



Analysis of movement patterns based on origin-destination matrix

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ABSTRACT

Background: Transportation is a crucial element in the development of a region. The commonly used planning model is the trip distribution model, which is represented in the form of a Destination Origin Matrix (MAT). This study examines transportation and traffic patterns in North Sinjai District, focusing on origin–destination movements. It highlights the role of the Destination Origin Matrix (MAT) in modeling mobility, planning transport systems, and understanding socio-economic and land use influences on movement. **Methods:** This research was conducted in North Sinjai District, an urban area divided into seven zones based on community activity centers: trade and services, settlements, education, offices, health, worship, and public spaces. The study mapped origin–destination movements and assessed regional function management using literature review, observation, questionnaires, and interviews. The study in North Sinjai District involved 300 respondents across seven zones. **Findings:** Results show adults dominated respondents, with students as the largest occupational group. Private motorcycles were the most used vehicles. Health zones had the highest origin movements, trade and services zones the highest destinations, while residential and public spaces were the lowest. Desire Line analysis indicated strong interactions between health, offices, and trade zones, guiding land use management priorities and infrastructure allocation. **Conclusion:** The study indicates that strategic planning of regional transport flows, especially through the Destination Origin Matrix, can identify sector-specific needs, highlighting the requirement for enhanced infrastructure in the health zone. **Novelty/Originality of this article:** The novelty of this research lies in applying a detailed Destination Origin Matrix at a sub-district urban scale to guide resource allocation for specific community activity zones, particularly addressing health sector demand.

KEYWORDS: destination origin matrix (MAT); land use; movement patterns.

1. Introduction

Traffic and transportation are two interrelated concepts. Traffic refers to the movement of vehicles and people along a route or within an area. Meanwhile, transportation involves moving people and/or goods from one location (origin) to another (destination) using vehicle facilities. Based on Article 1 of Law Number 22 of 2009 concerning Road Traffic and Transportation, traffic is defined as the movement of vehicles and people in the road traffic space, which is an infrastructure designed to support the movement of vehicles, people, and/or goods through road facilities and their supporting infrastructure. According to Pangestuti (2021), Ali defines traffic as walking, moving back

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and forth, or traveling along a road, while Naning defines it as people moving from one place to another, with or without transportation.

Miro, in Ardiansyah (2015), defines transportation as the effort to move, transport, or divert an object from one place to another for specific purposes (Widyawati et al., 2020). One system that has changed rapidly is transportation, influenced by the community's social and economic development. This rapid change has created increasingly complex problems, especially in infrastructure and transportation facilities (Sinha et al., 2017). Therefore, transportation disruptions can significantly affect traffic flow, which in turn hinders the community's economic activities and interferes with social welfare (Kadarisman, 2015).

In transportation planning, there are four main stages in the planning model, one of which is the trip distribution stage, which is represented in the form of a Destination-Origin Matrix (MAT) (Akbar et al., 2020). Improving the transportation system is not easy, but it is possible. Building a quality transportation system takes significant time and cost. Not only are the government and related agencies responsible for improving Indonesia's public transportation system, but all elements of society must also actively support the government in building and implementing an effective public transportation system (Hrelja et al., 2020). The Destination Origin Matrix (MAT) is a two-dimensional matrix that shows the volume of movement between locations (zones) in a given area (Safitri, 2015). As Ansusanto (2013) explains, the MAT (Destination Origin Matrix) maps the amount of mobility or movement between zones in an area.

The Destination Origin Matrix (MAT) is crucial data in transportation planning and modeling in a study area. MAT describes the number of movements from the origin zone to the destination zone, so it plays an important role in the transportation planning process. Several factors can affect the accuracy of the Destination Origin Matrix generated from traffic flow data, including the type of trip distribution model used (Suyuti, 2007). Loading the Destination Origin Matrix into the transportation network aims to obtain traffic flow on each road segment and the total trips in the reviewed network (Zada, 2015).

Movement patterns in transportation systems are often illustrated through the flow of movement (vehicles, passengers, and goods) that move from the origin zone to the destination zone within a certain area and within a certain time span (Astutik, 2020). Transportation planners often use the Movement Matrix, also known as the Origin-Purpose Matrix (MAT), to describe movement patterns.

In the field of transportation planning and modeling, there are four stages of transportation modeling that are often used, namely: (1) Trip generation, (2) Trip distribution, (3) Mode selection (capital choice/capital split), and (4) Traffic assignment (trip assignment). The modeling stage that estimates the distribution of movements leaving a zone or heading to a zone is called traffic movement distribution (trip distribution). This movement distribution can be presented as a desire line or an origin-destination matrix (Septiyani, 2015).

Trip generation aims to develop a relationship model that links land-use parameters to the number of movements toward a unified zone. This model forecasts the number of movements made by individuals in each zone of origin. This process uses detailed data on movement revival levels, socio-economic attributes, and land-use characteristics (Ansusanto, 2013). This study examines how the amount of data and the location of traffic counts affect the Origin-Destination Matrix (SAT) of Sinjai City. The study is expected to provide an overview of the amount of data and the exact location of the traffic count survey, related to the efficiency of future surveys, to produce an optimal and highly accurate MAT to describe current and future movement patterns.

