https://doi.org/10.20965/jdr.2013.p0746

Paper:

Evidence-Based Analysis of Search and Rescue Operations Following the Great East Japan Earthquake

Atsushi Koresawa

Fire and Disaster Management Agency (FDMA), Ministry of Internal Affairs and Communication
2-1-2 Kasumigaseki, Chiyoda-ku, Tokyo 100-8927, Japan
E-mail: a.koresawa@soumu.go.jp

[Received March 26, 2013; accepted July 24, 2013]

The March 11, 2011 earthquake off Japan's northeast (Tohoku) Pacific coast and the resulting gigantic tsunamis took the lives of nearly 18,000 people in the devastated coastal communities. In the immediate aftermath of the disaster, now called Great East Japan Earthquake, search and rescue (SAR) for those who were trapped in tsunami waters and debris and who were missing was the top priority in the integrated emergency response. Eventually, SAR operations were performed on an unprecedented scale and complexity. This being the case, a strong interest in the details of these activities has surfaced and frequent enquiries have often been made both from within Japan and from overseas. Still, few studies have been conducted to-date on how SAR operations were performed and what lessons have been learned as a result. By analyzing the experiences of fire service rescue workers, this paper identifies challenges and gaps that the SAR system – institutions, policy frameworks and instruments, skills and techniques, equipment, etc. – could not fully deal with. This paper also looks at the lessons learned to examine the reasons behind them and to explore ways forward that may enable us to be better prepared for future disasters of a similar kind.

Keywords: Great East Japan Earthquake, tsunami, search and rescue (SAR), fire service, international aid

1. Introduction

The 2011 Great East Japan Earthquake was undeniably a catastrophe most of whose casualties were due to a series of gigantic tsunamis. In tsunami-hit coastal communities, large numbers of people were trapped by tsunami waters and debris awaiting the earliest possible rescue. The scale of search and rescue (SAR) operations was unprecedented in scale and complexity.

SAR operations began at the local level, conducted mainly by fire services, both professional and volunteer firefighting fighters, and the police. In maritime incidents, the Japan Coast Guard (JCG) played a major role. The Self Defense Forces (SDF) also joined them based on the requests by prefectural governors appealing to the national government. In the wake of the earthquake, 30,684 firefighters, 96,600 police officers and 10,580,000 SDF personnel were deployed, in addition to local first responders, in the hardest-hit areas from all over Japan to perform diverse activities including SAR [1].

Saving lives was the top priority in the immediate aftermath of the disaster, so the performance of SAR operations attracted strong political interest. Being responsible for SAR operations by fire services at Japan's Fire and Disaster Management Agency (FDMA), the author of this paper often receives inquiries about the realities of SAR operations both from within Japan and from overseas.

Despite strong interest, few studies have been conducted to-date on these issues. Academically, Hiroyuki Nakachi, Norio Maki and Haruo Hayashi analyzed the use of relief helicopters in the Great East Japan Earthquake and made proposals for improvement regarding laws, command systems, helicopter bases and back-up system [2]. Naruko Takanashi compared the official records of rescue operations in the earthquake to those of past disasters and concluded that numerical data and a solid methodology are lacking, such as in clear definitions of "rescue" vis-à-vis "extrication." She accordingly suggested that more work is required in recording and evaluating rescue activities [3]. In other disasters, Lih-Ren Sheu, Ban-Jwu Shih and Chuan-Wei Wu described SAR operations in the 1991 Ji-Ji earthquake in Taiwan [4], whereas the U.S. Fire Administration of the Federal Emergency Management Agency reported in detail on search and rescue operations following the 1994 Northridge earthquake [5]. Despite such work, scientific analysis of SAR operations in these studies have been limited.

In contrast, the Japanese government's ministries and agencies, including the FDMA, have conducted their own reviews of rescue activities in response to the Great East Japan Earthquake. The results of their reviews have been presented in their own white papers and reports. Nevertheless, the scope of these reviews is limited to the areas of individual organization's responsibilities and interests. This means that these ministries and agencies have failed to address issues that touch on generally recognized principles and cut across various policy fields, and have failed

1. The opinions expressed and arguments employed herein are those of the author and do not reflect any view or opinion of the FDMA.

to explore details in these matters.

Against such a background, the author initiated a study into the realities of the SAR operations in the Great East Japan Earthquake by establishing a study group of professional firefighters both at the FDMA and from local fire service departments, including those hardest-hit by tsunamis, namely, Sendai, Ishinomaki and Tagajo in Miyagi Prefecture and Rikuzen-takata in Iwate Prefecture. In so doing, the following four issues required special attention:

1 The so-called "golden 72 hours" has been widely recognized as a general limit on survival for those trapped under debris after a large earthquake. How was this general trend applicable this time?

2 The Great East Japan Earthquake was certainly unprecedented in scale and difficulty. How did the SAR system tackle the unprecedented challenges? What were the limitations or gaps identified?

3 SAR operations were conducted by various organizations from nationwide and even involved rescue workers from overseas. The effective coordination among them surfaced as a matter of critical importance. How was it performed? What were the limitations or gaps identified?

4 Being aware that there is a lack of analytical method and available scientific data, what methodology should be applied in investigating relevant issues?

These four issues have been the main drivers in this study, and the discussions that follow seek to explain how these issues have been addressed.

