World Academy of Science, Engineering and Technology
International Journal of Geotechnical and Geological Engineering
Vol:12, No:7, 2018

A Challenge to Acquire Serious Victims' Locations during Acute Period of Giant Disasters

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Abstract**—**In this paper, we report how to acquire serious victims' locations in the Acute Stage of Large-scale Disasters, in an Emergency Information Network System designed by us. The background of our concept is based on the Great East Japan Earthquake occurred on March 11th, 2011. Through many experiences of national crises caused by earthquakes and tsunamis, we have established advanced communication systems and advanced disaster medical response systems. However, Japan was devastated by huge tsunamis swept a vast area of Tohoku causing a complete breakdown of all the infrastructures including telecommunications. Therefore, we noticed that we need interdisciplinary collaboration between science of disaster medicine, regional administrative sociology, satellite communication technology and systems engineering experts. Communication of emergency information was limited causing a serious delay in the initial rescue and medical operation. For the emergency rescue and medical operations, the most important thing is to identify the number of casualties, their locations and status and to dispatch doctors and rescue workers from multiple organizations. In the case of the Tohoku earthquake, the dispatching mechanism and/or decision support system did not exist to allocate the appropriate number of doctors and locate disaster victims. Even though the doctors and rescue workers from multiple government organizations have their own dedicated communication system, the systems are not interoperable.

Keywords**—**Crisis management, disaster mitigation, messing, MGRS, Satellite communication system.

I. INTRODUCTION

JAPAN is a country with an advanced telecommunications infrastructure [1]. We are also equipped with an advanced medical response system at the time of disaster [2]. Despite that, Japan suffered a serious damage at the time of the Great East Japan Earthquake occurred on March 11th, 2011.

Japan's advanced telecommunications network is used for people to enjoy digital video contents and TV phone calls at normal times. At the time of large-scale disasters, it is also used as a wide-area medical emergency information system. This system is developed by the Health, Welfare, and Labor Ministry and it is an application of the public communication network to emergency use. At the time of disasters, doctors and paramedics entered information about the casualties including the medical triage results into the system. Then, it allocates patients to emergency hospitals across the nation to provide the appropriate medical care. At the time of 3.11 disaster, the system was there but did not work as it was intended [3]. Meanwhile, Japan's medical response system for large-scale disasters has been improved through serious disaster experiences [4]. Today, the Japan Self Defense Forces and inter-prefectural medical teams named form Disaster Medical Assistance Team (DMAT) are called to at the time of large-scale disasters. At the time of 3.11, DMAT was appropriately formed and dispatched to the disaster sites in Tohoku immediately after the earthquake but failed to maximize its duty [5].

On March 11, 2011, huge tsunamis swept the vast area of Tohoku, causing a complete breakdown of all the infrastructures including telecommunications (Fig. 1). Without telecommunications network available, the wide-area medical emergency information system failed to activate, and there was no way to locate casualties who are in need of emergency medical treatment.

Without telecommunications network available, the wide-area medical emergency information system failed to activate, and there was no way to locate casualties who are in need of emergency medical treatment. Without such information available, it is assumed that DMAT was not able to perform its best to save lives [5].

In this paper, we propose a concept of Emergency Information Network System which is using the next-generation mobile telecommunications function equipped with the disaster response mode, instead of using the telecommunications infrastructure. This function enables the mobile network and terminals in ordinary use to shift into the information sharing system for a medical emergency at the time of large-scale disasters.

The disaster rescue operation is conducted in four phases: the first 72 hours, one week, one month and until the normal life is restored. At the time of large-scale disasters, the rescue operation during the first 72 hours is critical to minimize the casualties. The successful operation requires accurate information about the number of casualties, their locations, and states, and such information must be acquired as soon as possible (Fig. 2).

This problem can be recognized as a serious dilemma; victims can send SOS signal if our telecommunications network has no damage. It is impossible for humans to make something absolutely unbreakable. It is necessary to devise

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mythologies on how to respond when it gets broken.

