FIRE VEHICLE ROUTE, RESPONSE TIME, AND SERVICE COVERAGE OPTIMIZATIONS IN PEKOJAN URBAN VILLAGE,TAMBORA SUBDISTRICT FIRE HOTSPOT OF JAKARTA CITY INDONESIA

Isradi Zainal[1], Fatma Lestari[2], Satriadi Gunawan[3], Andrio Adiwibowo[4]
Abdul Kadir[5], Noor Aulia Ramadhan[6]
Occupational Health and Safety Department, Faculty of Public Health, Universitas Indonesia[1,2,4,5]
Fire and Rescue Agency, DKI Jakarta[3], Disaster Risk Reduction Center, Universitas Indonesia[6]
isradizainal@gmail.com[1] , fatma@ui.ac.id[2]

ABSTRAK

Salah satu tantangan dalam mengelola bahaya kebakaran di lingkungan perkotaan adalah bagaimana mengoptimalkan rute layanan kebakaran, meningkatkan waktu tanggap, dan meningkatkan cakupan layanan. Belakangan ini, tantangan ini semakin menjadi-jadi karena kemacetan lalu lintas jalan dan lebar jalan yang tidak mencukupi yang biasa terjadi di kota-kota berpenduduk di kawasan Asia Tenggara. Salah satu titik api perkotaan di Kota Jakarta yang berpenduduk padat adalah Kelurahan Pekojan, Kecamatan Tambora. Kecamatan ini dilayani oleh Pemadam Kebakaran Angke yang terletak di bagian barat daya Pekojan. Kemudian penelitian ini bertujuan untuk mengevaluasi dan membandingkan rute yang dioptimalkan untuk kendaraan pemadam kebakaran yang diberangkatkan dari Stasiun Pemadam Kebakaran Angke untuk melayani 12 RW di Pekojan. Metode yang digunakan adalah optimasi rute dan alat analisis jaringan dalam Sistem Informasi Geografis (SIG) dan data geospasial terkait termasuk unit lingkungan, jaringan jalan, kemacetan lalu lintas, dan lokasi stasiun pemadam kebakaran. Analisis data jaringan geospasial dengan GIS memiliki keunggulan sebagai metode untuk merancang dan menganalisis strategi routing dan menentukan rute yang paling optimal untuk kendaraan pemadam kebakaran. Berdasarkan hasil dan dengan kecepatan kendaraan pemadam kebakaran 40 km/jam, rata-rata jarak rute yang dioptimalkan untuk perjalanan dari stasiun pemadam kebakaran ke RW adalah 1,092 km (95%CI: 0,888-1,3 km) dengan waktu respons rata-rata 1,638 menit (95% CI: 0,869-2,41 menit). Menurut model GIS, waktu respon 1 menit hanya mencakup 22,77% wilayah Pekojan. Dengan meningkatkan response time menjadi 2 menit, maka mobil pemadam kebakaran dapat menjangkau 98,9% area Pekojan (AIC= 0,06). Terlepas dari kenyataan bahwa rute kendaraan pemadam kebakaran dan waktu respons dapat dioptimalkan, rute-rute tersebut ditantang oleh kemacetan lalu lintas jalan. Kemacetan ini membatasi kecepatan kendaraan pemadam kebakaran hingga kurang dari 20 km/jam, seperti yang diamati pada 11,59% dari rute yang dioptimalkan. Jangkauan pelayanan kendaraan pemadam kebakaran juga terbatas karena sempitnya jalan.

Kata Kunci : GIS, kendaraan pemadam kebakaran, analisis jaringan, optimasi, rute

ABSTRACT

One challenge in managing fire hazards in an urban setting is how to optimize the fire service route, increase the response time, and increase service coverage. Recently, this challenge is becoming imminent due to road traffic congestion and insufficient road widths that are common in populated cities in the Southeast Asia regions. One of the urban fire hotspots in populated Jakarta City is Pekojan Urban Village, Tambora Subdistrict. This subdistrict is served by Angke Fire Station located in Pekojan's southwestern parts. Then this research aims to evaluate and compare optimized routes for fire vehicle dispatched from Angke Fire Station to serve 12 neighborhood units (in Bahasa is RW) in Pekojan. The method used the route optimization and network analysis tools in Geographic Information System (GIS) and its related geospatial data including neighborhood units, road networks, traffic congestion, and fire station locations. Geospatial network analysis of data by GIS has an advantage as a method to design and analyze the routing strategy and determine the most optimized route for fire vehicles. Based on the results and with the fire vehicle speed of 40 km/h, the average optimized route distances to travel from the fire station to RWs were 1.092 km (95%CI:

0.888-1.3 km) with an average response time of 1.638 minutes (95%CI: 0.869-2.41 min.). According to the GIS, model, response time of 1 minute only covers 22.77% of Pekojan areas. By increasing response time to 2 minutes, then fire vehicle can cover 98.9% of Pekojan area (AIC= 0.06). Despite the fact that the fire vehicle routes and response times can be optimized, those routes are challenged by the road traffic congestion. This congestion limits the speeds of fire vehicles to less than 20 km/h, as observed in 11.59% of the optimized routes. The service coverages of fire vehicles was also limited due to the narrow street.

Keywords *: GIS, fire vehicle, network analysis, optimization, route*

INTRODUCTION

Our urban environment is facing potential risks from urban fires, which are prevalent in nearly all of the country's urban cities (Baptist and Bolnick 2012, Owusu 2013). One of the serious consequences of unplanned development is an endless incident of urban fires (Twigg et al. 2017). Large amounts of urban fires in various forms are being generated as a result of increasing population and industrialization. As of now, 53% of the Indonesian population is part of the urban community and lives in urban areas. Unplanned road networks and urban fire service coverage optimizations are the most common issues associated with urban fire. Urban fires are regarded as one of the most serious urban issues, challenging municipal authorities at the sub district and urban village levels in terms of increasing response times and optimizing service coverage to best deliver the fire services. In today's society, the problem associated with response time and service coverage optimization is a complex vehicle network that causes congestion on fire vehicle routes. As a result, in order to reduce and manage urban fires, fire vehicle routes will need to be organized and managed by combinations of the latest technologies and methods that can support and sustain both communities and the environment.

