Location-Allocation Model for Victims and Health Workers during Post Earthquake-Tsunami Health Crisis in Padang City

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Location-Allocation Model for Victims and Health Workers during Post Earthquake-Tsunami Health Crisis in Padang City

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Abstract: The 2009 Padang earthquake resulted in 771 minor injuries, 431 serious injuries, and killed 383 people. The limited capacity for assistance forces victims to be placed in corridors, terraces, or emergency tents installed in hospitals. The Padang City Government estimates that 555,664 lives are at risk, with 29,520 minor injuries, 32,800 moderate injuries, and 131,201 serious injuries. Meanwhile, the number of health workers available is currently very limited. This study aims to determine hospitals, public health centers (puskesmass) and the number of temporary medical services (TMSs) to be opened, the number of victims, and the number of health workers (general practitioners, anesthetists, surgeons, and nurses) allocated to each health facility to minimize operational cost. The result of the model shows all existing hospitals and all puskesmass 84 TMSs in public hospitals and special hospitals, 20 TMSs in puskesmass and a dummy hospital. The objective function value obtained is IDR 5.62092 x 10^9. The operational cost include transportation cost for victims, transportation cost for health workers, and setup cost for opening temporary medical services. The results show that the operational cost will decrease along with the decrease in the number of victims in evacuation posts, causing a decrease in the total transportation cost of victims and the total transportation cost of health workers, but the total setup cost remains unchanged. The operational cost will increase along with the increase in the capacity of health facilities so that decreased in the total transportation cost of victims, increased in the total transportation cost of health workers, and the total setup cost remains unchanged.

Keywords: health workers, location-allocation, temporary medical services, victims

1. Introduction

Based on the 2019 World Risk Index[1)], Indonesia is ranked 37th with very high exposure to extreme natural events (21.20%), high vulnerability (49.93%), medium susceptibility (26.63%), huge lack of coping capacity (79.71%), and huge lack of adaptive capacity (43.44%). Indonesia has a world Risk index of 10.58%, which means with an increase of 0.04%, Indonesia could become a country with a very high World Risk Index (10.62%) if indicators of exposure, vulnerability, susceptibility, lack of coping capacity, and lack of adaptive capacity to extreme natural events are not controlled. Therefore, disaster management efforts are needed to prevent the country from having a very high World Risk Index.

An earthquake is an event due to a shift of rocks beneath the surface and can cause large ocean waves or tsunami[2)].On September 30, 2009, the entire West Sumatra region felt the shock of a very strong earthquake. An earthquake measuring 7.6 on the richter scale occurred off the coast of Sumatra, about 50 km northwest of the city of Padang. That earthquake killed 383 people and left 771 people with minor injuries, 431 people with serious injuries and several buildings including health facilities damaged. Several hospitals such as RSUP M Djamil, Reksodiwiryo Hospital, Selasih Hospital, Restu Ibu Hospital, and Siti Rahmah Islamic Hospital treated victims of minor and serious injuries. RSUP M Djamil was the hospital that accepted the most victims, which was around 500 people. Due to the limited capacity of inpatient rooms, the victims had to be placed in the corridors, terraces, and emergency tents installed in the hospital.

On the earthquake-tsunami Contingency Plan of Padang City[3)], the local government has estimated the impact if an earthquake-tsunami occurs in the city. A total of 555,664 people is at risk, with the death toll of 166,669 people, 55,404 people missing, 5,557 people displaced, 29,520 people with minor injuries, 32,800 people with moderate injuries, and 131,201 people with serious injuries. The estimated number of victims affected will also affect the number of beds in health facilities. Meanwhile, the availability of beds decreases due to damaged health facilities. One alternative that can be done is opening temporary medical services. Emergency Medical Centers such as hospitals and temporary health centers have an important role in serving victims and preventing loss of life after natural disasters. The opening of temporary medical services can assist health facilities that experience an accumulation of victims[4].

In addition, the number of health workers is very limited, even far from sufficient. A large number of disaster victims will need sufficient health workers so that first aid can be carried out. 2,624 doctors and 7,476 paramedics are needed. Currently, Padang City has 1,110 doctors consisting of health workers and specialist doctors and 3,627 health workers consisting of 2,727 nurses and 800 midwives [5]. This number is still far from the figure needed considering the large number of victims affected by the Padang earthquake-tsunami[3].