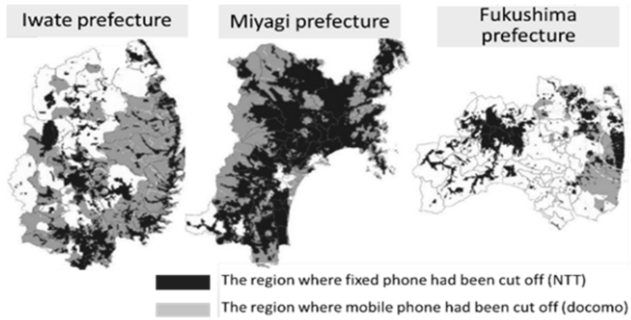

Fig. 1 Internet disconnection area on 13th March 2011 [6]

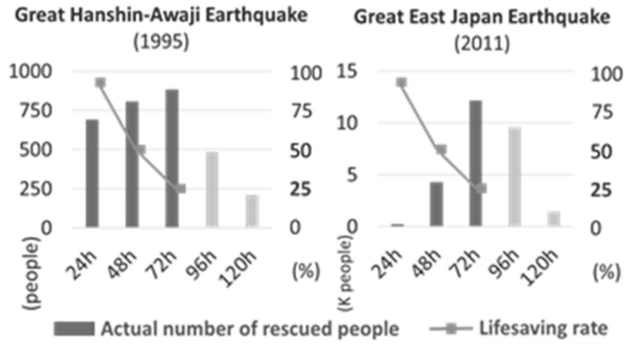

Fig. 2 Rapid decreasing of lifesaving rate during 72 hours after disaster occurrence, and actual numbers of rescue

II. DOUBLE-USE STRATEGY OF QZSS

In this section, we describe how to utilize QZSS from the viewpoint of double-use strategy, for solving the problem.

A. *Primary Usage of QZSS*

QZSS in one of Japanese National Projects, which is executed by the Management Strategy Division of Space in Cabinet Office Japan. Primary service of QZSS is performing highly accurate positioning by using it with Global Positioning System (GPS). In order to realize this, positioning signals of the same frequency and same time as GPS are transmitted from QZSS. The positioning distance error caused by the GPS satellite is the sum of satellite orbit error and satellite clock error. The distance is less than 1 m in theory of GPS positioning. However, a large error of about 10 m has occurred, in general. There are two main reasons for this. One is an error due to a small number of satellites, the other is the error due to the ionosphere. Especially, the latter's radio wave delay due to the ionosphere is occupied the largest part. The ionosphere is the layer of the atmosphere with the electricity in the vicinity of 100 to 1000 km above the sky. The speed slows down, when the radio waves from the satellite pass through the ionosphere. The errors will occur, because calculating the distance between the satellite and the user takes longer time than the actual distance, according to the radio arrival delay. QZSS is a solution to these problems.

As described above, the main function of the QZSS is supplementing the US GPS which calculates the position information by radio waves from the satellite.

B. *Secondary Usage of QZSS*

QZSS has secondary mission which is executed in the event of devastated disaster. It is called “Q-ANPI.” The infrastructures of the disaster area are almost destroyed, when a large-scale disaster such as a giant earthquake or tsunami occurs. There is a Q-ANPI plan in which the two-way communication function of QZSS, on S band, is used as an infrastructure for the serious disaster area. Some applications are being designed by National teams. For instance, there is a service to notify the location of evacuation centers and information on establishment, the number of refugees and the status of evacuation centers. In Japan, when disasters occur, pre-named public facilities are used as designated evacuation centers. Citizens in the vicinity come to evacuate to them. Rescue measures for these evacuation centers are preferentially taken according to our law. In these evacuation centers, equipment for two-way communication with QANPI is installed.

C. *Our System Design Based on QANPI*

What we focused on is the hyper acute phase when a huge disaster occurs (Section I). In this paper, it means about 24 hours after a disaster. The more severe the disaster, the more destructive the infrastructure is in that area, during this period. Communication infrastructure is no exception. Because of this, rescue experts cannot find out where people need life-saving measures. And they take about 48 hours after the disaster to search for them. To solve this problem, we decided to solve this problem by developing a dedicated application on the personal computer of the designated shelter where the QANPI communication device is installed. In the other words, QANPI is used as an emergency communication infrastructure in the hyper acute period when a huge disaster occurs. We will explain the following two points in the next section. One is how to estimate the location of a person who needs life-saving measures, and the other is the structure of the whole system.

