Spatio-temporal Analysis of Ambulance Services in Densely Populated Urban Area: A Case Study in Jakarta

[1*]Zakiul Fahmi Jailani, [2]Dita Nurmadewi, [3]Raden Bambang Sumanjaya, [4]Ni Kadek Sri Manik

[1,2,3,4]*Bakrie University*

**Email: zakiul.jailani@bakrie.ac.id*

Manuscript received: 15th July 2023; Received in revised form: 25th July 2023; Accepted: 20th August 2023

ABSTRACT

In Jakarta city, there are only 78 ambulance data points that are publicly accessible online, which this study utilized that includes ambulance data points retrieved from OpenStreetMap (OSM), and manually digitized ambulance data points from community/non-government organizations. With a total population of 10,679,951 Jakarta residents and these 78 ambulance data points, this study mapped the ambulance-to-population ratio, the ambulance coverage area, and the ambulance response time within 15 minutes timeframe in Jakarta. The analysis was conducted using a combination of Service Area and Overlay tools in QGIS (Quantum Geographic Information System) software. The findings revealed the current ambulance-to-population ratio in Jakarta fell short of the McSwain's recommended of one ambulance for every 50,000 people. Consequently, both the map of ambulance coverage area as well as the map of ambulance response time within 15 minutes were unable to encompass the entire expanse of Jakarta city. Designed with the purpose of delivering a systematic evaluation of ambulance services within the capital city of Indonesia, this study extends its potential utility to assessing ambulance services in other cities across the nation.

Keywords: Ambulance, GIS, OpenStreetMap, Jakarta

1. INTRODUCTION

Access to affordable, high-quality healthcare is part of United Nations's Sustainable Development Goals (SDG Target 3.8). Emergency medical services (EMS) are a crucial component of it since they can deliver life-saving care in times of medical emergencies, and it was discovered that locating ambulances to maximize minimum response time thresholds also maximized patient survival [1].

Ambulance services, as a crucial component of EMS, must deliver rapid and efficient responses to emergency situations to keep the patient's chance of survival high. One study suggests that there is a link between the response time of emergency ambulance personnel and the successful treatment of cardiac arrest patients [2]. The period of time between a call for an ambulance and the moment it arrives on the scene of the emergency is known as the ambulance response time [3]. There are a wide variety of patients who require rapid emergency response from ambulances, ranging from traffic accidents, fires, diseases, and natural disasters [4], to mental health patients [5].

Because of its accessibility (number of units, routes of travel and economic viability), ambulances are the major mode of emergency transport in Jakarta [6]. However, due to Jakarta's dense population, urbanization, and traffic congestion, ambulance response time

is frequently disrupted, resulting in prolonged delays and inadequate emergency response. Good access, for example, is essential for an effective handling of COVID-19 cases in an area, such as ambulance entry and the distribution of emergency help and vaccinations [7].

The awareness of using ambulance services is also very low as stated in a study that out of 1,964 patients surveyed in Jakarta, the majority of them prefer to use motorcycles or private cars to bring patients to the hospital [8]. Just 9.3% of patients in the survey reported using ambulances, and 38% of patients were unaware that ambulances were available to them. Reluctance to use ambulances could be due to the basic assumption of people who feel that the cost of using ambulances is more expensive compared to using other modes of transportation.

The purpose of this study is to conduct a spatio-temporal analysis of ambulance services in Jakarta in order to look at the current state of ambulance-to-population ratio, ambulance coverage area, and ambulance response time within 15 minutes timeframe in Jakarta. This study will review existing literature on ambulance services in urban areas with a geospatial approach. In order to pinpoint geographic patterns and temporal trends in ambulance response times, this study used a number of tools and techniques, such as QGIS for spatial analysis, and Python programming language for data processing.

The study's results are valuable for helping Jakarta's policymakers, healthcare providers, and emergency responders improve medical services and save more lives. This research, focused on assessing ambulance services in Indonesia's capital, also offers the potential to extend its insights to evaluate and improve similar emergency services in various cities throughout Indonesia, ultimately bolstering overall emergency response capabilities.