Sacco et al.[6] determined the probability of deterioration condition of the victims by 35% based on RPM (respiratory rate, pulse rate, and motor response). RPM is used to assess the victim's severity. Several studies related to saving injured victims during a disaster. Mills, Argon, and Ziya[7] determined the time the victim is served to estimate the number of survivors. Sung and Lee[8] determined ambulances assigned to the hospital, victims who are transferred to the hospital, and the time of arrival of victims to estimate the number of survivors. Yi and Odzamar[9] developed a linear equation for coordinating the transport of disaster commodities fromthe main supply center to distribution centers in affected areas and the transport of disaster victims from affected areas to temporary locations and permanent emergency units. This model used three categories of victims consisting of heavy, moderate, and light. Muaafa, Concho, and Ramirez-Marquez[10] proposed an optimization model and evolutionary algorithm to facilitate medical emergency response, including placing a temporary emergency unit (TEU) in certain areas, dispatching emergency vehicles to appropriate TEU, dispatching emergency vehicles to affected areas, and transporting TEU victims. This model does not use victim triage in transporting victims to TEU. Caunhye, Li and Nie[11] developed a location-allocation model that locates alternative care facilities and considers the triage of disaster victims and the movement of refugees due to catastrophic radiological disasters. This model takes into account the victim conditions resulting from external radiation exposure, light radiation exposure, and severe radiation exposure by dividing alternative treatment facilities into two types, type 1 for the medium and far-from-site zones and type 2 for the zones near the light site. Victims with external radiation exposure can be treated in type 1 alternative care facilities, victims with light radiation exposure in public health care centers, and victims with severe exposure in specialized health centers. Oksuz and Satoglu[4] developed a two-stage stochastic model to determine the location and number of victims in the temporary medical center (TMC) by considering the location of the existing hospital, the capacity of the health center, and the possibility of hospital damage. This model uses three types of victims, namely immediate, delayed, and minimal. Liu, Cui and Zhang[12] developed a model with two objectives, namely maximizing the estimated number of survivors and minimizing operational costs. This model considers immediate and delayed victims. Victims who cannot be accommodated in the hospital will be transferred to temporary medical service. The ratio of the number of doctors and the number of victims used in this model is 1:1. Rezapour et al.[13] developed an optimization model to determine the best strategy for allocating rescue and medical units to affected areas.

This study aims to minimize operational cost, victims with yellow triage will be transferred to inpatient puskesmas (public health center), victims with red triage will be transferred to the hospital to avoid overcapacity, and victims with deterioration conditions from yellow triage to red triage will be transferred from inpatient puskesmas to hospital.

2. Methodology

Logistics refers to a system whose components interact with the optimal use of resources to achieve objectives appropriately and effectively[14]. Logistics is a supply chain process that functions in the planning, implementation, control of efficiency and effectiveness of the supply and flow of goods, services, and information from start to finish for conforming to consumer needs [15]. Logistics affects the cost of the supply chain[16]. Supply chain can improve communication between consumers and suppliers[17].

The purpose of logistics is to distribute the finished product and raw materials at the right time and amount of use, in a usable state, to the required location, and at the lowest total cost. To achieve this goal, several logistics components are needed that are integrated, namely a network of facilities, transportation, supplies, information, and handling and storage[18].

Humanitarian logistics is the process of mobilizing people, resources, skills, and knowledge to help people affected by disasters[19]. Humanitarian logistics is the activity of planning, implementing, and controlling the flow of humanitarian aid efficiently, cost-effectively and storing humanitarian aid and related information, starting from the point of origin to the point of destination, the goal is to reduce the suffering of disaster victims[20].

Beamon[21] distinguishes between logistic disaster and commercial logistics on objectives, demand types, demand patterns, distribution networks, inventory control, information systems, and how to measure system performance.

In disaster relief operations, humanitarian logistics is fundamental. it involves transporting relief supplies such as food, water, medicine, clothing, and shelters to disaster victims to save lives and alleviate the suffering of those who are most vulnerable[22]. To reduce disaster risk, disaster management (DM) could be used. Disaster management plans are used to mitigate the impact of the breakdown of financial and technical activities due to disasters[23]. The DM is a four-phase process that includes mitigation, preparedness, responses, and recovery[24]. Pre-disaster activities, such as mitigation and preparedness, and post-disaster activities, such as reaction and recovery, could be classified based on the time [25]. The evacuation of victims is one of the activities of disaster response[26].

Hospital is a place for health services that organize individual health services including inpatient, outpatient, and emergency services[27]. According to the type of service provided, the hospital is distinguished into a public hospital and a special hospital. The Public Health Center or puskesmas is a service facility that prioritizes promotive and preventive efforts in the health work area that organizes public health efforts and first-rate individual health efforts. Puskesmas consists of the inpatient health center and inpatient health center [28].

2.1 System Description

Victims from the disaster locations will be transferred to field health facilities at the evacuation posts of each subdistrict to receive first aid. At the field health posts, health workers will carry out victim triage identification. In the earthquake-tsunami Contingency Plan of Padang City[3], injured victims are categorized into seriously injured victims, moderately injured victims, and minor injured victims. Seriously injured victims are victims with red triage, moderately injured victims are victims with yellow triage, and minor injured victims are victims with green triage. At the field health post, after being identified a victim is seriously injured (red triage), victim will be transferred directly to the hospital. if the victim is moderately injured (yellow triage), victim will be transferred to an inpatient puskesmas for rescue actions. Yellow triage victims with deterioration conditions will be transferred from puskesmas to the nearest hospital.

