

## A study on transportation activities of mass casualties in earthquake disaster by multi-agent simulation

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### ABSTRACT :

This paper attempts to construct multi-agent system simulation model by considering each activity of those groups and organizations that are related to transportation activities of those who have injured when the disaster occurs. To construct simulation model considering for earthquake disaster, each agent activity that are related to transportation activities in the Niigataken Chuetsu-oki Earthquake in 2007 are researched.

**KEYWORDS:** the Niigataken Chuetsu-oki Earthquake in 2007, transportation activities, multi-agent system simulation

### 1. INTRODUCTION

In many cases, a lot of people are injured in short time at large-scale accidents and natural disasters. In such a situation, if the injured people more than usual come to a specific hospital, it must be confused and there is a possibility that caused the delay of medical activities. Especially, at the earthquake disaster, because of the damage of the building, medical machines and lifeline etc, it is difficult for the hospital to keep same medical activities as usual. Therefore, some injured people can not receive the appropriate treatments, and there is a possibility that "Preventable Deaths" is caused as a result.

To prevent "Preventable Deaths", the injured people should not concentrate on specific hospitals but be transported to appropriate hospitals according to their injury level. To achieve it, it is necessary to model appropriately the transportation activity of the injured people from being rescued from the disaster sites to receiving treatment in the hospitals.

Therefore, to consider the action rule of each agent organization at the earthquake disaster and the influence of the earthquake damage, this paper aims to model the activities of each agent organization at the earthquake disaster by the hearing and the document investigation about the action of each agent organization that relates to the transportation activities in the Niigata Chuetsu-oki earthquake in 2007.

Moreover, this paper aims to discuss the method of transportation activities in the earthquake by using the modeled simulation model.

### 2. EACH AGENT'S MODELING IN THE NIIGATA CHUETSU-OKI EARTHQUAKE IN 2007

In this study, the following organizations were focused on as agent organizations that related to the transportation activities in the earthquake; (1) Hospital (2) Fire fighting organization (3) DMAT (Disaster Medical Assistance Team) (4) Self Defense Forces and the Japan Coast Guard (5) municipality (6) Injured people. Figure 2.1 shows the relation of each agent. Each agent was modeled based on each agent's action rule in the earthquake as follows. Table 2.1 shows each agent's characteristic, content of the activity, and the assumed range.

#### 2.1. Hospital

##### 2.1.1 Hospital in stricken area

The hospital in the Kashiwazaki city in Niigata prefecture

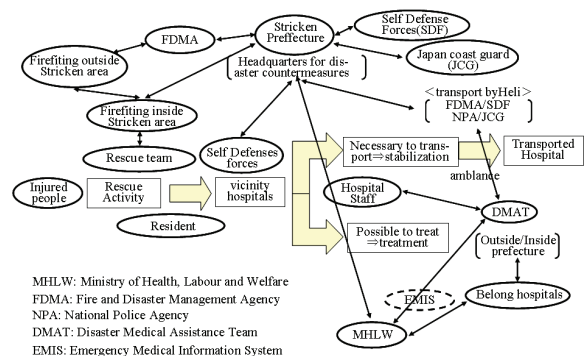


Figure 2.1 relationship of each agent

Table2.1 Each agent's characteristic, content of the activity, and the assumed range