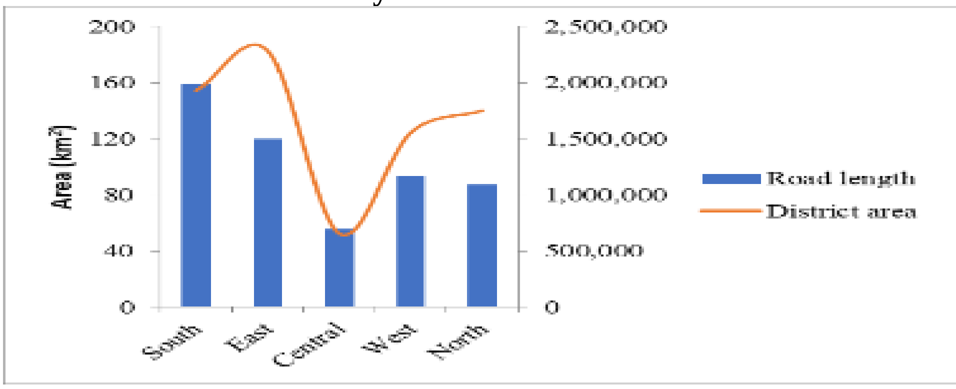
Because of the increment in urban fire cases, emergency services institutions must use the best training methods, equipment, instruments, and techniques to fulfil public expectations and needs and provide fire service as soon as possible (Aringhieri et al. 2017). The Geographic Information System (GIS) is one of the tools that aid in the improvement of emergency services institutions (Cova 1999, Milenkovic and Kekic 2016, Prabhakaran et al. 2017). The primary concern in the aftermath of a potential urban fire is reducing the consequence of the hazard. In this case, GIS is favoring risk evaluation and the advancement of long-term relief procedures. GIS can serve as the integrating center piece for an overarching disaster readiness and response system or as a portable, real time source of spatial information during the preparedness and response stages. Following a disaster, GIS is becoming increasingly important in assisting with the conveyance of emergency services and planning, including route optimization of fire service in urban settings (Vratonjić and Wittmann 2015).

Route optimization is an important tool for managing proper traffic, particularly in large cities. Network analysis using Geographic Information Systems (GIS) is one of the versatile methods that can be used (Bazargan, and Amirfakhriyan 2017, Sureshkumar 2017). The goal of route optimization is to find the shortest path and maximize the route's utilization. The use of route optimization (Pillac et al. 2013) in urban studies is critical and has been used in a variety of fields (Knyazkov et al. 2015, Kus et al. 2016). Malakahmad et al. (2014) used GIS-based route optimization to find the most effective and efficient waste collection routes in urban areas. As a result of employing the route optimization technique, it can minimize the route length by up to 22% and the collection duration was also reduced from 6,934 seconds to 4,602 seconds.

One of the growing applications of route optimization research is in the field of emergency (Tian et al. 2018) and fire service (Beaudry et al. 2010). It entails optimizing the routes for delivering emergency services (Ghadiri and Banar 2018) as well as fire services. Because it is critical that fire and rescue resources arrive at fire incident sites as quickly as possible. It is also critical that fire vehicles be stationed in areas where they can coordinate efficient responses. When fires occur, it is critical that the fire and rescue services respond quickly and efficiently to the fire sites. It is mostly necessary to respond quickly in t

CONTEXT OF THE JAKARTA, TRAFFIC, AND FIRE CASES Road conditions and traffic in Jakarta City

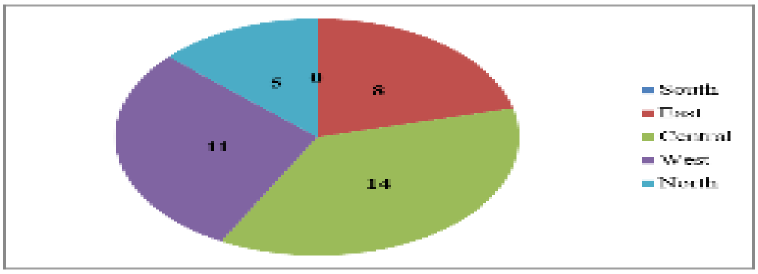
Jakarta City has a total area of 654 km^2 and is served by a road network with a total length of 6,432,473 m. Jakarta City is divided into 5 districts and, on average, each district has an area of 131 km^2 and is served with an average road length of 1.286,495 m (Figure 1). West Jakarta District, where Tambora Subdistrict is located, was ranked 3rd in terms of area and road length. This district is served by 1,169,976 m of road length. The width of the two lane road varied from 3.5 m to 11 m. Two lane road width ranges of 3.5 m to 6.5 m are for roads in the residential areas (Saleh 2016). The presence of narrow roads results from the demand for land due to the growing population in Jakarta City, where density equals 16,704 people per km^2.



(Data source: https://statistik.jakarta.go.id/).

Fig. 1. Two lane road length (m) and district area (km^2) of the 5 districts (South, East, Central, West, and North) in Jakarta City. Tambora Subdistrict is located in West Jakarta District

Transportation in Jakarta is challenged by traffic congestion recently. This congestion is related to multiple determinant factors. The main factors are the size of the roads, combined with the number of vehicles, vehicles that park on the road side, and large numbers of people visiting markets on the roadside. In Jakarta City, there are 39 congestion locations. According to Figure 2, the roads in West Jakarta District have the 2nd highest traffic congestion locations in Jakarta City.

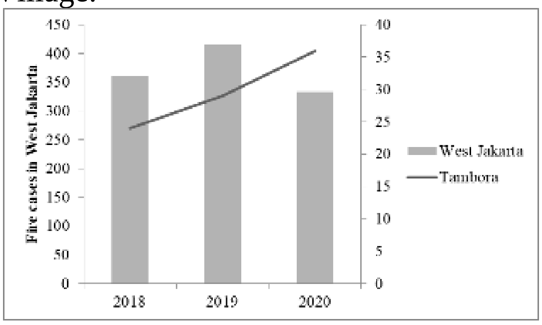


(Data source: https://data.jakarta.go.id/dataset//).