It is assumed that hospitals and inpatient puskesmass in the green zone are in good condition so that the facilities can be fully used. One of the satisfaction factors for post-disaster victims is the distance of settlement from the disaster area[29]. Victims with deterioration conditions from yellow triage to red triage in puskesmas or temporary medical service in yard puskesmas will be transferred to the nearest hospital. If the capacity of the existing hospitals and puskesmass during the emergency response time exceeds the number of victims, temporary medical services will be opened. Temporary medical services opened in the hospital yards, puskesmas yards, and special hospitals located in the green zone. Each temporary medical service has its capacity and setup cost. The setup cost includes costs for the procurement of tents, medical equipment, field beds, radio rigs, generators, fuel, and data boards. If the capacity of the hospitals, inpatient puskesmass, and temporary medical services still insufficient, the victims will be distributed to a dummy hospital. The proposed relief chain structure is shown in Fig. 1.

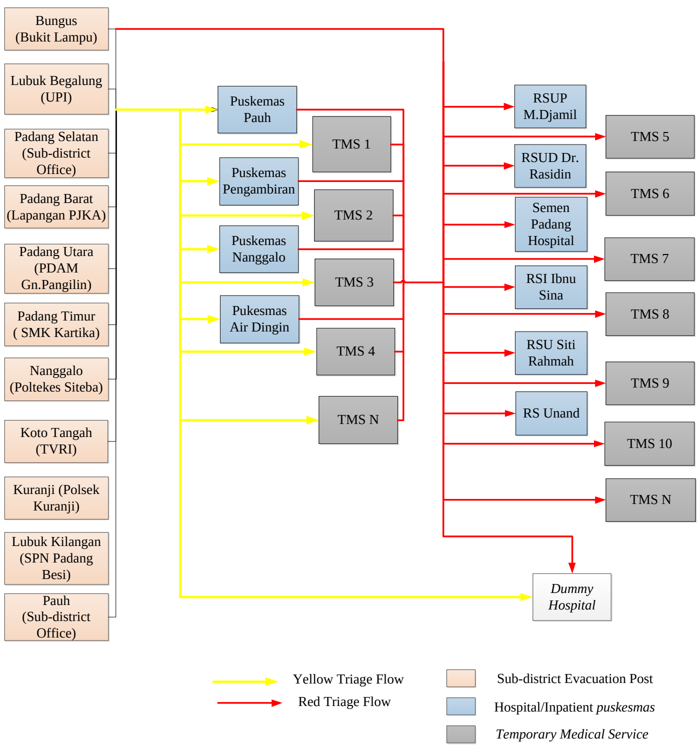

Fig. 1: Relief Chain Structure

2.2 Model Formulation

The model formulation of this study is as follows :

Sets

I	Hospitals	(i=1,2,…N)
J	Puskesmass	(j=1,2,…N)
V	TMSs for red triage	(v=1,2,…N)
W	TMSs for yellow triage	(w=1,2,…N)
X	Dummy hospital	
L	Evacuation posts	(l=1,2,…N)
O	BPBD (Regional Disaster Management Agency)	
H	Health workers	(h=1,2,…N)

Parameters

p_i	Capacity of hospital i
p_j	Capacity of puskesmas j
p_v	Capacity of TMS v
p_w	Capacity of TMS w
u_l	Number of red triage victims at the evacuation post l
y_l	Number of yellow triage victims at the evacuation post l
M	Big number
q	Cost of victim transportation
c	Cost of health worker transportation
g	TMS setup cost
λ	Probability deterioration the condition of the victims
a	Maximum number of TMSs v to be opened
z	Maximum number of TMSs w to be opened
β	Number of health workers needed for a patient
d	Distance
d_{li}	Distance of evacuation post l to hospital i

Decision Variables

h_i	Number of health workers in the hospital i
h_v	Number of health workers in the TMS v
h_j	Number of health workers in the puskesmas j
h_w	Number of health workers in the TMS w
h_x	Number of health workers in the dummy hospital x
s_{li}	Number of red triage victims from the evacuation post l to the hospital i
s_{lv}	Number of red triage victims from the evacuation post l to TMS v
s_{lx}	Number of red triage victims from the evacuation post l to dummy hospital x
t_{lj}	Number of yellow triage victims from the evacuation post l to the puskesmas j
t_{lw}	Number of yellow triage victims from the evacuation post l to TMS w
t_{lx}	Number of yellow triage victims from the evacuation post l to dummy hospital x
r_{ji}	Number of yellow triage victims that become red triage victims from the puskesmas j to the hospital i
r_{jv}	Number of yellow triage victims that become red triage victims from the puskesmas j to TMS v
r_{jx}	Number of yellow triage victims that become red triage victims from the puskesmas j to dummy hospital x
r_{wi}	Number of yellow triage victims that become red triage victims TMS w to hospital i
r_{wv}	Number of yellow triage victims that become red triage victims TMS w to TMS v
r_{wx}	Number of yellow triage victims that become red triage victims TMS w to dummy hospital x
o_v	Number of TMS v will be opened
o_w	Number of TMS w will be opened
o_i	1, if hospital i is selected and 0 otherwise
o_j	1, if puskesmas j is selected and 0 otherwise
o_x	1, if dummy hospital x is opened to red triage victims and 0 otherwise
p_x	1, if dummy hospital x is opened to yellow triage victims and 0 otherwise

