TEM Journal. Volume 13, Issue 1, pages 177-184, ISSN 2217-8309, DOI: 10.18421/TEM131-18, February 2024.

Optimization of Algorithms and Models in Two Scenarios for Picking up-Dropping off Disaster Victims in Islands Cities

Muhammad Muhammad [1,2], Hajjul Kamil [3], Muhammad Adlim [1], Irwandi Irwandi [4]

[1] Graduate School of Mathematics and Applied Sciences Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia
[2] Nursing Department of Aceh Health Polytechnic, Ministry of Health, Banda Aceh, 23111, Indonesia
[3] Department of Basic Nursing and Nursing Management, Faculty of Nursing, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia
[4] STEM Research Center (STEM - id), Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia

Abstract - Earthquakes in the past have caused significant damage, injuries, and deaths. The remaining resources do not equal the amount needed. For this reason, effective and efficient disaster management methods are needed. Learning from recent research that describes how they optimize the coordination function of hospital systems to overcome the imbalance between need and care capacity, we add the bed occupancy ratio (BOR) of healthcare facilities to the modeling. This paper aims to provide information about the distribution mechanism for injured victims by minimizing the total time to arrive at the healthcare facility. This victim evacuation modeling uses the integer linear programming method with two scenarios. Simulations were carried out on 164 injured victims, estimated by residents who live in areas that cross the Great Sumatran fault. The results show that the second scenario, which involves distributing it to the nearest healthcare facility, is 3.6 hours shorter compared to taking it to the general hospital in the first scenario.

DOI: 10.18421/TEM131-18
https://doi.org/10.18421/TEM131-18

Corresponding author: Hajjul Kamil,
Department of Basic Nursing and Nursing Management, Faculty of Nursing, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia
Email: hajjul.kamil@usk.ac.id

Received: 05 October 2023.
Revised: 16 January 2024.
Accepted: 24 January 2024.
Published: 27 February 2024.

Keywords **- PickingUp-dropping off, disaster victims, island cities.**

1. Introduction

Several earthquake events actually caused severe damage over a wide geographic area with significant injuries and deaths [1]. The remaining resources are not balanced with the needs in the affected areas [2]. The remaining human capabilities are sometimes very limited [3]. To survive they have to struggle, because almost all aspects of life such as: living supplies, medical resources, equipment, human resources, transportation and communication infrastructure are damaged [3].

The chances of survival of injured victims are closely related to the response time of the emergency services team [1]. Immediate medical assistance to injured victims is hampered [1]. Management of transportation of injured victims to hospitals in large cities is unstable and complicated [4]. Optimization of time and care is an important factor for the survival of seriously injured disaster victims [5]. This requires serious attention from disaster response management stakeholders. This extra attention is to reduce the death and suffering of victims [1].

Management of available resources must be carried out optimally [6]. Effective and rapid delivery of aid is essential to minimize loss of life and avoid disability [2]. On the other hand, in pre-disaster times pre-hospital care capabilities, rapid pre-hospital transportation, and early hospital and surgical care capabilities have been shown to improve work outcomes [5]. As practiced by the US military, they run an integrated system for casualty care. The aim is to ensure timely treatment of seriously injured victims.

This system starts with the victim at the point of injury and ends at a hospital located outside the active surgical area [5].

This challenge requires emergency management from the government to immediately formulate an emergency response plan. The plan includes a good decision-making system, producing effective and efficient solutions, and taking into account humanitarian principles [3]. Several existing models to address this challenge focus on reducing response times in the evacuation of disaster victims [1]. However, for a group of victims requiring urgent medical care, the approach of minimizing the total evacuation time to a specialized health center is sometimes inappropriate [1]**.** Apart from the time for medical treatment, another obstacle that must be taken into account in an effort to minimize the time required is the process of evacuating each victim [7]. The solution to the problem of evacuating victims after a large-scale disaster is to determine the point for collecting victims, first aid and stabilization, and determining the health facility to which the evacuation will take place [1].