Sinjai Regency is located in eastern South Sulawesi Province, with its capital in North Sinjai District. The district consists of nine sub-districts: West Sinjai District, Sinjai Borong District, South Sinjai District, Tellu Limpoe District, East Sinjai District, Central Sinjai District, North Sinjai District, Bulupoddo, and Pulau Sembilan. Astronomically, Sinjai Regency is located at coordinates between 5°02'56" and 5°21'16" South Latitude and 119°56'30" and 120°25'33" East Longitude (Sutrisni et al., 2014).

Sinjai Regency covers about 87,011 hectares and lies on the southeastern coast of South Sulawesi Province. Sinjai Regency's administrative boundaries include Bone Regency to the north, Bone Bay to the east, Bulukumba Regency to the south, and Gowa Regency to the west. Transportation in Sinjai Regency is influenced not only by activity within the region but also by flows from other regions, as Sinjai Regency lies on the Trans Sulawesi route.

North Sinjai District is a sub-district in Sinjai Regency with a population of 50,498 people and an area of 2,957 km². As the district capital, this sub-district consists of six sub-districts: Alewanuae, Biringere, Lamatti Rilau, Bongki, Balangnipa, and Lappa. This sub-district is coastal and borders Bone Regency. Most residents of North Sinjai District work in agriculture and trade. Research shows that this sub-district serves as a transportation hub, supports daily activities, and increases residential density.

2. Methods

The methods of implementing the activities used in this study include the location of the activity, data sources, data collection techniques, and data analysis methods, which are described as follows:

2.1 Location of activities

This activity was carried out in Sinjai City, which is located in North Sinjai District, Sinjai Regency. Administratively, the boundaries of the area are: to the north it borders Bone Regency, to the east it borders Bone Bay, to the south it borders East Sinjai District, and to the west it borders Central Sinjai District and Bulupoddo District. This activity area consists of seven functional areas: trade and service areas, settlements, education, offices, health, worship, and public spaces.

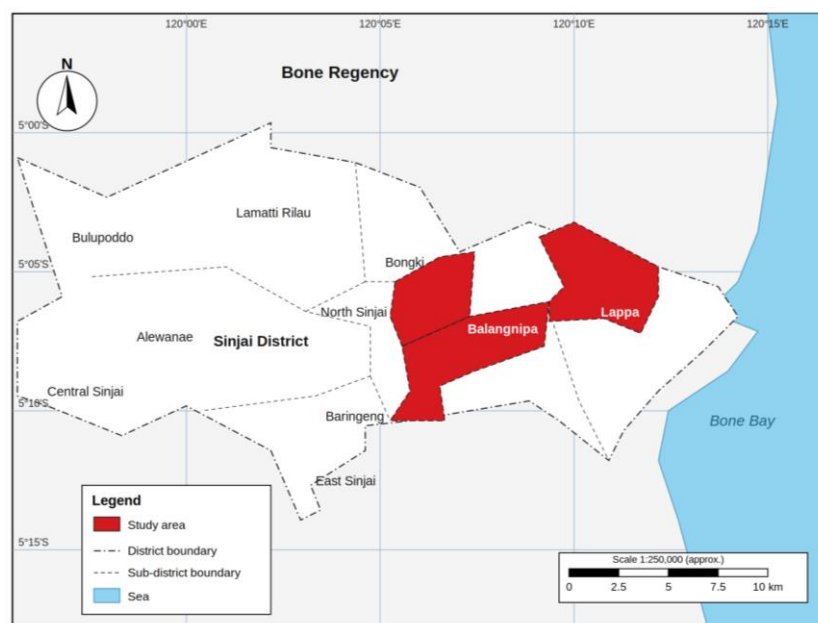


Fig. 1. Research location

2.2 Data sources and collection

This study used primary data collected directly from 300 community respondents through questionnaires and interviews. The respondents were located in trade and service areas, residential areas, educational institutions, offices, health facilities, places of worship, and public spaces in North Sinjai District, Sinjai Regency. The collected data included

personal characteristics, origin and destination movement data, estimated travel time to the destination, and estimated time spent at the destination.

Data collection involved literature review, field observation, questionnaires, and interviews. The literature review was conducted to obtain relevant references for the study. Field observations were undertaken to identify and verify the distribution of study locations and obtain more accurate information about the study area. Questionnaires were administered using Google Forms and completed directly by the respondents in each study zone (Palindang et al., 2020). In addition, direct interviews were conducted to obtain information regarding respondents' movement patterns, particularly their origins, destinations, and travel conditions.

2.3 Data analysis methods

The data were analyzed to determine land-use management directions based on origin–destination movement patterns, with North Sinjai District as the study area. Three analytical approaches were applied: Origin–Destination Matrix (ODM) analysis, Desire Line analysis, and the Sturges method. The Origin–Destination Matrix (ODM) is a two-dimensional matrix that describes movement volume between locations or zones within a specific area (Kumaat, 2013; Safitri, 2015). When applied to a transportation network, the matrix illustrates movement flows and patterns across the study area. Researchers can obtain ODM information through both conventional and unconventional methods (Aprilliansyah & Herman, 2015).