Fig. 2. Compositions of congested locations in 5 districts (South, East, Central, West, and North) in Jakarta City

Increasing fire cases in Tambora Subdistrict

Jakarta, as a densely populated capital city, is vulnerable and prone to fires (Sudiana et al. 2018a, Sudiana et al. 2018b). West Jakarta is one of the districts that frequently experiences fire cases. Figure 3 shows the trends of fire cases in West Jakarta for the period of 2018-2020. From 2018 to 2019, there was an increase in cases, and it declined from 2019 to 2020. Despite the fact that fire cases were declining at the district level, the fire cases in Tambora Subdistrict were showing an increasing trend. One of the fire hotspots in Tambora Subdistrict is Pekojan Urban Village.



(Data source: https://jakbarkota.bps.go.id/).

Fig. 3. Comparisons of fire cases in West Jakarta District and Tambora Subdistrict from 2018 to 2019

With a density of 36,104 people per km^2, Pekojan, is one of the urban villages in Tambora Subdistrict with a high risk of urban fire. A record shows that once a fire in Pekojan burned 200 houses. Simultaneously, it has been theorized that rapid urbanization unquestionably increases pressure on urban infrastructure and services, much of which has not been provided in a sustainable manner to anticipate rapid urban growth. This condition has resulted in poor urban service delivery, including fire service, in the majority of developing-country cities. As a result, delivering fire service immediately is a major issue in such a densely populated area. Pekojan is only served by one nearby fire station, which is the Angke Fire Station (Figure 4). This fire station is equipped with a medium and large-sized fire vehicle (Table 1). The full-size fire truck has a width of 2.455 m and the medium-sized fire vehicle's width is 1.945 m.

Taking this into account, this study seeks to determine the optimal route and response time of fire vehicles in order to cover all Pekojan areas. The novelty of this research is that it is the first in Indonesia to use and implement GIS-based network analysis to select the optimal route for a fire vehicle, using Jakarta and vulnerable Pekojan Urban Village as an example. Despite the presence of extensive literature on emergency vehicle routing presented by Chen et al. (2012), Qin et al. (2017), and Anuar et al. (2021), the study is different from what has already been elaborated since this study incorporated traffic congestion influences on optimal route. In countries in Southeast Asia, traffic congestion is one of the primary problems that have multiplier effects on every aspect of life (Kitamura et al. 2018) and this issue then should be considered.

Table 1. Medium and large-sized fire vehicle specifications available in Angke Fire Station.

Variable	Medium	Large
Width	1.945 m	2.455 m
Length	6.026 m	9.410 m
Weight	2,216 kg	4,960 kg
Speed	97 km/h	94 km/h
Water tank capacity	3,500 l	6,000 l

with medium and large-sized fire vehicles (Photo source: Google Street View).

Fig. 4. Angke Fire Station in Pekojan's southwestern parts, Tambora Subdistrict, West Jakarta District

METHODS

The study area was located in the West Jakarta District of Jakarta City (Figure 5). In the West Jakarta District, there were eight sub districts. The method used the route optimization and network analysis tools in Geographic Information System (GIS) and its related geospatial data including neighborhood units, road networks, traffic congestion, and fire station locations. Geospatial network analysis of data by GIS has an advantage as a method to design and analyze the routing strategy and determine the most optimized route for fire vehicles. Based on the results and with the fire vehicle speed of 40 km/h, the average optimized route distances to travel from the fire station to RWs were 1.092 km (95%CI: 0.888-1.3 km) with an average response time of 1.638 minutes (95%CI: 0.869-2.41 min.). According to the GIS, model, response time of 1 minute only covers 22.77% of Pekojan areas. By increasing response time to 2 minutes, then fire vehicle can cover 98.9% of Pekojan area (AIC= 0.06).

RESULTS

The results is Figure 6 depicts the estimated and optimized GIS-based routes for the fire vehicle from FS Angke to access 12 RWs in the Pekojan Urban Village. Because of the differences in location, the optimized route took different paths to find the shortest route. Because the FS Angke was located in the southwest corner of Pekojan, the majority of the selected routes ran from South to North and South to East. The GIS network analysis calculated the length of each line representing a road and chose the shortest length. The trends of the optimized routes are depicted in Figure 7. It was obvious that the optimized routes became longer as they followed the locations of RWs. RWs that were located in the southern and central parts of Pekojan had shorter distances. While RW that was located in the North parts including RW 10, 11, and 12, more distances were required. Then there was a linear trend of RW locations with the optimized routes.

The average optimized routes were 1.092 km (95%CI: 0.888-1.3 km). Following the procedure, assuming that the average fire vehicle speed to deliver the service was 40 km/h then it was estimated that the average response time according to optimized routes was 1.638 minutes (95%CI: 0.869-2.41 min.) and this is still below the compulsory fire vehicle response time with a value of 5 minutes.

Figure 8 presents the modelled fire service coverage areas according to maximum values of response times as measured in this study with the maximum value was closed to 2 minutes. In Figure 8, the numbers of RW and areas of Pekojan Village, sized at 0.78 km^2 that can be covered with response time values of 1-2 minutes, were calculated. With a response time of 1 minute, the fire vehicle can only cover 6 RWs and 22.77% of the Pekojan areas. By increasing the response time to 1.5 minutes, the numbers of RWs and areas that can be covered were increased to 11 RWs and 75.76%. The highest coverage was reached with a 2 minute response time. In this situation, all RWs and 98.9% of the Pekojan area were covered.

