoring system that is not only spatial-based but also has high data transparency. Blockchain-based traceability technology offers secure, transparent, and real-time product status recording, so that quality discrepancies or distribution violations can be immediately detected and followed up in an accountable manner [9].

The use of GIS has proven effective in mapping contamination risks, supporting spatial-temporal audits, identifying clusters of violation-prone areas, and strengthening prevention policies [10]–[13]. while spatial mapping with GIS plays an important role in identifying areas with high food insecurity and serves as a basis for policies and interventions in priority areas [14]–[16]. Previous studies have also shown that the integration of spatial and social network analysis (GIS–SNA) is effective for identifying patterns of vulnerability influenced by environmental factors and social relationships, including mapping disease distribution and regional vulnerability [17]–[20], while spatial network analysis and GIS encourage a shift in public health and surveillance approaches from reactive to preventive through spatial risk analysis and connectivity-based intervention design [8], [11], [13]. Based on empirical conditions in the Tanimbar Loka POM working area—namely, inspection coverage that only reaches 38.86% of 776 food distribution facilities with 27% TMK, geographical and logistical challenges in the 3T archipelago, limited transportation infrastructure and information technology, and the suboptimal use of spatial data and network analysis in surveillance planning—a gap has been identified in that inspection planning is not yet fully based on regional risk and distribution network connectivity [1], [4], [5]. On the other hand, various previous studies have consistently shown the great potential of GIS and SNA approaches to improve the effectiveness of supervision, but there has been no study that specifically integrates these two approaches to optimize the inspection of food distribution facilities in 3T island regions such as Tanimbar Islands Regency and Southwest Maluku Regency, so there is a research gap that needs to be filled. Therefore, the research questions in this study are: how to map the vulnerability profile of TMK food distribution facilities and the characteristics of the inspection network at the subdistrict level in the Tanimbar Loka POM working area, and how to formulate recommendations for optimizing inspections based on spatial and social network analysis in island regions. In line with this, the objectives of this study are: first, to identify the profile of vulnerability mapping of TMK food distribution facilities at the sub-district level; second, to analyze the characteristics of the food distribution facility inspection network at the sub-district level; and third, to develop recommendations for optimizing food distribution facility inspections based on the results of spatial and social network analysis in the Tanimbar Loka POM working area.

2. LITERATURE REVIEW

2.1 *Operations Management*

According to Heizer et al. [21], operations management is the activity of transforming inputs into valuable outputs, which in the context of Loka POM Tanimbar is the foundation for ensuring that food distribution facilities are inspected effectively and efficiently in challenging island regions. Operations management plays a strategic role in creating excellence through location effectiveness, service quality, and resource efficiency [21], with key decisions including location, process design, and quality [21]. Location strategy is crucial because it must consider island accessibility, transportation costs, extreme weather, and food distribution risks, while process design requires flexible standardization with the support of GIS and SNA-based technology, as well as continuous data-based quality control. GIS itself plays an important role in the storage, access, and analysis of spatial data to support more accurate and efficient location decision-making [21].

2.2 *Quality Management*

Quality management is a structured approach within an organization to direct activities so that products, services, and processes meet or exceed established standards [22]. with the main foundation being an evidence-based approach that emphasizes decision-making based on accurate data and information through a systematic process of data collection, analysis, and utilization [22]. Quality management systems are also greatly influenced by location factors because the distribution of goods and services depends on geographical variables such as distance, transportation infrastructure, and environmental conditions. in archipelagic regions such as the Tanimbar Islands Regency, the quality of medicine and food distribution is not only determined by production standards, but also by the effectiveness of sea transportation and storage conditions during travel, so that the application of quality management in distribution supervision needs to be adjusted to spatial or location dimensions [22].

2.3 *Location Theory*

According to Suma & Pratama [23], the concept of geographical location refers to the position of a place on earth that can be understood nominally (place name), relatively (based on site and situation), absolutely (latitude-longitude coordinates), and cognitively (individual mental perception of a place), while the concept of distance relates to the value of an object based on its distance from other objects, which includes absolute distance (physical), relative distance (time, cost, energy), and cognitive distance (perceived distance) [23]. The concept of accessibility refers to the level of ease or difficulty in reaching a location from another location, which is influenced by terrain, transportation, and interregional communication. It is explained through transportation technology theory, walking distance theory, and multimodal accessibility theory, whereby advances in transportation technology and the economy have made interregional accessibility easier, although remote villages remain more difficult to reach than urban areas [23], [24].

2.4 *Geography Theory*

Geography is a branch of science that studies the earth and all its components by explaining the similarities and differences between phenomena on land, in the oceans, and in the atmosphere, as well as human activities in the fields of economics, demography, socio-culture, and politics [23], with a focus on the study of the distribution of natural and social phenomena and how humans adapt to space and their environment through behavioral changes in response to these conditions [23]. Geography studies phenomena logically and based on empirical data through observation, analysis, explanation, and prediction of issues of spatial inequality, the environment, disasters, poverty, and sustainable development, as well as utilizing technology such as computers to collect, store, integrate, and analyze data on the earth's surface as a basis for solving various social problems [23].

2.5 *Geographic Information System Theory*

According to Longley et al. [25], GIS is a computer-based system for capturing, storing, analyzing, and presenting location-based data to support visual and quantitative spatial decision-making, including distribution mapping, risk assessment, and logistics planning. Longley et al. [25] emphasize that GIS acts as an evidence-based policy tool in public organizations to identify uninspected facilities, measure the scope of supervision, develop risk-based inspection plans, and visualize the results of supervision as a form of accountability. In the context of archipelagic regions such as the Tanimbar Islands and Southwest Maluku, GIS is a strategic technology for overcoming location and accessibility constraints through georeferenced distribution facility mapping to support equitable monitoring based on geographical evidence.

2.6 *Spatial Network Theory*

A spatial network is a graph structure in which nodes can be mapped geographically, with two main types being planar networks (nodes and edges are directly in physical space such as road networks) and non-planar networks (edges can overlap each other such as communication networks) [13]. Barthelemy [26] explains that spatial networks are a special form of complex networks that consider spatial dimensions, so that the position of nodes has functional implications such as distance, transportation costs, and accessibility, making them relevant for distribution and surveillance analysis in archipelagic regions such as the Tanimbar Islands and Southwest Maluku Regencies. Furthermore, Barthelemy [26] emphasizes that spatial networks are particularly suitable for transportation and distribution studies because they can model actual inter-island connectivity, which is influenced by maritime barriers, weather, and transportation limitations, with the support of metric analyses such as betweenness centrality for the identification of strategic nodes, shortest path analysis for modeling the shortest access, and cluster analysis for viewing the concentration of violations in spatial networks.

2.7 *Social Network Analysis Theory*

Social networks refer to systems of relationships between social entities (actors) such as individuals, groups, or organizations that are connected through various types of relationships, both on an interpersonal scale (egocentric network) and between broader entities [19]. Wasserman & Faust [27], explain that Social Network Analysis (SNA) is a methodological approach that focuses on the patterns of relationships between actors—not just on individual attributes—to understand how relationship structures shape the flow of information, goods, and influence, including in food distribution and control systems. Social networks consist of nodes as entities and edges/ties as relationships such as transactions, communication, or information flows [27], which can be analyzed through indicators such as degree centrality, betweenness centrality, closeness centrality, as well as network density and modularity to identify key actors, intermediaries, and network clusters. Furthermore, the concept of Spatial Social Network (SSN) emphasizes that nodes in social networks are also embedded in geographical space so that social relations interact with spatial dimensions, where physical proximity does not always determine the existence of social relations and vice versa [20].

