Rethinking Mass Casualty Distribution – Embedding a Resilient Hospital Selection Algorithm into a Mass Casualty Distribution Simulation Model

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ABSTRACT

Considering hospitals' resilience potential in addition to the shortest-distance and medical-care adequacy policy to distribute mass casualties (MC) is an imperative practice for mass casualty distribution decision making. This study developed a novel hospital selection algorithm composed of driving time from the disaster site to hospital, care adequacy, and mobilization ability to determine the best hospital choice for MC distribution. Next, we developed an MC distribution simulation model embedding the algorithm to generate optimized distribution decisions for various MC incident scenarios. The simulation model was tested by using the Formosa Fun Coast Dust Explosion. Regarding super overload on some responsible emergency hospitals in the FFCDE event, the model with mobilization ability shows a better-balanced distribution of mass casualties to the initial receiving hospitals than without the ability. The study findings can contribute to surge capacity planning and resource assessment of emergency medical services for future disasters.

KEYWORDS

Decision making; Emergency Medical Service; Resilience, Mass Casualty Distribution; Discrete-event simulation.

INTRODUCTION

Large-scale events can produce casualties that threaten medical care systems. Decision making on the distribution of mass casualties to appropriate hospitals is a critical practice in mass casualty incident (MCI) management. Depending on the magnitude of the event, hospitals with different levels of surge capacity following a mass casualty incident fall into varying degrees of overwhelmed by the influx of patients, impacting the hospital's functional operations, and consequently on the safety of casualties.

In general, there are two principles of hospital selection for MC distribution, which include: the shortest distance from the disaster scene to individual hospitals and medical care adequacy accordingly for the received patients (Emergency Medical Services Act, 2013). The first principle is convenient to apply by using the information from the internet. The second principle relies on static government data about hospital medical care capacity. However, these data do not tell the hospitals' resilience potential, such as the mobilization ability to extend their emergency care capability. Disasters seem to become increasingly common in current decades. To better prepare emergency care service staff to offer patients timely and appropriate care for survival in various challenging situations during or after disasters, it is critical to learn how to distribute mass casualties and deploy resources for emergency medical care.

The purpose of the study is first to develop a hospital selection algorithm composed of driving time from the disaster scene to individual hospitals, care adequacy, and mobilization ability to determine the best hospital choice for MC distribution. Next, embedding the algorithm to develop a mass casualty distribution simulation model to generate optimized MC distribution decisions for various MC incident scenarios.

METHODS

The algorithm development collected data, including hospital capacity in beds, staff, and accreditation results for the emergency responsibility hospital (ERH) from the open government data (MOHW, 2017; MOHW, 2020) as the input for computing the hospital's care adequacy and mobilization ability, followed by the calibration of the algorithm parameters based on the interview data with 36 key participants from the emergency operation centers and five initial recurving hospitals (Chuang, Woods, Ting, et al., 2019; Chuang, Woods, Lee, et al., 2018; Chuang, Chang, Woods, et al., 2018). Hospital's address is used to extract the shortest driving time from a disaster scene via the Google Map API. Total 205 emergency responsibility hospitals in Taiwan were collected.

Modeling the mass casualty distribution system used the discrete event simulation technique in the Anylogic software. The simulation model was developed into eight modules (Figure 1): the initiation module of a mass casualty incident, the data module of setting parameters in the user interface and import data, and the module of rescue, triage, waiting for ambulances, hospital selection, distribution, and export data.

