Proceedings of the 9th International Conference on
Applied Operational Research (ICAOR 2017)
Chung Yuan Christian University
Taoyuan, Taiwan
18-20 December 2017

Modeling emergency medical response to a mass casualty incident in multiple locations

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Abstract

During the emergency response to mass casualty incidents decisions relating to the extrication, transporting and treatment of casualties are made in a real-time, sequential manner. In order to increase survival rates of casualties, the total response time of casualties, including waiting times at emergency sites, transportation times, waiting times at hospitals, and treatment times, needs to be minimized. The stochastic nature of injury degree and treatment time of casualties is considered in this study. We developed a multi-stage heuristic on a rolling time horizon to help decisions-makers make rescue decisions of emergency response to mass casualty incidents. Simulation of a multi-server queueing system with heterogeneous service times is embedded in the algorithm. The heuristic is evaluated over several potential problems, with results confirming its effectiveness.

Keywords: mass casualty incidents; multi-stage heuristic; transition probability; multi-server queue with heterogeneous service times

Introduction

The hours following a severe disaster is the golden time to rescue casualties, and the rescue must be based on the medical emergency response system (MERS). MERS is a mechanism that ensures casualties receive necessary medical emergency aid before they arrive at the hospital, and that the decision-maker sends the injured to an appropriate hospital, which are the most important parts in the emergency response system (ERS) in disaster-stricken areas. MERS is established in order that rescue workers can reach a disaster-stricken area as soon as possible after a disaster occurs, plan the emergency medical services required for casualties, and guarantee coordinated operations and information exchange among different medical organizations (Mears et al. 2002). Therefore, the incident command system must be in charge of coordinated operations among different medical organizations (such as medical centers and regional and local hospitals), and immediately integrate relevant information (incident location, transportation time, strategy of medical dispatch, patient, and existing medical resources), in order to make appropriate rescue decisions.

During the emergency response to mass casualty incidents (MCI) decisions relating to the extrication, treatment and transporting of casualties are made in a real-time, sequential manner. With the prerequisite that the disaster command center can obtain immediate and accurate information regarding emergency resources, Lin (2017) proposes a stochastic dynamic programming model to conduct practical exploration of the emergency response to MCI. In this study, we develop a multi-stage heuristic on a rolling time horizon to solve the Lin's model.

Literature Review

Medical emergency response system (MERS) has attracted the attention of scholars in the operation field since the 1960s, and the topics for discussion include the fixed location of the ambulance base,

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the dispatch of rescue, the quantity and type of ambulances, and the flexible parking locations of available ambulances; however, it was not until a decade ago that other research topics, such as MCI and after-disaster medical response, began to gain public attention.

Gong and Batta (2007) elaborated on the distribution and re-distribution of ambulances during disaster relief, and proposed a clear mathematical planning mode to predict the time-based increase in mass casualties after a disaster. With the limited number of ambulances, as designated by the predictive model, they calculated the time for rescue and improved rescue performance.

Wilson et al. (2013) proposed a new multi-objectives optimization model to minimize the number of casualties and sufferers, and maximize the efficiency of transportation, which considered MCI features, including the uncertainty of the physical conditions of casualties, the spatial feature of points with numerous and severe disasters, the importance of choosing an appropriate hospital for each casualty, and the time-based increment in the capacity of the hospital. They solve the model with the constructivist heuristic algorithm and the variable neighborhood descent algorithm.

Salman and Sezer (2014) put forward an analytic architecture to determine the location and size of field hospitals constructed after disasters. In the study, the multi-period mixed integer planning mode was adopted to make the plans regarding capacity distribution and casualty transportation to hospitals after disasters, which aimed to minimize the total transportation time, the time of waiting for rescue, and the weight cost of the establishment cost of newly-built field hospitals according to the existing ambulances, the accessibility of hospital resources, and the location and size of newly-built field hospitals.

The above studies delved into the effects of uncertainties on MERS and rescue; however, they all concentrated on the locations of medical emergency facilities and the distribution of medical resources before and after disasters. However, none of the studies explored the uncertainty that the injuries of casualties might deteriorate with the passage of time and the randomness of treatment time of casualties at hospitals. For that reasons, this study probes into the issues regarding the dispatch of emergency services to MCI in multiple locations, with emphasis on the abovementioned two aspects.