The results of this study, obtained by using a GIS-based optimization approach, have optimized the response times of fire vehicles and the response times in Pekojan. Even though the Pekojan was only served by one fire station, this optimization could be developed. This result in Pekojan was comparable to the other cities that had more than one fire station. Previous research on the comparison of fire service response times on the number of fire fighter stations in Dubai City shows that a five minute (300 seconds) response time necessitates 13 stations, a four minute (240 seconds) response time necessitates 20 stations, and a three minute (180 seconds) response time necessitates 25 stations. In the United States, the fire vehicle arrived at the incident location with a nine-minute response time since the fire, despite being in the most densely populated area of California. This addresses the fact that protecting against urban fire disasters requires a quick response. According to the National Fire Protection Association (NFPA) Standard of fire response time (Taridala 2017), the required response time for the arrival of the first fire vehicle at a fire suppression incident is four minutes (240 seconds) or less, and/or eight minutes (480 seconds) or less for the deployment of a full first alarm assignment at a fire suppression incident. In this study, the optimal response time was two minutes, which was sufficient to cover the entire Pekojan area of 0.78 km^2.

Figure 9 shows that increasing response times can result in increased fire vehicle service coverage. In this case, this includes the number of RWs and the size of service areas. Response times have been found to be significantly related to fire service area increments rather than the number of RWs covered. AIC values of 0.06 supported the correlation of response time with service area (Table 2). This study's use of GIS-based optimization routes in the field of emergency and fire service is consistent with other studies. The use of GIS in emergency vehicles provides a flexible tool for management, visualization, and traffic network analysis. It generally provides tools for determining the shortest or fastest route through a network (Panahi and Delavar 2009) as well as reducing travel time (Billa et al. 2014, Ghaderi et al. 2017). Achieving effective fire vehicle routing reduces response time and thus improves emergency response performance (Fukushima and Moriya 2020). Because of its specific GIS capabilities for analyzing spatial networks, it can be used as a proxy for a decision support system for dispatching and routing emergency vehicles, including fire vehicles. The effective management of fire vehicle routes to fire hotspots is a critical component of the quality of fire services provided to vulnerable areas such as Pekojan Urban Village. The best option for reducing fire service response time is to use such GIS-based technologies (Pasha 2006), as well as to have a recent and well-established database of specific locations such as neighborhood units, road networks, and fire stations. However, these are insufficient; the state of the roads in some parts of Pekojan prevents emergency services from intervening in a timely manner. While GIS plays an important role in fire service transportation analysis due to the impacts of road conditions and traffic on reducing response time. optimized routes (shaded area is 95%CI) with 12 RW locations in South-North directions.

ISSN 2623-1581 (Online)
ISSN 2623-1573 (Print)

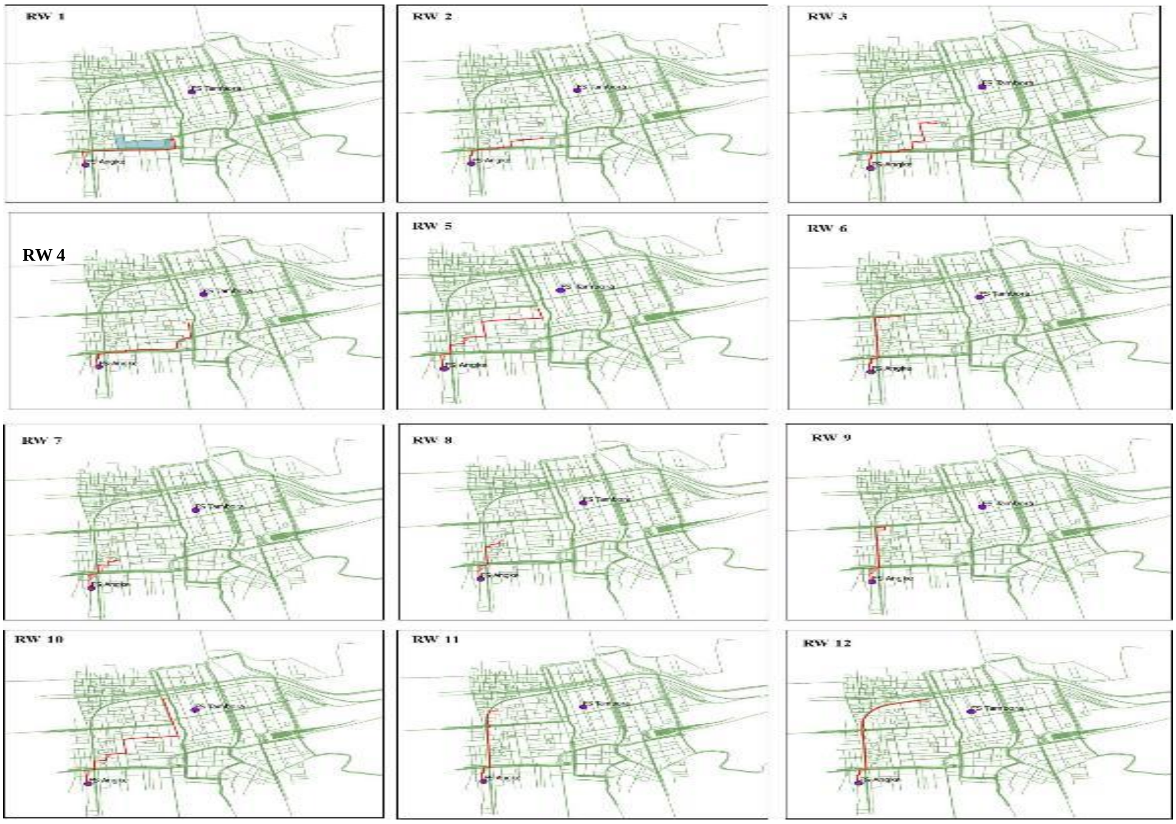


Fig. 6.Estimated optimized routes from Angke Fire Station (FS Angke) to access 12 neighborhood units (RWs) in Pekojan Urban Village, Tambora Subdistrict, West Jakarta District, Indonesia.