III. IDENTIFYING STRATEGY FOR ACQUIRING SEVERE VICTIMS POSITION

To solve the problem, we employed two technical methods. The other is employing Military Grid Reference System (MGRS) for messing geographic map to indicate the area [6]. Our system concept for solving the problem is to suppose that there is a possibility that seriously affected people may be in areas where people have not escaped, by collecting where the people who evacuated came from.

A. *Methane as Disaster Medical Protocol*

North Atlantic Treaty Organization (NATO) developed a protocol to share information for disaster medical decision-making as a system of minimum information necessary for rescue and life-saving immediately after occurrence [7]. It is aimed at efficient life-saving mainly in land-based local disasters (originally conflict and battle), and orally using the radio to communicate the situation and state of the disaster area according to the specified information structure meet. With local disasters, identification of the location of severe victim is relatively easy. On the other hand, advanced decision making is required for choosing tools and equipment necessary for rescue and lifesaving, and lifesaving medical methods at the site. For this reason, a wide range of knowledge and information such as the state of injury or illness, its cause and severity, and the optimal transportation means and portable facilities to that point are required. Against this backdrop, an information structure developed with the aim of sharing with the minimum amount of information required, which is a decisive expression sufficient for professional decision making, was sought. It was METHANE report. METHANE stands for Major Incident, Exact Location, Type of Incident, Hazard, Access to the Scene, Number of Causality and Expected Services, respectively. Currently, it is widely used not only for NATO but also for general disaster medical care. Major Incident Medical Management and Support (MIMMS) in the UK of developed countries of disaster medical care has deployed METAHNE reports to general disaster rescuers, etc. so that they can be used even in the event of natural disasters and traffic accidents. Currently, disaster medical experts from various countries of the African continent are using it as standard as well as Europe. It has been deployed in Japan since 1995 and spreading to Asian countries as well. Especially, in the acute phase of huge disasters (around 72 hours immediately after the disaster), it is an important time to minimize the damage. The METHANE report has been developed for that purpose. On the other hand, this was originally developed for the purpose of life saving immediately after the occurrence of local disasters such as conflict and combat that occurred on land. This means that it is easy to identify the location of devastated area.

Disaster lifesaving experts familiar with METAHNE will first identify Exact Location and collect and share the remaining information on this information. Using these accumulated results, it is used as a material for decision making.

In the event of the Great East Japan Earthquake, it took a long time to search where the seriously affected people were scattered. As a result, METHANE report gathered in position orientation did not work, during the acute period. We recognized specific importance and difficulty of the location of the seriously injured person.

B. Employing Messing Area Using MGRS

In Japan, when a huge disaster occurs, public facilities such as elementary schools function as specified evacuation centers. In each evacuation center, a computer equipped with a connection device with QZSS is installed. The victims evacuated from their position can send information to Crisis Management Center via Q-anpi on QZSS (as mentioned in Section II, Fig. 3). Q-anpi has been considered promising as a means of communication in the event of a disaster. On the other hand, its communication capacity is extremely small, so how to use it has become a big issue. The application that we designed this time was aimed not only for the people who evacuated but also to be able to assume the position of the serious person who pointed out as a problem in the previous section.

More precisely, people who evacuated to evacuation centers specify the area from where they came from. At this time, we will use the meshed geographic information in MGRS (Fig. 4). Our application system has data on how many people live per area. For instance, one can see that there are 12 inhabitants in the area in the top leftmost column in Fig. 4. On the other hand, one can also see that 11 people from the same area are escaping to evacuation centers. It means that most of civilians can escape from the area. But then, in the area in the lowermost row on the rightmost row, only 22 people have escaped to evacuation despite the presence of 22 people. It is supposed that this area has severe victims.