This model proposes to determine the pick-up point and evacuation destination for victims. The victim transportation schedule is created by considering travel time to health facilities. The model inputs include distance, vehicle speed based on continuous assessment of route conditions, heterogeneous emergency vehicles, vehicle capacity and departure points. This model also optimizes multi-period casualty evacuation to determine the location and capacity of emergency medical service facilities as performed [2].

For the delivery of emergency casualty transport, there are currently two main transport strategies, namely transporting injured people on a first-come, first-served basis, and transporting injured people with serious illnesses at random first, followed by transporting injured people with lighter conditions [3].

This study has formulated an optimization model for the number of victims who can be evacuated within the specified time period. This number of victims is adjusted to the results of previous modeling, namely a model for estimating the number of injured victims of earthquake disasters. This model can also be used to optimize first aid assistance and stabilization. The results of this estimation can be used for local-based emergency response planning [8] such as planning evacuation routes, planning destinations for referring injured victims, and planning health facilities [9]. Apart from that, this disaster victim evacuation optimization model can be carried out at any time in various scenarios, because it does not require a long time to calculate it.

As far as we have studied, there is no model for evacuating victims injured due to earthquakes that includes bed capacity in health facilities based on the Bed Occupancy Rate (BOR) as a constraint parameter. In general, this study will discuss the application of mathematical models with interger linear programming to optimize the shortest evacuation time for earthquake victims from affected locations to health facilities that are not affected by the disaster.

2. Materials and Methods

Mathematical model for transportation problems with the aim of minimizing total travel time and considering adding new destinations if capacity at the destination is full.

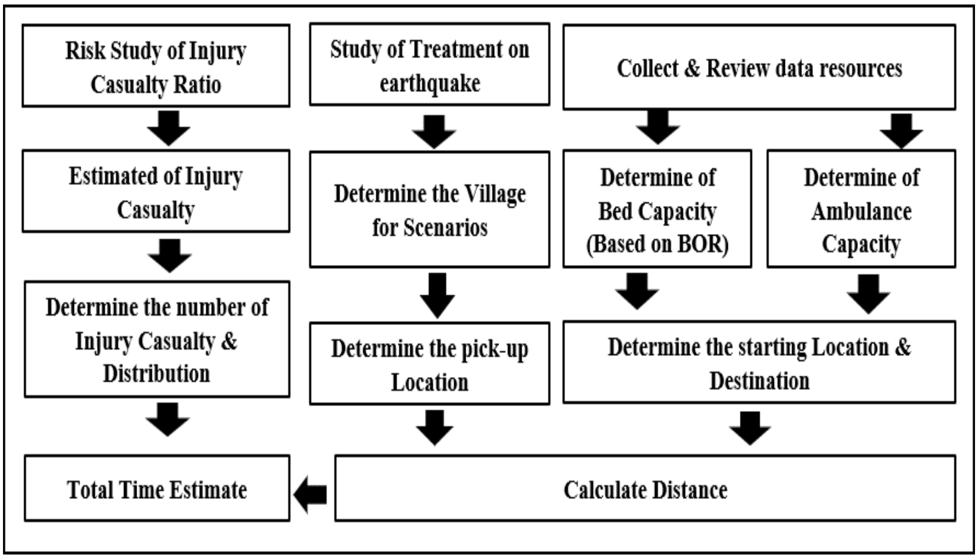

Figure 1. Pick up – delivery algorithm for disaster victim evacuation

This model was prepared using Matlab R2010b. The model assumptions are stated in the form of parameters and variables with the following explanation:

Parameter:

- N: number of points of origin (source village victims) = 5
- m: number of initial destinations (hospitals or health centers) = 8
- d_{ij}: distance between origin i and destination j (in kilometers)
- v: ambulance speed (40 km/hour)
- c_i: number of victims at origin i (if there are no victims, then supply = 0)
- b_i: total capacity of hospitals or health centers at destination j
- d_{ij}^*: distance between origin point i and new destination j (if new destination j exists as an emergency hospital)

Variables:

- x_{ij}: number of victims sent from origin i to destination j (decision variable)
- y_j: binary variable indicating whether destination j has reached maximum capacity ($y_j = 1$) or not ($y_j = 0$).