2. Methodology

In exploring these issues, this study utilizes two types of records concerning SAR activities following the Great East Japan Earthquake.

First, the study started by collecting and analyzing numerous reports, both published and unpublished, produced by fire departments and other organizations that participated in immediate response to the earthquake. It was found that these reports contained a large amount of narratives of personal experiences that well described hardships faced, rescue workers' thoughts in responding to unprecedented challenges, lessons learned and even new ideas. The majority of these are data that have already been described in these documents, but that largely remained unexploited and scattered among many different documents. They have also not yet been analyzed systematically.

Second, in addition to these documented narratives of experiences, the results of interviews conducted by the FDMA in February 2012 were also incorporated in this study. Although records of these interviews are unpublished, interviewees include fire departments (from Sendai, Fukushima, Tokyo, Niigata, Saitama, Chiba, Shizuoka, Akita, Sapporo, Osaka, Sakai, Kyoto and Nagoya) dispatched from other prefectures as emergency fire response teams (as detailed later). This documentation also includes interviews from prefectural air squads from Miyagi and Fukushima Prefectures.

Accordingly, the following steps were taken:

(i) Collected documents containing narratives of personal experiences and results of the FDMA's interviews were first examined carefully, then evidence related to SAR operations in general and the four issues in particular were identified.

(ii) Efforts were made to select evidence thought to contain some common aspects while not overlooking evidence that initially looked very unique or personal but, upon further examination, turned out to be insightful and valuable.

(iii) In order to complement these, a series of group interviews was conducted in July 2012 among the four fire service from tsunami-hit areas, namely, Sendai, Ishinomaki and Tagajo in Miyagi Prefecture and Rikuzen-takata in Iwate Prefecture. These interviews, focused on the first three of our four issues concerning the "golden 72 hours," SAR system capabilities and coordination issues. Individual interviews took almost one hour on average, followed by question and answer sessions.

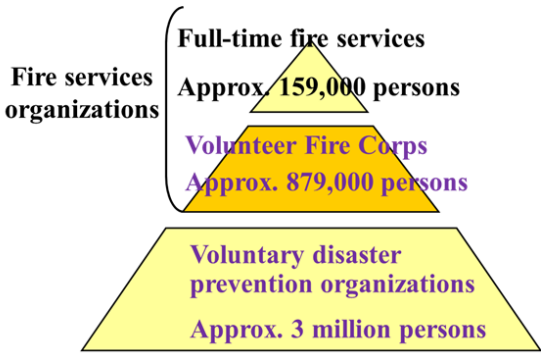
(iv) Inquiries were sent to individual experts, such as medical doctors and engineers, to further consolidate information.

Through these process, more than 170 pieces of evidence were detected that were then categorized by type of issue and examined to clarify challenges, gaps and lessons learned by applying the KJ method (only part of selected evidence is presented below). Selected evidence was scrutinized by study group members for relevance and whether more evidence, views or opinions were to be considered. Having analyzed collected evidence and identified challenges, gaps and lessons learned, this study examines the reasons behind them and explores possible solutions and ways to move forward.

3. SAR operations by Fire Services

3.1. Framework of Fire Services in Japan

Japan's fire service system is largely decentralized, with fire departments established at the municipal level (an only exception being the Tokyo Fire Department established at the prefectural level). Japan's current 791 fire departments comprise 159,000 personnel. In addition to work performed by professional firefighters, volunteer firefighting corps (shobodan in Japanese) play a vital role specifically at the community level (**Fig. 1**). Volunteer firefighters are engaged in their own regular jobs such as farming, fishing and shopkeeping under ordinary circumstances, but they also serve as part-time local government



Source: FDMA

Fig. 1. Overview of Japan's fire service.

officials called on to respond to both natural and man-made disasters. Japan's 2,263 volunteer firefighting corps consist of 897,000 personnel nationwide [6].

Following the Great East Japan Earthquake and tsunami, local fire department and volunteer firefighting corps personnel responded immediately by shutting down water gates, delivering tsunami warnings to local residents, and guiding evacuees to safer places. In doing so, however, 242 volunteer firefighters and 27 professional firefighters very unfortunately died in the process [6].

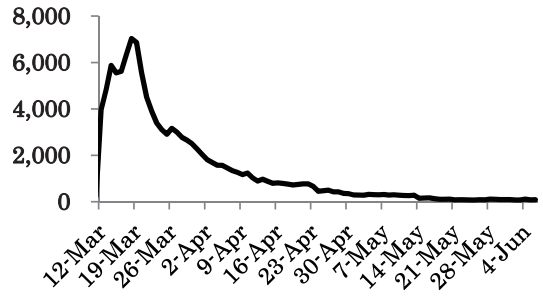
With local fire department's response capacity limited by the tsunami, fire departments in less affected inland areas in the same prefectures dispatched their personnel to tsunami-devastated areas based on mutual aid systems to provide support such as SAR, fire suppression, and transport of the injured.

In the majority of incidents, such intra-prefectural support may have sufficed. In such a large-scale disaster, however, further support was needed from elsewhere. The system of emergency fire response teams was developed based on experience gained in the 1995 Great Hanshin-Awaji (Kobe) earthquake, and the size and reach of these teams has been growing since their inception. At present, 4431 units from 781 fire departments nationwide are registered, consisting of command and control, fire suppression, SAR, HAZMAT (Hazardous Material), logistic support, EMS (Emergency Medical Service), air squads, etc. [6].