Desire Line analysis was used to visualize the relationship between movement origins and destinations. A desire line represents a straight line connecting the origin and destination of a movement, with the direction and magnitude reflecting the volume of passenger and goods movement (Palindang et al., 2020). The Sturges method was used to determine the appropriate number of data intervals, or bins, for the histogram. The method was introduced in the Journal of the American Statistical Association in 1926 and assumes that a dataset can be approximated by a symmetrical binomial distribution (Sari, 2018). The number of class intervals was calculated using the following formula:

$$K \approx 1 + 3,322 \log n \quad (\text{Eq. 1})$$

where K represents the number of class intervals, and n represents the total number of observations. The calculated number of class intervals was used to organize the data into appropriate groups for frequency distribution analysis. This classification facilitated interpretation of data distribution patterns and supported presenting the results as a histogram.

3. Results and Discussion

The research was carried out on May 25-26, 2023, which included holidays and weekdays, in North Sinjai District, Sinjai Regency. North Sinjai District covers 29.57 km². Administratively, North Sinjai District consists of six villages, namely Alewanuae Village, Biringere Village, Lamatti Rilau Village, Bongki Village, Balangnipa Village, and Lappa Village. North Sinjai District functions as a residential area, a center for government and private offices, and a trade center for Sinjai City (Risnawati, 2022). Balangnipa Village is the capital of North Sinjai District. The data recapitulation includes passengers' age, gender, and occupation, as well as their origin and destination, obtained through questionnaires at seven community movement distribution points in North Sinjai District. The collected data were used to identify travel characteristics and movement patterns within North Sinjai District. These findings provided a basis for analyzing the distribution of community movements and understanding the study area's transportation needs.

3.1 Questionnaire recapitulation results

From questionnaires and interviews with several respondents, the study obtained questionnaire recapitulation results from seven movement zones/nodes in North Sinjai District, Sinjai Regency. These results consist of three determining parameters, namely age, gender, and origin and destination of 300 respondents, which can be seen as follows. The recapitulation results provide an overview of the respondents' demographic characteristics and movement patterns across the seven zones/nodes in North Sinjai District, Sinjai Regency. These data are used to identify variations in travel patterns based on age, gender, and origin–destination characteristics. The findings provide a basis for further analysis of respondents' mobility and movement patterns within the study area.

3.1.1 Age and gender

Data were collected from respondents through questionnaires and interviews to determine the number of male and female respondents by age category: adolescents (12–25 years old), adults (26–65 years old), and the elderly (over 65 years old). The following graph shows the breakdown of respondents by age and gender. Based on the graph above, the most dominant age group is adults (26–65 years), with 194 people: 89 men and 105 women. Meanwhile, the youngest age group is the elderly (over 65 years), with 10 people: 5 men and 5 women. Overall, 300 respondents were included, consisting of 130 men and 206 women. These findings indicate that adults made up the largest proportion of respondents, suggesting this age group was most represented in the study. The distribution of respondents by age and gender provides an overview of the demographic characteristics of the participants.

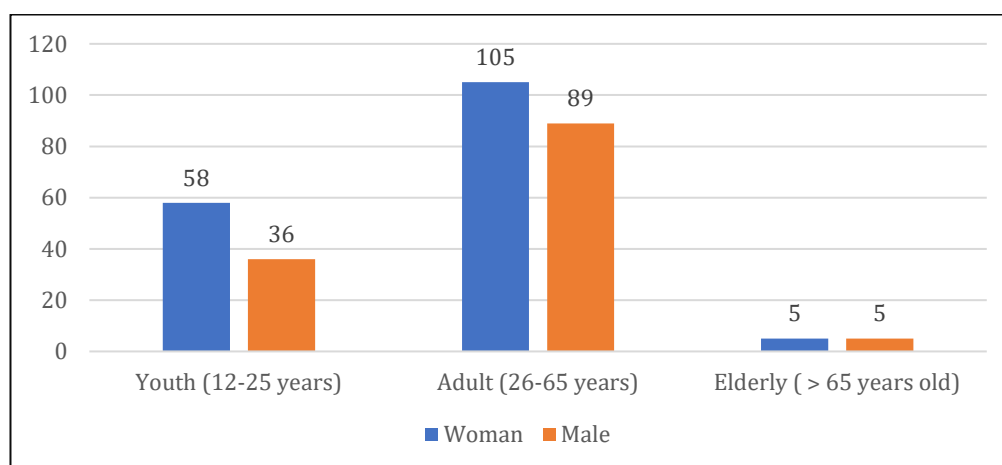


Fig. 2. Age and gender recapitulation graph

3.1.2 Jobs

Data collection through questionnaires and interviews identified the number of respondents who were students, civil servants, teachers and honorary staff, traders/self-employed, housewives, farmers, and fishermen. The recapitulation of respondents' work status is shown in the following graph. Based on the questionnaire results shown in the image above, students are the most dominant group, with a total of 110 people. Meanwhile, fishermen are the least common occupation, with a total of 5 people. The total number of respondents was 300. This distribution indicates that students represent the largest occupational group among the respondents, while fishermen account for the smallest proportion. The diversity of occupations reflects the different socioeconomic backgrounds of the participants involved in this study. These findings provide an overview of the respondents' occupational characteristics, which may help contextualize the interpretation

of the research results.