Objective Function:

Minimize

$$Z = \Sigma \frac{d_{ij}}{V} x_{ij} + \Sigma \frac{d_{ij}^*}{v} x_{ij}, \tag{1}$$

For every positive integer i and j.

Constraint:

1. Capacity constraints at destination:
   $$\sum x_{ij} \leq b_j(1 - y_j), \tag{2}$$
   For each goal j.

2. Obstacles to victims at the point of origin:
   $$\sum x_{ij} \leq c_i, \tag{3}$$
   For each origin point i that has a value or victim c_i.

3. Non-negativity constraints:
   $$xij \geq 0, \tag{4}$$
   For each origin point i and each destination j.

4. New destination distance constraints:
   $$d^*ij \leq d_{ij}+0.5, \tag{5}$$
   for each i and j that change the distance is 0.5 km for field hospitals which are located not far from regional general hospitals.

5. New goal capacity constraints:
   $$\sum xij = bj\ yj, \tag{6}$$
   for each new simplified goal yj=1.

This model can find the optimal solution to send victims from 5 points of origin to destination by minimizing the total travel time at a speed of 40 km/hour, ensuring that the number of victims transported does not exceed capacity at each destination, meeting supplies at each source that has victims, and consider adding new destinations if destination capacity is full.

This research uses two case approaches, namely bringing disaster victims to the main health facility and bringing disaster victims to the nearest health facility. The first approach uses the Northwest Corner method (NWC) [10], [11] and the second approach uses the Vogel's Approximation Method (VAM) [12], [13].

3. Results and Discussion

Victim evacuation is an activity with the aim of delivering disaster victims to receive more optimal health services that are appropriate to their condition or level of emergency. To make this activity a success, support from resources and conditions of public facilities is very necessary. However, earthquake events often result in a shortage of resources for emergency medical services such as ambulances and emergency units. These resources must be managed effectively to save as many lives as possible. Important decisions that must be taken within the limited time to operate an emergency medical services system include prioritization of patients for ambulance transport and selection of destination hospitals [14]. The actual conditions of resource support are used as supporting parameters in developing this model. This model was developed so that it can be used according to the actual conditions of the parameters. This is done to anticipate the uncertainty of post-disaster conditions. The following supporting parameters are required:

Distance and travel time

Based on the results of measuring the distance between source and destination, the distance that must be traveled from the village/gampong to the health facility is presented in Table 1. This distance is calculated starting from the central point of residence in each village to the available health services based on the distance traveled on Google Map in 2023. The central residence chosen in this scenario is in the selected village area and is close to the great Sumatran fault that passes through the city of Sabang. The location of the incident what is assumed in this model is a residential center that can be accessed by ambulance like the model developed [15].The travel time calculation is based on the time span for picking up and dropping off the victim. The time spent by both is assumed to be no different.

We refer to the article [15] which also explains that the travel time needed to evacuate 1 victim is the sum of the time spent picking up the victim at the source point and the time taking him/her back to the health facility. In this situation, the victims are in the same location, such as modeling the victim evacuation route [16], the closer the distance between victims will reduce the amount of time used.