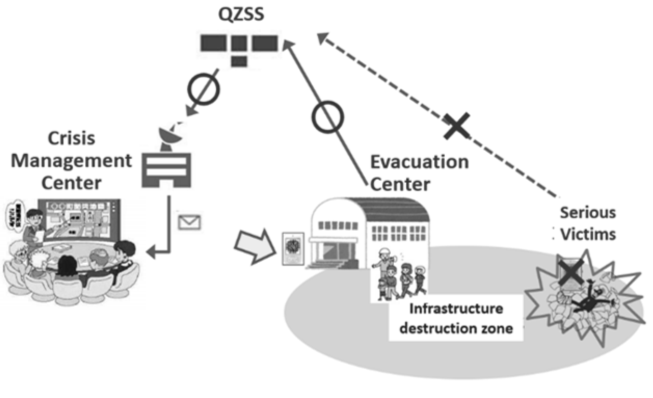

Fig. 3 Designated evacuation center for wide area disaster

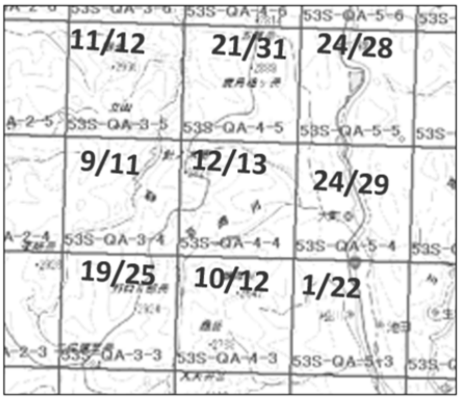

Fig. 4 Mesh-shaped map on our application

IV. A Completed System Overview

Our system design consists of three subsystems. It is called System of Systems [8]. This section shows the result of system completion by using the most distinctive features parts.

Fig. 5 is representative GUIs of one subsystem operated in evacuation facilities during disaster occurrence. The user selects an arbitrary mesh on left map from where he/she escapes and selects how severe situation on right menus.

Fig. 6 is representative GUIs of another subsystem operated in crisis management center during disaster occurrence. Information sent from above evacuation facilities is aggregated and displayed on the meshed map. Also, victims' severe levels are on each evacuation facility.

Fig. 7 is representative GUIs of the other system operated by disaster life-saving doctors, Disaster Medical Assistant Team (DMAT). They use special protocol for sharing information for disasters and lifesaving, therefore this GUI is designed to handle it. The result of their inputs is available to see on the above subsystem at crisis management center. Therefore, they can utilize this information for choosing and providing an appropriate team of disaster life-saving doctors into each mesh.

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Fig. 5 Operation at evacuation center

Fig. 6 Operation at crisis management center

Fig. 7 Operation at devastated area

V. EVALUATION

We positioned our problem issue in Section I. That is how to suppose the area of severe victims during an acute period of giant disasters. Since it was difficult to do so, it took time to search and rescue started after 48 hours since the disaster. The model is presented as dotted line in Fig. 8. We examined the effect of the developed system. Specifically, in the area where it is expected that the next big earthquake and tsunami will come next time, it was assumed that it occurred, and the application was operated at the evacuation center. As a result, it turned out to be a solid line model in Fig. 8.

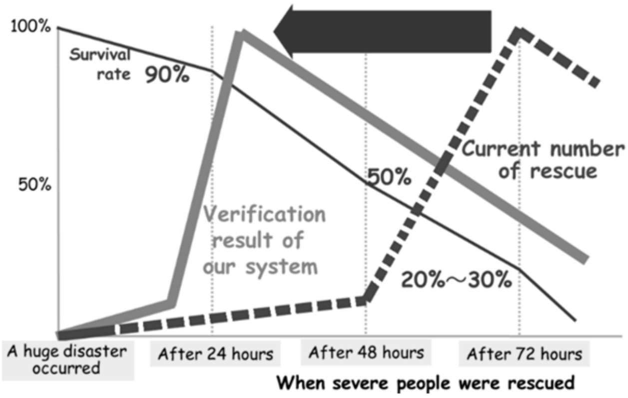

Fig. 8 Model of lifesaving rate

VI. SUMMARY

Our target was to acquire serious victims' locations in the Acute Stage of Large-scale Disasters, in an Emergency Information Network System designed by us. To solve the problem, we employed two technical methods. One is utilizing Quasi-Zenith Satellite System (QZSS) as an ad-hoc communication network during an acute period of giant disaster. The other is employing Military Grid Reference System (MGRS) for messing geographic map to indicate the area geographic messing based on MGRS. It was decided that our system would be enhanced as a national project. According our evaluation, we examined the effect of the developed system.

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