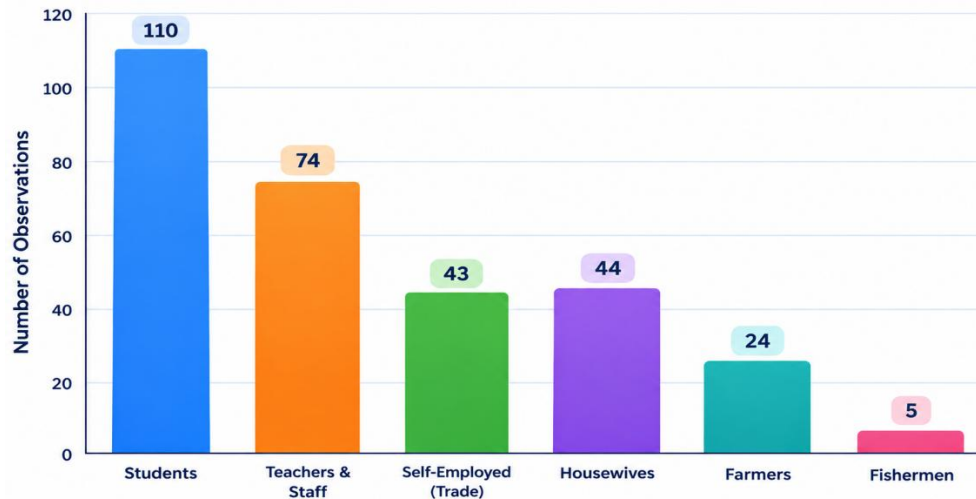


Fig. 3. Passenger work recapitulation graph

3.1.3 Vehicle type

Data were collected from 300 respondents through questionnaires and interviews to identify the vehicle type used and determine how many respondents used cars and motorcycles as private and public vehicles. The recapitulation of the vehicle type used by each respondent is shown in the following graph.

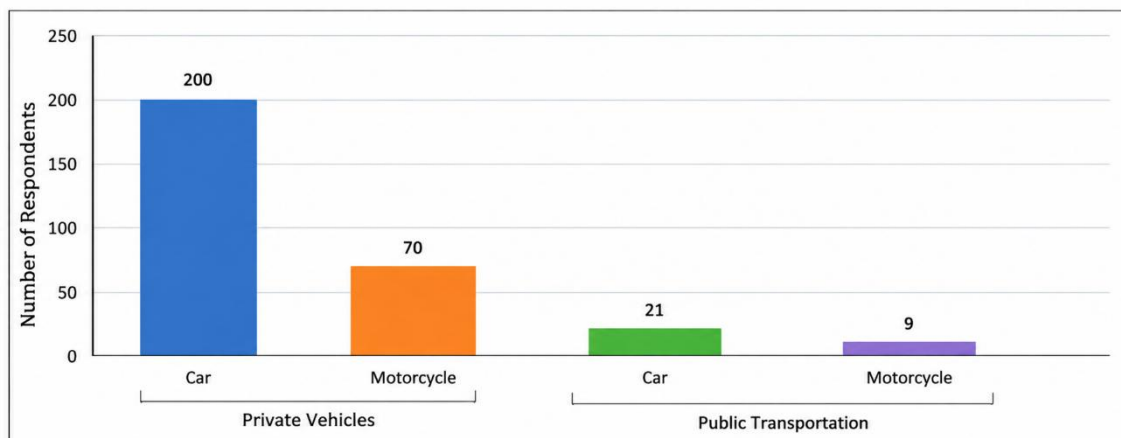


Fig. 4. Passenger vehicle type recapitulation graph

Based on the questionnaire results shown in the image above, private vehicles are the most widely used, especially motorcycles, with 200 users. In contrast, the least-used vehicle type is public transportation in the form of motorcycles, with 9 users. The total number of respondents was 300.

3.1.4 Movement recapitulation

Movement interactions in the activity centers of North Sinjai District are divided into seven main zones: settlements, health, offices, education, trade and services, worship, and public spaces. This movement is divided into two categories: origin movement, which shows the number of individuals moving out of an area, and destination movement, which reflects an area's attractiveness as a destination. The recapitulation and analysis of the movement are shown in the following graph.