Table 1. Distance from village center to health facilities [in kilometers]

Village	Hospital & Public Health Center							
	Suka jaya	Jaboi	Cot Bau	Paya Seunara	Iboih	Pria Laot	Navy Hospitals	General Hospitals
Kuta Ateueh	9.9	15.0	5.2	6.0	19.0	11.0	1.0	0.6
Kuta Timu	8.2	12.0	3.5	4.0	16.0	9.1	2.6	1.8
Kuta Barat	12.0	17.0	6,8	7.5	20.0	13.0	2.9	2.1
Ie Meuleee	8.3	14.0	5.4	7.0	20.0	12.0	1.4	2.5
Cot Bak UU	7.6	13.0	2.9	6.4	19.0	11.0	2.1	2.7
Aneuk Laott	9.4	13.0	4.7	3.9	16.0	9.0	4.6	3.8
Ujoeng Kareungg	6.6	12.0	4.2	7.7	20.0	13.0	7.0	4
Krueng Rayaa	9.4	13.0	4.7	1.8	14.0	6.9	5.0	4.2
Paya Seunaraa	11.0	12.0	6,7	0.5	12.0	4.6	7.0	6.2
Cot Abeuk	3.8	9.0	3.6	9.3	22.0	14.0	8.2	8.4
Balohan	3.0	4.0	7.1	11.0	23.0	16.0	11.6	10.5
Batee Shok	16.0	11.0	11.0	5.2	9.4	1.9	11.7	10.9
Anoe Itam	6.5	10.0	7.6	13.0	26.0	18.0	10.1	11.3
Paya	12.0	6.4	12.0	6.0	15.0	5.8	12.5	11.7
Jaboi	8.0	1.9	12.0	10.0	19.0	12.0	16.6	15.4
Beurawang	9.1	3.1	13.0	13.0	19.0	13.0	17.7	16.6
Keuneukai	10.0	4.4	15.0	9.2	18.0	11.0	17.4	16.6
Iboih	27.0	25.0	23.0	16.0	4.3	13.0	22.8	22.1

Vehicle Speed

Another parameter required in this model is the speed of the evacuation vehicle. This speed is the average speed of the vehicle used to travel to pick up and deliver victims via the same route. The average speed scenario used in testing this model is 40 km per hour. This value was determined based on the results of researchers' tests by driving a four-wheeled vehicle with an engine capacity of 1500 cc during the day coupled with tools for assessing the geographical, physical conditions and density of Sabang city routes. In applying the disaster victim evacuation process model, it is important to always assess route conditions, traffic management, designation of fast access roads, and that they can be passed smoothly [17].

Health Service Capacity

To obtain data regarding the capacity of health facilities, we conducted a field survey at 2 hospitals (General Hospitals and Navy Hospitals) and 6 PHC Community Health Centers) in the city of Sabang in March 2023. For data on bed capacity in health facilities, we used primary data on health facilities in 2022, in the form of total Beds and BOR, except for health facilities which do not have inpatient facilities, BOR does not exist. Meanwhile, the number of vehicles for evacuating victims, as shown in Table 2, is taken based on the number of ambulances that can still be used at health facilities. These vehicles can still be used to transport patients to referral health facilities. The following is the latest capacity of health facilities.