2.8 Previous Research and Research Framework

Various studies show that GIS is effective for mapping risks, connectivity, and distribution in the context of food security and public services, such as TMK food clusters [28], food safety audit visualization [12], demographic-based restaurant inspections [13], household food insecurity [16], and health risk zone mapping [18]. On the other hand, SNA is used to analyze social and spatial networks in various contexts, including disease transmission and regional network analysis [17], [20], [29]. The integration of GIS and networks has proven to be capable of shifting surveillance from reactive to preventive [11], as well as strengthening distribution transparency through logistics technology [9]. However, these studies have not specifically integrated GIS and SNA for the surveillance of food distribution facilities in 3T island regions based on BPOM SIPT data, thus creating a gap that this study fills.

Island regions such as the Tanimbar Islands and Southwest Maluku Regencies face serious limitations in food distribution monitoring due to limited transportation access, uneven infrastructure, and suboptimal use of spatial and network analysis. Inspection patterns still tend to be administrative and not fully based on regional risk, opening up loopholes for the undetected circulation of TMK food. Therefore, this study adapts the integration of GIS and SNA as developed by He et al. [28] and Li et al. [13] to map geographical distribution, risk clusters, and priority nodes for surveillance based on centrality as a basis for strengthening food surveillance strategies in island regions.

Figure 2. Conceptual Framework
Source: [13], [28]

3. METHOD

3.1 *Type of Research*

This research uses a descriptive quantitative approach with a positivistic paradigm, aiming to systematically and measurably explain the phenomenon of food distribution facilities in island regions based on geographical variables and social networks through the integration of Geographic Information System (GIS) and Social Network Analysis (SNA) [30], [31]. This research is exploratory in nature with a case study strategy at Loka POM Tanimbar, using secondary data from food distribution facility inspections without direct intervention, and is not intended to test causal relationships, but rather to map, describe, and interpret phenomena correlational [32]. The unit of analysis includes organizations and individuals, with the active involvement of researchers in the entire process of data processing and analysis objectively [31], and uses a longitudinal design for the 2020–2024 period to obtain a representative overview of the monitoring profile. This approach allows for the mapping of the vulnerability of food distribution facilities with TMK status, analysis of the connectivity of inspections between island regions, and the formulation of recommendations for optimizing food distribution supervision based on regional risk [30]–[32].

3.2 *Operational Variables*

In a quantitative approach, variables derived from theoretical concepts need to be operationalized through measurement instruments in order to produce numerical data that can then be analyzed statistically [30]. All variables in this study were sourced from data on food distribution facility inspection reports in the Tanimbar Loka POM working area through the Indonesian Food and Drug Administration's Integrated Reporting Information System (SIPT) application. This study identifies three main groups of variables directly related to the results of food distribution facility inspections, namely facility classification, product finding category, and inspection result conclusions, all of which are measured on a numerical scale.

Table 1. Operational Variables

Variable	Sub-Variable	Indicator (Scale)
Classification of Facilities	Modern Retail Facility	Numeric
	Traditional Retail Facility	Numeric
	Importer/Distributor Warehouse	Numeric
Product Findings Category	Expired	Numeric
	Damaged	Numeric
Inspection Result Conclusion	Compliant (MK)	Numeric
	Non-Compliant (TMK)	Numeric
Food Distribution Facility Risk	Number of Non-Compliant (TMK)	Total TMK per sub-district (Numeric)
	Percentage of Non-Compliant (TMK)	(Number of TMK/Number of Inspections) × 100% (Numeric)
	Spatial Autocorrelation of TMK	Moran's I, z-score, p-value (Numeric)
	Regional Risk Level	Hotspot Class (Ordinal)
Inspection Network of Food Distribution Facilities	Node (Vertex)	Number of nodes (Numeric)
	Edge (Connection)	Number of connections (Numeric)
	Degree Centrality	Degree centrality value per sub-district (Numeric)
	In-Degree	In-degree value (Numeric)
	Out-Degree	Out-degree value (Numeric)
	Betweenness Centrality	Betweenness centrality value (Numeric)
	Closeness Centrality	Closeness centrality value (Numeric)

Variable	Sub-Variable	Indicator (Scale)
	Eigenvector Centrality	Eigenvector centrality value (Numeric)
	Network Density	Network density value (Numeric)
	Average Path Length	Average path length value (Numeric)
Optimization of Food Distribution Facility Inspections	Priority Area	Priority inspection sub-districts (Descriptive)
	Inspection Pattern	Adaptive inspection recommendations (Descriptive)

3.3 *Population and Sample*

The population in this study includes all food distribution facilities and inspection networks located in the working area of Loka POM Tanimbar, where the population is understood as all elements or units that are the focus of the study [32], so that all food distribution facilities in Tanimbar Islands Regency and Southwest Maluku Regency are included in the population elements. The sampling technique used was purposive sampling, which is the deliberate selection of samples based on certain criteria relevant to the research objectives [31], with a focus on food distribution facilities and inspection networks that play a central role in the food distribution system as the main unit of analysis.

3.4 *Data Collection and Data Sources*

Data collection in this study used secondary data, namely reports on the inspection of food distribution facilities in the working area of Loka POM Tanimbar through the Integrated Reporting Information System (SIPT) application of the National Agency of Drug and Food Control (Badan POM), which according to Sekaran & Bougie [32] is data collected by other parties and reused for research purposes. The reliability of secondary data was considered in terms of timeliness, accuracy, relevance, and cost efficiency [32], so that the data used was up to date, credible, relevant to the research objectives, and efficient. All data was sourced from official SIPT documents for 2020–2024 and supported by spatial data in the form of shapefiles of subdistrict administrative boundaries in the Tanimbar Islands and Southwest Maluku Regencies obtained from the official portal of the Geospatial Information Agency (BIG), making it suitable for use as the basis for spatial and network analysis in this study.

3.5 *Data Analysis Techniques*

Data analysis in this study was carried out in stages according to Creswell & Creswell [30], starting from data preparation, descriptive analysis, Geographic Information System (GIS)-based spatial analysis, to Social Network Analysis (SNA) and integrative analysis for the formulation of recommendations. Spatial analysis was performed using QGIS and ArcGIS to map the distribution of facilities, identify vulnerability patterns, and detect risk clusters through Global Moran's I and Hot Spot Analysis (Getis-Ord Gi*). Meanwhile, social network analysis was conducted using Gephi to examine the characteristics of the inspection network based on central nodes, transit lodgings, and food distribution facilities with indicators of degree, weighted degree, betweenness, eigenvector, closeness, harmonic closeness, eccentricity, and modularity class. The combined results of GIS and SNA were then integrated to determine priority subdistricts and compile recommendations for optimizing food distribution facility inspections based on regional risk.

The validity and reliability of the research were ensured through several approaches, namely the validity of data sources originating from the Integrated Reporting Information System (SIPT) of the National Agency of Drug and Food Control (BPOM) as the official national system, spatial validity through overlaying geocoding coordinates with official shapefiles from the National Geospatial Information Agency (BIG) using QGIS and Google Maps, and model validity through the consistency of spatial and network analysis results. Reliability was tested by comparing the mapping results in QGIS with ArcGIS and National Geographic Map, as well as overlaying the modularity class results from Gephi to QGIS to ensure the geographical consistency of the inspection network [31], [32]. The overlay results showed consistent distribution patterns and network clusters, thereby strengthening the credibility of the research findings.

4. RESULTS AND DISCUSSION

4.1 Descriptive Analysis with Geographic Information System Mapping

Descriptive analysis based on Geographic Information System (GIS) using QGIS 3.42.1 shows that findings of products that do not meet requirements (TMK) during the 2020–2024 period in the Tanimbar Loka POM working area were dominated by expired products, while damaged products fluctuated and were relatively smaller in number. Spatially, South Tanimbar District was the area with the highest concentration of TMK findings, followed by North Tanimbar and Moa Lakor, in line with the high number of distribution facilities and trading activities in the area. In Tanimbar Islands Regency, TMK findings were concentrated in economic activity centers, while in Southwest Maluku Regency, the distribution was more widespread with Moa Lakor as the dominant point. The low number of findings in several other subdistricts reflects the limited scope of supervision due to geographical and transportation constraints.