Agent		Characteristic / activity	Assumed range
Injure People	Seriously	$RmnT \leq 240$ : coming to hospital	seriously:30
	middle / slightly	middle : $240 \leq RmnT \leq 600$ , slightly : $600 \leq RmnT$	middle : 70, slightly : 300
Firefighting Organization	HQ inside stricken area	Rescue team call to arms / information gathering · Assistance request	Kashiwazaki City firefighting headquarter
	HQ outside stricken area	Assistance dispatch	19 firefighting in Niigata prefecture
	Rescue helicopter	Transportation to hospital	Neighbor prefecture (Yamagata, Fukushima, Nagano, Toyama, Gunma)
SDF	GSDF	information gathering / Transportation to hospital / dispatch liaison officer to headquarters for disaster countermeasures	JGSDF 12th Brigade (Scout×1, transport×1)
	ASDF		Niigata Rescue team (Scout×1, transport×1)
JCG	9 <sup>th</sup> regional		Transport×1
Local government	Cities / Towns / villages	Establish headquarters for disaster countermeasures / information gathering	Kashiwazaki city
	Administrative divisions	information gathering / Transportation to hospital / dispatch liaison officer to headquarters for disaster countermeasures / Assistance request of EFRT and DMAT / information gathering by the Rescue helicopter	Niigata Prefecture
Hospitals	Inside stricken area	receipt of injured / triage / treatment	Kariwa district general hospital
	Inside stricken area	Dispatch DMAT / receipt of injured	46 hospitals
	DMAT / hospitals inside Pref.	triage / treatment / coordination of transport	29 team

where six or more in the seismic intensity was experienced has not been reinforced. Therefore, because of the damage of the buildings and medical equipment, scattering of medical equipment and lifeline disruptions, it was impossible to do as same medical activities such as X rays and operations as usual. For that reason, hospitals which are not reinforced are assumed that they can receive and treat only minor injured people, and can only receive but do not treat middle and seriously injured people, and these injured people consider the target of transportation.

#### 2.1.2 Hospital outside stricken area

The hospitals outside the stricken area did as same medical services as usual in the earthquake. Moreover, seriously injured people are transported to the hospitals with ICU injured-bed outside the stricken area in the earthquake. Therefore, it is assumed that the seriously injured people are transported only to the hospital with ICU injured-bed in the analysis.

### 2.2. Fire fighting organization

#### 2.2.1 Fire fighting organization in stricken area

The activity of the Kashiwazaki City fire fighting headquarter, the fire fighting organization in the stricken area, is as follows; (1) force mobilization based on the report, (2) Assistance request to Chuetsu region, the inner Niigata prefecture fire fighting organization and Emergency Firefighting and Rescue Teams ( EFRT ) and (3) the report member's dispatch to the hospital.

##### (1) Force mobilization based on report

From the research on the Kashiwazaki City fire fighting headquarters, it is assumed that there is one emergency call for ambulance every 30 seconds for first an hour after the disaster occurs, and one emergency call every 60 seconds for continuing an hour. The Rescue teams are sent to the seriously injured people's call. After all rescue team are sent, the headquarter receive the emergency call, but they can not send the team until the sent rescue team ends the duty or the assistance force etc. come to the fire fighting headquarter

##### (2) Assistance request

According to the Kashiwazaki City fire fighting headquarters, the rush of the emergency call early after the disaster occurs decided to request the assistance team. Therefore, it is assumed that when the number of emergency call in one hour for each after the disaster occurs exceeds ten, the assistance from the Chuetsu region fire fighting organization is requested, in the case fifteen, the assistance from the inner Niigata prefecture fire fighting organization is requested, in the case twenty, the assistance from EFRT are requested.

(3) Dispatch liaison officer to hospital in stricken area

At the same time when the Kashiwazaki City fire fighting headquarters requests the assistance of the prefecture fire fighting organization, it dispatches liaison people to the hospital. The mission of liaison officer is assumed the information gathering on the hospital state and report to the fire fighting headquarters.

*2.2.2 Fire fighting organization outside stricken area*

The fire fighting organization outside the stricken area send the team by the assistance request from the fire fighting headquarters in the stricken area or the independent judgment based on the media information. In this research, The fire fighting organization outside the stricken area assumes to send the team by the assistance request from the fire fighting headquarters in the stricken area. The range of assistance team assumes all the Niigata prefecture fire fighting headquarters, and the number of assistance team is assumed one per each fire fighting headquarters. Moreover, the mobilization about aviation unit of EFRT is assumed from the prefecture neighbor to Niigata Prefecture; Fukushima and Akita, Gunma, Tochigi, Toyama, and Nagano.