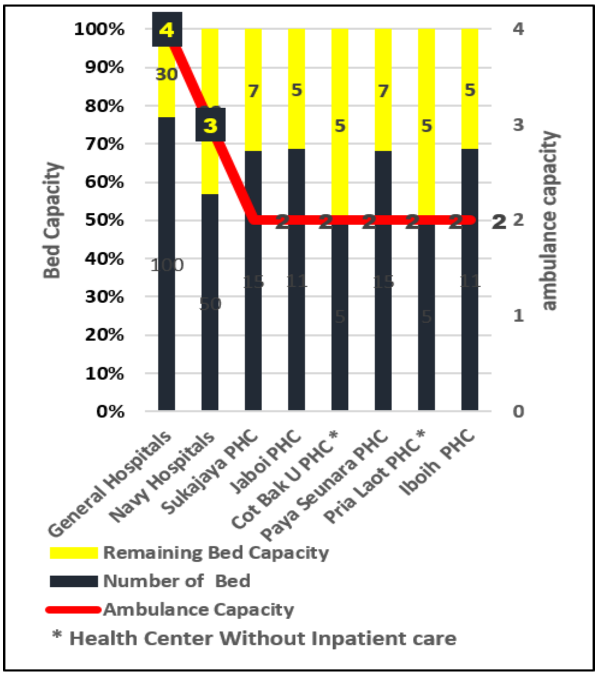

Figure 2. Hospital & PHC Capacity

The condition of primary health care and hospital capacity is always changing, especially during disaster conditions. The condition of emergency and ambulance installations and evacuation routes must always be taken into consideration in the victim evacuation plan [17]. Coordination between health services cannot be stopped, to reduce the mismatch between needs and availability of facilities [18]. The utilization of health resources must be supplemented with quality of service to reduce side effects on victims [19].

Estimated Number of Casualties

For this study, we took estimates of injury victims from the results of research conducted [20]. As a constraint, injury victims in disaster areas can be divided into four categories, namely they estimate injury victims based on serious injuries with top priority treatment, moderate injury victims with delayed treatment, light injury victims and unhelpful injury victims [21]. The number of victims in each category cannot be ascertained [2]. Victims in the moderate injury category can wait for treatment or be transported to a health facility.

Table 2. Population and estimated victims

No	Village	Number of Population	Estimated Number of Victims
1	Kuta Ateueh	4249	0
2	Kuta Timu	2415	0
3	West Kuta	3883	0
4	Ie Meulee	4813	0
5	Cot Bak U*	7798	78
6	Aneuk Laot*	1342	14
7	Ujoeng Kareung	710	0
8	Krueng Raya*	2091	21
9	Paya Seunara	3175	0
10	Cot Abeuk*	1116	12
11	Balohan*	3805	39
12	Batee Shok	1766	0
13	Anoe Itam	848	0
14	Paya	741	0
15	Jaboi	901	0
16	Beurawang	416	0
17	Keuneukai	1056	0
18	Iboih	1434	0

** A village crossed by the Great Sumatran fault*

In emergency response operations, it is necessary to quickly determine priority treatment for victims [14]. However, estimating the number of victims is an important step in disaster emergency response planning. The aim of estimating the number of victims is to provide an initial estimated condition of the possible impacts caused by an earthquake, so that it can assist in planning and coordinating emergency responses. Estimates of the number of victims are usually based on information and data available at the early stages of an earthquake. The following is an estimate of the number of victims in a simulation of a 7.5 SR earthquake strength based on a minimum estimate on one fault that we quoted from paper [22]. This study uses population data from [23] as in Table 2 as a basis for estimating the number of injured victims.

We chose five villages that are most at risk because they are crossed by the Great Sumatran faults as described below [22]. These five villages are at risk of victims. This is due to the geographical location of the village which is at the fault location. The predicted villages are Balohan, Cot Abeuk, Cot Bak U, Aneuk Laot, and Krueng Raya. To estimate injured victims, we took 1 percent of the population or less than the estimate that was carried out in the city of Banda Aceh by [20] namely 6.8 percent.

Simulation results

In developing the victim evacuation optimization model, problem solving is grouped into two stages. The first stage is determining the vehicle route and number of victims transferred, and minimizing the number of resource problems. The second stage is the stage of overcoming the problem of victims who cannot be reached by services [1]. For emergency response planning scenarios, data on important routes for the distribution of victims and resources is needed [24]. Based on the simulation results of the linear program that has been prepared, the following results are obtained: Scenario 1 is the scenario for the decision to transport priority victims from the village closest to the General Hospital. Scenario 2 involves the decision to transport victims from the village to the nearest health facility.

Running results for Scenario 1 are: The total time needed to evacuate 164 seriously injured victims, from the victim collection point at the disaster location to the health service location based on the capacity of the nearest health service is = 11.5 hours. Meanwhile, for Scenario 2, the total time needed to evacuate injured victims from the collection point for injured victims at the disaster location to the nearest health service is = 7.9 hours. This time does not include pause time or temporary suspension of the victim evacuation process. This approach treats response time as a goal or constraint by minimizing the total amount of response time or setting a maximum time limit for treating a victim [1]. Dispatch and routing models are dynamically updated in disaster situations, to minimize total time [3].