Min

$$\sum_{l\in L}\sum_{i\in I} qd_{li}s_{li} + \sum_{l\in L}\sum_{v\in V} qd_{lv}s_{lv} + \sum_{l\in L}\sum_{x\in X} qd_{lx}s_{lx} + \sum_{l\in L}\sum_{j\in J} qd_{lj}t_{lj} + \sum_{l\in L}\sum_{w\in w} qd_{lw}t_{lw} + \sum_{l\in L}\sum_{x\in X} qd_{lx}t_{lx} +$$
$$\sum_{l\in L}\sum_{j\in J} qd_{lj}t_{lj} + \sum_{l\in L}\sum_{w\in w} qd_{lw}t_{lw} + \sum_{l\in L}\sum_{x\in X} qd_{lx}t_{lx} + \sum_{j\in J}\sum_{i\in I} qd_{ji}r_{ji} + \sum_{j\in J}\sum_{v\in V} qd_{Jv}r_{wv} + \sum_{j\in J}\sum_{x\in X} qd_{jx}r_{jx} +$$
$$\sum_{w\in W}\sum_{i\in I} qd_{wi}r_{wi} + \sum_{w\in W}\sum_{v\in V} qd_{wv}r_{wv} + \sum_{w\in W}\sum_{x\in X} qd_{wx}r_{wx} + \sum_{v\in V} go_{v} + \sum_{w\in W} go_{w} +$$
$$\sum_{o\in O}\sum_{i\in I} cd_{oi}h_{i} + \sum_{o\in O}\sum_{v\in V} cd_{ov}h_{v} + \sum_{o\in O}\sum_{j\in J} cd_{oj}h_{j} + \sum_{o\in O}\sum_{w\in W} cd_{ow}h_{w} + \sum_{o\in O}\sum_{x\in X} cd_{ox}h_{x} \qquad \ldots(1)$$

$$\sum_{i\in I} s_{li} + \sum_{v\in V} s_{lv} + \sum_{x\in X} s_{lx} = u_l \qquad (l \in L) \qquad \ldots(2)$$

$$\sum_{j\in J} t_{lj} + \sum_{w\in W} t_{lw} + \sum_{x\in X} t_{lx} = y_l \qquad (l \in L) \qquad \ldots(3)$$

$$\lambda t_{lj} \le \sum_{i\in I} r_{ji} + \sum_{v\in V} r_{jv} + \sum_{x\in X} r_{jx} \qquad (j \in J) \qquad \ldots(4)$$

$$\lambda t_{lw} \le \sum_{i\in I} r_{wi} + \sum_{v\in V} r_{wv} + \sum_{x\in X} r_{wx} \qquad (w \in w) \qquad \ldots(5)$$

The objective function (1) is minimize the total transportation cost of victims from evacuation posts to health facilities, total setup cost for opening temporary medical services, and transportation cost for health workers. Constraint (2) implies the number of red triage victims, namely victims from evacuation post *l* to hospital *i*, TMS *v*, and dummy hospital *x*, is equal to the total number of red triage victims in the evacuation post *l*. Constraint (3) implies the number of yellow triage victims, namely victims from the evacuation post *l* to the puskesmas *j*, TMS *w*, and dummy hospital *x*, is equal to the total number of yellow triage victims in the evacuation post *l*. Constraint (4) implies the number of yellow triage victims with deterioration conditions to red triage from puskesmas *j* to hospital *i*, TMS *v*, and to the dummy hospital *i* at the puskesmas *j*. Constraint (5) implies the number of yellow triage victims from TMS *w* to hospital *i*, TMS *v*, and dummy hospital *x* in TMS *w* with deterioration condition to red triage.

$$\sum_{l\in L} s_{li} + \sum_{j\in J} r_{ji} + \sum_{w\in W} r_{wi} \le b_i o_i \qquad (i \in I) \qquad \ldots(6)$$

$$\sum_{l\in L} s_{lv} + \sum_{j\in J} r_{jv} + \sum_{w\in W} r_{wv} \le b_v o_v \qquad (v \in V) \qquad \ldots(7)$$