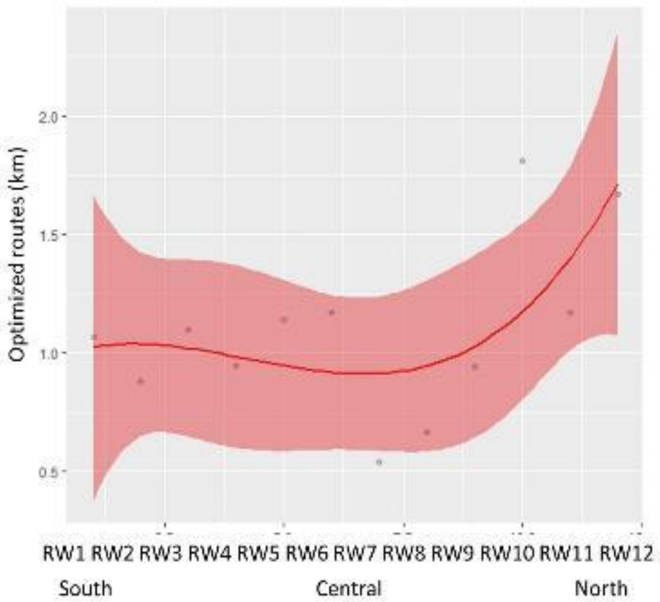


Fig. 7. Correlations and trends of fire vehicle

ISSN 2623-1581 (Online)
ISSN 2623-1573 (Print)

Fig. 8. RWs and areas of Pekojan are covered by 1,1.5, and 2 minute fire vehicle response times.

Table 2. Akaike Information Criterion (AIC) of fire vehicle response times, numbers of covered RWs, and areas of Pekojan

Model	AIC
(Fire vehicle response times) (numbers of covered RWs)	2.99
(Fire vehicle response times) (numbers of covered areas)	0.06*

*Best model

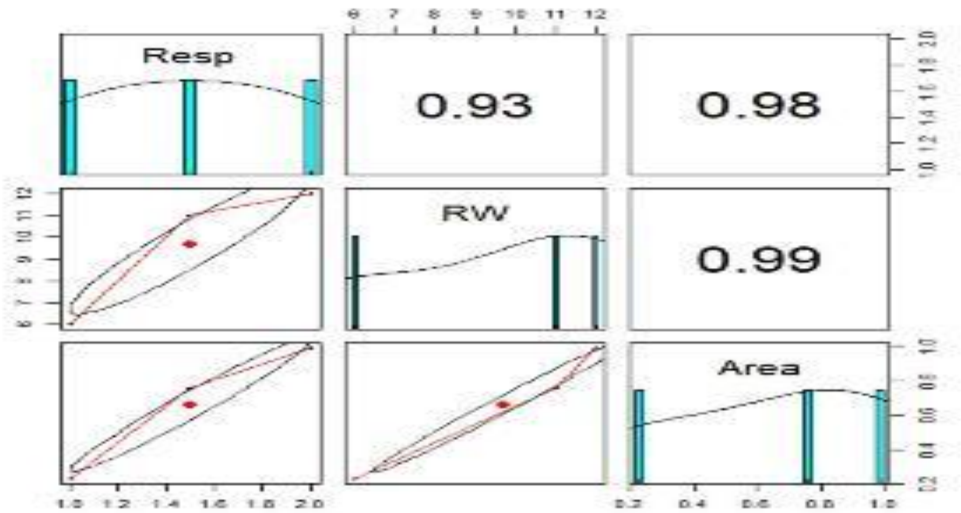


Fig. 9. Correlations of fire vehicle response times with the numbers of covered RWs and areas of Pekojan.

Roadblocks caused by fallen trees, electrical poles, or traffic congestion, road surface damage (Feng et al. 2017), crossroads, and even speed bumps are examples of barriers (Sari 2017). Traffic congestion combined with traffic lights can jeopardize the ability of a fire engine to deliver its service by delaying it. As a result, in large cities, an emergency vehicle or a fire vehicle may become stuck (Shelke et al. 2019). Traffic congestion and traffic light will yield less significant impacts in Indonesia and in real time situation. This condition is related to the traffic

ISSN 2623-1581 (Online)
ISSN 2623-1573 (Print)

regulations that have prioritized access for emergency vehicles, including fire vehicles and ambulances in the roads. Despite being supported by the regulations, the implementation of optimized routes is still facing challenges.

Challenges In Fire Vehicle Routing Optimization

The traffic congestion analysis shows that road networks in Pekojan have experienced congestion. Figure 10 shows that congestions were observed mainly in RW 01, RW 02, RW 03, RW 10, and RW 12. This condition has impacted the optimized route from Angke Fire Station to those RWs. The constant speed of 40 km/h might not be achieved since on some road segments of the optimized routes, the speeds are limited to less than 20 km/h. It is estimated that 11.59% of the optimized routes are experiencing traffic congestion (Figure 11). The congestion was occurring most often on weekdays rather than weekends. On weekdays, the peak of congestion was mostly from 8:00 AM to 5:00 PM. The congestion was reduced from 5:00 PM to midnight (Figure 12).

In Pekojan, despite the daily activities and high volume of traffic, the congestion was also caused by the vehicles that parked on the roadside and clogged the fire vehicle (Figure 13). This issue was in agreement with other studies where the road congestion phenomenon driven by chaotically misplaced and parked vehicles is increasingly posing a significant consequence to the normal traffic of fire vehicles. The increasing number of vehicles in urban areas occurs because private cars provide convenience to urban life. However, this has many consequences for fire service in urban settings (Xia et al. 2017). When the narrow residential roads and fire vehicle access areas are clogged with parked vehicles, it will reduce the speed of the fire vehicle since the vehicle has to slow down to avoid a collision with the parked vehicles. In our study, in fact, the roads were not solely clogged by cars. As observed in Pekojan, large numbers of motorcycles were also clogging the roads. Sometimes, the obstruction forces the fire vehicle to park immediately on the nearest main road, far from the fire scene.

Fig. 10. Speed (km/h) and road traffic congestion levels of covered RWs in Pekojan Urban

Village, Tambora Subdistrict, West Jakarta District, Indonesia.