Approximately one hour after 14:46 on March 11 when the first major tremor jolted northeastern Japan, the FDMA Commissioner activated the system by requesting fire heads to mobilize their emergency fire response teams. In the end, over 30,000 personnel, equivalent to almost one fifth of all fire service personnel in Japan, were dispatched from 44 prefectures to the 3 hardest-hit prefectures of Iwate, Miyagi and Fukushima, where they served for 88 days at a maximum as shown in **Fig. 2**.

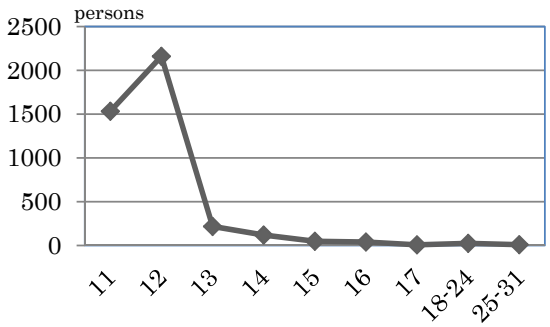
3.2. Results of SAR Operations

Following the earthquake and tsunami, fire service personnel together with the police, JCG and SDF conducted SAR operations in tsunami-ravaged communities, saving the lives of nearly 27,000 people according to the



Source: FDMA

Fig. 2. Scale of emergency fire response teams.



Source: Calculated from data compiled in [7]

Fig. 3. Numbers rescued by local fire departments.

government's Extreme Disaster Management Headquarters [1]. This is the official figure, but details have not been disclosed, so this study instead examines figures reported by 17 fire service departments located in the tsunami-affected prefectures of Aomori, Iwate, Miyagi, Fukushima and Ibaraki. **Fig. 3** shows the total number of people rescued by local fire service departments [7].

As shown in the graph, the number of people rescued on the first day, March 11, was surpassed by that rescued on the second day, March 12. This indicates that SAR operations expanded on the second day due to the fact that the earthquake hit at 14:46 on March 11 and was followed by tsunamis that continued striking coastal communities and hampering the response capacity of local fire service personnel and police. The number of those rescued drops sharply on the third day, which almost fits in with "golden 72 hours" (discussed later).

Based on this overview, this study goes on to analyze the detailed evidence collected mainly as personal narratives.

4. Possible Survival and Lifesaving

After catastrophic disasters, the possibility of survival for those trapped under rubble or confined within collapsed structures drops sharply over time. Specifically, the so-called "golden 72 hours" is generally regarded as the limit of survival time for such victims. Questions have thus been raised on how applicable this general assumption was following the Great East Japan Earthquake.

In fact, rescue workers were well aware of this trend, manifested typically as follows:

- If we could rescue as many disaster victims as possible within the first 72 hours as a benchmark, it would eventually result in a maximum number of lives saved [7].

- We found almost no survivors where we were deployed after the first 48 hours or 2 days [8].

Notwithstanding such a wide-spread assumption, different observations have often been presented by experts. It was reported, for example, that 81% of fatalities in the 1995 Kobe earthquake occurred within three hours after the earthquake hit [9]. Yoshiaki Kawata once acknowledged that "it is true that 96% of survivors were rescued within the so-called 'golden 72 hours' as observed in the US and Europe. In Japan, however, where most houses are wooden, compared to European and North American countries, where most houses are concrete or stone, rescue operations must focus on 24 hours rather than 72 to save as many survivors as possible" [10]. Ota and Nakajima (2012) showed, for example, in analyzing 26 earthquakes worldwide, that the limitation on survival varies greatly from an average of 4.7 days that was also as long as 2 weeks if the conditions of confined space and the availability of food and water are favorable [11].

While these observations may appear contradictory at first glance, they demonstrate the great variability among different disaster situations so that the "golden 72 hours" comes somehow to be a dubious concept. In fact, little scientific knowledge has been consolidated to back up this concept, with only available data being that of numbers of people rescued instead of the number of survivors over time. Scientific data on survival in the Great East Japan Earthquake was not available at the time of this writing and, for a number of reasons that this paper is too limited to cover, is unlikely to become available in future.

By examining the possibility of survival from a different angle, information on causes of death provides some insight. Police reported that more than 90% of deaths, as revealed by autopsy, were due to drowning [12] although details are not known. The collected evidence in this study reveals a slightly different story, in effect, with many rescue workers testified that a large proportion of fatalities seem to have been caused, or affected at least, by hypothermia, i.e. low body temperature, as manifested typically by the following:

- Many deaths appeared to be related to hypothermia as they were caught in tsunami waters despite a lack of fatal injuries. With power outages limiting the use heating appliances, those rescued could only be wrapped, at best, in blankets after their wet clothing was removed [8].

- Many more survivors might have been spared even outdoors if the disaster had occurred during warmer weather instead of at the end of winter [13].

The following observations presented from a medical point of view support this observation:

- Some tsunami victims, who had survived even after accidentally swallowing muddy water, remained trapped in water at 7.2 degree Celsius, suffered hypothermia, then died following cardiopulmonary arrest in water. The cause of death in these cases may have been reported as drowning [14].