$$o_v \le a \qquad (v \in V) \qquad \ldots(8)$$

$$\sum_{j\in J} t_{lj} \le b_j o_j \qquad (j \in J) \qquad \ldots(9)$$

$$\sum_{w\in W} t_{lw} \le b_w o_w \qquad (w \in W) \qquad \ldots(10)$$

$$o_w \le z \qquad (w \in W) \qquad \ldots(11)$$

Constraint (6) ensures the total number of victims who are transferred from evacuation *l* to hospital *i*, from puskesmas *j* to hospital *i*, and from TMS *w* to hospital *i* is less than or equal with the capacity of the selected hospital. Constraint (7) ensures that the total number of victims from evacuation post *l* to TMS *v*, from puskesmas *j* to TMS *v*, and from TMS *w* to TMS *v*, is less than or equal to the capacity of TMS *v* opened, where TMS *v* is less than or equal to the maximum number of TMS *v* to be opened. Constraint (8) ensures the number of TMS opened does not exceed the maximum number of TMS that can be opened. Constraint (9) explains that the total number of victims who are transferred to puskesmas *j*, namely from evacuation post *l* to the puskesmas *j*, is less than or equal to the capacity of the selected puskesmas *j*. Constraint (10) ensures that the number of victims from evacuation *l* to TMS *w* is less than or equal to the capacity of TMS *w* opened, where TMS *w* is less than or equal to the maximum number of TMS *w* to be opened. Constraint (11) ensures that the number of TMS *w* opened does not exceed the maximum number of TMS *w* that can be opened.

$$\sum_{i\in I}\sum_{l\in L} s_{li} + \sum_{i\in I}\sum_{j\in J} r_{ji} + \sum_{i\in I}\sum_{w\in W} r_{wi} +$$
$$\sum_{v\in V}\sum_{l\in L} s_{lv} + \sum_{v\in V}\sum_{j\in J} r_{jv} + \sum_{v\in V}\sum_{w\in W} r_{wv} >$$
$$(b_i + b_v a + f_v) o_x \qquad (x \in X) \qquad \ldots(12)$$

$$\sum_{j\in J} t_{lj} + \sum_{w\in W} t_{lw} > (b_w z + b_j) p_x \quad (x \in X) \qquad \ldots(13)$$

$$\sum_{x\in X} s_{lx} + \sum_{x\in X} r_{jx} + \sum_{x\in X} r_{wx} \le Mo_x \quad (x \in X) \qquad \ldots(14)$$

$$\sum_{x\in X} t_{lx} \le Mp_x \quad (x \in X) \qquad \ldots(15)$$

Constraints (12) and (13) ensures the total number of victims is greater than the total capacity of health facilities available at the dummy hospital to be opened. Constraints (14) and (15) ensures the total number of victims who are transferred to the dummy hospital, namely from evacuation post l to the dummy hospital x, from TMS w to the dummy hospital x, and from the puskesmas j to the dummy hospital x, is less than or equal to Big Number capacity if the total number of victims exceeds the capacity of the available health facilities.

$$\beta(\sum_{l\in L} s_{li} + \sum_{j\in J} r_{ji} + \sum_{w\in W} r_{wi}) \le h_i \quad (i \in I)\ (h \in H) \quad \ldots(16)$$

$$\beta(\sum_{l\in L} s_{lv} + \sum_{j\in J} r_{jv} + \sum_{w\in W} r_{wv}) \le h_v \quad (v \in V)\ (h \in H) \quad \ldots(17)$$

$$\beta \sum_{j\in J} t_{lj} \le h_j \quad (j \in J)\ (h \in H) \qquad \ldots(18)$$

$$\beta \sum_{w\in W} t_{lw} \le h_w \quad (w \in W)\ (h \in H) \qquad \ldots(19)$$

$$\beta(\sum_{x\in X} s_{lx} + \sum_{x\in X} r_{jx} + \sum_{x\in X} r_{wx} + \sum_{x\in X} t_{lx}) \le h_x \quad (x \in X)\ (h \in H) \qquad \ldots(20)$$

$o_i, o_j, o_x, p_x \in \{0,1\}$ …(21)

h_i, h_v, h_j, h_w, h_x integer …(22)

o_v, o_w integer …(23)

$s_{li}, s_{lv}, s_{lx}, t_{lj}, t_{lw}, t_{lx}, r_{ji}, r_{lv}, r_{jx}, r_{wv}\ r_{wi}, r_{wx}$ integer …(24)

Constraint (16) implies the number of victims from evacuation post l to hospital i, puskesmas j to hospital i, and TMS w to hospital i is less than or equal to the number of health workers h in hospital i. Constraint (17) implies the number of victims from evacuation post l to TMS v, puskesmas j to TMS v, and TMS w to TMS v is less than or equal to the number of health workers h in TMS v. Constraint (18) implies the number of victims from evacuation post l to puskesmas j, is less than or equal to the number of health workers h in puskesmas j. Constraint (19) implies the number of victims from evacuation post l to TMS w is less than or equal to the number of health workers h in TMS w. Constraint (20) implies that the number of victims from evacuation post l to dummy hospital x, puskesmas j to dummy hospital x, and TMS w to dummy hospital x is less than or equal to the number of health workers h in dummy hospital x. Constraint (21) defines the binary variable of health facility if selected/opened. Constraint (22) defines the integer variable of health workers. Constraint (23) defines of integer variable of TMS opened. Constraint (24) defines of integer variable of the victims.

2.3 Case Study

The model developed was implemented based on the population of Padang city 2020 in Statistics Indonesia of Padang City[30]. The population of Padang City 2020 is grouped according to the percentage of victims in the earthquake-tsunami Contingency Plan of Padang City.