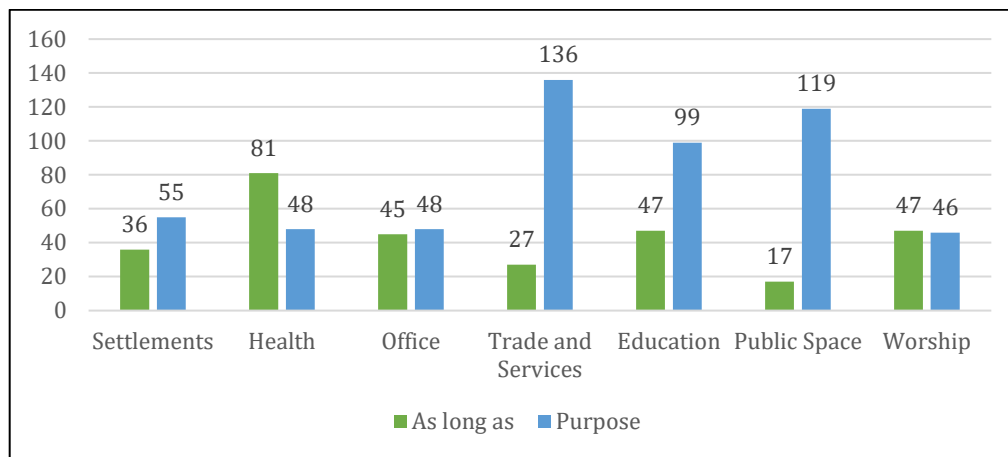


Fig. 5. Passenger origin and destination recapitulation chart

Based on the graph above, the highest origin point is the health zone with 81 movements, while the lowest origin point is the public space zone with 17 movements. In contrast, the highest destination was the trade and services zone with 136 movements, and the lowest was the residential zone with 55 movements. The total movement reached 551.

3.2 Origin and purpose matrix analysis

Origin and Destination Matrix (MAT) analysis is a two-dimensional matrix that shows movement volumes between zones within a region. The rows represent the origin zone, while the columns indicate the destination zone. In this context, the Origin-Destination Matrix in Sinjai City has 7 movement nodes. The results of the Destination Origin Matrix analysis are shown in the following table and graph.

Table 1. Destination origin matrix

Purpose	Settlements	Education	Office	Health	Worship	Trade & services	Public space	Total
As long as								
Settlements		15	7	6	9	18	17	72
Education	17		8	13	10	21	20	89
Office	9	26		7	5	28	18	93
Health	17	29	12		15	42	38	153
Worship	5	14	6	13		18	19	75
Trade & Services	3	9	10	3	5		7	38
Public space	4	6	5	6	2	8		31
Total goals	55	99	48	48	46	136	119	551

Table 1 presents the origin–destination matrix of trips by seven main activity purposes: settlements, education, offices, health facilities, worship, trade and services, and public spaces. The survey recorded 551 trips in total, with health-related activities generating the most trips (153), followed by trade and services (136) and public spaces (119). In terms of trip origins, health-related activities also recorded the highest number of outgoing trips (153), followed by office activities (93) and education (89). This pattern indicates that health facilities, commercial activities, and public spaces function as important activity centers that generate considerable movement within the study area.

The origin–destination pattern further shows that trips between different activity functions are relatively interconnected. The highest movement is from health-related activities to trade and services (42 trips), followed by movement from health-related activities to public spaces (38 trips). Office-related activities also generate substantial movement toward trade and services (28 trips), while education-related activities generate 21 trips toward trade and services and 20 trips toward public spaces. Meanwhile, settlements contribute 18 trips each toward trade and services and public spaces, indicating

that residential areas are important sources of movement to supporting activities. Overall, the matrix shows that daily mobility in the study area is not concentrated in a single activity type but is characterized by interactions among residential, employment, educational, health, commercial, worship, and public-space functions. These interconnected movements indicate the intensity of activity interactions and can help explain travel patterns and transportation demand within and around the Bantaeng Industrial Area.