From a temporal perspective, the number of inspections and the proportion of TMK facilities show annual fluctuations, with a surge in the percentage of TMK in 2022 and a decline in 2024. South Tanimbar Subdistrict consistently records the highest number of MK and TMK facilities, reflecting the high intensity of surveillance as well as the high risk of food distribution that is not yet fully controlled. Meanwhile, Moa Lakor and North Tanimbar also show a fairly good level of compliance through a significant number of MK facilities. This pattern confirms that areas with high distribution activity need to be a top priority in risk-based supervision, not only based on the number of facilities, but also the proportion of violations that occur.

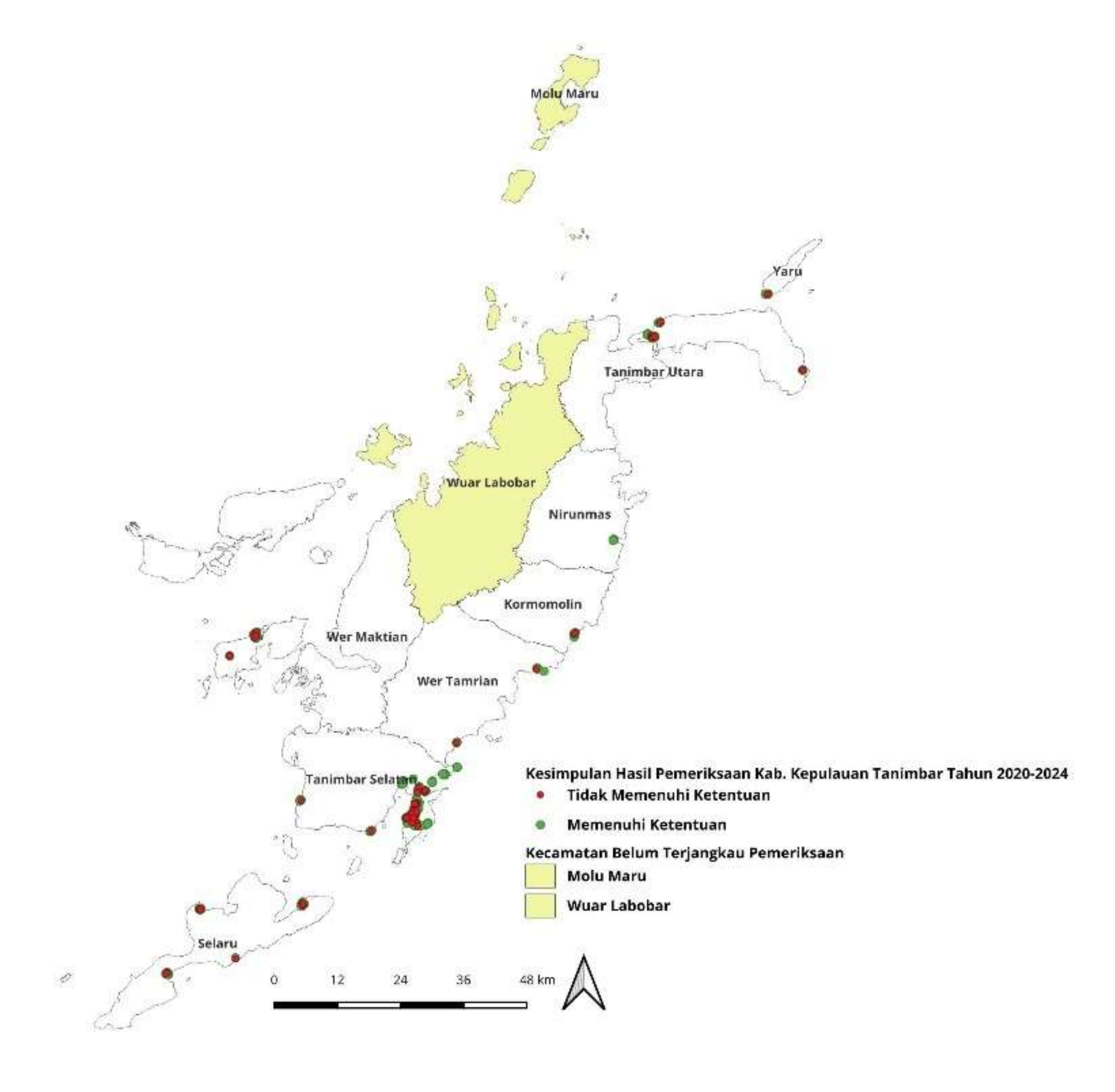

Figure 3. Map of the Results of Food Distribution Facility Inspections in Tanimbar Islands Regency for 2020–2024

Source: (Processed Data from QGIS, 2025)

The map of food distribution facility compliance over the last five years shows that each point represents an inspection location with MK and TMK categories distinguished by color codes, where the highest concentration of inspections occurred in the main land area of Tanimbar Islands Regency, particularly in South Tanimbar, North Tanimbar, and part of Kormomolin, with the highest accumulation of TMK facilities in South Tanimbar as the center of government and trade. In contrast, the West Maluku Regency (MBD) shows a much lower inspection density, with inspections generally focused on Moa Lakor District, Letti Island, and part of the Babar Islands, while most other districts have not been reached. TMK findings in MBD tend to appear in relatively accessible areas, confirming that limited sea transportation, extreme weather, and uncertain ship schedules are major obstacles to surveillance. This map clearly reveals surveillance gaps between regions, particularly in remote areas such as Damer, Dawelor Dawera, the Romang Islands, Lakor Island, Wetang Island, Wetar and its variants, Mdona Hiera, and Masela Island, which, despite having small-scale food distribution activities, are still not covered by regular surveillance and have the potential to become hidden hotspots.

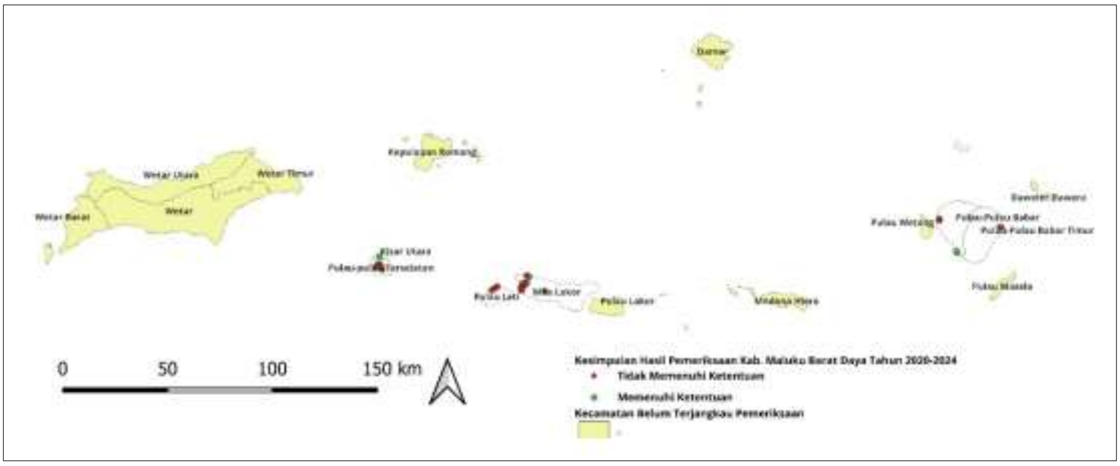

Figure 4. Map of Conclusions from the Examination of Food Distribution Facilities in Southwest Maluku Regency for 2020–2024

Source: (Processed Data from QGIS, 2025)

Figure 4 shows the spatial distribution of food distribution facilities inspected in the Southwest Maluku Islands (MBD) region over the past five years, which shows a lower density of inspection points compared to the Tanimbar Islands Regency, with inspection coverage limited to only a few subdistricts. Inspections were more focused on Moa Lakor Subdistrict and several areas on Letti Island and Babar Islands, while most other subdistricts were not covered, with TMK facilities mainly found in government centers or more accessible areas. This situation confirms the main obstacles to surveillance in MBD, such as limited access to sea transportation, extreme weather, and uncertainty regarding pioneer ship schedules, as explained in Figure 4. This map also reveals gaps in surveillance between regions, where remote areas such as Damer, Dawelor Dawera, the Romang Islands, Lakor Island, Wetang Island, Wetar, West Wetar, East Wetar, North Wetar, Mdona Hiera, and Masela Island are still not covered by regular surveillance, even though they still have food distribution activities, albeit on a small scale.