2.4 Data Collections

Based on the earthquake-tsunami Contingency Plan of Padang City[3], each subdistrict has a subdistrict evacuation post scattered throughout Padang City. The location of subdistrict evacuation posts in Padang city is shown in Table 1.

Table 1. Subdistrict Evacuation Posts

Subidistricts	Evacuation Posts	Symbol
Bungus Teluk Kabung	Bukit lampu	I_1
Lubuk Begalung	Kampus UPI	I_2
Padang Selatan	Subdistrict Office	I_3
Padang Barat	Lapangan PJKA	I_4
Padang Utara	PDAM Gn Pangilun	I_5
Padang Timur	Komplek SMK Kartika	I_6
Nanggalo	Poltekes Siteba	I_7
Koto Tangah	TVRI By Pass	I_8
Kuranji	Polsek Kuranji	I_9
Lubuk Kilangan	SPN Padang Besi	I_{10}
Pauh	Subdistrict Office	I_{11}

The number of victims affected is based on the total population of the City of Padang 2020. The number of displaced victims is 59% of the total population. The number of victims who suffered minor injuries was 9%, moderate injuries 10%, serious injuries 40%, and non-injury 41% from the total displaced population[3]. The number of victims affected in one day is shown in Table 2.

Table 2. Number of Affected Victims

Subdistrict	Yellow Triage victims	Red Triage victims
Bungus Teluk Kabung	1,526	6,105
Lubuk Begalung	7,586	30,343
Padang Selatan	3,572	14,289
Padang Barat	2,724	10,896
Padang Utara	4,211	16,846
Padang Timur	4,720	18,878
Nanggalo	3,706	14,824
Koto Tangah	12,027	48,107
Kuranji	9,247	36,987
Lubuk Kilangan	3,456	13,825
Pauh	4,641	18,565

Currently, Padang City has 27 hospitals in the red zone and the green zone of the earthquake-tsunami. There are six general hospitals (RSU) and six special hospitals in the green zone, and other hospitals in the red zone. The general hospitals are RSUP M Djamil, Semen Padang Hospital, RSU Siti Rahmah, RSUD Dr. Rasidin, RSU Unand and RSI Ibnu Sina, while the special hospitals are RSIA Cicik, RSIA Siti Hawa, RSJ Puti Bungsu, RSKB Kartika Docta and RSKGM Baiturrahmah. The special hospitals will be used as temporary medical services for victims with red triage. Then, Padang City has 23 puskesmass namely inpatient and non-inpatient puskesmass. There are 4 inpatient puskesmass in the green zone, namely Puskesmas Pengambiran, Puskesmas Nanggalo, Puskesmas Pauh and Puskesmas Air Dingin. The temporary medical services occupy the hospital yards, the puskesmas yards, and the special hospitals in Padang City. The distance between evacuation posts and health facilities is determined using the Google Maps application, where the calculation process is carried out by selecting the shortest route from one location to another. The capacity of health facilities is determined based on the number of beds available in each health facility. The capacity of the TMS in the public hospital yard and special hospital is assumed to be able to accommodate 7 tents, with each tent having a capacity of 20 victims and TMS occupies puskesmas yard can accommodate 5 tents.

Setup cost is the cost for procurement of goods when TMS is opened. The setup cost for opening TMS is IDR 29,850,000, it includes cost for tents, field beds, radio rigs, generators, fuel, and data boards. The victim transportation cost includes transportation costs from the evacuation posts to the health facilities, while the health worker transportation cost is the transportation costs from the BPBD to the health facilities. The transportation cost for the victim is IDR 981.25 per victim and the transportation cost for a health worker is IDR 140.17 per health worker. The number of health workers needed based on the Ministry of Health of the Republic of Indonesia is a general practitioner for 40 victims, a surgeon for 25 victims, and an anesthetist for 75 victims, and a nurse for a victim[31)]. The deterioration probability of the victim condition is 35%[6)].

3. Results And Discussions

LINGO 18.0 software was used as problem-solving software. The software runs on a Personal Computer with an AMD A9-9420 Processor, 4 GB RAM, and a 64-bit operating system. This study aims to calculate transportation costs for victims, transportation costs for health workers, and TMS setup costs. Fig. 2 below shows the result of Lingo.