- Attention must be paid to the fact that these tsunamis hit Japan's far northeast (Tohoku) where it was snowing on March 11. Many of the deaths reported due to drowning may actually have been due to hypothermia. This also suggests that many more lives would have probably been saved if the disaster had occurred in summer [13].

This evidence suggests that survival was greatly affected by frigid weather and would have been better under more favorable weather conditions.

It is also important to note that many cases of survival and rescue occurred well beyond "golden 72 hours." The most noted case was that of an 80 year old woman and her grandson who were rescued in Ishinomaki, Miyagi prefecture, on March 20, nine days after the earthquake. Although they had suffered some frostbite, their place of refuge was a confined space in a half-destroyed house that gave them access to food and water. This compares with the news from Bangladesh of a woman rescued 16 days after a building collapsed in May, 2013 killing over 1,000, but the woman survived thanks to access to food under the rubble.

Analysis results thus far suggest three conditions favorable to survival and rescue:

1) The "golden 72 hours" should be viewed as a benchmark not applicable to all types of disasters, since there is certainly great variability.

2) Saving lives remains a race against time whose favorability drops sharply under harsh weather conditions.

3) Survivors have a higher possibility of survival and rescue beyond 72 hours if other conditions, such as access to food and water, are present.

5. SAR Capacity Against Tsunamis

5.1. SAR Techniques and Methods

SAR operations are conducted in Japan by various organizations, such as the fire service, police, JCG and SDF, each of which has its own advantages. Fire service rescue workers have advantages, for example, in technical rescues whereas police and SDF have advantages in conducting diverse massive-scale activities self-sufficiently.

The capability of fire service rescue workers has been upgraded based on experience within the last decades, most notably, the 1995 Kobe Earthquake, the 2004 Niigata Chuetsu Earthquake, and the 2005 Amagasaki rail

Source: FDMA

Fig. 4. Rescue operation from the rubble.

crash. The FDMA has promoted developments by setting rules and standards, and by providing financial, technical and material support.

From an international aspect, Japan disaster relief teams (JDR) dispatched overseas upon request by recipient countries have been classified "heavy" (the best of three ratings of "light," "middle" and "heavy") by the International Search and Rescue Advisory Group (INSARAG).

Despite these developments over the last decade, the following evidence suggests limitations and gaps that SAR techniques and equipment do not sufficiently cover:

- In the 1995 Kobe Earthquake, many victims buried under rubble were found by neighbors. Such possibilities were rarely available in the 2011 case, however, because most neighbors had already evacuated to non-neighborhood locations [13].
- Tsunami inundation areas became like marshy land where good use could not be made of advanced USAR techniques … The biggest obstacle in SAR operations, for example, was "water" [8].

Many tsunami victims were found under the rubble of houses that had been washed away from their original sites. Remaining water and the spread of debris in tsunami inundation areas greatly hampered SAR activities as shown in **Fig. 4**.

5.2. Equipment Effective in Tsunami Inundation Areas

In tsunami inundation areas, evidence indicates that road conditions prevented large fire service vehicles from moving around easily:

- Fire engines were stationed on highways far behind tsunami-hit areas. Rescue sites that were reached were covered in debris. Because rescue workers could not go back easily to fire engines, they had no choice but to carry chain saws, hand axes, portable hydraulic devices, etc., that were ultimately inefficient in rescue and assistance [7].
- Heavy vehicles such as fire engines equipped with large pump and rescue trucks were not suitable in tsunami-inundated areas, in contrast, smaller vehicles, station wagons and smaller trucks that were used to transport rescue personnel and survivors were useful [15].

In addition to small vehicles, small boats were required for SAR activities in tsunami-inundated areas. Aluminum and plastic boats were more useful than rubber boats and even water bikes and jet skis are reported to have been utilized effectively:

- More small boats made available could have saved more lives [13].
- Plastic boats were most useful in SAR operations in inundated areas because they were light and easy to move through debris from one place to another with a minimum of personnel required, since even two persons could move them easily [13].
- Aluminum boats were more useful than rubber boats which were easily holed or otherwise damaged by floating debris [13].
- SAR operations were started by using water jets with aluminum boats connected to them … Rescue workers continued to transfer survivors back and forth until 5 o'clock the next morning, with more than 100 persons eventually rescued … Water jets proved easy to use even in shallow water and were effective in SAR operations in tsunami-inundated areas [16].

The above evidence confirms that rescue workers faced difficulties associated with tsunami inundation, muddy or polluted water, widespread and floating debris, destroyed buildings, etc. Certain equipment and vehicles, such as small vehicles and plastic or aluminum boats are thus required to further strengthen tsunami response capacity.

5.3. Heavy Machinery Use

SAR operations following the earthquake and tsunami were conducted mainly using manual labor and portable devices. The use of heavy machinery such as hydraulic shovels and cranes was often required as evidenced by the following:

- We did not use much heavy machinery in initial stages to help ensure the rescue of those who might still be alive under rubble. We started using heavy machinery to remove rubble after that. We came to realize that the use of heavy machinery was very effective and could ensure very sensitive manipulations [17].

Despite the necessity, it is difficult for financial and technical reasons for individual fire departments to acquire and maintain heavy machinery of their own. This suggests the following alternatives:

Source: Fire Chief's Association of Japan

Fig. 5. Rescue work using heavy machinery.