4.2 *Spatial Analysis*

Spatial analysis in this study was conducted to identify patterns of food distribution facilities that are TMK geographically in the working area of Loka POM Tanimbar (Tanimbar Islands Regency and Southwest Maluku) using a Geographic Information System (GIS) through ArcGIS with two main techniques, namely Hot Spot Analysis (Getis-Ord Gi*) and Global Moran's I. Hot Spot Analysis was used to detect high-risk areas based on both the absolute number of TMK and the percentage of TMK to the total number of inspections, while Global Moran's I was used to assess the existence of spatial autocorrelation globally. The results of the analysis show that South Tanimbar District consistently emerged as the main hotspot in several years of observation, both in terms of absolute number and percentage of TMK, in line with its position as a center of economic activity and concentration of food distribution facilities. while other areas such as North Tanimbar, Moa Lakor, Wer Tamrian, East Babar Islands, and Selaru also emerged as hotspots in certain years, mainly based on the ratio of TMK to the number of inspections. These findings confirm that surveillance efforts should not only focus on areas with the highest number of facilities, but also on areas with proportionally high levels of non-compliance, so that surveillance strategies can be developed in a more equitable, adaptive, and spatially risk-based manner.

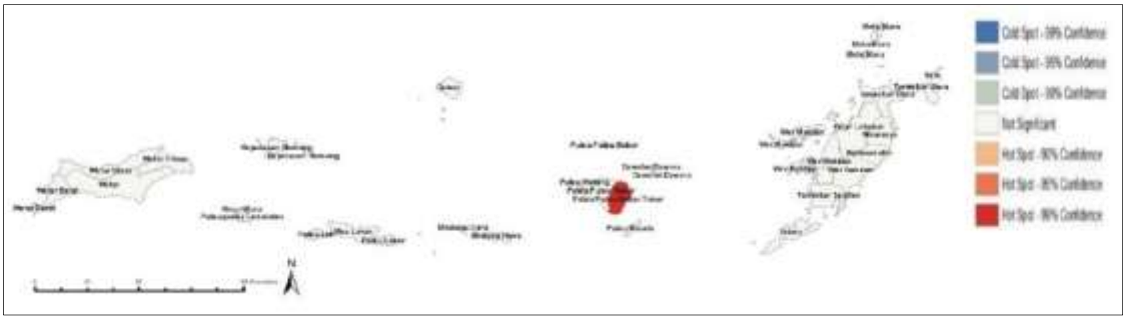

Figure 5. Hot Spot Analysis Map (Getis-Ord Gi*) Percentage of TMK to the Number of Food Distribution Facility Inspections in 2020–2024
Source: (Processed Data from ArcGIS, 2025)

Figure 6. Hot Spot Analysis Map (Getis-Ord Gi*) Number of TMK Food Distribution Facility Inspections 2020–2024
Source: (Processed Data from ArcGIS, 2025)

Figure 5 shows the results of the *Hot Spot Analysis (Getis-Ord Gi*)* based on the number of TMK food distribution facilities collected over a five-year period (2020–2024). Meanwhile, Figure 6 shows the results of the *hotspot* analysis based on the percentage of TMK to the number of inspections in the same period. In Figure 6, it appears that South Tanimbar District has consistently been the main hotspot for the absolute number of TMK. This confirms that for five consecutive years, this region has been the center of food distribution violations, largely driven by large volumes of facilities, the dominance of traditional retailers, and high product turnover. In Figure 6, based on proportion, regions such as the subdistricts in East Babar Islands emerge as significant hotspots, even though the number of inspections is low. This shows that even though inspections in these regions are low, the violation rate (TMK) is actually high in percentage terms.

4.3 *Global Moran's I Analysis*

Global Moran's I analysis is used to measure global spatial autocorrelation to determine whether the distribution of food distribution facilities with TMK in the Tanimbar Loka POM working area for the 2020–2024 period is clustered, random, or dispersed. Unlike hotspot analysis, which is local in nature, Moran's I is comprehensive (global) with a value range between +1, which indicates positive clustering, 0, which indicates a random pattern, and –1, which indicates dispersion. In this study, Global Moran's I was applied to two main variables, namely the absolute number of TMK and the percentage of TMK to the number of inspections, with the statistical test results displayed in the form of Moran's I index values, z-scores, and p-values as the basis for interpreting the overall spatial pattern.

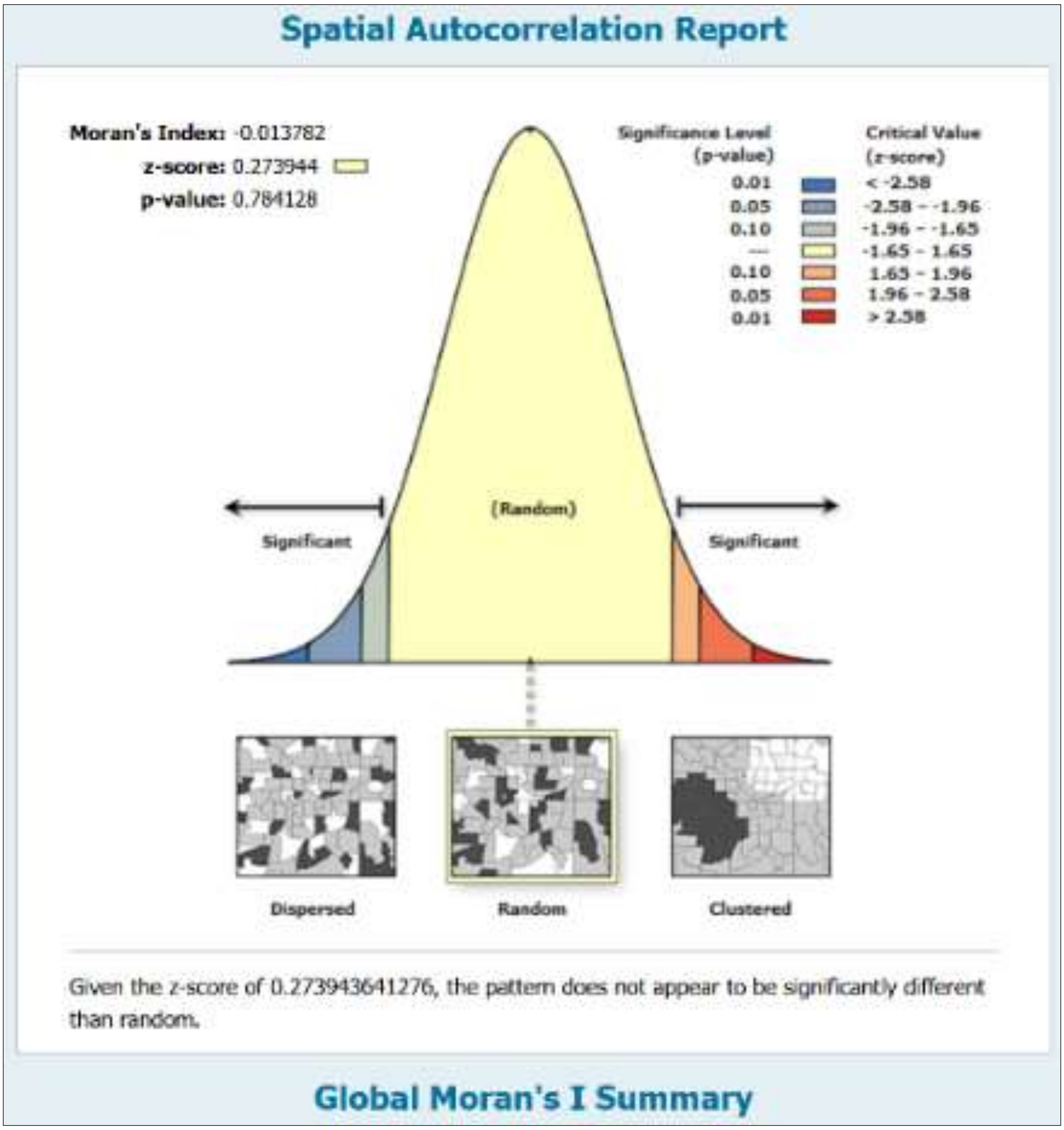

Figure 7. *Global Moran's I statistic* Number of TMK Food Distribution Facility Inspections 2020–2024