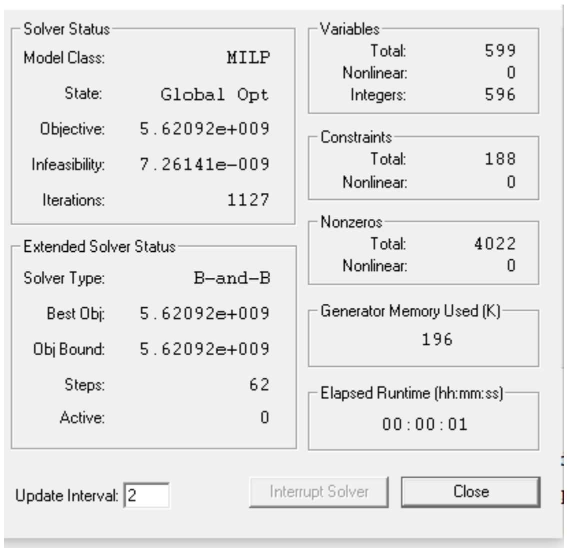

Fig. 2: Report

Fig 2 shows that the time needed to solve the problem is a second. The result obtained is a Global Optimal Solution with an objective of IDR 5.62092 x 10^9. One of the decision variables of the model in this study is the decision to allocate the number of red triage victims, yellow triage victims, and yellow triage victims with deterioration conditions to red triage that is transferred to health facilities. Table 3 shows the allocation of red triage victims that are transferred from evacuation post l to hospital i, TMS v, and dummy hospital x.

Table 3. Allocation of Red Triage Victims

From \ To	i_1	i_2	i_3	i_4	i_5	i_6	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	x
l_1			144						140										5,821
l_2																			30,343
l_3													166	174					13,949
l_4	800						140									180			9,776
l_5				124						140							194		16,388
l_6																			18,878
l_7											132								14,762
l_8		112			169			140										145	47,541
l_9																			36,987
l_{10}						104						70			454				13,127
l_{11}												7							18,565
Total	800	112	144	124	169	104	140	140	140	140	132	0	166	174	454	180	194	145	226,137

The number of red triage victims allocated to RSUP M Djamil (i_1) is 800 people, Dr. Rasidin Hospital (i_2) is 112 people, Semen Padang Hospital (i_3) 144 people, RSI Ibnu Sina (i_4) is 124 people, Siti Rahmah Hospital (i_5) is 169 people, and Unand Hospital (i_6) is 104 people. The allocation of yellow triage victims from evacuation posts l to puskesmas j TMS w and dummy hospital x is shown Table 4.

Table 4. Allocation of Yellow Triage Victims

From \ To	j_1	j_2	j_3	j_4	w_1	w_2	w_3	w_4	x
l_1		10				100			1.416
l_2									7.586
l_3									3.572
l_4									2.724
l_5									4.211
l_6	10								4.710
l_7			10				100		3.596
l_8				10				100	11.917
l_9					100				9.147
l_{10}									3.456
l_{11}									4.641
Total	10	10	10	10	100	100	100	100	56.976

Allocation of yellow triage victims to Puskesmas Pauh ($j1$) is 110 people where 10 people are allocated to puskesmas and 100 people to TMS w, Puskesmas Pengambiran ($j2$) is 110 people where 10 people are allocated to the puskesmas and 100 people to TMS w, Puskesmas Nanggalo ($j3$) is 110 people where 10 people are allocated to the puskesmas and 100 people to TMS w and Puskesmas Air Dingin ($j4$) is 110 people where 10 people are allocated to puskesmas and 100 people to TMS w. The number of yellow triage victims who exceeded the capacity was allocated to a dummy hospital. The allocation of victims with deterioration condition from yellow triage to red triage from puskesmas j to hospital i, TMS v, and dummy hospital x is shown Table 5.

Table 5. The Allocation Victims with Deterioration Conditions in Puskesmas j

From \ To	i_1	i_2	i_3	i_4	i_5	i_6	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	x
j_1																			4
j_2																			4
j_3											4								
j_4											4								
Total	0	0	0	0	0	0	0	0	0	0	8	0	0	0	0	0	0	0	8

Yellow triage victims with deterioration condition in puskesmas allocated from Puskesmas Nanggalo (j_3) and Puskesmas Air Dingin (j_4) to Siti Rahmah Hospital (v_5) is 8 people, from Puskesmas Pauh (j_1) and Puskesmas Pengambiran (j_2) to dummy hospital (x) is 8 people. The allocation of victims with deterioration condition from yellow triage to red triage from TMS w to hospital i, TMS v, and dummy hospital x is shown Table 6.

Table 6. The Allocation Victims with Deterioration Conditions in TMS w

From \ To	i_1	i_2	i_3	i_4	i_5	i_6	v_1	v_2	v_3	v_4	v_5	v_6	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	x
w_1																			35
w_2																			35
w_3											35								
w_4											35								
Total	0	0	0	0	0	0	0	0	0	0	70	0	0	0	0	0	0	0	70

Yellow triage victims with deterioration condition in TMS w allocated from Puskesmas Nanggalo (w_3) and Puskesmas Air Dingin (w_4) to Siti Rahmah Hospital (v_5) is 70 people, from Puskesmas Pauh (j_1) and Puskesmas Pengambiran (j_2) to dummy hospital (x) is 70 people. The allocation of health workers is also one of the decision variables of the model in this study. The number of health workers namely general practitioners (h_1), surgeons (h_2), anesthetists (h_3) and nurses (h_4) allocated to hospital i, TMS v, TMS w, puskesmas j, and dummy hospital is shown Table 7.