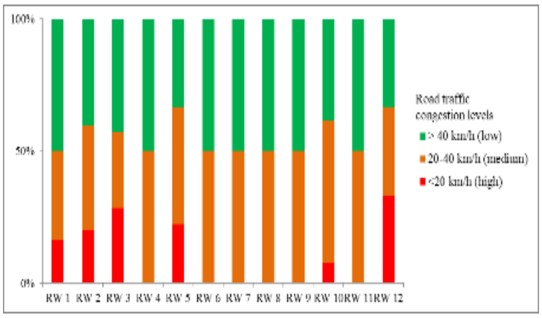
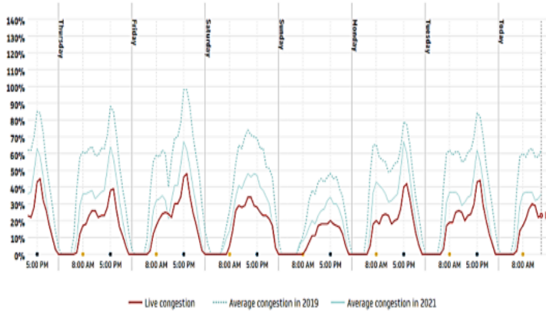


Fig.11. Percentages and compositions of speed (km/h) and road traffic congestion levels of optimized routes from Angke Fire Station to each RW in Pekojan Urban Village, Tambora Subdistrict, West Jakarta District, Indonesia.



Index accessed from https://www.tomtom.com).

Fig. 12. Daily traffic index pattern for 1 week in Jakarta City (Data source: TomTom Traffic

ISSN 2623-1581 (Online)
ISSN 2623-1573 (Print)

Fig. 13. Road conditions (a) and some challenges in fire vehicle routing optimization include traffic congestion (b), narrow roads (c), and fire vehicle access clogged with parked cars (d) (Photo source: Google Street View).

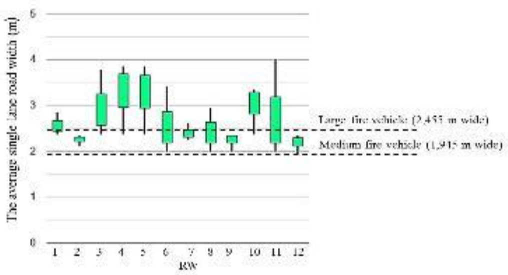


Fig. 14. The average single lane road width (m) in each RW in comparison to widths of medium and large-sized fire vehicles operating in Pekojan Urban Village, Tambora Subdistrict, West Jakarta District, Indonesia.

Another specific issue that challenges the fire vehicle routing optimization in Pekojan is the width of the road. Considering the size of medium and large-sized fire vehicles, not all roads can be accessed by the fire vehicles, especially the large ones (Figure 14). All roads in Pekojan are two-lane roads, and some roads are narrow. Those roads are sized at 1.9 m wide per lane and cannot be accessed by a large-sized fire vehicle since the width of the large-sized vehicle is 2.455 m. As a result, only four optimized routes can be accessed by large-sized fire vehicles. In contrast, a medium-sized fire vehicle can access all optimized routes. This finding is corroborated by a previous study (Lee et al. 2020) that confirmed narrow access roads as a potential issue that can interrupt the efforts of fire vehicles to reach the fire site and extinguish the fires immediately.

DISCUSSION

Optimized Fire Vehicle Routes

In optimizing fire vehicle routes, this study uses GIS network analysis over existing methods (Chen et al. 2012, Qin et al. 2017, Pella and Ose 2018, Anuar et al. 2021). The GIS based network analysis tool is a versatile approach for resolving any cost-distance queries. This method is very intuitive and user-friendly, and it can be very convenient in determining the best route based on whatever criteria are specified.

The number of emergencies and urban fire incidents, whether from the studied area or another urban area, has increased dramatically in recent years, particularly during the summer. Fire departments are equipped with the essential equipment and gear to deal with these emergency situations, but obstacles frequently arise, preventing fire fighters from responding promptly and on time (Taylor 2008). Among the problems that commonly occur in urban areas are road construction, traffic accidents, congestion, and passing trains that obstruct the access of fire vehicles. This condition has made the available road network and fire vehicle routes more vulnerable, resulting in a delay in fire service response time.

An urban fire case is an unpredictable situation that makes it impossible to localize and prevent potential fire service and emergency situations. This encourages fire service providers to use all available resources to respond as quickly as possible in emergency situations. Because both time and distance are critical in an emergency, the cartographic analyses of the current study implemented in the Pekojan area were used to select the most optimized routes that fire vehicles can use to deliver fire service with the shortest response time. The operation areas for emergency situations were designed based on the time it takes the fire vehicle to reach the scene of the fire occurrence, regardless of where it is located within the Pekojan area. Currently, the optimized time it takes a fire vehicle to arrive at the site of a fire occurrence varies between 60 and 120 seconds.

One of the most important aspects of providing fire service in a city is response time. Pekojan Urban Village is one of the densest settlements in Jakarta's Tambora Subdistrict. While the dense settlement's high population can reduce fire service response time. A large population concentrated in a small geographic area has a greater impact on urban environmental and spatial issues such as building density, road congestion, sophisticated road networks, and fire vehicle routes. Even densely built-up areas, when combined with building materials, structures, and inter-building distances, pose a high risk of urban fires.

Response time may be longer in this situation, which is characterized by dense building and complicated fire vehicle routes, resulting in increased risk and impact of urban fire. The situation in Pekojan is comparable to that in Kendari City (Taridala 2017). During one of the largest fires in 2015, fire fighters arrived at the scene 15 minutes after the fire was declared. The high urban city intensity and urban risk level in Kendari City, Indonesia are primarily the result of a very limited number of fire fighter stations, with one station serving the entire urban area, combined with a delayed and slow fire fighter response time service. As a result, the average response time from the start of the fire is more than 15 minutes.

CONCLUSION

The goals of this paper can be found in the creation of cartographic products that expose the areas of Pekojan covered by 1, 1.5, and 2 minute fire vehicle response times in order to facilitate fire service activity. These goals were met with the help of the network analyst extension. The GIS was used to successfully model and simulate the optimized routes for automated emergency vehicle response for fire incident intervention. The study confirms GIS's capability as an authentic decision-support tool in determining the optimal route for fire vehicles. This study, to the best of our knowledge, also provides a systematic method to assist in the application of an optimized transportation routing system that is combined with a GIS based method and represents the actual road networks in Pekojan Urban Village.