Source: (Processed Data from ArcGIS, 2025)

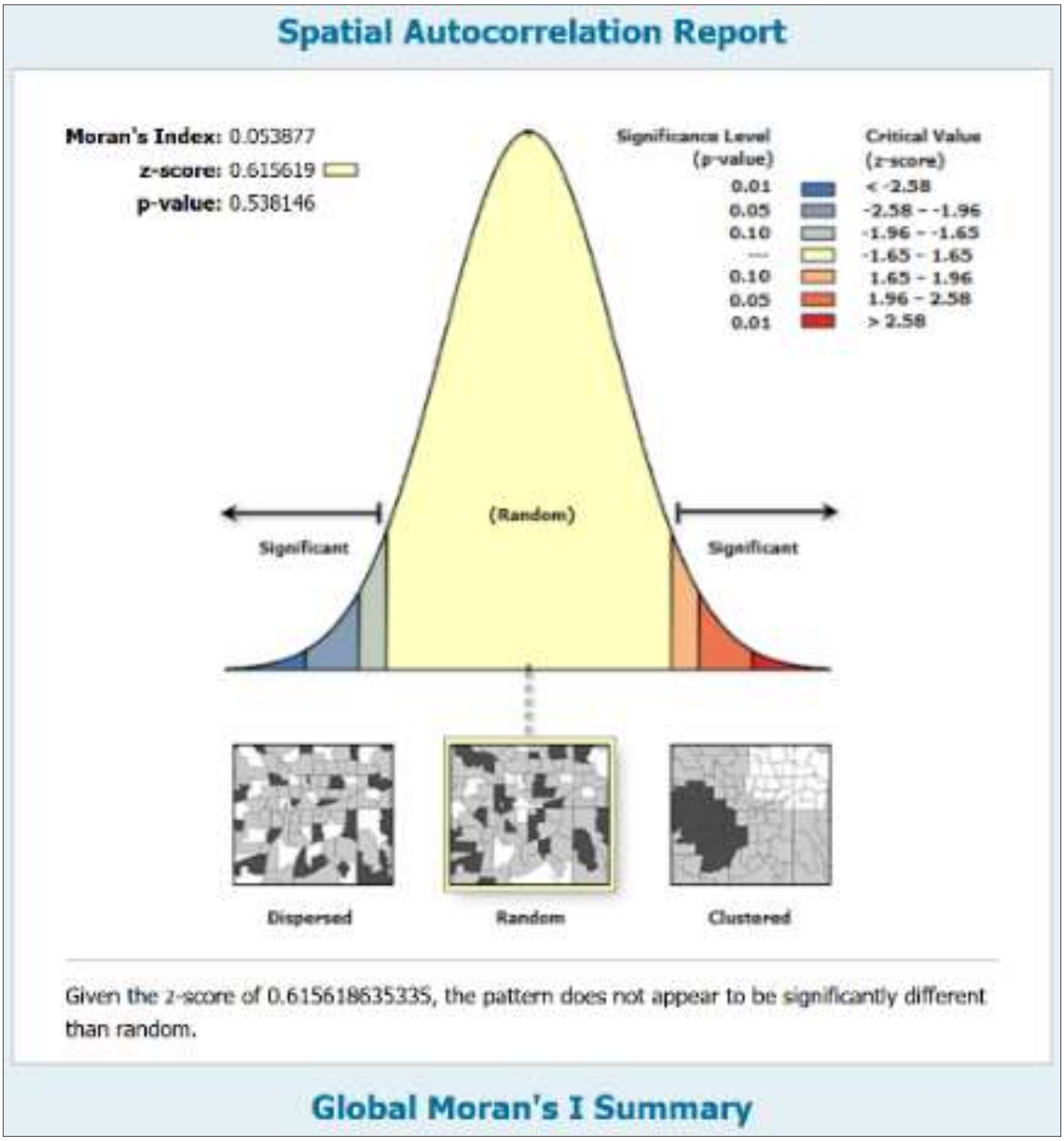

Figure 8. Global Moran's I statistic Percentage of TMK to the Total Number of Food Distribution Facility Inspections in 2020–2024
Source: (Processed Data from ArcGIS, 2025)

An analysis using the Global Moran's I spatial statistical approach was conducted to measure the level of spatial autocorrelation or regional clustering based on the results of the TMK food distribution facility inspection during the 2020–2024 period. The two variables tested were the absolute number of TMK, visualized in Figure 7, and the percentage of TMK to the total number of inspections, visualized in Figure 8. The results show that in 2020, the Moran's I value for the number of TMK was positive (0.0466) with a z-score of 2.198 and a p-value of 0.0279, which means that there was significant spatial autocorrelation—TMK tended to be clustered in certain areas such as South Tanimbar. However, from 2021 to 2024, the Moran's I value for the number and percentage of TMK was very close to zero or negative and all were not statistically significant (p-value > 0.05), indicating that the distribution of TMK was random and did not form spatial clusters. Cumulatively (2020–2024), the Global Moran's I value for the number of

TMK is -0.0138 and for the percentage of TMK is 0.0539 with p-values of 0.784 and 0.538, respectively, further confirming the absence of a significant spatial clustering pattern in the last five years.

Visually, Figure 7 shows that although there are several points of TMK concentration—such as in government centers or economic activity centers—the pattern does not form a consistent spatial cluster at the global level. Figure 8, which shows the percentage of TMK violations relative to the total number of inspections, also shows a random distribution without any significant clustering patterns, indicating that the violation rate is not concentrated in certain areas. These findings indicate that food surveillance in 3T regions such as the Tanimbar Islands and Southwest Maluku needs to be carried out using a micro approach because there are no areas that consistently form spatial risk clusters. The absence of significant long-term spatial autocorrelation indicates that TMK risk is dynamic and influenced by local factors, such as transportation access, the distribution season, the literacy level of business actors, and the frequency of inspections. Therefore, spatial-based surveillance strategies should be upgraded from the subdistrict level to the village or facility level and supported by regular spatial data updates. In conclusion, the combination of analysis and visualization in Figures 8 and 9 shows that the distribution of TMK does not form a globally significant spatial cluster, but still requires intensive attention at the local level through a more granular and risk-based spatial approach.

4.4 *Characteristics of the Food Distribution Facility Inspection Network.*

In accordance with the second research question regarding the characteristics of the food distribution facility inspection network at the subdistrict level in the Tanimbar POM Office working area, the analysis was conducted using the Social Network Analysis (SNA) approach to map the structure of relationships and interactions between nodes in the surveillance system during the 2020–2024 period, which included the Tanimbar Loka POM Office in Saumlaki as the inspection center, lodgings as initial transit posts in North Tanimbar, Selaru, Moa Lakor, the Southern Islands, and the Babar Islands, as well as all food distribution facilities in each sub-district as inspection targets, with edges representing inspection relationships weighted based on the number of facilities. This approach aims to understand the level of connectivity, centrality, and isolation between regions in the context of a challenging archipelagic geography, so that it can be evaluated whether the surveillance system is centralized or has formed a mutually supportive network, while providing an empirical picture as a basis for strengthening and optimizing the cross-regional surveillance network.