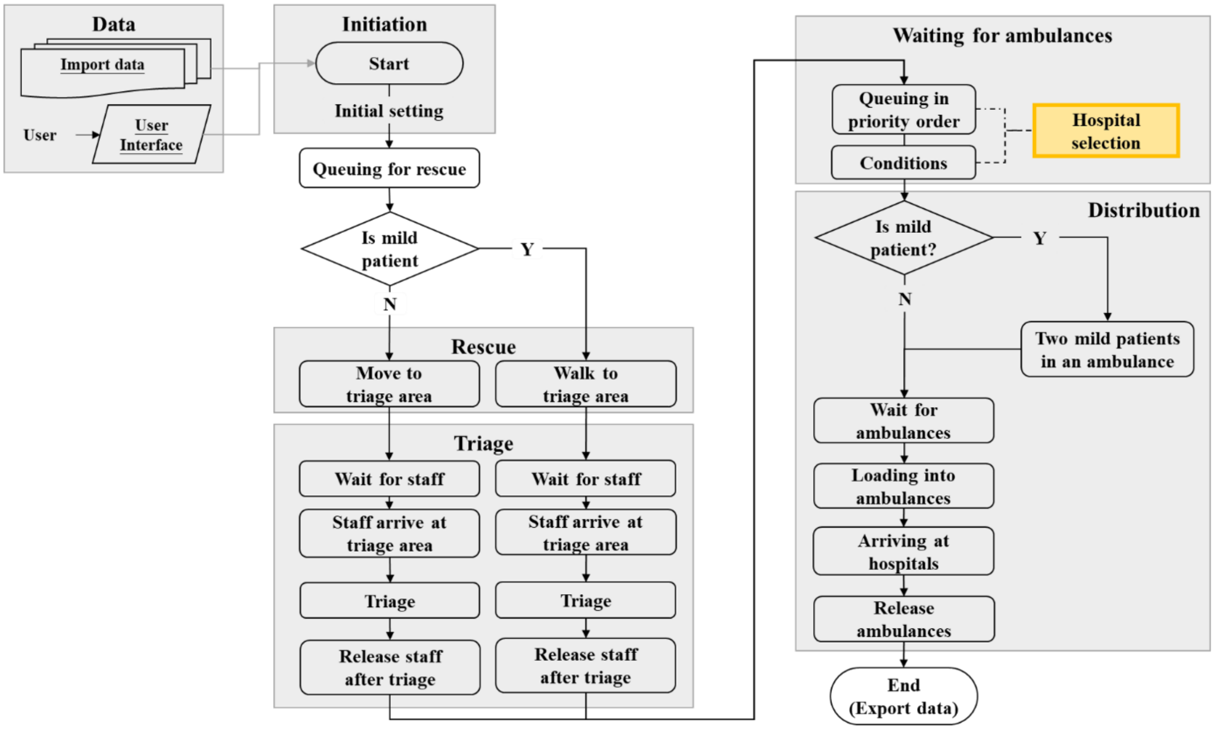

Figure 1. The simulation model framework

The Formosa Coast Dust Explosion (FFCDE) event was adopted to test the model. The FFCDE event occurred on Jan 27, 2015 at Color Play Asia water part party in New Taipei City, Taiwan. The flammable properties of the swimwear in which attendants were dressed resulted in large total body surface area burns (TBSA, average 44 %; 281 people with TBSA > 40%, 41 people > 80%). One bus and 144 regular ambulances were deployed to the field. A total of 301 (60.3%) patients were distributed to hospitals via ambulance; others were self-transported to hospitals. Within 6 hours, 499 burn victims had been transported to 36 hospitals including 10 large medical centers, 23 regional hospitals, and 3 district hospitals across regions (MOHW, 2017).

RESULTS

Hospital Selection algorithm

The hospital selection algorithm is to prioritize hospitals identified in the area to support mass casualty distribution decision making. A hospital selection algorithm was developed, which hospital score $Score_{ij}$ is an equation constructed by three elements in equation (1): normalized driving time, normalized care adequacy adjusting by patient load on hospitals, and normalized mobilization ability.

$$\begin{aligned} Score_{ij} &= x_{ij} + y_{ij}\left(1 - z_{ij}\right) + y_{ij}w2_{ij} \\ &= x_{ij} + y_{ij}\left[1 - \frac{\sum_{i=1}^{3} w1_{ij} \times RC_{ij}}{ED\ Beds_j}\right] + y_{ij} \times \frac{Total\ Medical\ Staff_j}{Critical\ Beds_j} \end{aligned} \quad (1)$$

Where i =1, 2, 3 indicates the patient severity, the i =1 indicates mild, the i =2 indicates moderate, the i =3 indicates severe.

Where j=1, 2, 3, …, n is the individual hospital number identified in the area to support mass casualty incident.