**2.3. DMAT**

*2.3.1 Timing of mobilization*

DMAT in the Niigata prefecture can be send by the independent judgment, but DMAT outside the stricken prefecture usually wait for the request from the struck prefecture. In the Niigata Chuetsu-oki earthquake, many DMAT outside the stricken prefecture also wait for the request of the struck prefecture, only a few DMAT outside are sent by an independent judgment. In this research, it is assumed that DMAT in the Niigata prefecture are sent to the hospital that have the fear of damage when it experienced more than six or less in the seismic intensity inside the prefecture by an independent judgment. On the other hand, for DMAT outside the stricken prefecture, time of the assistance request from the struck prefecture was assumed as a parameter.

*2.3.2 Activity in the struck hospital*

The following are assumed as the activity of DMAT that arrived at the hospital in the stricken area.

(1) Establishment of command and control, liaison and coordination systems

The member of DMAT that arrived first establishes the command and control, liaison and coordination systems.

(2) Triage support

DMAT execute triage to the injured people who comes to the hospital before DMAT arrives and the triage is executed by the hospital staff and comes to the hospital after DMAT arrives. In this research, an upper bound of the number of triage staff is assumed six. The slightly injured and people more than the middle injured are selected by the triage.

(3) Treatment support

It is assumed that DMAT treat the more than middle injured who require surgical stabilization before transportation with the ambulance or helicopter. 15 minutes for treatment is assumed for each injured people. The staff of hospital in the stricken area and the inner prefecture assistance hospital treated slightly injured. 5 minutes for treatment is assumed for each injured people.

(4) Transportation activity

It is assumed that DMAT arrange transportation outside the stricken area for the seriously injured people by the helicopters. First, they select the hospital to transport. Second, they select medical staffs that take care of the serious injured people and secure the ambulance to carry the injured people to the Sato pond stadium that is separate from the hospital at about 1.5km and temporary heliports. They transport them to the Sato pond stadium with the secured ambulance.

**2.4. The Self Defense Forces and the Japan Coast Guard**

*2.4.1 Range of force*

The target Self Defense Forces in the analysis is the Ground Self-Defense Force, the Air Self-Defense Force and the Japan Coast Guard. The number of forces is assumed as in Table 6.

*2.4.2 Content of activity*

The information gathering, the dispatch of the liaison officer to the stricken prefecture, and the transportation activity are assumed as the activity of the Self Defense Forces in the analysis.

### 2.5. Municipality after the disaster occurs

First, Niigata Prefecture establishes headquarters for disaster countermeasures, secondary headquarters gathers information. Headquarters requests EFRT to the Fire and Disaster Management Agency (FDMA) according to the request from the fire fighting headquarters in the stricken area. Moreover, headquarters establishes "the large area assistance and the rescue group" that consist of liaison officers from fire fighting, police, and another organization such as the Self Defense Forces. Headquarters began to gather information by Niigata Prefecture air rescue team at the same time when it request EFRT. In the earthquake, the Niigata Prefecture air rescue team that received the assistance request from the headquarters is sent. From the reconnaissance of the damage of main road, the buildings of main organization and Sato pond stadium as transportation base from the sky, it confirmed that Sato pond stadium can use as transportation base. In this research, the first duty of the Niigata Prefecture air rescue team is assumed the gathering of damage information, and after the duty ends, it assumed the gathering of damage information or transportation activity by the situation.

### 2.6. Injured people

The following three states are assumed as the injury state of the injured people; "Seriously injured", "Middle injured" and "Slightly injured". As an index that evaluated each injury, the time "RmnT" was assumed for which time if an injured people is not any treated, one was not able to be recovered. The relation between the state of the injury and each RmnT was assumed as shown in Table 6. Moreover, time that the injured people came to the hospital was assumed. Each injured people call to the fire fighting headquarters in the stricken area, and two injured people per a minute can call to the headquarters.