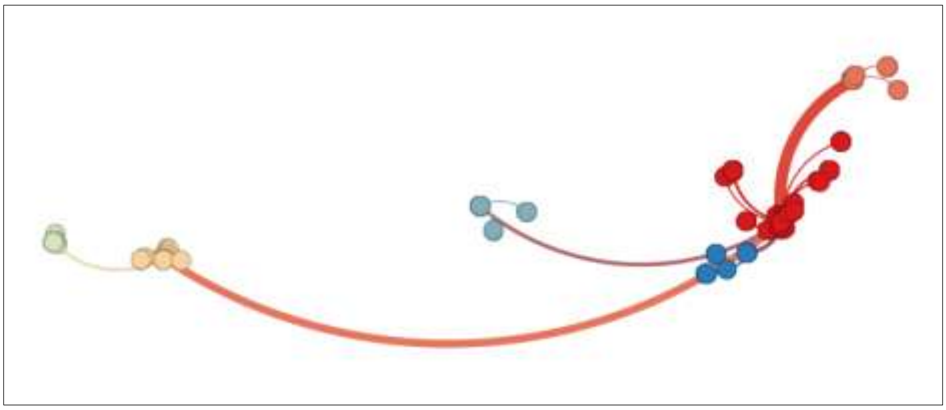

Figure 9. Modularity Class of the Food Distribution Facility Inspection Network for 2020–2024

Source: (Processed Data from Gephi, 2025)

Figure 9 shows a visualization of the modularity class of the food distribution facility inspection network by Loka POM Tanimbar for the period 2020–2024, which shows the grouping of nodes into communities based on the level of internal connectivity, where nodes in one cluster have stronger connections than other clusters. The results show that Loka POM Tanimbar is at the center of the network and is connected to almost all modularity classes as a central node, while other clusters are formed according to geographical boundaries and transportation access, such as on the Babar Islands, Moa Lakor, Selaru, and the Southern Islands, which tend to be isolated in their respective groups. This structure shows that the surveillance network is still fragmented and highly dependent on the center, with weak horizontal connections between regions, which has the potential to hinder information flow, early detection, and response speed to violations. These findings underscore the need to strengthen local surveillance clusters, enhance collaboration between regional nodes, and strengthen inter-island connectivity so that the surveillance system becomes more collaborative and adaptive in the archipelago.

Table 2. Results of Social Network Analysis with Connectivity and Strategic Position Indicators

Subdistrict-Level Network	Degree	Weighted Degree	Betweenness Centrality	Eigenvector Centrality
Loka POM Tanimbar	760	784	945,404	1.000000
Distribution Facilities in Kormomolin	1	1	0	0.034700
Distribution Facilities in Nirunmas	1	1	0	0.034700
Distribution Facilities in South Tanimbar	1	1	0	0.034700
Distribution Facilities in Wer Maktian	1	1	0	0.034700
Distribution Facilities in Wer Tamrian	1	1	0	0.034700
Accommodations in North Tanimbar	204	215	268,163	0.154089
Distribution Facilities in North Tanimbar	1	1	0	0.007444
Distribution Facilities in Yaru	1	1	0	0.007444
Accommodations in Selaru	130	133	175,182	0.100864
Distribution Facilities in Selaru	1	1	0	0.004989
Accommodations in Moa Lakor	208	217	339,039	0.159098
Distribution Facilities in Moa Lakor	1	1	0	0.007640
Distribution Facilities in Leti Island	1	1	0	0.007640
Accommodations in Southwest Islands	58	60	79,458	0.032117
Distribution Facilities in North Kisar	1	1	0	0.002126
Distribution Facilities in Southwest Islands	1	1	0	0.002126
Accommodations in Babar Islands	68	71	93,063	0.065052
Distribution Facilities in Babar Islands	1	1	0	0.003123
Distribution Facilities in East Babar Islands	1	1	0	0.003123

Source: Processed Data from Gephi (2025)

Table 2 presents the results of Social Network Analysis that describe the connectivity and strategic position of nodes in the food distribution monitoring system in the Tanimbar Loka POM working area for the 2020–2024 period through the indicators of degree, weighted degree, betweenness centrality, and eigenvector centrality. The results show that Loka POM Tanimbar occupies a very central and dominant position with a degree value of 760, betweenness centrality of 945.404, and eigenvector centrality of 1,000, confirming that almost all network connectivity flows depend on this one central node. In contrast, most other nodes, such as Nirunmas, Kormomolin, Wer Maktian, Leti Island, and the Southern Islands, only have a degree of 1, betweenness of 0, and very low eigenvector centrality, indicating linear connectivity and a lack of horizontal networking between regions. This structure reflects a highly centralized surveillance system that is vulnerable to operational disruptions at the central node, while transit nodes such as lodgings in North Tanimbar, Selaru, and Moa Lakor serve as logistical bridges with relatively higher betweenness values despite not being main nodes.

Table 3 Results of Social Network Analysis with Accessibility and Efficient Distance Indicators in the Network

District-Level Network Node	Modularity Class	Eccentricity	Closeness Centrality	Harmonic Closeness Centrality
Loka POM Tanimbar	0	3	0.6640224	0.760365
Distribution Facility in Kormomolin	0	4	0.3991585	0.419361
Distribution Facility in Nirunmas	0	4	0.3991585	0.419361
Distribution Facility in South Tanimbar	0	4	0.3991585	0.419361
Distribution Facility in Wer Maktian	0	4	0.3991585	0.419361
Distribution Facility in Wer Tamrian	0	4	0.3991585	0.419361
Accommodation in North Tanimbar	1	4	0.4504590	0.514465
Distribution Facility in North Tanimbar	1	5	0.3106309	0.328637
Distribution Facility in Yaru	1	5	0.3106309	0.328637
Accommodation in Selaru	5	4	0.4302994	0.479796
Distribution Facility in Selaru	5	5	0.3009093	0.315636
Accommodation in Moa Lakor	2	3	0.4685545	0.526353
Distribution Facility in Moa Lakor	2	4	0.3191298	0.334680
Distribution Facility in Leti Island	2	4	0.3191298	0.334680
Accommodation in Southernmost Islands	3	4	0.3275029	0.361384
Distribution Facility in North Kisar	3	5	0.2467487	0.258644
Distribution Facility in Southernmost Islands	3	5	0.2467487	0.258644
Accommodation in Babar Islands	4	4	0.4147479	0.450750
Distribution Facility in Babar Islands	4	5	0.2932207	0.304743
Distribution Facility in East Babar Islands	4	5	0.2932207	0.304743

Source: Processed Data from Gephi (2025)

Table 3 presents the results of social network analysis that focuses on the aspects of accessibility and distance efficiency between nodes in the food distribution monitoring network of Loka POM Tanimbar for the period 2020–2024 through the indicators of modularity class, eccentricity, closeness centrality, and harmonic closeness centrality, which show that Loka POM Tanimbar again occupies the most central and efficient position with the highest closeness value (0.664), harmonic closeness of 0.760, and the lowest eccentricity (3), thus acting as the main central node that can reach the entire network the fastest. while peripheral areas such as North Kisar, the Southern Islands, and the Eastern Babar Islands have very low closeness values (<0.33) and the highest eccentricity (5), indicating isolated and difficult-to-reach conditions; intermediate nodes such as Selaru, Moa Lakor, and North Tanimbar show moderate efficiency and have the potential to be developed as intermediary nodes. However, overall, the network structure is still very centralistic, relying on a single central node without strong local monitoring clusters, making it vulnerable to operational obstacles and slowing down response times in 3T areas. These conditions then became the basis for optimizing inspections through the integration of GIS and SNA results with network overlay stages into QGIS, the designation of high-risk and highly connected subdistricts as priorities, and the preparation of area- and risk-based monitoring recommendations that are more relevant to the characteristics of the Tanimbar archipelago.