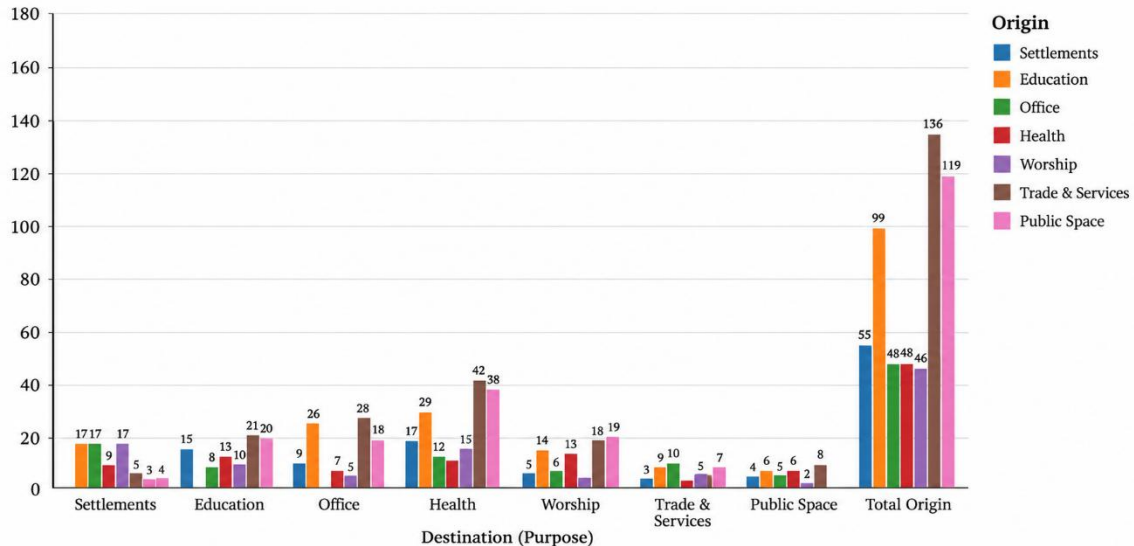


Fig. 6. Destination origin matrix graph

Based on the figure above, the health zone dominates total origins with 153 points, while the public space zone records the lowest number of origins, at 31 points. In addition, the trade and services zone has the highest total destinations (136 points), while the residential zone has the lowest (55 points).

3.3 Land use

Land use at the study site in North Sinjai District is divided into seven zones: settlements, health, offices, worship, education, public spaces, and trade and services. The following image shows this in more detail.

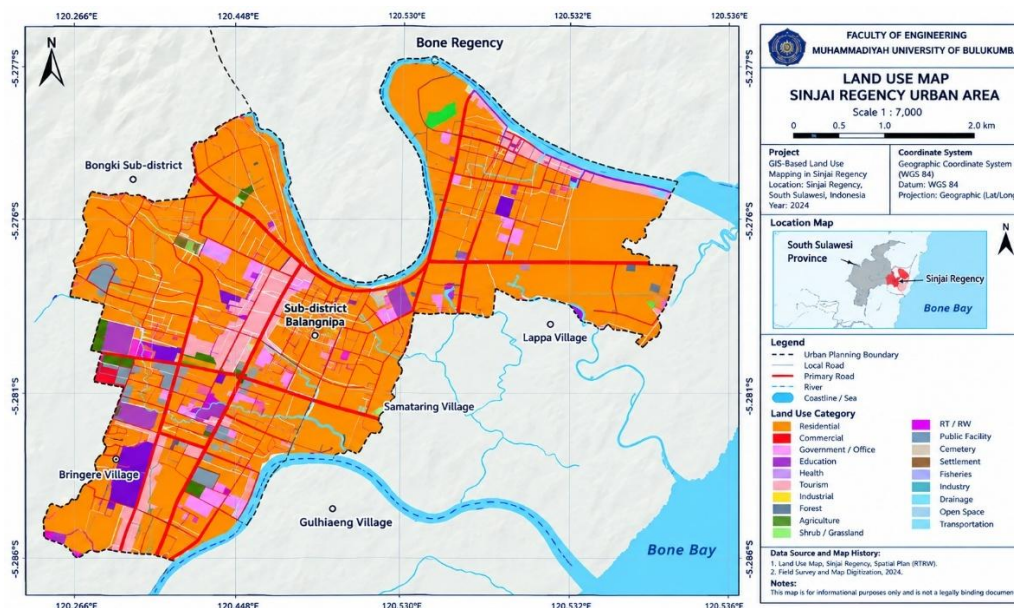


Fig. 7. Land use map

Based on the map above, land use in North Sinjai District is dominated by residential zones. This is due to North Sinjai District's role as a center for government and private offices, as well as a trade center for Sinjai City.

3.4 Regional function zone

The functional zone of the area is determined based on observations and interpretation of the latest imagery. Land use zoning in the urban area of North Sinjai District includes residential zones, health, offices, trade and services, education, public spaces, and worship. The results of the image interpretation related to the area's functional zones are shown in the following graphs and maps.

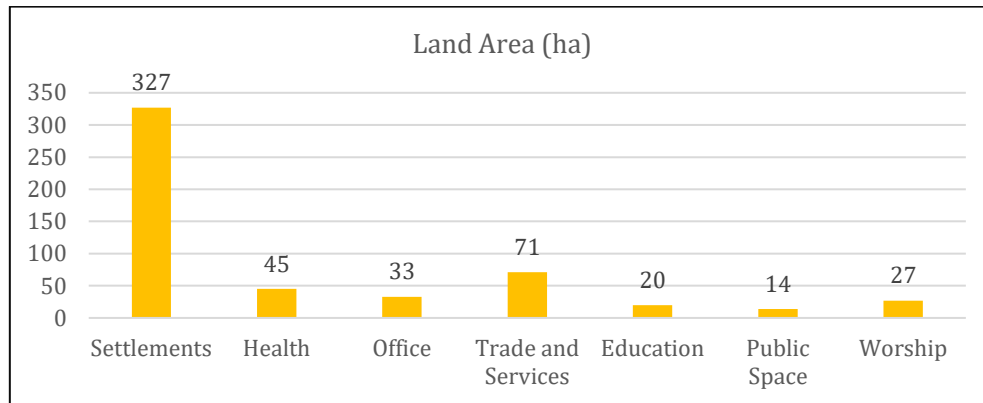


Fig. 8. Zoning graph of functional area of North Sinjai District

Based on the functional zoning map of the North Sinjai District urban area, residential zones dominate land use, covering 327 ha. This indicates that most of the territory is used for housing, reflecting high residential activity among the local population. Next, trade and services cover 71 ha. This zone indicates significant economic activity to meet community needs. Meanwhile, healthcare facilities occupy 45 ha, and office areas cover 33 ha. Educational zones cover 20 ha, followed by places of worship (27 ha) and public spaces (14 ha).