## 3. Simulation of injured people transportation

The transportation of the seriously injured people is simulated by using each modeled agents.

### 3.1. Assumption damage of hospital

It is assumed that damage is concentrated on the Kashiwazaki city as well as the Chuetsu-oki earthquake. The hospital in the stricken area considered in the simulation is only Kariwa district general hospital. It can not treat seriously injured people because of the damage of building and lifeline.

### 3.2. Assumed parameter

#### 3.2.1 Analysis time

The simulation analyzed for 600 minutes from the disaster occurs at 10:13 to 20:13. Time interval was one minute. In this analysis, the influence on the action rule of each agent by the time zone of disaster is not considered.

#### 3.2.2 The target injured people

The target number of injured people is 400; 30 people are the seriously injured, 70 people are the middle injured and 300 people are the slightly injured. Because 80% or more injured people come to the hospital within three hours from the earthquake disaster occurs the change of the time of coming to the hospital was assumed as shown in Figure 3.1.

#### 3.2.3 Method of transportation of seriously injured people

In the Chuetsu-oki earthquake, the injured people were transported to the hospital outside the stricken area by the process of showing in Figure 3.2. The following item is necessary to transport the injured people to the hospital outside the stricken area; the local firefighting liaison, medical staff who take care of the

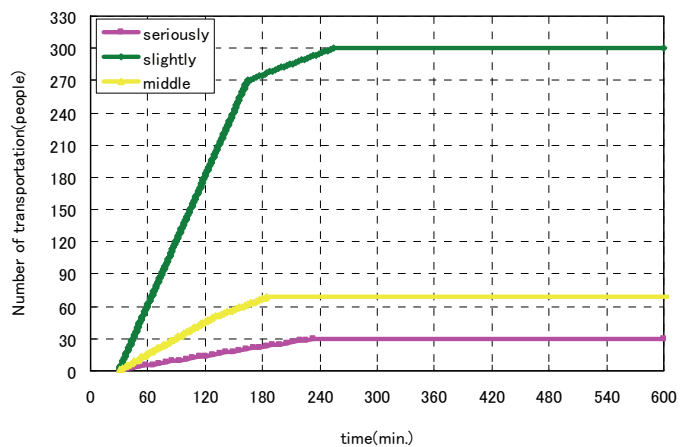


Figure3.1 Time of coming to the hospital

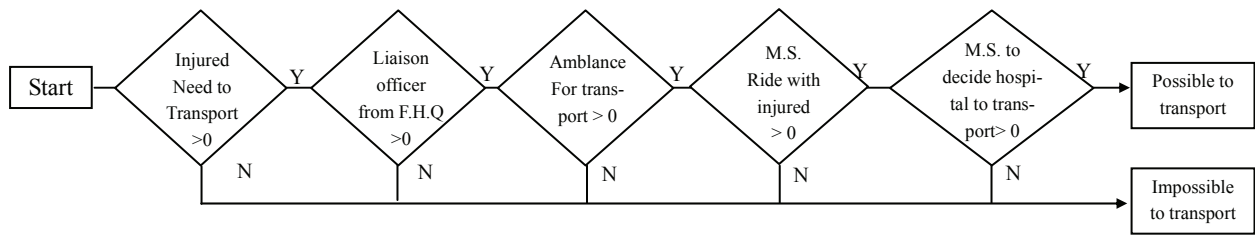


Figure 3.2 Method of transportation of seriously injured people

injured people, general DMAT who decide hospital to transport and the ambulance for the transportation from the hospital to the heliport. In many cases, DMAT ride on the ambulance or helicopter with injured people. In this research, processes for the injured people transportation is assumed as same as in the earthquake. The following three cases were assumed as alternatives of the hospital to transport in consideration of the select method of the hospital to transport in the Chuetsu-oki earthquake.