The study's findings show that GIS-based real-time and dynamic routing of fire vehicles is far more efficient and effective than the static solution. This efficiency is highlighted when previously unknown sophisticated traffic networks can be analyzed and avoided using network analysis. This paper makes a significant contribution by determining optimized routes on a massive scale that can address the challenge of providing a minimum response while gaining large service coverage. The method used in this paper has significantly reduced the response time of emergency fire vehicles, providing better opportunities to save more lives and prevent the loss of vital property due to fire incidents.

The approach used in this study can also be applied to other urban disasters that may occur in urban settings, such as land liquefactions and earthquakes. GIS-based network analysis can be expanded to optimize emergency services so that they arrive at disaster sites as soon as possible. Besides that, the findings of this study also raise an issue and awareness about other variables that may limit the emergency services in particular urban villages in Southeast Asian that are characterized by narrow road, vehicle parking and occupying the roads, and traffic congestion.

Fire service optimization, in particular in populated urban settings, is still neglected. This study, to the best of our knowledge, has contributed to and advanced fire management systems. The network analysis informs the fire chief and urban planner on how to improve their services. The limitations of this study were more related to the multiple variables that went beyond the method and scientific approach. The best method can be found in the form of an optimized route, which in fact is compacted by the presence of parked vehicles. To solve this issue, the recommendation for city planning is that strict parking regulations should be prioritized along with statewide law enforcement.

ACKNOWLEDGMENTS

Thank you to the head of the central jakarta fire fighting for the permission to do the research here. and thank you to all fire fighters who helped to do this research.

REFERENCES

Alazab, A., Venkatraman, S., Abawaj, J., Alazab, M. (2011). *An optimal transportation routing approach using gis-based dynamic traffic flows*. The 3rd International Conference on Information and Financial Engineering IPEDR 12.

Aringhieri, R., Bruni, M.E., Khodaparasti, S., Van Essen, J.T., (2017). *Emergency medical services and beyond:* Addressing new challenges through a wide literature review. Computers & Operations Res. 78, 349-368. https://doi.org/10.1016/j.cor.2016.09.016.

Baptist, C., Bolnick, J., (2012). *Participatory enumerations, in situ upgrading and mega effects*: The 2009 survey in Joe Slovo, Cape Town. Environ. Urban. 24, 59–66.

Bazargan, M., Amirfakhriyan, M., (2017). *Optimal routing of emergency relief vehicles using routing algorithm in GIS* (case study: Mashhad City). GeoRes. 32 (3), 35-51. https://doi.org/ 10.29252/geores.32.3.35.

Beaudry, A., Laporte, G., Melo, T., Nickel, S., (2010). *Dynamic transportation of patients in hospitals*. OR spectrum. 32(1), 77-107. https://doi.org/10.1007/s00291-008-0135-6.

Billa, L., Pradhan, B., Yakuup, A., (2014). *GIS routing and modelling of residential waste collection for operational management and cost optimization.* Pertanika Journal of Science and Technology. 22, 193-212.

Chen, Y., (2012). *The Study of vehicle routing model in emergency situations. Advanced Materials Research*. 433-440. 4807-4812. https://doi.org/ 10.4028/www.scientific.net/AMR.433-440.4807.

Cova, T., (1999). *GIS in emergency management.*

Feng, G., Su, G., Sun, Z.,(2017). *Optimal route of emergency resource scheduling based on GIS. 1-5*. The 3rd ACM SIGSPATIAL Workshop.

Fukushima, F., Moriya, T., (2020). *Objective evaluation study on the shortest time interval from fire department departure to hospital arrival in emergency medical services using a global positioning system — potential for time savings during ambulance running*. IATSS Research. 45.

Ghaderi, G., Brussel, M., van den Bosch, F., Grigolon, A.B., (2017). *Reducing travel time in Bus Rapid Transit through limited stop services, a GIS based approach*. Computers in Urban Planning and Urban

Management (CUPUM), 11-14 July 2017 at Adelaide, Australia

Ghadiri, N.M., Banar, M., (2018). *Emergency response time minimization by incorporating ground and aerial transportation.* Annals of Optimization Theory and Practice. 1(1), 43-57. https://doi.org/10.22121/AOTP.2018.108905.1004.

Graur, D.,(2017). *GIS analysis of road network accessibility for emergencies managed by firefighters (case study – Suceava County, Romania)*. Acta Geobalcanica 3-2, 65-70.

Keenan, P., (2008*). Modelling vehicle routing in GIS.* Operational Research. 8, 201-218. https://doi.org/10.1007/s12351-008-0021-7.

Kitamura, Y., Hayashi, M., Yagi, E., (2018). *Traffic problems in Southeast Asia featuring the case of Cambodia's traffic accidents involving motorcycles*. IATSS Research. 42. https://doi.org/10.1016/j.iatssr.2018.11.001.

Knyazkov, K., Derevitsky, I., Mednikov, L., Yakovlev, A., (2015). *Evaluation of dynamic ambulance routing for the transportation of patients with acute coronary syndrome in Saint-Petersburg. Procedia Computer Science*. 66, 419–428. https://doi.org/ 10.1016/j.procs.2015.11.048

Kůs, K., Cheu, R.L., Horák, T., (2016). *GIS approach in vehicle route optimization for residential recyclables collection*. 2016 Smart Cities Symposium Prague (SCSP). 1-6, https://doi.org/10.1109/SCSP.2016.7501024.

Lee, Y., Kim, M., Lee, J., (2020). *Firefighting in vulnerable areas based on the connection between fire hydrants and fire brigade*. Sustainability. 13. 98. https://doi.org/10.3390/su13010098.

Lindeskov, C.K., (2002). *Ambulance allocation using GIS* Technical University of Denmark, Denmark.

Malakahmad, A., Bakria, P., Radin, M., Khalil, N.D., (2014). *Solid waste collection routes optimization via GIS techniques in Ipoh city, Malaysia.* Procedia Engineering. 77, 20 – 27. https://doi.org/10.1016/j.proeng.2014.07.023.