Research Methodology

The randomness of the location and quantity of casualties, or the seriousness of their injuries, are not considered in this study. After obtaining information regarding rescue demands from the medical emergency management database, this study focuses on how to dispatch emergency aid to MCI in multiple locations according to existing medical emergency resources. In particular, this study considers the time-dependent and random characteristics of the injury levels of the casualties, meaning the injuries of casualties who have not been rescued would deteriorate with the passage of time. Furthermore, the treatment time of casualties is related to the seriousness of injuries and personal physical conditions, and thus, is regarded as a random variable.

The basic assumptions of this study are, as follows:

1. Assumptions regarding casualties:
   (1) The injuries of casualties are evaluated by medical staff in the disaster-stricken area and are divided into three levels -- “Slight”, “Medium”, and “Serious”, given the location and quantity of casualties and the seriousness of initial injuries.
   (2) The injuries of casualties who have not been rescued would deteriorate with the passage of time, and thus, are related to the seriousness of initial injuries and the period of treatment postponement, which can be predicted with the transition probability according to the Markov Chain.
   (3) Direct transportation is adopted in the transportation of casualties.
   (4) Carpooling is adopted for the transportation of casualties with slight or medium injuries. Casualties with different levels of injuries will not be transported in the same vehicle.
   (5) Exclusive vehicles are used for the transportation of casualties with serious injuries, and each casualty is transported in one vehicle.
   (6) The possibility that casualties are transferred to another hospital after receiving treatment in the current hospital is not considered.
2. Assumptions regarding fire-fighting units
   (1) The fire-fighting units in this study refer to public units, and exclude private rescue units and

other private associations and institutions.
  (2) The rescue radius of ambulances of the fire-fighting units is given.
  (3) The quantity of available ambulances of the fire-fighting units is given.

3. Assumptions regarding ambulances
  (1) The ambulances are regarded as common ambulances.
  (2) During the planned period, an ambulance is not required to return to its fire-fighting unit after transporting casualties to the hospital from the emergency rescue station, meaning it can remain at the hospital and transport other casualties from a previous disaster-stricken area or a new area until the end of the planned period.
  (3) The routes of casualty transportation are confirmed as effective routes in advance, thus, the uncertainty of the time for casualty transportation is not taken into consideration. Moreover, the assumed speed of ambulances for casualty transportation is given, without considering traffic jams.
4. Assumptions regarding hospitals
  (1) The location and initial capacity of emergency hospitals are given.
  (2) Special emergency medical care is not considered.

Pratikakis *et al*. (2007) proposed a solution algorithm to approximately solve a real-world SDP model by iteratively solving a mixed integer programming model on a rolling time horizon. As the proposed SDP model with simulation cannot be solved by an algorithm of exact solutions, this study develops a heuristic to approximately solve the proposed SDP model. The brief ideas are, as follows:

1. In temporal stage *t*, predict the numbers of casualties of different injury levels in the future temporal stages (*t*~*T*); the predicted numbers of casualties of different injury levels in the future temporal stages (*t*~*T*) in disaster-stricken areas is taken as the input data of this proposed SDP model of emergency rescue dispatch for MCI; next, search the solutions to obtain good decisions in the temporal stages (*t*~*T*); carry out the dispatch plan of emergency rescue for MCI in temporal stage *t*; then simulate and evaluate the estimated values of total queue time $W_i^h(t)$ for casualties with different injury levels for medical treatment at the hospitals, as well as the quantity $N2_i(t)$ of casualties who arrive, but queue for treatment at the hospital in temporal stages *t* according to the injury level of casualties transported to the hospitals and the numbers of available medical teams at the hospitals in the temporal stages (*t*~*T*).