(1) Transport to the hospitals where DMAT and the assistance hospital staffs that act in the stricken hospital belong

Injured people are transported to the hospitals where DMAT and the assistance hospital staffs that act in the stricken hospital belong and which have the ICU injured bed. The advantage of this method is that confirmation of the condition of the hospital to transport (Number of empty ICU injured beds etc.) is easy.

(2) Transport to outside stricken area where Nagaoka Red Cross hospital was made relay point

The Nagaoka Red Cross hospital is located in Nagaoka City next to Kashiwazaki City. This hospital is one of the disaster base hospital that 14 exist in the prefecture, and only the basic disaster base hospital in the prefecture. Although Nagaoka City also had experienced six or more in the seismic intensity during the Chuetsu-oki earthquake, the earthquake has not influenced on hospital functions, the hospital can work as usual. In the middle of transportation activity in the Chuetsu-oki earthquake, select method of hospital to transport has changed to the method that injured people are transported from Sato pond stadium to the Nagaoka Red Cross hospital, and they are transported from the Nagaoka Red Cross hospital to another hospital that can receive if necessary. As a result, this select method reduced the labor of general DMAT to coordinate hospital to transport, and transportation activity worked smoothly.

Therefore, it is assumed that injured people are transported from Sato pond stadium to the Nagaoka Red Cross hospital, they are transported from the Nagaoka Red Cross hospital to another hospital that can receive if necessary in the analysis.

(3) Transport to the disaster base hospital in the stricken prefecture and neighbor prefectures

First, injured people transports to disaster base hospital with ICU injured bed in the stricken prefecture. After the hospital in the stricken prefecture is impossible to receive injured people, the disaster base hospitals with ICU injured bed in the neighbor prefecture receive injured people.

The system "EMIS" has been introduced in the whole prefecture that share information on damages of the hospital in the stricken area and request information with related organizations such as hospitals with DAMT, related government offices, municipality, fire fighting by inputting information by related organizations. This case assumed that this system works effectively in the stricken area region at the disaster.

#### 3.2.4 Timing of request outside prefecture DMAT

From (2-3)(a), it is thought that the arrival time of DMAT relates to the alternatives of the hospital to transport. Moreover, arrival of the outside prefecture DMAT at the hospital in the stricken area at the early stage increases man power in the stricken hospital at the early stage. Therefore, the parameter as the time of assistance request from the stricken prefecture to DMAT is assumed as follows;

(d) Request it at the same time as requesting EFRT.

(e) Request it one hour after the request of EFRT.

Table 3.1 Analysis Cases

	Hospital to Transport	Timing of Assistance request
Case1-1	(a)	(d)
Case1-2	(a)	(e)
Case1-3	(a)	(f)
Case2-1	(b)	(d)
Case2-2	(b)	(e)
Case2-3	(b)	(f)
Case3-1	(c)	(d)
Case3-2	(c)	(e)
Case3-3	(c)	(f)



(f) Request it three hours after the request of EFRT.

As a result, 9 analytical cases shown in Table 3.1 are analyzed.

### 3.2.5 Hospitals where seriously injured people are transported

The hospitals where seriously injured people are transported are all located in Niigata prefecture and have ICU injury bed. Moreover, these hospitals have the heliport outside or inside the site.

### 3.3. Analysis result

Figure 3.3 shows the change of the time of the number of seriously injured people in each hospital.

#### 3.3.1 Influence of alternatives of transportation on transportation time

From the comparison among Case1-1, Case2-1 and Case3-1, about the required time for which all seriously injured person transported from Kariwa district general hospital after the disaster occurs, Case1-1 is about 570 minutes, Case2-1 is about 420 minutes and Case3-1 is about 410 minutes. Although the timing of request of outside prefecture DMAT is at the same time as requesting EFRT, Case1-1, transportation to the hospitals where DMAT and the assistance hospital staffs that act in the struck hospital belong, is 160 minutes later than case2-1, Transportation to outside stricken area where Nagaoka Red Cross hospital was made relay point, and 120 minutes later than case3-1, transportation to disaster base hospital in struck prefecture and the vicinity prefecture. From this analysis, it suggested the effectiveness of the method of making the base hospital that has not lost the medical treatment function a relay point in the vicinity of the medical institution in the stricken area and transporting the injured person outside the stricken area.