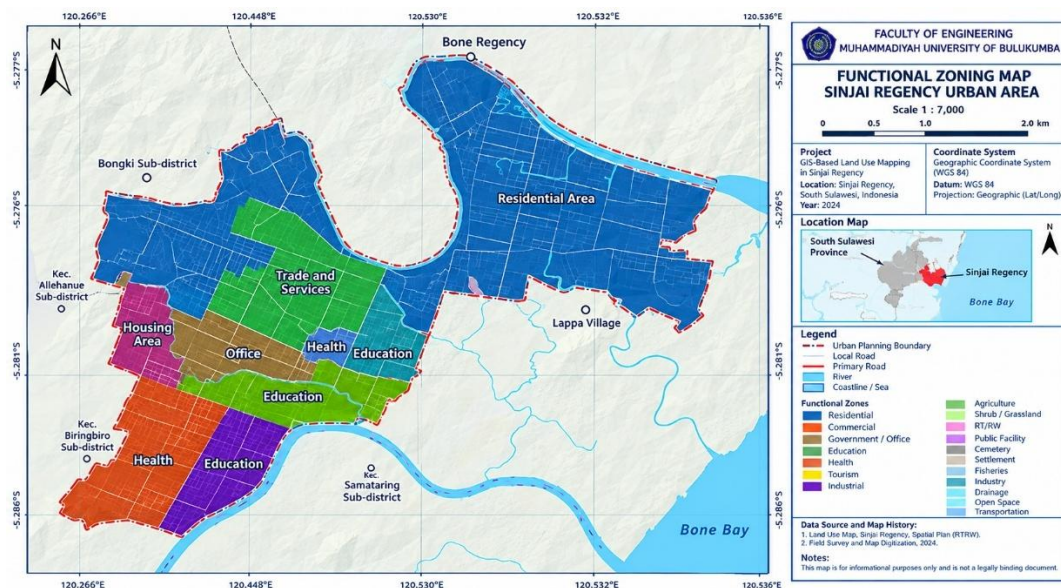


Fig. 9. Zoning map of area function

The relatively small size of public spaces compared to other zones highlights the need to provide open spaces and public facilities that foster social interaction and enhance the

quality of the urban environment. Overall, the land-use pattern in the North Sinjai District urban area shows residential functions dominate, supported by facilities for trade and services, healthcare, offices, education, public spaces, and places of worship. This composition reflects the area's character as an urban zone defined primarily by residential living, public services, and economic activities.

Based on the graphs and maps above, it can be seen that the results of the analysis of the existing research area in North Sinjai District show the formation of seven land use zones. The residential zone has the highest area, which is 137 ha, because North Sinjai District functions as the capital of Sinjai Regency and is the center of community activities, so this zone is more dominant. On the other hand, the smallest zone is found in public spaces with an area of 14 ha.

3.5 Desire line analysis

Desire Line analysis was used to map the journeys of 300 respondents. Based on the results of questionnaires and interviews, this analysis evaluated the origin and destination of the trip to identify the level of linkage between the seven existing zones, which were categorized as high, medium, and low. The results of the Desire Line analysis can be seen in the following map image.