2. The next temporal stage *t* + 1 and the number of casualties of different injury levels who have not been rescued at each emergency rescue station are realized, and the numbers of casualties of different injury levels during the temporal stages (*t+2*~*T*) are re-predicted. Likewise, the updated number of casualties of different injury levels who have not been rescued is taken as the input data of the SDP model for decision solutions regarding emergency rescue in the temporal stages (*t+1*~*T*); meanwhile, the dispatch plan of emergency rescue for MCI in temporal stage (*t* + 1) will be implemented; then the estimated values of the total queue time for casualties with different injury levels for medical treatment at the hospitals, as well as the quantity of casualties who arrive, but queue for treatment at the hospital, are simulated and evaluated in the temporal stages (*t* + 1).

3. This process is repeated until temporal stage *T* ends.

The detailed processes of the multi-stage heuristic on a rolling time horizon are, as follows:

Step 1: Initial setting
  Step 1.1: Set the duration of a time period and the number of stages.
  Step 1.2: Read the basic information about the disaster-relief components for the given rescue.
    1. The locations and number of disaster-stricken areas, as well as the number $G_m^h(0)$ of casualties of different injury levels in the disaster-stricken areas in the initial stage.
    2. The locations of the fire-fighting units to which the ambulances initially belong, as well as the quantity ($\left|K_j^1(0)\right|$, $\left|K_i^2(0)\right|$) of ambulances available in the initial stage.
    3. The locations of hospitals, and the medical capacities $P_i(0)$ of the hospitals in the initial stage.

4. The relative severity α_1^h for an incident commander when casualties are left un-rescued in the disaster-stricken area.
5. The relative severity α_2^h for an incident commander when casualties have to queue for treatment in the medical emergency hospital.

Step 1.3: Calculate the shortest travel time among the fire-fighting areas, hospitals, and disaster-stricken areas.

Step 1.4: Set the initial number of stages as "1" ($t = 1$)

Step 2: Select a targeted emergency rescue station $\hat{m}$ in disaster-stricken areas according to the casualty distribution of temporal stage *t*

Step 2.1: Calculate the total number $G_m^h(t)$ of casualties of different injury levels who wait for rescue at each emergency rescue station in the disaster-stricken areas in temporal stage *t*;

$$G_m^h(t+1) = N1_m^h(t) - \sum_{h<h'} \delta_m^{hh'}(t+1) + \sum_{h'<h} \delta_m^{h'h}(t+1) \qquad \forall h, m \tag{16}$$

Step 2.2: Determine the prioritized emergency rescue station $\hat{m}$ for rescue according to one of the principles of selecting an emergency rescue station.

<u>Principle 1 of selecting an emergency rescue station</u>: select an emergency rescue station $\hat{m}$ for the greatest number of casualties with serious injuries.

<u>Principle 2 of selecting an emergency rescue station</u>: select an emergency rescue station $\hat{m}$ for the greatest number of casualties with medium or serious injuries.

Step 3: Select an ambulance $\hat{k}$ for rescuing the casualties at the targeted emergency rescue station $\hat{m}$ according to the ambulances distribution of temporal stage *t*

Step 3.1: Select an ambulance $\hat{k}$ for rescue at the targeted emergency rescue station $\hat{m}$ in temporal stage *t*, with the prerequisite that "the total number of ambulances leaving for the hospital or the fire-fighting unit does not exceed the total number of ambulances that are standing by at the unit in the temporal stage."

<u>Principle 1 of selecting an ambulance (according to distance)</u>:

When the ambulances of fire-fighting units or hospitals can serve all emergency rescue stations in disaster-stricken areas, select an ambulance $\hat{k}$ that can arrive at the targeted emergency rescue station $\hat{m}$ within the shortest time.

<u>Principle 2 of selecting an ambulance (according to regional areas of responsibility and distance)</u>:

The ambulances of fire-fighting units or hospitals must first serve the emergency rescue stations in their regional areas of responsibility. If there are no requests for emergency rescue in their regional areas of responsibility, the ambulances can serve other emergency rescue stations outside their regional areas of responsibility. The first choice is to select an ambulance $\hat{k}$ that can arrive at the targeted station $\hat{m}$ within the shortest time, and departs within the same regional areas of responsibility of the targeted station $\hat{m}$. The second choice is to select an ambulance $\hat{k}$ that can arrive at the targeted station $\hat{m}$ within the shortest time outside their regional areas of responsibility of the targeted station $\hat{m}$. Due to unfamiliarity with traffic routes, the travel time must be magnified by 1.1 times.