#### 3.3.2 Influence of the timing of request outside prefecture DMAT on transportation time

From the comparison of Case1 series (Case1-1, Case1-2, Case1-3), about the required time for which all seriously injured person transported from Kariwa district general hospital after the disaster occurs, Case1-1 (Request it at the same time as requesting EFRT.) is about 570 minutes, Case1-2 (Request it one hour after the request of EFRT) is about 580 minutes. In this analytical condition, it suggests that the one hour delay of the request time of

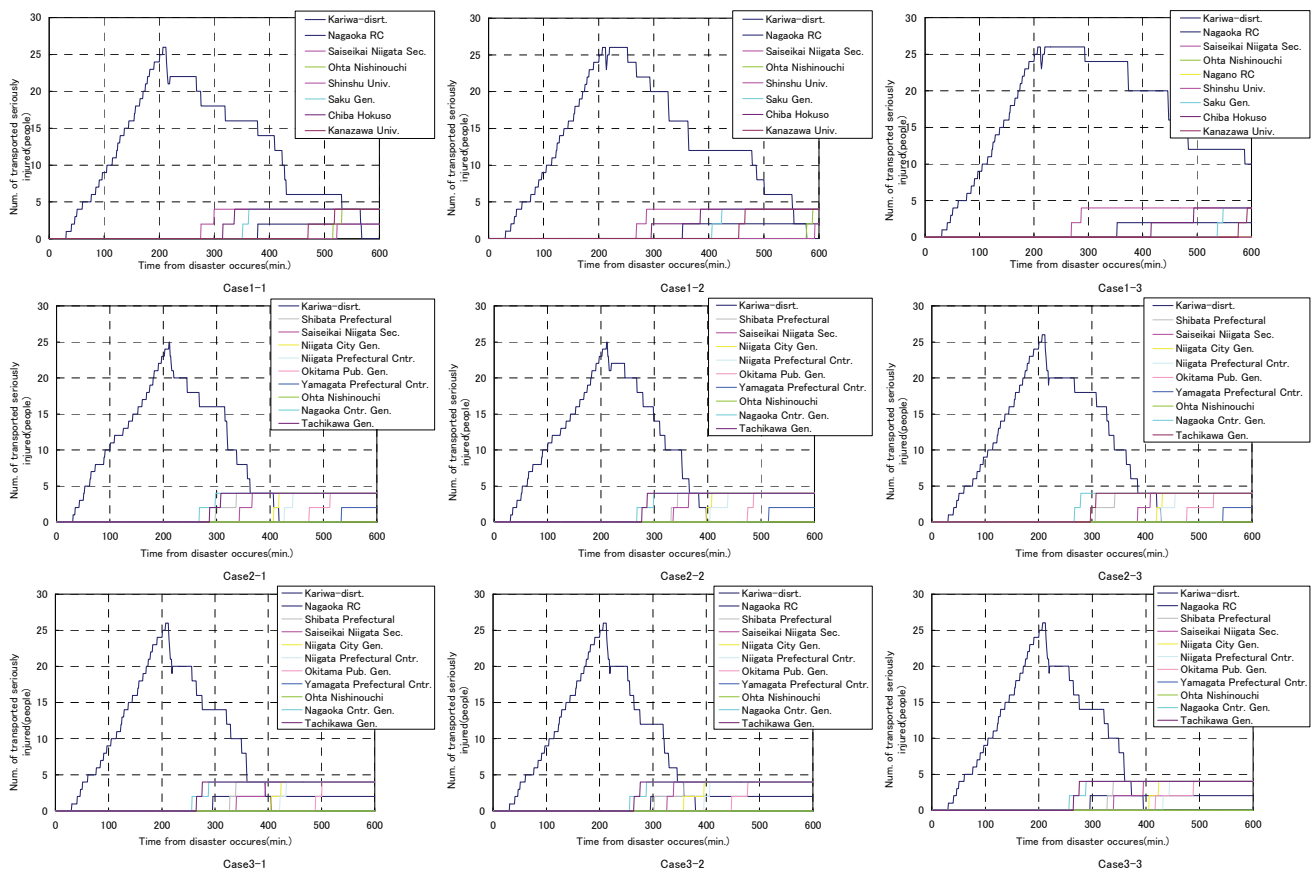


Figure 3.3 The change of the time of the number of seriously injured people in each hospital

DMAT is not influenced on the delay of transportation too much. However, Case1-3 (Request it three hours after the request of EFRT) is exceeding 600 minutes, about 690 minutes. It suggested that the two hours delay of the request time of DMAT results two hours delay of the transportation time. On the other hand, from the comparison of Case2 series (Case2-1, Case2-2, Case2-3), the required time for which all seriously injured person transported from Kariwa district general hospital after the disaster occurs is between 400 and 430 minutes, and From the comparison of Case3 series (Case3-1, Case3-2, Case3-3), the time is between 380 and 410 minutes. It suggests that the influence of the delay of the timing of the request outside the prefecture DMAT on transportation is little for the Case2 series and the Case3 series.

#### **4. SUMMARY**

To construct multi-agent simulation models which can consider transportation activities of those who have been seriously injured and the use of medical resources including manpower and implements and medical materials during the disaster in order to propose the optimum conditions of those activities as an end goal, this study considers the action rule of each agent organization at the earthquake disaster and the influence of the earthquake damage on the action rule, and modeled the action rule of each agent organization at the earthquake disaster. The result is described as follows.

(1)The action rule of each agent related to the injured person transportation in the Niigata Chuetsu-oki Earthquake was investigated.