The driving time x_i is from the disaster scene to each hospital, and the y_{ij} is a digital number representing care adequacy shown in Table 1. Based on the hospital accreditation results, each hospital is accredited as a specific medical care capacity. However, only the three primary levels of ERH (1: severe level, 2: medium level, 3: general level in Table 1) are utilized by the local emergency operation centers for mass casualty distribution. The study adopts the additional six sub-levels to create a new two-digit care capacity code corresponding to the patient's triage level. Besides, hospital care adequacy was dynamic changing as the patient surge arrived. Thus, the y_{ij} has to be adjusted accordingly by the penalty parameter z_{ij}. The z_{ij} is the quotient of summation of weighting factor $w1_{ij}$ multiplying received casualty RC_{ij} divided by the $ED\ Bed_j$. The penalty z_{ij} increases as the hospital receives more patients, and the higher the penalty parameter, the lower the care adequacy. Based on the interview data, the more staff hospital has, the more supporting workforce they can mobilize.

The mobilization weight $w2_{ij}$ is determined by the ratio of total medical staff *Total Medical Staff*$_j$ in a hospital to the amount of critical beds *Critical Beds*$_j$. It means the number of staff per critical bed that a hospital can utilize, the higher the ratio is, the higher the mobilization ability. The total medical staff sum of number of staff in the surgery, emergency department, anesthesia, plastic surgery, neurosurgery, oral pathology, oral maxillofacial, internal medicine, general western medicine, pediatrics, radiation therapy, neurology, orthopedics. The critical beds sum of acute beds, ICU beds, *ED Bed*$_j$, hospitalist beds. The mobilization weight reflects the mobilization ability of a hospital.

The hospital score *Score*$_{ij}$ is the sum of three major parameters. In the simulation model, each patient has a list of scores for all possible sending hospitals according to their triage level. The hospital would have a higher score if the x_{ij} is less, y_{ij} is higher, z_{ij} is lower, $w2_{ij}$ is higher. The highest hospital score responding to a patient indicates the best choice hospital for the patient in the perspective of global optimization of mass casualty distribution.

Table 1. Medical-care adequacy matrix

Emergency Responsibility Hospital (ERH) level	EOC adopted Primary ERH levels	y_severe	y_moderate	y_mild
General	1	10	10	30
General + Medium EM	1	11	11	31
General + Medium ICU	1	11	11	31
General + Medium EM, PN	1	12	12	32
General + Medium EM, MT	1	12	12	32
General + Medium EM, ICU	1	12	12	32
General + Medium EM, AS, ICU	1	13	13	33
General + Medium EM, STEMI, ICU	1	13	13	33
General + Medium EM, AS, MT	1	13	13	33
General + Medium EM, AS, STEMI, ICU	1	14	14	34
General + Medium EM, AS, PN, ICU	1	14	14	34
General + Medium EM, MT, ICU	1	13	13	33
Medium Temp	2	20	30	20
Medium	2	20	30	20
Medium*	2	20	30	20
Medium* + Severe AS	2	21	31	21
Medium* + Severe STEMI	2	21	31	21
Medium* + Severe AS, STEMI	2	22	32	22
Medium* + Severe EM, AS, STEMI	2	23	33	23
Medium + Severe AS	2	21	31	21
Medium + Severe STEMI	2	21	31	21
Medium + Severe PN	2	21	31	21
Medium + Severe AS, STEMI	2	22	32	22
Medium + Severe AS, STEMI, ICU	2	23	33	23
Medium + Severe EM, AS, STEMI, PN, ICU	2	25	35	25
Severe	3	30	20	10

Note: AS: Acute Stroke, STEMI: ST-Elevation Myocardial Infarction, PN: High risk Pregnancy and Neonates, MT: Major Trauma, EM: Emergency Medicine, ICU: Intensive Care Unit.

Any of y_severe, y_moderate, y_mild is a two-digit code representing hospital care adequacy corresponding to a patient's triage level in the perspective of optimal care. Source: MOHW, 2020.

Total transportation time and number of initial receiving hospitals

The model shows less total transportation time for distributing 301 patients than in the event (Table 2). The number of initial receiving hospitals (IRHs) in simulation has 18 more hospitals than in the actual event.