Step 3-2: Remove ambulance $\hat{k}$ from the set of available ambulances $K_{\hat{j}}^1(t)$ of the fire-fighting unit $\hat{j}$ in temporal stage *t.*

(Step 3-2: Remove ambulance $\hat{k}$ from the set of available ambulances $K_{\hat{i}'}^2(t)$ of hospital $\hat{i}'$ in temporal stage *t.*)

Step 4: Select a hospital $\hat{i}$ for treating the casualties at the targeted emergency rescue station $\hat{m}$ according to the conditions and services of hospital of temporal stage *t*

<u>Principle 1 of selecting a hospital (according to distance)</u>: select a hospital $\hat{i}$ with the shortest time from the targeted emergency rescue station $\hat{m}$.

Principle 2 of selecting a hospital (according to distance and remaining capacity): select a hospital only from those hospitals that have at least *x*% of remaining capacity. Reselect a hospital $\hat{i}$ with the shortest time from the targeted emergency rescue station $\hat{m}$. If no hospital can meet these requirements, lower threshold *x*% of remaining capacity till a hospital is selected.

Step 5: Determine the number of casualties at the targeted emergency rescue station $\hat{m}$ to be rescued according to the casualty statistics of temporal stage *t*

Step 5.1: According to the principle of transporting casualties, where “priority is given to those with serious injuries, followed by those with medium injuries, and then, those with slight injuries”, the casualties with different injury levels at the targeted emergency rescue station $\hat{m}$ are picked up by one. Let the targeted injury level be $\hat{h}$.

Step 5.2: With the prerequisite that the maximum number of casualties to be transported by an ambulance for casualties of different injury levels is limited to $v^{\hat{h}}$, one ambulance can only rescue casualties of the same injury level and the number $Q_{\hat{i}}(t)$ of the remaining capacity of the selected hospital $\hat{i}$, determine the number $X1^{\hat{h}}_{\hat{j}\hat{m}\hat{i}}(t)$ of casualties of the given injury level $\hat{h}$ transported by the chosen ambulance $\hat{k}$ of fire-fighting unit $\hat{j}$ from the targeted emergency rescue station $\hat{m}$ to the selected hospital $\hat{i}$ or the number $X2^{\hat{h}}_{\hat{i}'\hat{m}\hat{i}}(t)$ of casualties of the given injury level $\hat{h}$ transported by the chosen ambulance $\hat{k}$ of hospital $\hat{i}'$ from the targeted emergency rescue station $\hat{m}$ to the selected hospital $\hat{i}$. That is,

$$X1^{\hat{h}}_{\hat{j}\hat{m}\hat{i}}(t) = \min\left[L^{\hat{h}}_{\hat{m}}(t), v^{\hat{h}} Z1^{\hat{h}\hat{k}}_{\hat{j}\hat{m}\hat{i}}(t), Q_{\hat{i}}(t)\right], \text{ if } \hat{k} \in K^{1}_{\hat{j}}(t) \tag{2}$$

$$X2^{\hat{h}}_{\hat{i}'\hat{m}\hat{i}}(t) = \min\left[L^{\hat{h}}_{\hat{m}}(t), v^{\hat{h}} Z2^{\hat{h}\hat{k}}_{\hat{i}'\hat{m}\hat{i}}(t), Q_{\hat{i}}(t)\right], \text{ if } \hat{k} \in K^{2}_{\hat{i}'}(t) \tag{3}$$

Step 6: Update the values of other variables in the temporal stage *t*

Step 6.1: Update the dispatch of ambulances, $Z1^{\hat{h}}_{\hat{j}\hat{m}\hat{i}}(t) = 1$ or $Z2^{\hat{h}}_{\hat{i}'\hat{m}\hat{i}}(t) = 1$, according to the results of Step 5.