- Fire departments could buy or borrow heavy machinery from construction companies, but the majority must request it through contracts. The problem with this kind of arrangement is that it may take time to mobilize such equipment, particularly on weekends or at night [7].
- Agreements fire departments had with construction and demolition firms to clear road obstacles sometimes worked very well but other times did not work at all. We thus must reexamine agreements thoroughly. We also must regularly conduct joint exercises to develop closer relationships through which we can recognize each other on sight [7].

Evidences so far indicate the following:

1) The use of heavy machinery, as shown in **Fig. 5**, is indispensable both in clearing road obstacles and in reaching victims buried under rubble.
2) Even though fire departments do not own heavy machinery of their own, it is useful and effective to have prior agreements with construction and demolition firms as necessary.
3) Close relationships must be developed enabling rescue workers and construction firm personnel to recognize each other on sight.

5.4. Safety Control and Health Care

It was deeply regrettable that so many professional and volunteer fighters became victims of the tsunami while on duty closing water gates, prompting and guiding local residents to evacuate to safer sites, and conducting SAR activities.

These experiences underscored the need to ensure the safety of first responders. Among the many opinions expressed afterward in this regard are the following:

- We recognized a strong need to raise the safety awareness of firefighters engaged in activities in areas where tsunami waves might occur more than once [7].
- The timing, procedures and commands in evacuation should be made very clear to ensure the safety of volunteer and professional firefighters [7].

SAR operations were conducted under harsh conditions, specifically extremely low temperatures that put the health of personnel in danger. Health care and safety control are indispensable and mutually reinforcing in effectiveness as explained here:

- Daily meals are an important source of vitality enabling firefighters and other rescue workers to continue hard work under difficult conditions. They came back to camp, consumed preserved food, such as dry packed rice, napped briefly, and went back to their work. I felt that their morale could be weakened under such circumstances [6].
- We returned to camp after conducting field activities without rest, but had neither ways to dry our wet uniforms nor makeshift cots to sleep on. Eventually, we had to sleep in our vehicles. We could hardly recover from even a day's fatigue [8].
- We could not sleep at all at camp. It was very windy and temperatures hovered around below zero ... ample reason for accidents to happen without warning [6].

Based on such hardships, many proposals have been made concerning health care and protection against cold weather, including the following:

- We were not prepared for cold weather ... The air dome tents, sleeping bags and mats that we brought with us were not sufficient to get a sound sleep below freezing [17].
- Camping in severely cold weather increased rather than relieved fatigue, which could threat health. This made clear to us the necessity to have sleeping bags, oil heaters and other equipment ... We must improve facilities for efficiently providing food to all personnel dispatched to the field and maintaining physical strength, nutrition support and health care [17].

It has been shown that safety control and health care were not taken into sufficient consideration, and have emerged as indispensable to supporting SAR operations, particularly under harsh weather conditions. Safety control and health care should be treated as immediate-need items, not as separate issues to be considered "later."

5.5. Backup Logistics Support

As stated, the emergency fire response teams were dispatched to disaster-hit regions from all around Japan, and the scale of problems they faced was unprecedented. Communities also faced unexpected difficulties and thus had to respond flexibly according to the circumstances as follows:

- As the number of the emergency fire response teams increased, one difficulty was ensuring camping sites for them [7].

In addition, there were also difficulties in securing food, fuel supplies and other necessities as follows.

- There were severe fuel shortages in communities because most fuel suppliers were damaged and service stations were closed and without a power supply. Our fire department stored fuel to some extent, but it was not sufficient. We had agreements with fuel suppliers, but they also faced shortages because wholesale dealers of oil products did not continue supplying them [16].

- We were most inconvenienced by the lack of latrines. Camping tents and food supplies were provided by logistical support teams, but we had not thought much of latrines and the need to take our "discharges" back with us. It was a really major concern [6].

Ensuring camping sites, food and fuel supplies, and latrines are all important elements in field-support activities. Many new ideas emerged based on such experiences and we must strengthen backup logistically as follows:

- We must be self-sufficient in field activities, including meals and logistics alike. We felt awfully tired even though our dispatch lasted only three days. As a result, we came to realize that if support teams could facilitate camping and food distribution more efficiently, operations and response would also be more efficient and enable us to stay longer and help in disaster-hit areas [17].

- The reason we managed to focus on SAR operations without worrying about food, clothing and shelter was logistical support ... In the wake of a disaster, it facilitates the smooth start of field operations if logistical support teams are dispatched as part of advance teams to make necessary preparations before main teams arrive [7].

It was concluded that logistical support encompassing food, fuel, latrines and other necessities is essential and an important element in supporting long-term field activities. It was found that fire services were not planned enough for sending personnel for prolonged periods of time, so it is extremely important to further strengthen backup logistics support functions.

6. Coordination Issues

6.1. Coordination Among First Responders in Japan

In tsunami-inundated areas, buildings and other landmarks were washed away, making it difficult to spot even your own location. Accordingly, various means were reported for devising clear targets for SAR activities, including the following:

- With most buildings swept away, it was difficult to identify even a current position ... so we realized the necessity to communicating well with the SDF and police to avoid overlapping search areas and to make SAR operations more efficient [17].