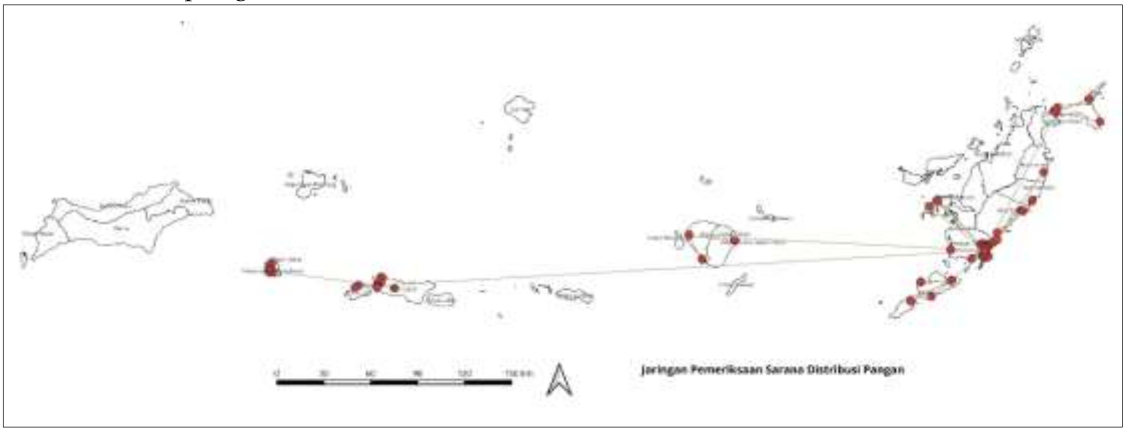

Figure 10. Food Distribution Facility Inspection Network for 2020–2024 Plot in QGIS
Source: (Source: Processed Data from Gephi and QGIS, 2025)

Figure 10 displays a visualization of the food distribution facility inspection network for the 2020–2024 period, mapped geographically using QGIS, where each node represents the location of a food distribution facility or the accommodation point of the inspection team, while the connecting lines show the inspection relationship between these nodes with Loka POM Tanimbar as the center of the network. This map shows a highly centralised inspection pattern with an uneven distribution of the network—dense in relatively accessible areas such as South Tanimbar, North Tanimbar, and Moa Lakor, but minimal to non-existent in remote areas such as Wetar Island, Masela Island, and Romang—as well as the almost complete absence of horizontal connections between regional nodes, which indicates the lack of an independent local monitoring network and a high dependence on the central node, making the monitoring system vulnerable to delays in response in the event of operational obstacles at Loka POM Tanimbar.

4.5 *Discussion*

Discussion of the research results shows that the vulnerability profile of food distribution facilities in the Tanimbar Loka POM working area is greatly influenced by the geographical characteristics of the archipelago, limited accessibility, and the structure of economic activity. The distribution of food distribution facilities is concentrated in subdistricts that are administrative and economic centers, such as South Tanimbar and Moa Lakor, with a dominance of traditional retailers that are at high risk of stock management and storage problems. This condition is in line with the findings of He et al. [28] that substandard food tends to be concentrated in distribution nodes with high connectivity. On the other hand, the existence of 13 subdistricts that have not been inspected indicates blind spots in supervision that have the potential to hide the risks of TMK food distribution, especially in areas with maritime transportation barriers, uncertain ship schedules, and weather factors. In this context, Location and Accessibility Theory emphasizes that relative distance and accessibility determine surveillance opportunities and hidden risks in 3T areas [23], while Quality Management Theory places location and logistics flow factors as important determinants of distribution quality [22].

The pattern of TMK product findings is dominated by expired products every year, with a peak in 2022 and a relative decline in 2024, while damaged products tend to fluctuate but still show weaknesses in quality management at the facility level. Getis-Ord Gi* hotspot analysis reveals that

South Tanimbar consistently emerges as a hotspot for absolute TMK numbers, while when viewed from the percentage of TMK to the number of inspections, subdistricts such as East Babar Islands, Wer Tamrian, and Selaru emerge as proportional hotspots despite low inspection volumes. This confirms that areas with few inspections can have very high levels of non-compliance and should not be overlooked in risk-based surveillance planning. On the other hand, the results of Global Moran's I show that, in general, there is no consistent global spatial autocorrelation from year to year, so that the distribution of TMK does not form stable spatial clusters and is more dynamic and contextual. Thus, a macro-spatial approach alone is not sufficient; surveillance requires more granular risk mapping down to the village and facility level, with regular updates of spatial data to capture local risk dynamics.

The results of Social Network Analysis (SNA) confirm that the network structure of food distribution facility inspections in the Tanimbar Loka POM working area is highly centralized, with Loka POM acting as the central hub with the highest degree, betweenness, closeness, and eigenvector centrality. Almost all distribution facilities and lodging points are linearly connected to Loka POM without horizontal connections between sub-districts, while nodes in outlying areas such as Letti Island, North Kisar, the Southern Islands, and the Eastern Babar Islands are in eccentric positions with low closeness and high eccentricity, indicating a high level of isolation in the monitoring network. The modularity class visualization shows that clusters are formed more due to geographical access limitations and transportation route patterns than the existence of a strong local surveillance network, and the absence of intermediate nodes (sub-hubs) causes the flow of information and surveillance responses to be highly dependent on a single central node. This network structure increases the vulnerability of the system when the center faces operational obstacles, and at the same time indicates the need to restructure the surveillance network towards a more decentralized, collaborative, and resilient form.

The integration of GIS and SNA analysis in this study produced strategic recommendations for optimizing food distribution facility inspections in the archipelago, through the application of risk-based surveillance, prioritization of areas based on a combination of risk volume and intensity, and strengthening of intermediate nodes in strategic locations such as Moa Lakor, Selaru, and North Tanimbar. This approach is in line with the GIS concept for evidence-based policy, which places spatial information as the basis for determining intervention priorities [25], as well as the principles of operations management that emphasize the importance of location decisions and ease of access in the design of public service systems [21]. Furthermore, the results of this study reinforce the findings of Emch et al. [17] and Roziqin & Hasdiyanti [18] regarding the importance of integrating spatial and social dimensions to improve the effectiveness of area-based surveillance. The operational recommendations formulated include the implementation of absolute and proportional hotspot-based inspections, the strengthening of horizontal networks between regions, the expansion of coverage to non-accessible areas through cross-sectoral synergies, the capacity building of business actors—especially traditional retailers—and the development of GIS and SNA-based digital dashboards to support more adaptive and real-time route planning and risk monitoring.

5. CONCLUSION

Based on the analysis and discussion, several research conclusions can be drawn: The vulnerability mapping profile of non-compliant food distribution facilities (TMK) at the sub-district level within the Loka POM Tanimbar working area reveals spatial imbalances in inspections, influenced by the archipelago's geographical characteristics, with Tanimbar Selatan Sub-district identified as a high-risk hotspot. Limited transportation connectivity and infrastructure have left 13 sub-districts unreachable by inspections, creating blind spots with high risks of non-compliant food circulation. Distribution facilities are concentrated in administrative and economic centers like Tanimbar Selatan and Moa Lakor, with traditional retail facilities being highly vulnerable due to weak stock management and internal controls, as reflected in the dominant findings of expired products. Remote areas exhibit higher vulnerability proportionally due to limited inspections. Additionally, the inspection network characteristics at the sub-district level are still centralized, lacking horizontal development. Social Network Analysis indicates that inspections are concentrated in a few sub-districts with high connectivity and strategic roles, while other sub-districts are isolated, limiting inspection efficiency and weakening the distribution of supervision. To optimize inspections in the archipelagic region, a risk-based approach integrated with spatial and social network analysis is essential. By combining spatial vulnerability mapping and network inspection characteristics, a more adaptive basis for determining inspection priorities, resource allocation, and designing supervision strategies that account for the geographical limitations, transportation connectivity, and infrastructure in the archipelago can be achieved.