Step 6.2: Calculate arrival time $Y1^{\hat{h}\hat{k}}_{\hat{j}\hat{m}i}(t)$ of ambulance $\hat{k}$ of fire-fighting unit $\hat{j}$ that transports casualties of injury level $\hat{h}$ from emergency rescue station $\hat{m}$ in the disaster-stricken area to hospital $\hat{i}$ in temporal stage *t* or arrival time $Y2^{\hat{h}\hat{k}}_{\hat{i}'\hat{m}\hat{i}}(t)$ of ambulance $\hat{k}$ of hospital $\hat{i}'$ that transports the casualties of injury level $\hat{h}$ from emergency rescue station $\hat{m}$ in the disaster-stricken area to hospital $\hat{i}$, according to the results of Step 6-1.

Step 6.3: Calculate and update number $N1^{\hat{h}}_{\hat{m}}(t)$ of the casualties of different injury levels who have not been rescued at emergency rescue station $\hat{m}$ in the disaster-stricken area.

Step 6.4: Calculate the number of casualties of different injury levels who have arrived at hospital $\hat{i}$ and update number $Q_{\hat{i}}(t)$ of the available capacity of the hospitals.

Step 6.5: According to the arrival time $Y1^{\hat{h}\hat{k}}_{\hat{j}\hat{m}i}(t)$ of ambulance $\hat{k}$ of fire-fighting unit $\hat{j}$ to determine which temporal stage ambulance $\hat{k}$ belongs to; if the arrival time $Y1^{\hat{h}\hat{k}}_{\hat{j}\hat{m}i}(t)$ is earlier than the finish time of this temporal stage $\overline{E}_{t'}$, put this ambulance $\hat{k}$ into set $K^{1}_{\hat{j}}(t')$ of available ambulances of fire-fighting unit $\hat{j}$ in temporal stage *t’*.

(Step 6.5: According to the arrival time $Y2^{\hat{h}\hat{k}}_{\hat{i}'\hat{m}\hat{i}}(t)$ of the ambulance $\hat{k}$ of the hospital $\hat{i}'$, determine which temporal stage the ambulance $\hat{k}$ is belongs to. If the arrival time $Y2^{\hat{h}\hat{k}}_{\hat{i}'\hat{m}\hat{i}}(t)$

is earlier than the finish time of this temporal stage $\bar{E}_{t'}$, put this ambulance $\hat{k}$ into the set $K_{\hat{i}}^{2}(t')$ of available ambulances of the hospital $\hat{i}'$ in the temporal stage *t'*.)

Step 7: Judgment of the termination of the casualty dispatch of the temporal stage *t*

Step 7.1: If there is no available capacity of any hospitals, i.e., $\sum_{i} Q_i(t) = 0$, go to Step 8.

Step 7.2: If there are no available ambulances at any fire-fighting units or hospitals, i.e., $\sum_{j} \left|K_j^1(t)\right| + \sum_{i} \left|K_i^2(t)\right| = 0$, go to Step 8.

Step 7.3: If there are any casualties who have not been rescued at the emergency rescue station in the disaster-stricken areas, i.e., $\sum_{m} \sum_{h} N1_m^h(t) = 0$, go to Step 2; otherwise, continue.

Step 8: Simulate and estimate the time for casualties to queue for medical treatment at the hospitals according to the realized plan of the casualty dispatch in temporal stage *t*

A multi-server queueing system with heterogeneous service times is simulated and repeated for 30 times. Take the average value to estimate the total queue time $W_i^h(t)$ for casualties with different injury levels for medical treatment at the hospitals, as well as the quantity $N2_i(t)$ of casualties who arrive, but queue for treatment at the hospitals in temporal stage *t*.

Step 9: Calculate the total weighted time of casualty dispatch of MCI in temporal stage *t*

$$R_t = \sum_{j} \sum_{m} \sum_{i} \sum_{k \in K_j^1(t)} \alpha_1^h Y1_{jmi}^{hk}(t) X1_{jmi}^{hk}(t) + \sum_{i} \sum_{m} \sum_{i'} \sum_{k \in K_i^2(t)} \alpha_1^h Y2_{imi'}^{hk}(t) X2_{imi'}^{hk}(t) + \sum_{h} \alpha_1^h \sum_{m} \Delta N1_m^h(t) + \sum_{h} \alpha_2^h \sum_{i} W_i^h(t) \tag{4}$$

where Δ represents the time period of each temporal stage.