Table 2. Comparison of transportation time and resources utilized between the FFCDE event and the simulation model

Number of patients	Categories			FFCDE	Model	Difference
301	Transportation time for all patients by ambulance depart from the disaster scene			6 hrs.	4 hr. 41 mins	-1 hr. 19 mins
	Ambulance	Number of ambulances		144*	144	0
		Number of round trips	2 trips	*	2	-
			3 trips	*	140	-
			4 trips	*	2	-
495**	ERH level	Severe Hospital		19	17	-2
		Medium Hospital		13	20	+7
		General Hospital		4	17	+13
		Total		36	54	+18

** In the FFCDE event, only number of ambulances were recorded, and buses were used to transport patients*

*** 495 patients are used only to compare number of initial receiving hospitals between the FFCDE event and the model due to about 40% of mass casualties were self-transported.to hospitals.*

Table 3 shows more initial receiving hospitals were identified in the simulation model than in the FFCDE event, and severe-level ERHs received more moderate and mild patients in the FFCDE than in the simulation, and more moderate and mild patients were sent to medium-level ERHs in the simulation model than the FFCDE.

Table 3. Number of patients received by triage level corresponding to ERH level

ERH level	Severe patients FFCDE/model (gap)		Moderate patients FFCDE/model (gap)		Mild patients FFCDE/model (gap)		Total IRHs FFCDE/model (gap)	
Number of initial receiving hospitals (IRHs)								
Severe Hospital	17 / 15	(-2)	16 / 13	(-3)	12 / 1	(-11)	19 / 17	(-2)
Medium Hospital	10 / 4	(-6)	11 / 19	(+8)	7 / 7	(0)	13 / 20	(+7)
General Hospital	1 / 2	(+1)	3 / 4	(+1)	2 / 14	(+12)	4 / 17	(+13)
Total	28 / 21	(-7)	30 / 36	(+6)	21 / 22	(+1)	36 / 54	(+18)
Number of patients								
Severe Hospital	195 / 208	(+13)	111 / 46	(-65)	67 / 4	(-63)	373 / 258	(-115)
Medium Hospital	45 / 28	(-17)	42 / 97	(+55)	16 / 26	(+10)	103 / 151	(+48)
General Hospital	7 / 11	(+4)	6 / 16	(+10)	6 / 59	(+53)	19 / 86	(+67)
Total	247		159		89		495	

Note: ERH: emergency Responsibility Hospital.

Comparison of number of patients received by IRHs in different characteristics

Table 4 shows that severe patients were most likely sent to public medium-level hospitals in the FFCDE event than in the model, and moderate patients were most likely sent to private medium-level hospitals in the model. Mild patients were likely sent to private severe-level hospitals in the FFCDE event.

Table 4. Comparison of number of patients received between public and private hospitals

ERH level, ownership	Severe patients FFCDE/model (gap)		Moderate patients FFCDE/model (gap)		Mild patients FFCDE/model (gap)		Total patients FFCDE/model (gap)	
Severe Hospital								
Public Hospital	61 / 60	(-1)	39 / 13	(-26)	19 / 0	(-19)	119 / 73	(-46)
Private Hospital	134 / 148	(+14)	72 / 33	(-39)	48 / 4	(-44)	254 / 185	(-69)
Medium Hospital								
Public Hospital	36 / 22	(-14)	31 / 40	(+9)	5 / 14	(+9)	72 / 76	(+4)
Private Hospital	9 / 6	(-3)	11 / 57	(+46)	11 / 12	(+1)	31 / 75	(+44)
General Hospital								
Public Hospital	7 / 2	(-5)	2 / 7	(+5)	0 / 12	(+12)	9 / 21	(+12)
Private Hospital	0 / 9	(+9)	4 / 9	(+5)	6 / 47	(+41)	10 / 65	(+55)
Total patients	247		159		89		495	

Note: ERH: emergency Responsibility Hospital.

Although the total number of initial receiving serve-level ERHs is a minor difference between the FFCDE event and the model, there is a large variance of 115 patients sent to the severe-level ERHs between these two (Table 5). The highest difference in total patients between the FFCDE event and the model occurs in hospital S01. S01 is the nearest severe-level ERH to the disaster scene. The real case sent 26 more patients to the hospital than in the simulation model, which included 21 moderate patients. As a result, the emergency department of hospital S01 was super overload and had to break through the challenges beyond its surge capacity (Chuang, Chang, Woods, et al., 2018). The second-highest difference is in hospital S13 (a public hospital). The hospital received 15 more moderate patients and 10 more mild patients in the FFCDE event than in the model. The third-highest difference is in hospital S04. In general, mass casualties were distributed more balanced in the model than in the real event.