Milenković, M., Kekić, D., (2016). *Using GIS in emergency management*. Sinteza 2016, 202-207. https://doi.org/10.15308/Sinteza-2016-202-207.

Moyo, T., Kibangou, A., Musakwa, W., (2020). *Exploring the potential of traffic index data to analyze essential traffic impact in developing cities*. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. XLIII-B4-2020. 137-141. . https://doi.org/10.5194/isprs-archives-XLIII-B4-2020-137-2020.

Ogunwolu, L., Sosimi, A., Jagun, O., Onyedikam, C., 2019. Optimal routing for automated emergency vehicle response for incident intervention in a traffic network. Journal of Applied Sciences and Environmental Management. 22. 1941. https://doi.org/10.4314/jasem.v22i12.12.

Owusu, M., (2013). Community-managed reconstruction after the 2012 fire in Old Fadama, Ghana. Environ. Urban. 25, 243–248. https://doi.org/10.1177/0956247812469928

Panahi, S., Delavar, M., (2009). Dynamic shortest path in ambulance routing based on GIS. International Journal of Geoinformatics. 5, 13-19.

Pasha, I., (2006). *Ambulance management system using GIS*, Department of Computer and Information Science. Linköping University SE-581 83 Linköping, Sweden.

Pella, H., Ose, K., (2018). Network analysis and routing with QGIS. https://doi.org/10.1002/9781119476726.ch4.

Pillac, V., Gendreau, M., Guéret, C., Medaglia, A.L., (2013). *A review of dynamic vehicle routing problems*. European J. Operational Res. 225(1), 1-11. https://doi.org/10.1016/j.ejor.2012.08.015.

Prabhakaran, S., Sindhu, K., Akash, R., Arunkumar, V., Krishna, L., Manikandan, D., (2017). *XREWQ* analyst. JARDCS. 2, 834-841.

Pramanik, Md., Rahman, Md., Anam, A., Ali, A., Amin, Md., Rahman, A., (2020). *Modeling traffic congestion in developing countries using Google Maps data. arXIv*. https://doi.org/arXiv:2011.02359v1 [cs.CY].

Priyadharshini, A., Francina , J., (2018). S*ite selection and route optimization for solid waste disposal for Tiruchirappalli corporation using GIS.* IJERT. 6(14)

Qin, J., Ye, Y., Cheng, B., Zhao, X., Ni, L., (2017). *The emergency vehicle routing problem with uncertain demand under sustainability environments*. Sustainability. 9. 288. https://doi.org/10.3390/su9020288.

Ramírez, Y., (2020). Developing a traffic congestion model based on Google Traffic Data: a case study in Ecuador. https://doi.org/10.5220/0009594501370144.

Rybansky, M., (2014). *Modelling of the optimal vehicle route in terrain in emergency situations using GIS data.* IOP Conference Series: Earth and Environmental Science. 18. https://doi.org/10.1088/1755-1315/18/1/012131.

Saleh, F.S. (2016). *Road analysis of M.H. Thamrin and Merdeka road network. RADIAL – juRnal perADaban saIns,* rekayAsa dan teknoLogi Sekolah Tinggi Teknik (STITEK) Bina Taruna Gorontalo. 4(2), 155-162.

Sapateiro, C., Antunes, P., (2009). *An emergency response model toward situational awareness improvement.* The 6th International ISCRAM Conference – Gothenburg, Sweden.

Sari, F., (2017). A GIS based new navigation approach for reducing emergency vehicle s response time. Selcuk University Journal of Engineering ,Science and Technology. 5, 47-60. https://doi.org/10.15317/Scitech.2017.69.

Shelke, M., Malhotra, A., Mahalle, P., (2019). *Fuzzy priority based intelligent traffic congestion control and emergency vehicle management using congestion-aware routing algorithm.* Journal of Ambient Intelligence and Humanized Computing.https://doi.org/10.1007/s12652-019-01523-8

Sudiana, N., Rofara, O., Astisiasari., (2018a). *Urban fire risk analysis of DKI Jakarta Province*. Jurnal Sains dan Teknologi Mitigasi Bencana. 13(2).

Sudiana, N., Umbara, R.P., Zahro, Q., 2018b. *Study on the capacity of Cakung District towards urban fire disaster.* Jurnal Sains dan Teknologi Mitigasi Bencana. 13(1), 44-56.

Sureshkumar, M. (2017). *GIS based route optimization for effective traffic management.*

Taylor, M.A.P., (2008). *Critical transport infrastructure in urban areas: impacts of traffic incidents assessed using accessibility based network vulnerability analysis.* Growth and Change. 39(4), 593-616.

ISSN 2623-1581 (Online)
ISSN 2623-1573 (Print)

https://doi.org/10.1111/j.1468-2257.2008.00448.x.

Taridala S., (2017). *Expert System Development for Urban Fire Hazard Assessment.* Study Case: Kendari City, Indonesia. IOP Conf. Ser.: Earth Environ. Sci. 79.

Tian, R., Li, S., Yang, G., (2018). *Research on emergency vehicle routing planning based on short-term traffic flow prediction*. Wireless Pers. Commun. 102, 1993–2010. https://doi.org/10.1007/s11277-018-5251-2.

Twigg, J., Christie, N., Haworth, J., Osuteye, E., Skarlatidou, A., (2017). *Improved methods for fire risk assessment in low-income and informal settlements.* International Journal of Environmental Research And Public Health. 14(2), 139. https://doi.org/10.3390/ijerph14020139.

Ulander, A., (2015). *Optimization based decision support tools for fire and rescue resource planning*. Linköping University.

Vratonjić, M., Wittmann, H., (2015). *Using and optimising GIS in an emergency response*. Europe an Emergency Association.

Xia, Z., Li, H., Chen, Y., (2017). *An integrated spatial clustering analysis method for identifying urban fire risk locations in a network-constrained environment: a case study in Nanjing, China*. ISPRS International Journal of Geo-Information. 6. 370. https://doi.org/10.3390/ijgi6110370.

Yuan, Y., Zhou, X., Yang, M., (2019). *Emergency logistics vehicle routing optimization based on insufficient supply*. E3S Web of Conferences 136.