Scenario 1

No	Village	Estimasi Jumlah Korban	RSU Sabang	RS AL	Cot Bak	Suka Jaya	Paya Seunara	Jaboi	Pria laot	Iboih	RS LAP
1	Kuta Ateueh	0									
2	Kuta Timu	0									
3	Kuta Barat	0									
4	Ie Meulee	0									
5	Cot Bak U	78	30	38	5	5					
6	Aneuk Laot	14				2	7	5			
7	Ujoeng Kareung	0									
8	Krueng Raya	21							5	5	11
9	Paya Seunara	0									
10	Cot Abeuk	12									12
11	Balohan	39									39
12	Batee Shok	0									

Scenario 2

No	Village	Estimasi Jumlah Korban	RSU Sabang	RS AL	Cot Bak	Suka Jaya	Paya Seunara	Jaboi	Pria laot	Iboih	RS LAP
1	Kuta Ateueh	0									
2	Kuta Timu	0									
3	Ie Meulee	0									
5	Cot Bak U	78		38							40
7	Aneuk Laot	14									14
9	Ujoeng Kareung										
11	Krueng Raya	21					7		5	5	4
13	Paya Seunara										
14	Cot Abeuk	12	3		5						4
16	Balohan	39	27			7		5			
18	Batee Shok	0									

Figure 3. Determine the starting location and destination

In developing the victim evacuation optimization model, problem solving is grouped into two stages. The first stage is determining the vehicle route and number of victims transferred, and minimizing the number of resource problems. The second stage is the stage of overcoming the problem of victims who cannot be reached by services [1]. For the delivery of emergency casualty transport, there are currently two main transport strategies, namely transporting injured people on a first-come, first-served basis, and transporting injured people with serious illnesses at random first, followed by transporting injured people with lighter conditions [3]. In its application, the objective function, decision variables, constraints, and assumptions must be derived from data in order to test the effectiveness of the proposed procedures [25]. Mass or disaster casualty care management requires coordination between stakeholders, for example search and rescue officers, ambulances, maintenance, and the police to expedite the evacuation process [26] as well as to evacuate victims to health services [1]. Distance to the nearest health facility has a significant influence on transportation decisions [27].

4. Conclusion

In island cities, limited facilities and infrastructure are the obstacles to the distribution of injured victims due to earthquakes. Obtaining aid takes a long time for assistance to reach the disaster location. The resulting model has made strategic decisions quickly and optimally in using remaining resources, such as vehicles, bed capacity, and human resources, in situations of post-disaster uncertainty. This research has provided a scenario model for evacuating earthquake-injured victims that can minimize the time for picking up and dropping off victims at health facilities. The result is that the second evacuation scenario, which guides distribution to the nearest health service, is shorter than the first scenario and involves taking the victim to a public hospital. The first scenario takes 11.5 hours to evacuate, while the second only takes 7.9 hours. This model can also be used as a medium for effective route planning with minimal time during emergency response.

References:

[1]. Bronfman, A., Diego, B. G., Alvarez, P. P., Reid, S., & Paredes-Belmar, G. (2022). The Casualty Stabilization–Transportation Problem in a Large-Scale Disaster. *Sustainability (Switzerland)*, *14*(2). Doi: 10.3390/su14020621

[2]. Sun, H., Wang, Y., & Xue, Y. (2021). A bi-objective robust optimization model for disaster response planning under uncertainties. *Computers and Industrial Engineering*, *155*(99), 107213. Doi: 10.1016/j.cie.2021.107213