Table 7. The Allocation of Health Workers

From \ To	i_1	i_2	i_3	i_4	i_5	i_6	v_1	v_2	v_3	v_4	v_5	v_6
h_1	20	3	4	4	5	3	4	4	4	4	4	4
h_2	32	5	6	5	7	5	6	6	6	6	6	6
h_3	11	2	2	2	3	2	2	2	2	2	2	2
h_4	800	112	144	124	169	104	140	140	140	140	140	140

Table 7. The Allocation of Health Workers (Continued)

From \ To	v_7	v_8	v_9	v_{10}	v_{11}	v_{12}	j_1	j_2	j_3	j_4	w_1	w_2	w_3	w_4	x
h_1	5	5	12	5	5	4	1	1	1	1	3	3	3	3	7.080
h_2	7	7	19	8	8	6	1	1	1	1	4	4	4	4	11.328
h_3	3	3	7	3	3	2	1	1	1	1	2	2	2	2	3.776
h_4	166	174	454	180	194	145	10	10	10	10	100	100	100	100	283.191

Allocation of health workers to RSUP M Djamil (i_1) is 20 general practitioners, 31 surgeons 11 anesthetists and 800 nurses, Dr. Rasidin Hospital (i_2) is 3 general practitioners, 5 surgeons, 2 anesthetists, and 112 nurses, Semen Padang Hospital is 4 general practitioners, 6 surgeons 2 anesthetists, and 144 nurses, RSI Ibnu Sina (i_3) is 4 general practitioners, 5 surgeons 2 anesthetists, and 124 nurses. Based on the result obtained from Lingo Software, the temporary medical services that are opened consist of 7 TMSs in each public hospital and special hospital and 5 TMSs in each puskesmas *i*n the green zone. The opening of a dummy hospital is carried out because of overcapacity in all health facilities. Table 8**.** shows the opened/selected health facilities.

Table 8. The Opened/Selected Health Facilities

Health Facility	Decision variable	Health Facility	Decision variable	Health Facility	Decision variable
i_1	1	v_5	7	j_3	1
i_2	1	v_6	7	j_4	1
i_3	1	v_7	7	w_1	5
i_4	1	v_8	7	w_2	5
i_5	1	v_9	7	w_3	5
i_6	1	v_{10}	7	w_4	5
v_1	7	v_{11}	7	x	1
v_2	7	v_{12}	7		
v_3	7	j_1	1		
v_4	7	j_2	1		

The result of the model shows all existing hospitals and all puskesmass, 84 TMSs in public hospitals and special hospitals, 20 TMSs in puskesmass and a dummy hospital. The objective function value obtained is IDR 5.62092 x 10^9 (100%).

The sensitivity analysis was carried out to show the effect of changes in the parameters of the number of victims and changes in the maximum number of TMSs to be opened. The sensitivity analysis is shown by the number of victims decreases because the earthquake that occurred is smaller so that not the victims are affected less. The decrease in the number of victims by 90% (to 10%) of the victims in evacuation posts resulted in a total cost of IDR 3.337447 x 10^9 and the decrease in the number of victims by 50% (to 50%) of the victims in evacuation posts resulted in a total cost to IDR 4.352471 x 10^9 caused allocation of the number of victims becomes small. This decrease in the number of victims leads to a decrease in the total transportation cost of victims and the total transportation cost of health workers. Total setup cost does not change because the number of victims still exceeds the capacity of hospitals, puskesmass, and TMSs that exist. The sensitivity analysis is shown by the capacity of health facilities increased because overcapacity exists in health facilities. The increase in capacity of health facilities to 200% in a total cost of IDR 5.599965 x 10^9 and increase in capacity of health facilities to 400% in a total cost of IDR 5.6310771 x 10^9. The increased capacity of health facilities causes the total transportation cost of victims to decrease, the total setup cost does not change and the total transportation cost of health facilities to increase. The decrease of total transportation cost of victims because of the increasing number of alternative health facilities available, so that victims allocated to the nearest health facilities. Setup cost does not change because the number of victims still exceeds the capacity of hospitals, puskesmass, and TMSs that exist so that the setup cost does not change.

4. Conclusions

This study has developed a location-allocation model for the number of victims and health workers, and determined hospitals, public health centers (puskesmass*)*, and Temporary Medical Services (TMSs) to be opened in the post-earthquake-tsunami in Padang City. The objective of this model is to minimize the total transportation cost of victims, total setup cost, and total transportation cost of health workers. The result of the model shows all existing hospitals and all puskesmass 84 TMSs in public hospitals and special hospitals, 20 TMSs in puskesmass and a dummy hospital. The objective function value obtained is IDR 5.62092 x 10^9 (100%). The total operational cost will decrease along with the decrease in the number of victims in evacuation posts, causing a decrease in the total transportation cost of victims and the total transportation cost of health workers, but the total setup cost remains unchanged. The total operational cost will increase along with the increase in the capacity of health facilities, resulting in a decrease in the total transportation cost of victims, an increase in the total transportation cost of health workers and the total setup cost remains unchanged. Further research can be developed by adding minor injured victims (green triage). The model may also consider the cost, and location of dummy hospitals.

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