Implementation of a disaster management system for local governments in Japan

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Abstract. Reconstruction after the Great East Japan Earthquake in March 2011 has been delayed. To suitably respond to similar large-scale disasters in the future, the implementation of a disaster management system at the local municipal level, aimed at rapid reconstruction that includes management of processes from pre-disaster to the reconstruction phase, is required. In this study, we develop a prototype of such a system, which is referred to as the Local Government Disaster Management System (LGDMS). For our study, we collaborate with a municipality in Kochi, Japan. In the LGDMS prototype, we use a Work Breakdown Structure (WBS) format, wherein the contents of each activity and roles of different organizations in those activities are defined based on a study of organizational problems and law and regulation issues among the central government, prefectoral governments, and municipal governments. The Construction Management Committee of the Japan Society of Civil Engineers (JSCE) established a subcommittee for this research. This subcommittee is composed of university faculty members, local consulting engineers, and administrative officials in Tohoku and Kochi. The subcommittee is striving to implement LGDMS in several municipalities in Kochi.

1. Introduction
After the Great East Japan Earthquake in 2011 (GEJE), disaster management including pre-disaster planning, rescue operations, recovery efforts, and reconstruction became a priority in Japan. Disaster management efforts focused specifically on municipal governments being at the forefront when any kind of disaster is occurring. Kakuzaki et al [1] summarized necessary activities and procedures of the activities for each aspect of disaster management. A management system which includes WBS (work breakdown structure), the contents of each activity, and work sequence to facilitate rapid and efficient recovery for any phase was developed in the research. It was named Disaster Management System. Researchers developed a prototype of the system for rural municipal governments in Japan, which they called the Local Government Disaster Management System, or LGDMS.

Any existing plans of rural municipal governments such as disaster prevention plans, debris disposal plans, temporary housing construction plans, evacuation plans, etc., successfully address damage predictions such as number of fatalities, number of collapsed buildings, amount of debris, etc. However,
the quantity of work needed, necessary resources, ability to provide the resources, etc., are not clearly stipulated in these plans.

To re-establish an enjoyable livelihood for sufferers, debris disposal is the top priority. However, temporary housing should also be provided as soon as possible. Debris disposal and temporary housing are Critical Path of reconstruction procedures. Municipal governments should prepare large portions of land for temporary storage of debris and temporary housing. Along with land, municipalities should provide significant manpower, materials, and equipment for reconstruction.

In 2016, the Construction Management Committee of Japan Society of Civil Engineers (JSCE) established a research subcommittee to develop and install disaster management systems for local governments. This article introduces previous efforts of the research subcommittee. The subcommittee consists of university researchers, administrative officials of Kochi Prefecture government, administrative officials of municipal government in Kochi, administrative officials in charge of reconstruction work in Ishinomaki City, where the GEJE hit, and local consulting engineers.

2. Background of efforts
Kakuzaki et al [1] pointed out that almost no rural municipal governments were able to formulate basic plans for quick recovery during the GEJE. Figure 1 shows the number of municipal governments segmented by duration that formulated basic plans for recovery during the GEJE. Many municipal governments took 6-12 months to create a basic plan. On the other hand, recovery policies in Kobe City after the Great Hanshin Awaji Earthquake in 1995 were created two months after the earthquake and, the concrete recovery plan was formulated 5 months after the earthquake. In the case of the tsunami disaster caused by Hokkaido-Southwest-Earthquake in 1993, a relocation plan to move to higher elevations was formulated five months after the earthquake.

The cause of this contrast was thought to be the difference between the experience of big developing projects and the limited organizational capability of municipal governments. Kobe City is part of megacity, and has extensive experience with war damage reconstruction from World War II through urban redevelopment projects, port development projects, etc. In contrast, scale of almost all municipal governments which were damaged by GEJE were small; therefore, they had a very different experience.

Figure 2 shows the classification by population of municipalities that are expected to be affected by the future Nankai megathrust earthquakes. There are 189 municipalities with a population of less than 200,000; 66% of these municipalities have a population of less than 50,000 and around 60-500 administrative officials. These municipal government do not have the ability to defend themselves against a huge natural disaster. Authors tried to develop and install disaster management systems for these small local governments.

**Figure 1.** Number of municipal governments segmented by duration to formulate basic plans for recovery from the Great East Japan Earthquake 2011.

**Figure 2.** Classification by population of municipalities that are expected to be affected by the future Nankai megathrust earthquakes.
3. Issues to be addressed in LGDMS

3.1. Problems that occurred during reconstruction after the GEJE

The reconstruction of many damaged areas was delayed because of the time it took for debris disposal and infrastructure restoration, delay of formulation of recovery plans, and added time to form a social agreement. H. Toba, Mayor of Rikuzen Takata City, stated that “Budgeting of our reconstruction projects were assessed by national government. Their assessment procedure was same as usual situation, many our projects was not applicable for their assessment stand ard. These are the harmful effects of compartmentalized administration system. [2].” For example, the national policy of debris disposal for this disaster was to “promote the use of recyclable resources.” This policy was the same as usual situation. To follow this policy, there must be extensive amounts of land for the temporary storage of debris. General land-use was restricted to ensure that there would be enough land to store the debris. An overflow of debris, which occurred in almost every damaged area, disturbed rapid reconstruction.