Especially, as an organization that related to the injured person transportation, the action rule of hospitals that are located inside and outside a stricken area, the fire fighting organization, DMAT, the Self Defense Forces, the Japan Coast Guard, and the municipality were investigated.

(2) Based on the research, the action rule of each agent organization was modeled at the earthquake disaster. Moreover, the methods of transporting the injured person in the Chuetsu-oki earthquake were considered by using the constructed simulation model. The following findings were obtained.

(2-1)About the influence of selection condition of transportation for seriously injured person on transportation time, from the comparison of the required time for which all seriously injured person transported from Kariwa district general hospital after the disaster occurs,

The case that EMIS work effectively when the disaster occurs is the fastest. The case that neighbor disaster base hospital is used as relay point is fast in the second, and the delay from the fastest case is about 60 minutes. Transportation to disaster base hospital in struck prefecture and the vicinity prefecture is the slowest, and the delay from the fastest case is about 130 minutes. It suggested the effectiveness of the method of making the base hospital that has not lost the medical treatment function a relay point in the vicinity of the medical institution in the stricken area and transporting the injured person outside the stricken area.

(2-2) About the influence of the timing of request outside prefecture DMAT on transportation time,

From the comparison of transportation to the hospitals where DMAT and the assistance hospital staffs that act in the struck hospital belong, about the required time for which all seriously injured person transported from Kariwa district general hospital after the disaster occurs, the case in which (Request it at the same time as requesting EFRT.) is about 570 minutes, the case in which Request it one hour after the request of EFRT) is about 580 minutes. In this analytical condition, it suggests that the one hour delay of the request time of DMAT is not influenced on the delay of transportation too much. However, the case in which Request it three hours after the request of EFRT) is exceeding 600 minutes, about 690 minutes. It suggested that the two hours delay of the request time of DMAT results two hours delay of the transportation time.

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