Based on the research results and conclusions, several recommendations are provided as follows: First, Loka POM Tanimbar is advised to implement a spatial- and risk-based inspection planning system systematically, using the vulnerability mapping of TMK at the sub-district level as a basis for determining inspection priorities. This approach is expected to reduce blind spots in supervision, increase coverage of remote areas, and optimize resource utilization amidst the limitations of transportation and infrastructure in the archipelago. Second, strengthening the connectivity of the inspection network across sub-districts is needed to reduce the centralized supervision pattern. Loka POM Tanimbar should develop a more distributed inspection pattern through horizontal connectivity, clustering inspection areas, and enhancing cross-sector coordination to improve efficiency, reach, and equitable food safety protection across the entire working area. Third, the integration of Geographic Information System (GIS) and Social Network Analysis should be developed as a decision-support tool for data-driven supervision, combining inspection data, spatial vulnerability maps, and inspection network characteristics. This approach is expected to support the establishment of more objective and adaptive supervision priorities according to regional risks, as well as serve as a foundation for monitoring, evaluating performance, and formulating effective and sustainable food distribution facility supervision policies in the archipelagic regions.

REFERENCES

[1] BPOM, "Peraturan Badan Pengawas Obat dan Makanan Nomor 9 Tahun 2020 tentang Rencana Strategis Badan Pengawas Obat dan Makanan Tahun 2020-2024. Badan Pengawas Obat dan Makanan.," 2020.

[2] Loka POM Tanimbar, "Keputusan Kepala Loka Pengawas Obat dan Makanan di Kabupaten Kepulauan Tanimbar Nomor HK.02.02.36B.36B5.12.21.38 Tahun 2021 tentang Rencana Strategis Loka Pengawas Obat dan Makanan di Kabupaten Kepulauan Tanimbar Tahun 2020-2024. Loka POM di Kabupaten Kep." 2021.

[3] Perpres, "Peraturan Presiden Nomor 80 Tahun 2017 tentang Badan Pengawas Obat dan Makanan.," *Sekretariat Negara Republik Indonesia.*, 2017.

[4] Loka POM Tanimbar, "Laporan Kinerja Loka POM di Kabupaten Kepulauan Tanimbar tahun 2024.," 2025.

[5] Loka POM Tanimbar, "Laporan Tahunan Loka POM Tanimbar tahun 2024.," 2025.

[6] S. Widiyanesti and Y. Fernando, "A Review of Supply Chain Risk Management in Agribusiness Industry," *Adv. Methodol. Technol. Bus. Oper. Manag.*, pp. 1225–1235, 2019.

[7] M. Irjayanti, A. M. Azis, Susilawati, and A. R. Sobari, "Transformative innovations igniting coffee supply chain process efficiency," *J. Innov. Entrep.*, vol. 14, no. 1, p. 44, 2025, doi: 10.1186/s13731-025-00486-9.
[8] Y. Leosari, J. A. Uelmen, and R. M. Carney, "Spatial evaluation of healthcare accessibility across archipelagic communities of Maluku Province, Indonesia," *PLOS Glob. Public Heal.*, vol. 3, no. 3, p. e0001600, 2023.
[9] A. Alamsyah *et al.*, "Blockchain traceability model in the coffee industry," *J. Open Innov. Technol. Mark. Complex.*, vol. 9, no. 1, p. 100008, 2023.
[10] L. H. Beni, S. Villeneuve, D. I. LeBlanc, and P. Delaquis, "A GIS-based approach in support of an assessment of Food Safety Risks," *Trans. GIS*, vol. 15, pp. 95–108, 2011.
[11] E. F. S. A. (EFSA), A. F. Jijón, R. Costa, K. Nicova, and G. Furnari, "Review of the use of GIS in public health and food safety," Wiley Online Library, 2022.
[12] S. Kuan, N. L. Chin, and T. P. Tee, "QGIS Application for Spatial and Temporal Visualisation of Data for Food Safety Audits in Malaysia.," *Malaysian J. Med. Heal. Sci.*, vol. 19, 2023.
[13] X. Liang and Y. Kang, "A review of spatial network insights and methods in the context of planning: Applications, challenges, and opportunities," *Urban informatics Futur. cities*, pp. 71–91, 2021.
[14] M. Apriyanto and R. Rujiah, "Analisis tingkat ketahanan pangan terhadap kerawanan pangan menggunakan metode GIS (Geographic Information System)," *J. Food Syst. Agribus.*, vol. 5, no. 1, pp. 54–61, 2021.
[15] S. E. Bradley, J. Heuer, B. Hahm, K. Pettey, and K. Besterman-Dahan, "Identifying Areas of High Vulnerability for Rural Veteran Food Insecurity," *J. Prim. Care Community Health*, vol. 15, p. 21501319241277412, 2024.
[16] T. R. Jerumeh, "Mapping the spatial distribution of household food insecurity in Nigeria," *GeoJournal*, vol. 89, no. 4, p. 154, 2024.
[17] M. Emch, E. D. Root, S. Giebultowicz, M. Ali, C. Perez-Heydrich, and M. Yunus, "Integration of spatial and social network analysis in disease transmission studies," *Ann. Assoc. Am. Geogr.*, vol. 102, no. 5, pp. 1004–1015, 2012.
[18] A. Roziqin and F. Hasdiyanti, "Pemetaan Daerah Rawan Penyakit Demam Berdarah Dengue (DBD) di Pulau Batam," *J. Integr.*, vol. 9, no. 2, pp. 106–112, 2017.
[19] A. Naud, C. Sueur, B. Chaix, and Y. Kestens, "Combining social network and activity space data for health research: tools and methods," *Health Place*, vol. 66, p. 102454, 2020.
[20] D. Sarkar, C. Andris, C. A. Chapman, and R. Sengupta, "Metrics for characterizing network structure and node importance in Spatial Social Networks," *Int. J. Geogr. Inf. Sci.*, vol. 33, no. 5, pp. 1017–1039, 2019.
[21] J. Heizer, B. Render, C. L. Munson, and P. Griffin, "Operations management: Sustainability and supply chain management," 2020.
[22] R. P. Baali, Saerang A. A., Anwar, U. A. A., Widiana, I. N. W., Sudirjo, F., Herdiansyah, D., Hina, H. B., Widarman, A., Fitriyani, Z. A., Zen, A., Dulame, I. M., Wirkasuma, K. W., & Hati, *Manajemen Kualitas*. CV GETPRESS INDONESIA, 2023.
[23] N. N. Suma, "Dasar-Dasar Geografi (Data, Fakta dan Fenomena)," *Yayasan Abdulloh Arief.*, 2023.
[24] S. Widiyanesti and B. Mahardhika, "The Circular Economy of the Food Bank Supply Chain in Bandung City , West Java," 2025.
[25] P. A. Longley, M. F. Goodchild, D. J. Maguire, and D. W. Rhind, *Geographic information science and systems*. John Wiley & Sons, 2015.
[26] M. Barthelemy, "Directed and Mixed Graphs," in *Spatial Networks: A Complete Introduction: From Graph Theory and Statistical Physics to Real-World Applications*, Springer, 2021, pp. 23–37.
[27] S. Wasserman and K. Faust, "Social network analysis: Methods and applications," 1994.
[28] Y. He, J. Jiang, and S. Li, "The circulation analysis of substandard foods in China based on GIS and social network analysis," *PLoS One*, vol. 16, no. 3, p. e0248037, 2021.
[29] M. Bastian, S. Heymann, and M. Jacomy, "Gephi: an open source software for exploring and manipulating networks," in *Proceedings of the international AAAI conference on web and social media*, 2009, vol. 3, no. 1, pp. 361–362.
[30] J. W. Creswell and J. D. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications, 2018.
[31] S. Sugiyono, "Metode Penelitian Pendidikan Pendekatan Kualitatif, Kuantitatif dan R & D," *Alf. Bandung*, 2018.
[32] U. Sekaran and R. Bougie, *Research methods for business: A skill building approach*. john wiley & sons, 2016.