As stated above, national regulations for usual situation was d irectly applied to disaster reconstruction phase. Attempting to meet these regulations was one of the causes of the delayed reconstruction. It is important to note that each municipal government has significantly different issues depending on its local situation. Municipal governments and residents must make efforts that correspond to each local community’s individual situation.

As a result of delayed reconstruction, the needs for each resident shifted from the planning phase. For example, Kuboyama et al [3] studied the amount of public housing supply, resident’s demand of housing, and the future population in Ishinomaki City, Miyagi prefecture. This city was the worst-hit area. The municipal government formulated housing supply plans based on opinion surveys of residents taken in the early stage of reconstruction. However, population outflow was continuously occurring in the reconstruction phase. The number of households that residents wanted was far below the planned number of households.

3.2. Necessity of not “Disaster Prevention” and “Pre-Disaster Recovery Planning” but LGDMS

Typhoon disasters led the national government to establish The Disaster Countermeasures Basic Act in Japan in 1961. According to the Basic Act, Japan’s basic stance on natural disasters including earthquakes, typhoons, and tsunamis is to prevent damage by developing facilities such as levees. After the Great Hanshin Awaji Earthquake in 1995, almost all Japanese people recognized the limits of this “Disaster Prevention” plan. Later, “Pre-Disaster Recovery Planning” became more common.

Yamanaka [4] shows two interpretations of “Pre-Disaster Recovery Planning” used in Japan. One is "provisioning the disaster and promoting city planning that leads to the minimization of damage” and the other is to "clarify the procedure of recovery measures, and advance collection and confirmation of basic data on recovery before the disaster." Almost all present efforts for “Pre-Disaster Recovery Planning” in Japan are at the starting phases and final phase of reconstruction. The former are detailed disaster forecasting, evacuation, rescue, stockpiling and develop earthquake resistance. The latter are consensus development the future image of the area after the disaster. Both of them are important. However, a more important issue in areas damaged by the GEJE is the move from the starting phase to final phase—especially considering that the countermeasures of tsunami disasters have different characteristics than that of inland earthquakes, as shown in figure 3[1]. In the case of inland earthquake disasters, each phase progresses in stages. In the case of tsunami disasters, rescue operations and restoration work of the living environment are prolonged, and reconstruction overlaps. The image of the disaster, recovery, and reconstruction is thus different and requires different ideas.
3.3. Established prototype of LGDMS

Kakuzaki et al [1] and Kakuzaki [5] established and proposed a prototype of LGDMS with the following procedure:

- Extraction and structuring of all activities necessary for the process from the disaster to evacuation, rescue, restoration, and reconstruction (Establish WBS; Work Breakdown Structure)
- Define relationships and sequence of all activities
- Input all structured activities into project management software
- Estimate and input work volume, necessary duration, and resource of each activities into project management software
- Check constraints such as time, cost, resources, and residents’ opinions of the municipal government, fellow residents, and local industries
- If original plan cannot satisfy the constraint, reconsider the total plan including changing the scope of the work

The above procedure is a quite normal project management strategy. However, scope identification of the process from evacuation, rescue, restoration, and reconstruction is not easy because responsibility of the work in usual situation belong to a single division and others belong to multiple departments. When a disaster occurs, every job should be managed under a single policy and plan for reconstruction. However, Japanese municipalities do not summarize all the steps that must be taken against a disaster.

The creators [1] tried to extract all works and establish WBS in Konan City, Kochi, Japan. Konan City is located on the Shikoku Island southwest of Japan. The overall population of Konan City is around 34,000, 370 of which are administrative officials. They have a long coastline, making them especially concerned about the predicted tsunami damage, (maximum 17 m), that could be caused by the future Nankai megathrust earthquakes. The mayor clarified his attitude to tackle disasters seriously, also promoting plans to relocate to a higher elevation. Konan City is one of the municipalities with the most suitable conditions to establish a versatile LGDMS prototype, considering the urgency, scale, and geographical and topographical conditions. In field work, we held discussions and interviews with the staff of the Disaster Countermeasures Bureau and related departments, including the mayor, regarding the current state of disaster countermeasures. The creators [1] showed concrete problems with the current countermeasure plan and proposed the introduction of a disaster management system. After that, with the cooperation of the city staff, the creators [1] extracted the disaster countermeasure work and created the WBS based on it. The created WBS is composed of 357 activities. Some of the tasks required for the rescue phase are shown in figure 4.