2. Data and Methodology

2.1 Data

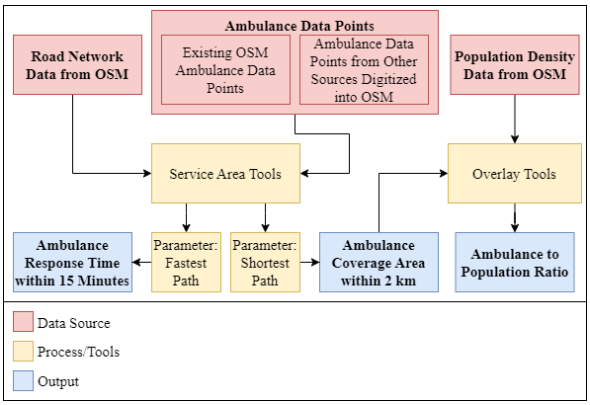

Figure 1. Research flowchart

The main data required for this research were location data in the form of ambulance data points (health facilities or non-governmental organizations), population density data, and the Jakarta Road network (see Figure 1).

This study utilized a variety of data sources, with a focus on OpenStreetMap (OSM), which relies on the volunteer community's strength in collaboration to maintain accurate and up-to-date data despite having an open editing framework [9] [10] [11]. OSM provided ambulance data, road network data, and data of Jakarta population density per sub-district. In addition to the non-hospital ambulance data, this study also enhanced its dataset by manually digitizing ambulance locations stationed within the hospital premises, a process that involved verifying ambulance presence through hospital data in Google Maps as well as OSM and direct confirmation with hospital management.

In another case, there were many ambulance data that had not been digitized and made publicly available online coming and acquired from a range of sources, including government agencies, community organizations, and non-governmental organizations (NGOs) who have frequently collaborated to provide emergency medical care in underserved areas. In this study, the data were digitized and incorporated into

OpenStreetMap (OSM), resulting in a total of 78 ambulance data points across all regions of Jakarta, including the existing data already present in OSM. It is important to note that one ambulance data point in this study means it only represents one ambulance in real life.

2.2 Methodology

This research encompassed three distinct analyses: the ambulance-to-population ratio analysis, the ambulance coverage area analysis, and the ambulance response time within 15 minutes analysis. The latter two analyses employed a specialized algorithm known as the cost matrix algorithm, a variant of Dijkstra's algorithm [12]. This algorithm efficiently calculates the shortest path or distance from a set of input data points to all other points within a specified parameter.

The application of this Dijkstra's algorithm was facilitated through the Service Area tool within QGIS. In the context of the ambulance coverage area analysis, the parameter chosen was the 'shortest path', utilizing distance as the primary factor for calculation (see Figure 1). Conversely, for the ambulance response time analysis, the parameter employed was the 'fastest path', taking travel time into account as the primary factor for computation.

For the ambulance-to-population ratio analysis, an overlay tool was employed. This tool overlaid the population density data (see Table 1) onto the polygon representing the ambulance coverage area within a 2 km radius. In order to accommodate the demand for patient transportation to the nearest health facility, the suggested ratio according to McSwain is one ambulance for every 50,000 people [13].

Tabel 1. Total population in each administrative cities in Jakarta

Administrative cities	Total Population
Jakarta Utara	1,793,550
Jakarta Timur	3,083,883
Jakarta Barat	2,448,975
Jakarta Pusat	1,079,995
Jakarta Selatan	2,244,623
TOTAL	**10,679,951**

The ideal coverage area should ensure emergency responders to reach any location in a fair amount of time, regardless of traffic or other obstacles [14]. Recent research suggests that the standard coverage area for emergency services is less than 20 kilometers [15]. Our research suggested that the suitable coverage area for ambulance services would be less than 2 km due to highly urbanized areas such as in Jakarta, which has heavy traffic congestion, narrow roads, and other obstacles that can significantly hinder emergency response times.