[3]. Feng, Y., Liu, T., Hu, Z., Wang, D., Cheng, T. C. E., & Yin, Y. (2021). Casualty transport scheduling considering survival probability and injury classification. *Computers and Industrial Engineering*, *161*(February 2020), 107655. Doi: 10.1016/j.cie.2021.107655

[4]. Babaqi, T., & Vizvári, B. (2023). The post-disaster transportation of injured people when hospitals have districts. *Journal of Humanitarian Logistics and Supply Chain Management*, *13*(1), 61–73. Doi: 10.1108/JHLSCM-09-2021-0088

[5]. Kotwal, H., Staudt, A. M., Trevino, J. D., Valdez-Delgado, K. K., Le, T. D., Gurney, J. M., … Mann-Salinas, E. A. (2018). A Review of Casualties Transported to Role 2 Medical Treatment Facilities in Afghanistan. *Military Medicine*, *183*, 134–145.

[6]. Ebrahimi-Sadrabadi, M., Ostadi, B., Sepehri, M. M., & Kashan, A. H. (2023). Optimal resource allocation model in disaster situations for maximizing the value of operational process resiliency and continuity. *RAIRO - Operations Research*, *57*(3), 1539–1557. Doi: 10.1051/ro/2023048

[7]. Sularno, S., Mulya, D. P., Astri, R., & Mulya, D. (2021). Determination of The Shortest Route Based on BFS Algorithm for Purpose to Disaster Evacuation Shelter. *Scientific Journal of Informatics*, *8*(1), 33–42. Doi: 10.15294/sji.v8i1.27863

[8]. Apriyadi, R. K., Kurniawan, W., Yulianto, S., Dewa, I., Widana, K. K., Subiyanto, A., … Kuncoro, D. C. (2022). Estimasi Ancaman Gempabumi dan Tsunami di Kabupaten Pidie Jaya Aceh untuk Mendukung Keamanan Nasional, *6*(1), 1–7.

[9]. Mills, A. F., Argon, N. T., & Ziya, S. (2018). Dynamic distribution of patients to medical facilities in the aftermath of a disaster. *Operations Research*, *66*(3), 716–732. Doi: 10.1287/opre.2017.1695

[10]. Klinz, B., & Woeginger, G. J. (2011). The Northwest corner rule revisited. *Discrete Applied Mathematics, 159*(12), 1284–1289. Doi: 10.1016/j.dam.2011.04.007

[11]. Putra, F. E., Purba, H. H., & Anggraeni, I. A. (2020). The optimization of distribution and transportation costs for common good products. *International Journal of Industrial Optimization, 1*(2), 111. Doi: 10.12928/ijio.v1i2.2368

[12]. Balakrishnan, N. (1990). Modified Vogel's approximation method for the unbalanced transportation problem. Applied Mathematics Letters, 3(2), 9–11. Doi: 10.1016/0893-9659(90)90003-T

[13]. Amaliah, B., Fatichah, C., & Suryani, E. (2019). Total opportunity cost matrix – Minimal total: A new approach to determine initial basic feasible solution of a transportation problem. *Egyptian Informatics Journal, 20*(2), 131–141. Doi: 10.1016/j.eij.2019.01.002

[14]. Shin, K. & Lee, T. (2020). Emergency medical service resource allocation in a mass casualty incident by integrating patient prioritization and hospital selection problems. *IISE Trans*., 52 (10) 1141–1155. Doi: 10.1080/24725854.2020.1727069

[15]. Zhong, S., Cheng, R., Jiang, Y., Wang, Z., Larsen, A., & Nielsen, O. A. (2020). Risk-averse optimization of disaster relief facility location and vehicle routing under stochastic demand. *Transportation Research Part E: Logistics and Transportation Review*, *141*. Doi: 10.1016/j.tre.2020.102015