Step 10: Predict the number of casualties of different injury levels in temporal stage *t*+1

By using Eq. (5), update the number $\delta_m^{h'h}(t+1)$ of casualties of different injury levels of emergency rescue stations in the disaster-stricken areas according to the transition probabilities $\beta^{hh'}$ of casualties among the injury levels.

$$\delta_m^{hh'}(t+1) = MINT \sum_{h'} N1_m^h(t) \times \beta^{hh'} \qquad \forall h, m \tag{5}$$

Step 11: Judgment of the termination of the heuristic

Let *t* = *t* +1. If *t* > *T*, the algorithm will come to an end; otherwise, return to Step 2.

Case Study

For model demonstration, this study developed a numerical example with real-world data. Suppose that the case has five disaster-stricken areas, and the locations of the emergency rescue stations in the disaster-stricken areas, fire-fighting units, and hospitals as well as the medical emergency treatment capacity of the 11 hospitals are shown in Figure 1. There are 134 teams of medical emergency treatment. The 38 fire-fighting units have 76 ambulances, and the number of ambulances in each unit is two. This study involves the mass casualties of three injury levels. The total numbers of casualties is supposed to be 80 and the data regarding the numbers of casualties at the emergency rescue stations in the disaster-stricken areas are shown in Table 1. The settings of other parameters are, as follows:

1. Each period lasts for 15 minutes.
2. The rescue radius of each fire-fighting unit is 8 kilometers.
3. The shortest distance among the disaster-stricken areas, the fire-fighting units, and the hospitals is measured, and travel time is estimated at the average speed of 50 km/h.
4. An ambulance can transport 6 casualties with light injuries, 4 with medium injuries, and one with serious injuries.
5. The injury deterioration probabilities of casualties of different injury levels are shown in Table 2.
6. The relative importance of casualties with a slight injury to those with a medium injury to those

with a serious injury is 1:5:10.

7. Suppose that the medical emergency treatment time for casualties is a random variable, and follows normal distribution, its means and standards deviations are, as shown in Table 3.

This study conducts comparative analysis of the following two rescue dispatch principles:

1. Rescue dispatch principle 1

Priority is given to the emergency rescue stations in disaster-stricken areas with a larger number of casualties with serious injuries. The responsible area system is not applicable to the selection of ambulances. Priority is given to the ambulances of the fire-fighting units or hospitals that are closest to the emergency rescue stations in disaster-stricken areas.

2. Rescue dispatch principle 2

Priority is given to the emergency rescue stations in disaster-stricken areas with a larger number of casualties with medium or serious injuries. The responsible area system is applicable to the selection of ambulances. Priority is given to the ambulances of the fire-fighting unit that is responsible for the disaster-stricken area. If the number of ambulances is inadequate, the ambulances of other fire-fighting units will be dispatched according to the distance; but travel time will be magnified by 1.1.

The test results are shown in Table 4. A number in brackets refers to the average service time for a casualty, while a number outside brackets indicates the corresponding value according to the relative weight and summation of all those casualties. The total weight response time of the second rescue dispatch principle is the shorter than the first one. Casualties with slight injuries must queue for medical treatment, as the casualties with medium or serious injuries are prioritized in the distribution of medical resources. Intuitive rescue dispatch will cause the increment of total response time for casualties with slight injuries from 45.85 minutes to 53.00 minutes. The average of total response time of rescue for each casualty with a medium injury is about 7 to 8 minutes. The increment of total response time for casualties with medium injurie is less than 1 minutes. In addition, no casualties will die. Casualties with medium or serious injuries do not have to queue for medical treatment because the resources of the hospital are still available. Therefore, giving priority to the emergency rescue stations in a disaster-stricken area with a larger number of casualties with medium or serious injuries, as well as to the ambulances of the fire-fighting unit responsible for the disaster-stricken area, is suitable for the rescue dispatch of mass casualty incidents.