- We produced common-use cross-section maps and shared information on situations and activities among groups through daily meetings [6].

Based on such experiences, the following proposals were made to further improve coordination and cooperation in the field:

- We conducted SAR operations jointly with the SDF, which was quite difficult to coordinate for the first week ... but gradually as coordination improved and information was increasingly shared, it enabled even such collaboration as lending equipment and giving rides to each other [17].

- When we started SAR operation in disaster-hit areas, we found notices stating "Search finished, SDF," but this was not clear enough to know, for instance, whether there had been victims or not, whether searches had been completed or not, and so forth. Indeed, search operations sometimes were not very efficient due to duplication. Based on this experience, we concluded that there must be a unified marking system at least for emergency fire response teams [7].

- Up until now, there is no standardized or unified marking system ... We felt it was necessary for all fire departments in Japan to develop a new common-use marking system, to take into consideration the possibility of collaborating, for example, with overseas rescue teams [7].

These experiences highlighted the necessity of a shared information base, such as common-use maps and GIS, for first responders, both among fire services and among different kinds of first responders, such as police, the JCG and the SDF. Furthermore, a common-use marking system is required to share information and to improve the coordination of SAR operations on sites.

6.2. Coordination with SAR Teams from Overseas

In the aftermath of the Great East Japan Earthquake, SAR teams from 16 countries, 1 region and 2 international organizations came to Japan and conducted operations as shown in **Table 1**, the scale of which far exceeded that of the 1995 Kobe Earthquake.

A new system was developed after 1995 to better accept and coordinate with teams from overseas in the event of a major disaster in Japan, but the system did not work as expected, partly because of the huge scale of disaster

Table 1. Rescue teams from overseas.

Country/Region/ Organization	Number of workers	Operation period	Operations sites (City, Prefecture)
Rep. of Korea	1) 2 rescue dogs, 5 staff 2) 102 rescue members	1) 12-23 March 2) 14-23 March	Sendai, Miyagi
Singapore	5 staff members, 5 rescue dogs	12-15 March	Soma, Fukushima
Germany	41 rescue members, 3 rescue dogs	13-15 March	Minami-Sanriku, Miyagi
Switzerland	27 rescue members 9 rescue dogs	13-16 March	Minami-Sanriku, Miyagi
U.S.	141 rescue members 12 dogs	13-19 March	Ofunato and Kamaishi, Iwate
China	15 rescue members	13-20 March	Ofunato, Iwate
U.K.	69 rescue members 2 rescue dogs	13-17 March	Ofunato and Kamaishi, Iwate
New Zealand	1) Advanced team of 7 2) 45 rescue members	1) 13-18 March 2) 14-18 March	Minami-Sanriku, Miyagi
UNDAC	7 coordination specialist	13-23 March	Tokyo
UNOCHA	3 coordination specialist	13 March - 2 April	Tokyo
Mexico	12 rescue-related workers, 6 dogs	14-17 March	Natori, Miyagi
Australia	72 rescue members	14-19 March	Minami-Sanriku, Miyagi
France	134 rescue related workers	14-23 March	Natori, Miyagi Hachinoe, Aomori
Taiwan	28 rescue members	14-18 March	Natori and Iwanuma, Miyagi
Russia	1) 75 members 2) Approx. 80 members	1) 14-22 March 2) 16-22 March	Ishinomaki, Miyagi
Mongolia	12 rescue members	15-19 March	Natori and Iwanuma, Miyagi
Indonesia	11 rescue members	18-23 March	Kesennuma, Shiogama and Ishinomaki, Miyagi
South Africa	45 rescue members	18-25 March	Iwanuma, Natori, Ishinomaki and Tagajo, Miyagi
Turkey	32 rescue members	19 March - 8 April	Tagajo, Ogatsu, Ishinomaki and Shichigahama, Miyagi

Source: Based on information of Ministry of Foreign Affairs

impact and because of a lack of preparedness on the part of Japanese counterparts. Indeed, through experience in working with overseas rescue teams, many issues have surfaced or reemerged. These include the following:

- Liaison officers deployed by Japan's Ministry of Foreign Affairs and embassies of individual countries in Japan stayed in buses. Without the help of liaison officers in interpretation, for example, we had difficulty in communicating, at least at the beginning, although we gradually managed to communicate using gestures and other means [7].
- To prepare for future large-scale disasters, we must further improve standard operating procedures for accepting and working with teams from overseas and develop greater capacity to do so. It may also be necessary for Japanese rescue workers to familiarize themselves better with international rules and standards [7].

An interim report from a task force on emergency response that was established at the Japanese government's cabinet office states that "despite the government's request, some rescue teams from overseas did not operate self-sufficiently, particularly concerning transportation and fuel supplies ... Procedures for accepting overseas rescue must be further clarified" and "there is no legal system yet to compensate for damage and loss to be incurred by rescue and medical teams from overseas" [18].

Although systems for accepting foreign aid have been developed based on lessons learned from the 1995 Kobe Earthquake, these systems must be further strengthened based on Great East Japan Earthquake experience.

7. Reflections on Analysis Results

This study has analyzed challenges that fire service rescue workers faced while engaged in SAR operations following the 2011 Great East Japan Earthquake, gaps that the SAP system could not cover, and lessons learned.