[16]. Radiusman, Fauzi A, Mauldya M.A., Widodo A, S. M. (2020). Pemodelan matematika: model dan simulasi jalur evakuasi korban bencana gempa bumi di bangunan bertingkat, *EduMatSains : Jurnal Pendidikan, Matematika Dan Sains, 5*(1), 39–50. Doi: 10.33541/edumatsains.v5i1.1628

[17]. Toma-Danila, D., Tiganescu, A., D'Ayala, D., Armas, I., & Sun, L. (2022). Time-Dependent Framework for Analyzing Emergency Intervention Travel Times and Risk Implications due to Earthquakes. Bucharest Case Study. *Frontiers in Earth Science*, *10*(February), 1–17. Doi: 10.3389/feart.2022.834052

[18]. Ceferino, L., Mitrani-Reiser, J., Kiremidjian, A., Deierlein, G., & Bambarén, C. (2020). Effective plans for hospital system response to earthquake emergencies. *Nature Communications*, *11*, 1–12. Doi: 10.1038/s41467-020-18072-w

[19]. Lee, Y.-C., Wu, H.-H., Weng, S.-J., Huang, Y.-C., Hsieh, W.-L., & Huang, C.-H. (2016). Application of Hospital Information Systems-Construction of an Incident Reporting System. *TEM Journal*, *5*(4), 530–537. Doi: 10.18421/TEM54-18

[20]. Rusydy, I., Idris, Y., Mulkal, Muksin, U., Cummins, P., Akram, M. N., & Syamsidik. (2020). Shallow crustal earthquake models, damage, and loss predictions in Banda Aceh, Indonesia. *Geoenvironmental Disasters*, *7*(1). Doi: 10.1186/s40677-020-0145-5

[21]. Peng, Y., & Hu, H. (2021). Assessment of earthquake casualties and comparison of accuracy of five injury triage methods: Evidence from a retrospective study. *BMJ Open*, *11*(10), 1–7. Doi: 10.1136/bmjopen-2021-051802

[22]. Nanda, M., Rizal, S., Abdullah, F., Idroes, R., & Ismail, N. (2020). Mapping Faults Distribution Based on Dem Data for Regional Spatial Plan Assessment of Sabang Municipality, Indonesia. *International Journal of GEOMATE*, *19*(76), 197–204. Doi: 10.21660/2020.76.90787

[23]. BPS Sabang. (2022). *Kota Sabang Dalam Angka 2022*. BPS. Retrieved from: https://sabangkota.bps.go.id/publication/2022/02/25/65867289374afcea1e5ef9f0/kota-sabang-dalam-angka-2022.html [accessed: 10 August 2023].

[24]. Nikoo, N., Babaei, M., & Mohaymany, A. S. (2018). Emergency transportation network design problem: Identification and evaluation of disaster response routes. *International Journal of Disaster Risk Reduction*, *27*, 7–20. Doi: 10.1016/j.ijdrr.2017.07.003

[25]. Farahani, R. Z., Lotfi, M. M., Baghaian, A., Ruiz, R., & Rezapour, S. (2020). Mass casualty management in disaster scene : A systematic review of OR & MS research in humanitarian operations. *European Journal of Operational Research*, *287*, 787–819. Doi: 10.1016/j.ejor.2020.03.005

[26]. Berben, S. A. A., Vloet, L. C. M., Lischer, F., Pieters, M., & Cock, J. De. (2021). Medical Coordination Rescue Members ' and Ambulance Nurses ' Perspectives on a New Model for Mass Casualty and Disaster Management and a Novel Terror Attack Mitigation Approach in the Netherlands : A Qualitative Study, (October) *Prehospital and Disaster Medicine*, *36*(5), 519-525. Doi: 10.1017/S1049023X21000790

[27]. Fagerlind, H., Harvey, L., Candefjord, S., Davidsson, J., & Brown, J. (2019). Does injury pattern among major road trauma patients influence prehospital transport decisions regardless of the distance to the nearest trauma centre? - A retrospective study. *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, *27*(1), 1–9. Doi:10.1186/s13049-019-0593-7.