Table 5. Comparison of number of patients received between severe-level ERHs

Severe -level ERHs	Driving Time (mins)	Mobilization ability (w2)	FFCDE / Model (gap) 19 / 17 (-2)			
			Severe patients FFCDE/model (gap)	**Moderate patients** FFCDE/model (gap)	**Mild patients** FFCDE/model (gap)	**Total patients** FFCDE/model (gap)
S01	25	0.7045	17 / 20 (+3)	24 / 3 (-21)	8 / 0 (-8)	49 / 23 (-26)
S02	27	0.4183	24 / 36 (+12)	13 / 5 (-8)	8 / 0 (-8)	45 / 41 (-4)
S03	30	0.7172	14 / 26 (+12)	7 / 3 (-4)	7 / 0 (-7)	28 / 29 (+1)
S04	30	0.5616	27 / 9 (-18)	1 / 0 (-1)	3 / 0 (-3)	31 / 9 (-22)
S05	30	0.4322	9 / 18 (+9)	2 / 3 (+1)	2 / 0 (-2)	13 / 21 (+8)
S06	31	0.8841	44 / 30 (-14)	2 / 5 (+3)	2 / 0 (-2)	48 / 35 (-13)
S07	31	0.5248	8 / 8 (0)	2 / 1 (-1)	10 / 0 (-10)	20 / 9 (-11)
S08	32	0.5866	5 / 14 (+9)	10 / 3 (-7)	5 / 0 (-5)	20 / 17 (-3)
S09	32	0.4226	13 / 16 (+3)	0 / 4 (+4)	-	13 / 20 (+7)
S10	34	0.2408	2 / 5 (+3)	5 / 0 (-5)	2 / 0 (-2)	9 / 5 (-4)
S11	35	0.4562	2 / 8 (+6)	12 / 6 (-6)	-	14 / 14 (0)
S12	35	0.2733	1 / 4 (+3)	1 / 1 (0)	-	2 / 5 (+3)
S13	36	0.4635	10 / 11 (+1)	20 / 5 (-15)	10 / 0 (-10)	40 / 16 (-24)
S14	38	0.2298	6 / 1 (-5)	3 / 0 (-3)	6 / 0 (-6)	15 / 1 (-14)
S15	39	0.5634	4 / 2 (-2)	0 / 3 (+3)	-	4 / 5 (+1)
S16	40	0.5620	8 / 0 (-8)	6 / 4 (-2)	-	14 / 4 (-10)
S17	42	0.2273	-	2 / 0 (-2)	-	2 / 0 (-2)
S18	43	0.5279	1 / 0 (-1)	-	0 / 4 (+4)	1 / 4 (+3)
S19	60	0.2534	-	1 / 0 (-1)	4 / 0 (-4)	5 / 0 (-5)
Total patients			195 / 208 (+13)	111 / 46 (-65)	67 / 4 (-63)	373 / 258 (-115)

Note: ERHs: emergency Responsibility Hospitals.

There is a difference of 55 moderate patients sent to the medium-level ERHs between the FFCDE event and the simulation model (Table 6). The highest difference (+18) occurs in hospital M03, zero patient was sent to the hospital, but 6 severe patients and 12 moderate patients were sent to the hospital in the model. M03 is relatively a new medium-level private ERH comparing to other ERHs in the same area. MO2, M05 are the public ERHs in the area, and they received either more severe or moderate patients in the FFCDE event than in the model. Overall, five additional medium-level hospitals are included to receive patients in the model.