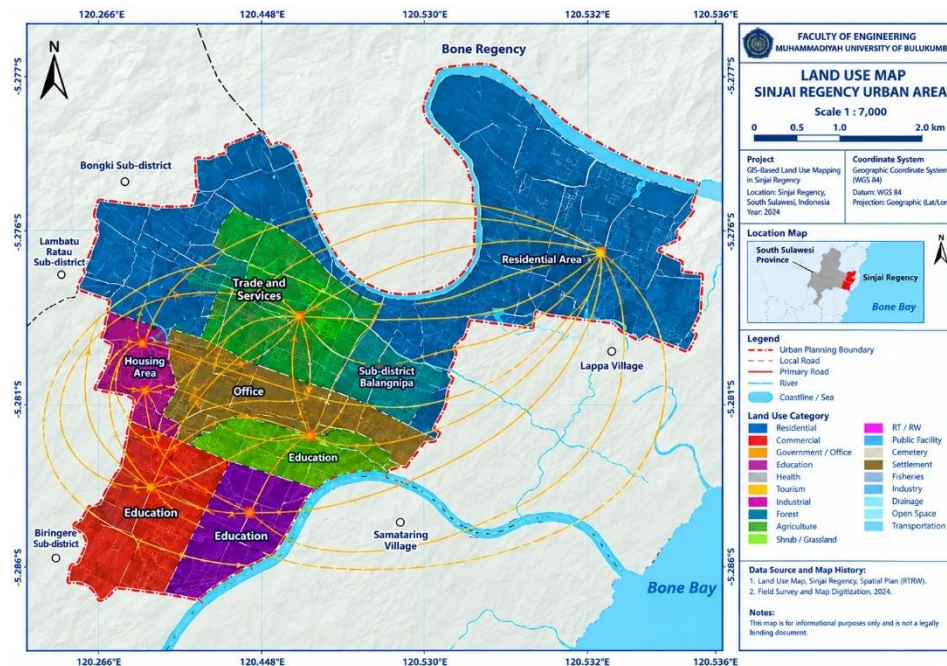


Fig. 10. Desire line map

Based on the map above, the analysis of existing land use in North Sinjai District shows the formation of seven interrelated activity centers. The strongest desire-line interactions were between health zones and trade and service zones, and between office zones and trade and service zones. Meanwhile, moderate linkage is observed between residential zones and health, education, trade and service zones, and public spaces. On the other hand, interactions with a low level of linkage occur between residential zones and zones of worship, office, education, and health.

3.6 Analysis of land use management directions

The Land Use Management Direction Analysis aims to produce a land use management direction map by first determining travel intervals based on questionnaire data from 300 respondents. These intervals are analyzed by journey origin and destination to identify

relevant movement patterns. The determination of the interval used in making the land use management direction map can be seen in the following table.

Table 2. Desire line determination interval

Movement	Frequency	Classification of wish lines
> 13	24	Low
14-27	13	Keep
28-42	3	Tall

Based on Table 2, the desire line interval for land use direction is divided into three classifications, namely high, medium, and low. The resulting land use management roadmap can allocate more land or resources to health zones to meet higher health-sector needs. In addition, public space zones require more attention to meet community needs, which can be done by expanding and improving infrastructure and other services. Given that the dominant objectives are in trade and service zones, strengthening the trade and services sector in land development is also important. In this context, it is necessary to improve infrastructure facilities, such as road capacity and transportation modes, to facilitate interaction between zones.

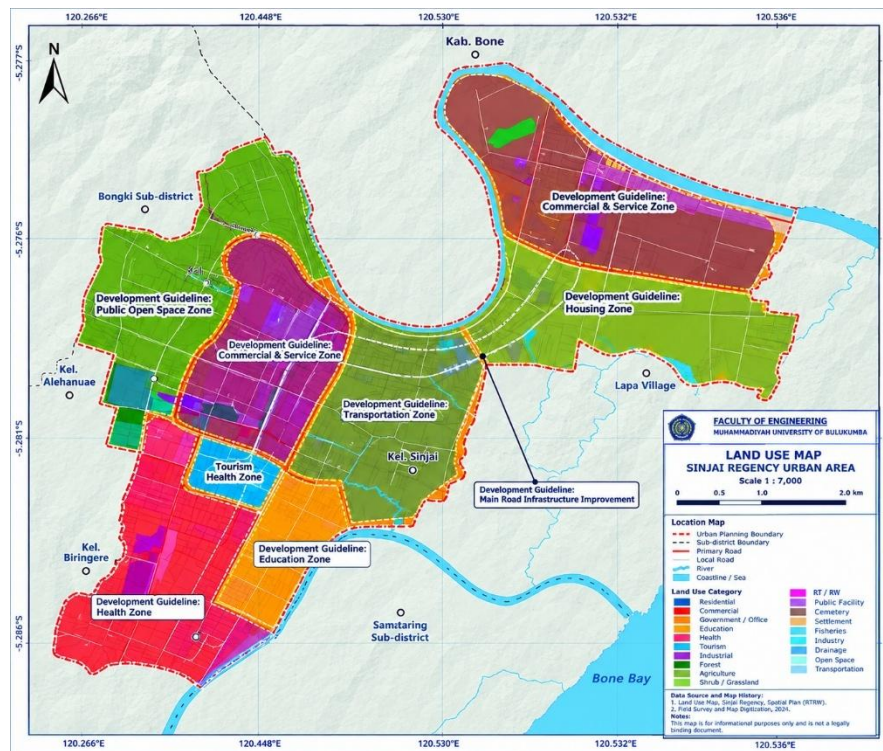


Fig. 11. Land use management direction map

4. Conclusions

Based on the study site results, the Origin-Destination Matrix analysis in the functional area of Sinjai City shows that more land or resources should be allocated to the health zone to meet the high demand in the health sector. This is important to improve access and quality of health services for the community.

In addition, public space zones need more attention to ensure the community's needs are met. This effort can be carried out by expanding and improving infrastructure facilities, such as parks, playgrounds, and gathering areas, as well as by providing better public services. Given that trade and service zones have the most dominant overall objectives, strengthening this sector in land development is also very important. Therefore, improving infrastructure, including increasing road capacity and providing efficient transportation

options, is needed to facilitate interaction between zones and support the smooth movement of people and goods in the area.

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Author Contribution

Conceptualization of the research framework, Y.R., A.I.A.; Methodology, R.S.; Spatial Analysis, M.F.; Field Survey, M.F., R.S., S.A.; Draft Preparation, R.S.

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Not available.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During preparation of this work, the authors used Grammarly to improve the grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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