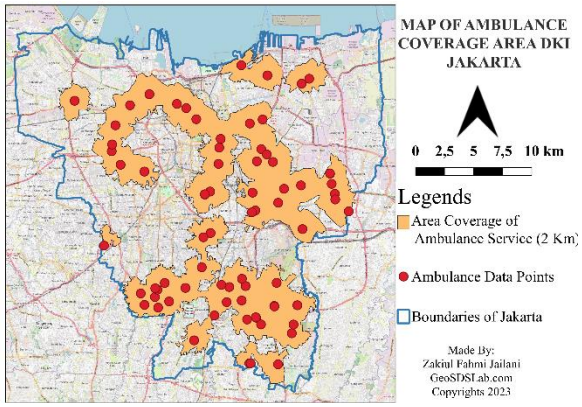

Figure 2. Ambulance coverage area

Another important analysis is the ambulance response time analysis, which refers to the amount of time it takes for emergency services to arrive at the scene of an incident after receiving a call for help. The Indonesian Ministry of Health has set a maximum emergency response time of less

than 15 minutes [15]. Failing to meet this standard can lead to treatment delays, deterioration of the patient's health, and even loss of life [16].

3. Result and Discussion

3.1 Coverage Area

The data required, which was stated in section 2, was used to analyze the ambulance coverage area in Jakarta. The research then performed a service area analysis which entails drawing a boundary that indicates the area that may be reached from the facility within a distance of 2000 meters. Several criteria were considered, including a default speed of 50 km/hour, and a travel distance range of 2000 meters in both directions from the facility to the emergency call.

The aforementioned result was then used to be aggregated by the conclave tool, in which resulted in a polygon of areas which depicts the overall area that ambulances could reach within the travel distance range given (Figure 2). The visual representation in Figure 2 showcases the red dots on the map, symbolizing the precise locations of ambulance data points, while the yellow polygons elegantly outline the extensive coverage areas where ambulance services are readily accessible, optimizing emergency response efficiency across Jakarta.

3.2 Ambulance-to-Population Ratio

Another important analysis to do is to calculate the ambulance-to-population ratio for different areas in Jakarta. This study utilized population density data per sub-district as the input layer and a 2 km coverage area polygon as the overlay layer for this analysis. The overlay tool calculated the overlap area between these two layers, giving us the population that falls inside the coverage area of each ambulance fleet location, thus revealing total population that can be served by the ambulance per sub-district (Figure 3).

The visually compelling choropleth map depicted in Figure 3 effectively communicates this valuable information, wherein areas shaded in darker red indicate a higher population being served by ambulance services, while lighter red areas represent fewer populations in each sub-district across all of Jakarta. This insightful representation empowers emergency planners and decision-makers to allocate resources and prioritize areas most in need of efficient ambulance services.

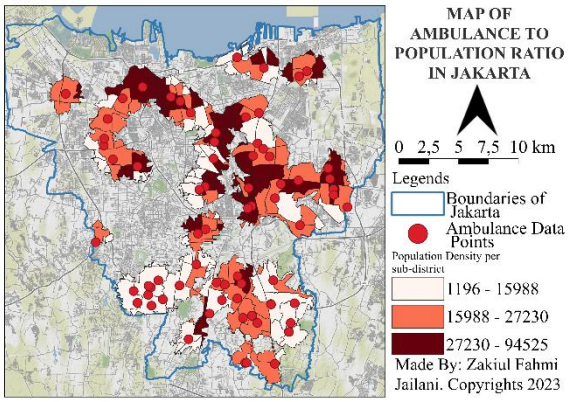

Figure 3. Ambulance-to-population ratio

The overlay tools using the 2 km coverage area polygon and 78 points of ambulance data reveals that the current ambulance fleet in Jakarta can serve a total population of 5,410,000 people, which is less than half of the city's entire population.