Analysis has shown that the fire service rescue workers saved many lives despite pressing dangers and numerous difficulties. Yet, this response to an unprecedented catastrophe has brought to light many gaps and new lessons have been learned as a result. Based on these, the following issues must be explored further and in depth as pointed out in the introduction to this paper.

The first issue concerns how the "golden 72 hours" was applicable to the 2011 earthquake and tsunami disaster. It has been greatly emphasized by the media and the public. As discussed in Section 4, "golden 72 hours" function as a benchmark but it is not a definite limit on survival. To the contrary, evidence has proven clearly that there is great variability among disasters. While saving lives is indeed a race against time and favorable results drop sharply under harsh weather condition, SAR operations must be conducted seamlessly assuming that those who are trapped under debris may survive well beyond 72 hours if conditions allow it, e.g. access to food and water.

The second issue concerns the capability of the SAR system in response to unprecedented challenges. As examined in Section 5, it is clear that while fire services rescue workers save many lives despite tremendous danger and numerous difficulties, many gaps have been identified, e.g. a lack of preparedness for tsunami disaster, severe weather, long-term and long-distance dispatch, safety and health care, and back-up logistics support. Since then, progress has been made on many fronts by individual organizations, but most have just started and thus will likely take some time to become truly operational. Further efforts must be made to speed up this process in view of imminent threats. More importantly, however, a closer look at areas where progress has been reported reveals that many areas are lagging behind.

Coordination among Japanese first responders is a case in point related to the third issue. Although coordination among first responders seems to have improved to some extent through revisions of disaster management plans and operating procedures and by conducting joint exercises and drills at the local level, its effects have yet to show more concrete results. The use of ICT and GIS to enhance information sharing surely will improve coordination on site, so more progress must be made in the field. More importantly however, ways of command and control and standard operating procedures have not been revised or developed much. While some suggest the introduction of the incident management system developed in the U.S. and introduced in many other countries, it has not yet been carefully examined or tested for whether it really fits Japanese circumstances or what it really improves. These require more in-depth investigation.

Likewise, coordination with overseas rescue teams is also lagging behind, perhaps in part due to its complex nature and politically and diplomatically sensitive issues. The system developed based on experience from the 1995 Kobe earthquake did not work smoothly as planned and no system yet exists to link on-the-ground needs, operational requirements and the capability of overseas rescue workers. Likewise, no solid system yet exists ensuring the effective deployment of overseas rescue teams in coordination with their Japanese counterparts, particularly at the local level. Much more must be done to speed up progress based on the experience of the Great East Japan Earthquake. In so doing, experiences in other developed nations such as 2005 Hurricane Katrina in the US and the 2011 Christchurch Earthquake would surely provide valuable input [19].

Finally, the methodology applied in this study must be re-examined. While research into the realities of SAR operations has been very limited, as noted in the introduction to this paper, other studies include those that compare USAR training facilities and systems of different countries [20, 21] and those that describe the international USAR system and activities of the UN Disaster Assessment and Coordination (UNDAC) system [22, 23]. These studies have discussed SAR activities but hardly touch upon the actualities of SAP operations.

In contrast, this study has provided evidence from personal narratives of real experiences and analyzed them. The methodology applied may not be very scientific, since it depends mainly on secondary information and the method of analysis is not sophisticated. Suggestions have thus been made to obtain more primary information by, for example, questionnaires and interviews and to analyze them more solidly. Likewise, issues related to coordination among Japanese first responders and overseas rescue teams as discussed may require further exploration suggesting other ways for these to move forward.

8. A Final Thought

Tsunamis are comparatively rare compared to disasters such as flooding, tropical cyclones and earthquakes. Once a tsunami occurs, however, its effects may be extremely devastating as exemplified by, among others, the 2004 Indian Ocean Tsunami and the 2011 Great East Japan Earthquake. Information on how emergency responses, particularly SAR operations, are performed in response to unprecedented challenges is scarce, so the results of this study and lessons from the Great East Japan Earthquake, should prove to be of great value and utility in better preparing ourselves for similar disasters in the future.

Acknowledgements

The author thanks the fire service personnel who provided important input for this study, specifically the Sendai fire department, the Ishinomaki district firefighting union, the Shiogama district firefighting union, and the Rikuzen-takada fire department. The author also thanks colleagues at the FDMA who, as members of the study group, provided material support and invaluable advice in conducting this study.

References:

[1] The Extreme Disaster Management Headquarters, "About the 2011 Earthquake off the Pacific Coast of Tohoku" (in Japanese), http://www.kantei.go.jp/saigai/pdf/201303261700jisin.pdf [accessed March 27, 2013]