Table 6. Comparison of number of patients received between medium-level ERHs

Medium -level ERHs	Driving Time (mins)	Mobilization ability (w2)	FFCDE / Model (gap) 13 / 20 (+7)			
			Severe patients FFCDE/model (gap)	**Moderate patients** FFCDE/model (gap)	**Mild patients** FFCDE/model (gap)	**Total patients** FFCDE/model (gap)
M01	22	0.2393	3 / 12 (+9)	5 / 2 (-3)	3 / 0 (-3)	11 / 14 (+3)
M02	25	0.1989	7 / 8 (+1)	20 / 5 (-15)	1 / 0 (-1)	28 / 13 (-15)
M03	26	0.2554	0 / 6 (+6)	0 / 12 (+12)	-	0 / 18 (+18)
M04	27	0.2015	0 / 2 (+2)	0 / 10 (+10)	-	0 / 12 (+12)
M05	29	0.1862	15 / 0 (-15)	0 / 6 (+6)	1 / 0 (-1)	16 / 6 (-10)
M06	32	0.2529	-	0 / 5 (+5)	-	0 / 5 (+5)
M07	32	0.2442	4 / 0 (-4)	2 / 7 (+5)	-	6 / 7 (+1)
M08	35	0.3846	-	0 / 10 (+10)	-	0 / 10 (+10)
M09	35	0.3014	-	0 / 4 (+4)	-	0 / 4 (+4)
M10	35	0.1549	4 / 0 (-4)	2 / 4 (+2)	-	6 / 4 (-2)
M11	36	0.1453	1 / 0 (-1)	1 / 4 (+3)	-	2 / 4 (+2)
M12	36	0.2500	2 / 0 (-2)	1 / 11 (+10)	3 / 0 (-3)	6 / 11 (+5)
M13	36	0.2050	3 / 0 (-3)	1 / 4 (+3)	-	4 / 4 (0)
M14	38	0.1076	4 / 0 (-4)	7 / 6 (-1)	4 / 2 (-2)	15 / 8 (-7)
M15	41	0.1522	-	1 / 2 (+1)	0 / 2 (+2)	1 / 4 (+3)
M16	42	0.0890	-	0 / 1 (+1)	0 / 4 (+4)	0 / 5 (+5)
M17	42	0.2527	-	0 / 2 (+2)	2 / 4 (+2)	2 / 6 (+4)
M18	46	0.2260	2 / 0 (-2)	1 / 1 (0)	2 / 4 (+2)	5 / 5 (0)
M19	46	0.1667	-	0 / 1 (+1)	0 / 4 (+4)	0 / 5 (+5)
M20	51	0.2330	-	1 / 0 (-1)	0 / 6 (+6)	1 / 6 (+5)
Total patients			45 / 28 (-17)	42 / 97 (+55)	16 / 26 (+10)	103 / 151 (+48)

Note: ERHs: emergency Responsibility Hospitals.

In Table 7, the model found extra 16 moderate patients sent to the medium-level ERHs. The general-level ERHs received 53 more mild patients in the model than in the FFCDE event; additional 13 general-level ERHs that their driving time to the disaster scene are within 25 – 66 minutes were included in the model to receive mild patients.

Overall, regarding the hospitals located within 35 minutes driving time to the disaster scene (Table 5-7), there are 30 hospitals, including 12 severe-level ERHs, ten medium-level ERHs, and eight general-level ERHs. Fifty-eight mild patients were sent these hospitals, including 47 sent to 9 severe-level, five sent to 2 medium-level, and six sent to 2 general-level in the FFCDE event. However, only 31 mild patients were distributed to 5 general-level ERHs in this area in the model.

Table 7. Comparison of number of patients received between general-level ERHs

General-level ERHs	Driving Time (mins)	Mobilization ability (w2)	FFCDE / Model (gap) 13 / 20 (+7)							
			Severe patients		Moderate patients		Mild patients		Total patients	
			FFCDE/model (gap)		FFCDE/model (gap)		FFCDE/model (gap)		FFCDE/model (gap)	
G01	25	0.3333	0 / 9	(+9)	0 / 2	(+2)	-		0 / 11	(+11)
G02	27	0.2393	7 / 2	(-5)	2 / 7	(+5)	-		9 / 9	(0)
G03	29	0.2411	-		3 / 4	(+1)	5 / 0	(-5)	8 / 4	(-4)
G04	33	0.2828	-		0 / 3	(+3)	0 / 16	(+16)	0 / 19	(+19)
G05	33	0.0870	-		-		1 / 4	(+3)	1 / 4	(+3)
G06	34	0.2462	-		-		0 / 2	(+2)	0 / 5	(+2)
G07	34	0.2045	-		-		0 / 5	(+5)	0 / 5	(+5)
G08	34	0.1048	-		-		0 / 4	(+4)	0 / 4	(+4)
G09	36	0.1096	-		-		0 / 4	(+4)	0 / 4	(+4)
G10	36	0.1087	-		-		0 / 2	(+2)	0 / 2	(+2)
G11	40	0.1333	-		-		0 / 4	(+4)	0 / 4	(+4)
G12	41	0.2143	-		-		0 / 2	(+2)	0 / 2	(+2)
G13	41	0.1420	-		-		0 / 4	(+4)	0 / 4	(+4)
G14	43	0.1532	-		-		0 / 4	(+4)	0 / 4	(+4)
G15	44	0.2197	-		-		0 / 4	(+4)	0 / 4	(+4)
G16	47	0.2174	-		-		0 / 2	(+2)	0 / 2	(+2)
G17	66	0.2830	-		-		0 / 2	(+2)	0 / 2	(+2)
G18	35	*	-		1 / 0	(-1)	-		1 / 0	(-1)
Total patients			7 / 11	(+4)	6 / 16	(+10)	6 / 59	(+53)	19 / 86	(+67)