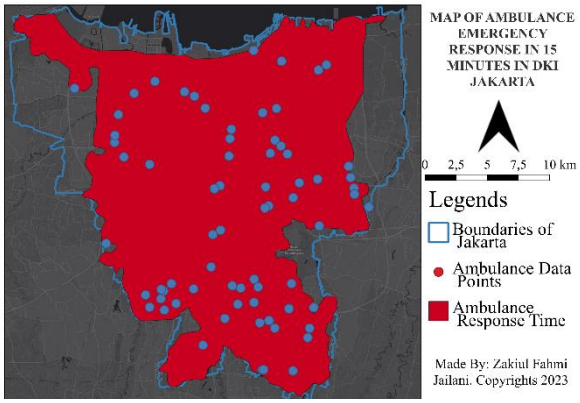

Figure 4. Ambulance response time within 15 minutes timeframe

By calculating the ambulance-to-population ratio for each sub-district, this research could identify areas where the demand for ambulance services is particularly high and where additional

resources may be needed to improve the quality of care. For example, certain sub-districts may have a high population density but a low ambulance-to-population ratio, indicating a coverage gap that must be remedied.

3.3 Ambulance Response Time

Regarding ambulance response time, this study employed the same analysis tool as utilized for the ambulance coverage area analysis, albeit with a distinct parameter setting.

Again, the tool utilized for this analysis was also the service area analysis, which could generate a boundary indicating the area that could be accessed by the ambulance in 15 minutes timeframe. For that, the parameter set was set according to the recommendations of the Indonesian Ministry of Health, which is 900 seconds (15 minutes multiplied by 60) and a default speed of 30 km/hour. Another essential parameter set was that the default direction is on forward direction and the path type taken in the analysis the ‘fastest path’, instead of the other parameter which is ‘shortest path’. It is worth mentioning as explained in section 2, the parameter 'fastest path' in this context refers to taking travel time as the primary factor for computation, rather than calculating the fastest path for each individual ambulance.

These combined process culminated in the creation of a visually striking red polygon that meticulously outlines the expansive region where ambulances can efficiently reach within the specified travel time constraint (Figure 4). The resulting polygon provides an intuitive and comprehensive representation, offering emergency planners and responders invaluable insights into the accessible areas, thereby facilitating the optimization of ambulance deployment and ensuring prompt and effective emergency medical services across the designated regions.

4. CONCLUSION

This study has presented a comprehensive spatio-temporal analysis to shed light on the current state of ambulance services in Jakarta which offers potential to extend its approach to evaluate similar emergency services in various cities througout Indonesia. It's crucial to emphasize that the ambulance data points examined in this research were publicly accessible online. However, it's important to acknowledge the possibility that additional ambulances exist in reality but haven't been digitally recorded.

The current state of ambulance-to-population ratio in Jakarta revealed that Jakarta’s present ambulance fleet of 78 has not been met with the McSwain’s recommended of one ambulance for every 50,000 people. Based on McSwain’s theory, the ideal number of ambulance fleet would be 215 to serve all 10,679,951 Jakarta residents.

According to both the map of ambulance coverage area and map of ambulance response within the 15 minutes timeframe this study generated, ambulance fleet were unable to encompass the entire expanse of Jakarta city.

It is worth noting that the current ambulance fleet data points are publicly available, but do not include data from the Jakarta Health Department. It is estimated that there are approximately 50 ambulance data points from the Jakarta Health Department, but the data could not be included in the final analysis because the data were not made publicly available.

Future studies should look into other factors that can help create a more detailed method to assess ambulance services in densely populated urban areas such as Jakarta. Data and factors that can be used are such as historical data from ambulance calls, road infrastructure, traffic congestion, and factoring in rush-hour time into the final analysis.

5. ACKNOWLEDGMENTS

We would like to convey our gratitude towards this research project grant funders and affiliates which are Open Mapping Hub-Asia Pacific (OMHAP) and Perkumpulan OpenStreetMap Indonesia (POI). Interactive WebGIS and data related to this research can be found at www.geosdslab.com.

6. REFERENCES

[1] R. McCormack and G. & Coates, "A simulation model to enable the optimization of ambulance fleet allocation and base station location for increased patient survival," *European Journal of Operational Research*, vol. 247(1), pp. 294-309, 2015.