[2] H. Nakachi, N. Maki, and H. Hayashi, "Proposal on the Effective Use of Relief Helicopters Based on Experience in the Great East Japan Earthquake," Journal of Disaster Research, Vol.7, No.sp, pp. 500-510, 2012.
[3] N. Takanashi, "Actualities of Rescue Activities at the Time of Disasters: How Many Lives Did Fire Service Save?," Monthly FESC, June 2013, Fire Equipment and Safety Center of Japan (in Japanese).
[4] L.-R. Sheu, B.-J. Shih, and C.-W. Wu, "The Search and Rescue Operation in Collapsed Buildings Caused by Earthquakes – A Case Study," 2000 Proceedings of the 17th ISARC, pp. 1-4, 2000, http://www.iaarc.org/publications/fulltext/isarc2000-183_TC1.pdf [accessed March 27, 2013]
[5] United States Fire Administration, Federal Emergency Management Agency, "Search and Rescue Operations Following the Northridge Earthquake: Technical Rescue Incident Report," 1994.
[6] Fire and Disaster Management Agency, "the 2012 White Paper on Fire and Disaster Management," 2013 (in Japanese).
[7] Fire Chief's Association of Japan, "the Record of Activities on the Great East Japan Earthquake," 2012 (in Japanese).
[8] Monthly SHOB: special edition, "Great East Japan Earthquake: Testimony from the Front Lines," Tokyo Horei Publishing Co. Ltd., Tokyo, 2012 (in Japanese).
[9] N. Aoki, A. Nishimura, E. A. Pretto, K. Sugimoto, J. R. Beck, and T. Fukui, "Survival and Cost Analysis of fatalities of Kobe Earthquake," Prehosp Emerg Care 8, pp. 217-222, 2004.
[10] Y. Kawata, "Synthesis of Lessons Learned from the hanshin-Awaji Earthquake," Journal of Municipal Problems, Vol.49, No.1, 553, pp. 14-32 (in Japanese).
[11] Y. Ohota and T. Nakashima, "An Extreme Value Analysis on Survival Times of Entrapped People under Collapsed Buildings by Earthquake," Report of Tono Research Institute of Earthquake Sceience, Vol.26, pp. 173-176, 2010 (in Japanese).
[12] National Police Agency, "White Paper on Police 2011," Digest Edition (in Japanese), www.npa.go.jp/hakusyo/h23/youyakuban /youyakuban.pdf [accessed March 27, 2013]
[13] Fire and Disaster Management Agency, "The Report of the Study Group on Fire Service's Activities to Tsunami Disaster of the Great East Japan Earthquake," 2013 (in Japanese).
[14] T. Yamanome, "the Acute Stage Disaster Medical Action at Iwate Prefectural Ofunato Hospital and Chronic Stage Disaster Medical management in Ofunato District in Tohoku Region Pacific Coast Earthquake and Tsunami," Japanese Journal of Disaster Medicine, Vol.17, No.1, July 2012 (in Japanese).
[15] Fire and Disaster Management Agency, the Proceedings of the 14th National Fire Service Rescue Symposium, 2012 (in Japanese).
[16] Shiogama District Firefighting Union Affairs, "The Great East Japan Earthquake: Voices at the Secenes," 2012 (in Japanese).
[17] Sendai City Fire Department, "the Record of Activities on the Great East Japan Earthquake," 2012 (in Japanese).
[18] Cabinet Office, "the Interim Report of a Task Force on Emergency Response," 2011 (in Japanese).
[19] Federal Emergency Management Agency (FEMA), 2012 International Search and Rescue (SAR) Workdhop: Summary Report, 2012.
[20] A. Yoshimura, H. Shimizu, F. Satoh, Y. Kako, and S. Tadokoro, "A Study on Perspectives of Desgins and Operations for US&R Infrastructure – Consideration from a Survey on Disaster City Training Facility –," Institute of Social Safety Sceience, No.13, Nov. 2010 (in Japanese).
[21] A. Yoshimura, F. Saitoh, S. Akitomi, S. Rodgers, F. Oyama, and Y. Kako, "A Study on the Implementation Strategy of Urban Search and Rescue for Japan Based on Comparative Surveys in the Unitted States and the United Kingdom," Institute of Social Safety Sceience, No.10, Nov. 2008 (in Japanese).
[22] Y. Okita, "My Thoughts on International Urban Search and Rescue (USAR)," Institute of Social Safety Sceience, No.19, Mar. 2013 (in Japanese).
[23] Y. Okita, "The UNDAC Team in Response to the Tohoku-Pacific Ocean Earthquake," Journal of Natural Disaster Science, Vol.30, No.2, 2011 (in Japanese).

Name:
Atsushi Koresawa

Affiliation:
Counselor, Civil Protection and Disaster Management Department, Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications

Address:
2-1-2 Chiyoda-ku, Kasumigaseki, Tokyo 100-8927, Japan

Brief Career:
1988 Joined National Land Agency, Government of Japan
1991-1994 UN-HABITAT
1997-2000 OECD
2001 Cabinet Office, Government of Japan
2002 Ministry of Land, Infrastructure, Transport and Tourism, Government of Japan
2009 Asian Disaster Reduction Center
2012 Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications, Government of Japan

Selected Publications:
• "Strengthening the Asian System for Disaster Risk Reduction," in RISK RETURNS, 2011.
• "HFA Implementation in Asia and the Pacific," in Asian Disaster Management News, Vol.16, No.2, May-August, 2010.
• "Main Features of Government's Initial Response to the Great East Japan Earthquake and Tsunami," Journal of Disaster Research, Vol.7, No.1, 2012.
• "Government's Response to the Great East Japan Earthquake and Tsunami," Journal of Disaster Research, Vol.7, No.sp, 2012.

Academic Societies & Scientific Organizations:
• Institute of Social Safety Science (ISSS)
• Japan Association for Real Estate Science (JARES)
• Science Council of Japan (SCJ)