Note: ERHs: emergency Responsibility Hospitals.

**The hospital G18 withdrew from the ERH on Mar. 1, 2017, but it was ERH at the FFCDE event in 2015 so that can not collect the hospital information data.*

Comparison between the algorithm with and without mobilization ability

While considering mobilization ability (w2), the severe-level ERHs can receive more severe patients in the model with w2 than without adopting mobilization ability. The medium-level ERHs can receive less severe patients but more moderate patients in the w2 model than without the w2 model (Table 8). However, the mobilization ability in the algorithm for hospital selection did not apparently affect the number of initial receiving hospitals.

Table 8. Difference between the algorithm with and without mobilization ability

ERH level	Severe patients without w2 model/ with w2 model (gap)		Moderate patients without w2 model/ with w2 model (gap)		Mild patients without w2 model/ with w2 model (gap)		Total IRHs without w2 model/ with w2 model (gap)	
Number of initial receiving hospitals (IRHs)								
Severe Hospital	14 / 15	(+1)	12 / 13	(+1)	4 / 1	(-3)	18 / 17	(-1)
Medium Hospital	5 / 4	(-1)	19 / 19	(0)	9 / 7	(-2)	20 / 20	(0)
General Hospital	3 / 2	(-1)	8 / 4	(-4)	14 / 14	(0)	17 / 17	(0)
Total	22 / 21	(-1)	39 / 36	(-3)	27 / 22	(-5)	55 / 54	(-1)
Number of patients								
Severe Hospital	162 / 208	(+46)	54 / 46	(-8)	12 / 4	(-8)	228 / 258	(+30)
Medium Hospital	61 / 28	(-33)	79 / 97	(+18)	30 / 26	(-4)	170 / 151	(-19)
General Hospital	24 / 11	(-13)	26 / 16	(-10)	47 / 59	(+12)	97 / 86	(-11)
Total	247		159		89		495	

Note: ERH: emergency Responsibility Hospital.

DISCUSION AND CONCLUSION

The study's findings highlight mass casualty distribution in an actual event could produce super overload on some initial receiving hospitals with the characteristics in nearby the disaster scene, public, and severe-level or medium-level ERHs. The sudden on-set event created extreme demand beyond their surge capacity regularly prepared. The initial receiving hospitals were pushed into a position that required them to develop additional surge capacity to provide care to the mass casualties. Fortunately, they succeed in providing emergency medical care to the patients in the FFCDE event. However, suppose the emergency medical services units and staff can exercise using the simulation model. In that case, they can learn how to effectively and efficiently respond to different scenarios in mass casualty distribution and preparedness planning.

Considering hospitals' mobilization potential for additional internal and external capacity, in addition to the registered capacity, which can extend hospitals' care capability toward more resilience. The simulation model adopts the resilience concepts and the successful hospitals' experiences performed in the FFCDE event to develop a novel hospital selection algorithm for supporting mass casualty distribution decision making. The algorithm is constructed by three elements: normalized driving time, normalized care adequacy adjusting by patient loading on hospitals, and normalized mobilization ability. The study shows the simulation model embedding the algorithm can produce an optimal mass casualty distribution results, including balanced distribution of mass casualties to the initial receiving hospitals, and less total transportation time. However, the algorithm may still need to be further advanced for handling dynamic changes of load and capacity. Using the simulation model can contribute to the resource assessment of emergency medical services and hospital surge capacity planning in different disaster scenarios.

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