[2] H. Mitcel, "Hubungan Respon Time Petugas Ambulans Gawat Darurat dengan Keberhasilan Penanganan Pasien Cardiac Arrest: Correlation between Response Time of Emergency Ambulance Officers and Successful Management of Cardiac Arrest Patients.," *Indonesian Scholar Journal of Nursing and Midwifery Science (ISJNMS)*, vol. 2(04), pp. 648-655, 2022.

[3] M. S. Desai, A. M. Rawani and M. I. M. & Loya, "REDUCING AMBULANCE RESPONSE TIME IN EMERGENCY MEDICAL SERVICES: A LITERATURE REVIEW.," *International Journal of Mechanical Engineering and Technology (IJMET)*, Vols. 10, 85-96., 2019.

[4] R. Heryani, "Penentuan Lokasi Optimal Public Safety Center Berbasis Risiko Bencana Di Kabupaten Barru= Optimal Location Determination Of Public Safety Center Based On Disaster Risk In Barru Regency," *Doctoral dissertation, Universitas Hasanuddin*, 2022.

[5] D. Huppert and M. & Griffiths, "Police mental health partnership project: police ambulance crisis emergency response (PACER) model development.," *Australasian Psychiatry*, Vols. 520-523, p. 23(5), 2015.

[6] P. Aitken, M. Elcock, N. Ballard and M. Hooper, "Retrieval and transport," *ABC of Prehospital Emergency Medicine*, 2013.

[7] M. V. Wirastri, N. Morrison and G. & Paine, "The connection between slums and COVID-19 cases in Jakarta, Indonesia: A case study of Kapuk Urban Village.," *Habitat International*, vol. 102765, p. 134, 2023.

[8] S. N. Brice, J. J. Boutilier, D. Gartner, P. Harper, V. Knight, J. Lloyd and M. Tuson, "Emergency services utilization in Jakarta (Indonesia): a cross-sectional study of patients attending hospital emergency departments," *BMC health services research*, vol. 22, no. 1, pp. 1-10, 2022.

[9] M. Minghini and F. Frassinelli, "Is OSM up-to-date?. Open Geospatial Data, Software and Standards," *Open Geospatial Data, Software and Standards*, vol. 4, no. 1, pp. 1-17, 2019.

[10] A. Y. Grinberger, M. Minghini, L. Juhász, G. Yeboah and P. Mooney, "OSM Science—The Academic Study of the OpenStreetMap Project, Data, Contributors, Community, and Applications," *ISPRS International Journal of Geo-Information*, vol. 11, no. 4, p. 2022, 2022.

[11] M. Raifer and a. et, "OSHDB: a framework for spatio-temporal analysis of OpenStreetMap history data," *Open Geospatial Data, Software and Standards*, vol. 4, no. 1, pp. 1-12, 2019.

[12] D. R. Aremu and O. A. Gbadamosi, "Design of a Modified Dijkstra's Algorithm for finding alternate routes for shortest-path problems with huge costs," in *2020 International Conference in Mathematics, Computer*

Engineering and Computer Science (ICMCECS), 2020.

[13] N. E. McSwain, "Prehospital emergency medical systems and cardiopulmonary resuscitation," *Trauma*, vol. 2, pp. 99-108, 1991.

[14] Ľ. Jánošíková, P. Jankovič, M. Kvet and F. & Zajacová, "Coverage versus response time objectives in ambulance location," *International Journal of Health Geographics*, vol. 20(1), pp. 1-16, 2021.

[15] A. Awad, H. Ali and D. R. S. Sumunar, "Measuring the spatial readiness of ambulance facilities for natural disasters using GIS networks analysis," *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, pp. 81-84, 2020.

[16] R. Y. Hsia, D. Huang, N. C. Mann, C. Colwell, M. P. Mercer, M. Dai and M. J. & Niedzwiecki, "A US national study of the association between income and ambulance response time in cardiac arrest.," *JAMA Network Open*, no. e185202-e185202, p. 1(7), 2018.

[17] B. P. Statistik, "Jumlah Penduduk Provinsi DKI Jakarta Menurut Kelompok Umur dan Jenis Kelamin 2019-2021," 2022.