Conclusions and Suggestions

In consideration of the features of mass casualty incidents in multiple locations, this study combined a multi-stage heuristic to establish new procedures for facilitating the decisions of the dispatch of emergency aid. Instead of following the common medical emergency system, this study suggests that casualties with slight or medium injuries should be transported in the same ambulance, meaning that the casualties of the same injury level should be transported to the hospital in the same ambulance, as compared with the traditional transport model featuring one casualty per ambulance. Adding the time-dependent change of injury level into decisions regarding the dispatch of rescue for mass casualty incidents prevents myopia, facilitates the evaluation of potential problems in the medical services capacity of the local medical emergency system, as well as the dispatch of medical emergency resources, and prevents more serious casualties caused by wrong or bad decisions.

According to the problems in the current stage, this study offers the following two suggestions for future studies: (1) these casualties with slight injuries can go to hospitals by themselves before the arrival of ambulances. Future studies can explore the gap between the time for casualties with slight injuries to see a doctor by themselves and the time for them to travel to the hospital via an ambulance. (2) There are different levels of emergency treatment hospitals. Future studies can delve into transporting casualties of certain injury levels to certain hospitals.

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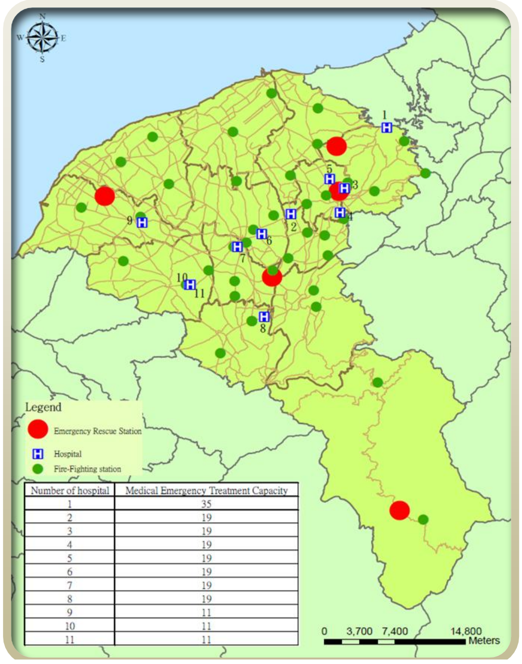

Number of hospital	Medical Emergency Treatment Capacity
1	35
2	19
3	19
4	19
5	19
6	19
7	19
8	19
9	11
10	11
11	11

Figure 1. Testing Network

Table 1: The Numbers of Casualties at the Emergency Rescue Stations

disaster-stricken areas	slight injury	medium injury	serious injury	total	%
No. 1: Sinwu	1	1	2	3	4%
No. 2: Fushing	0	0	1	1	1%
No. 3: Pingjhen	8	5	4	17	21%
No. 4: Taoyuan	7	25	8	40	50%
No. 5: Gueishan	5	9	5	19	24%
total	20	40	20	80	100%

Table 2: Injury Deterioration Probabilities of Casualties of Different Injury Levels

current status	new status			
	slight injury	medium injury	serious injury	death
slight injury	0.89	0.10	0.01	0.00
medium injury	0.00	0.80	0.15	0.05
serious injury	0.00	0.00	0.90	0.10
death	0.00	0.00	0.00	1.00

Table 3: Medical Emergency Treatment Time for Casualties Follows Normal Distribution

injury level	mean value (minutes)	standard deviation (minutes)
slight injury	5	1
medium injury	30	3
serious injury	50	6

Table 4: Testing Results

rescue dispatch principle	total time for prehospital service			total waiting time for rescues at the emergency rescue station			total queue time for treatment at the hospital			total weighted response time
	slight injury	medium injury	serious injury	slight injury	medium injury	serious injury	slight injury	medium injury	serious injury	
I	675 (33.75)	1650 (8.25)	850 (4.25)	0	0	0	385 (19.25)	0	0	3560 (65.5)
II	544 (27.2)	1530 (7.65)	850 (4.25)	0	0	0	373 (18.65)	0	0	3297 (57.75)

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