![Figure 3](image-url)
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4. Regional challenges in Shikoku Island

4.1. Transportation and resource problem of Shikoku Island

Emergency logistics transportation for the GEJE is usually called "Operation Comb" and it is well regarded. Okumura and Goso [6] simulated using the same measure for Shikoku Island. Because of the difference in geology and land between the Tohoku area and the Shikoku area, road damage is estimated to be 7.4 times more significant than the GEJE if the same operation is applied to future Nankai megathrust earthquakes, especially in the Kochi area, which is the farthest from mainland Japan among Shikoku Island. This means that Kochi will be isolated from the future disaster rescue phase, recovery phase, and reconstruction phase. Constraints on resources should also be considered in the above matter.

Hasegawa and Goso [7] investigated the amount of construction equipment in Kochi based on the Business Continuity Plan (BCP) of local construction companies. Figure 5 shows location of Kochi in Japan. Figure 6 shows the number of backhoes and operators in each area in Kochi. Figure 7 shows the amount of resource divided by the number of injured persons in case of future Nankai megathrust earthquakes. Figure 8 shows the number of these resources divided by the number of damaged buildings. Amount of resources are not same level of each area. These figures suggest that each area in Kochi must cooperate with each other during disasters. They are required to establish recourse exchange agreement between municipal government, prefectural government and local construction companies.
4.2. Simulation of relocation to higher elevation in Konan City, Kochi
Shioji et al [8] simulated relocation to a higher elevation in Konan City based on the actual situation of Higashi Matsushima City, Miyagi, which was damaged by the GEJE. In this study, WBS was created for the relocation project in Higashi Matsushima based on 201 documents (publicly issued documents by the city government and the minutes of the city council, etc.), interviews with concerned parties, and field surveys. Then, procedures of any activity—including construction work and procedures to obtain approval from governmental organization—were extracted, as shown in figure 9. Later, not only "damage estimate" such as the number of dead, number of damaged buildings, and amount of debris but also "work quantities" such as the number of temporary housing, amount of development land, and excavation volume were estimated.

The authors surveyed any formulated municipality’s plans for disaster all over Japan. However, we could not find a plan with concrete "work quantities." By using the above result, the authors compared four scenarios of a reconstruction schedule depending on the presence/absence of a housing relocation plan and presence/absence of a land-use plan for temporary debris storage. Figure 10 show the results of the schedule analysis. If the housing relocation plan and the temporary storage for disaster debris were decided before the disaster, the overall schedule of the relocation would be shortened by 540 days. Therefore, deciding a housing relocation plan and temporary storage for disaster debris before the disaster is very important, especially for promoting reconstruction. In order to further shorten the period, it is necessary to consider development that requires as little work as possible because assuming the availability of additional resources is not realistic, especially in the case of a major disaster that also affects other areas.
Figure 9. Procedures of relocation projects in Higashi Matsushima, Miyagi, Japan.

Figure 10. Result of schedule analysis on four scenarios of reconstruction for future Nankai megathrust earthquakes in Konan City.

5. Implementation of a disaster management system in Konan City, Kochi

5.1. Present situation of municipalities in Kochi
In Japan, the national government predicts damage based on the Disaster Countermeasures Basic Act, and the municipal governments are in charge of making their own plans. The subcommittee tried to obtain the existing disaster related plans such as countermeasure manuals and regional disaster prevention plans held by all municipal governments in Kochi and to verify the effectiveness of each plan. In addition, the subcommittee introduced the disaster management system to the municipalities by outlining problems such as consistency with other plans and presenting the review and correction.
measures of the whole plan to the municipal governments. Based on this policy, with the cooperation of the Kochi prefecture government, it was also possible to obtain the emergency function allocation plan of each municipal government. This plan tries to extract the necessary functions (temporary housing, shelter, etc.) that must be prepared for the predicted damage in the area, and confirms whether it can allocate existing resources (land, building, etc.) to these functions. Currently, there is no case in Japan where prefectural governments other than the Kochi have collected such information. Researchers believe that such advanced efforts originated from the severe conditions described in Chapter 4.

Table 1 shows part of the totalized result of the necessary functions for future Nankai megathrust earthquakes and existing resources of each municipal government. The future Nankai megathrust earthquakes are predicted in two cases as Level 1 (L1) and Level 2 (L2). Level 1 (L1) is similar to the past earthquakes that occur in the 90-150-year cycle. Level 2 (L2) is the largest earthquake, with a period of a thousand years or more. Not only collapse of many facilities by the earthquake and tsunami, but also Long-term inundation are concerned. Figure 11 show the comparison of the necessary amount of temporary housing for an L2 earthquake between secured sites for temporary housing summarized by five districts in Kochi.

The issues identified in this are as follows:

- Municipalities on the coast cannot ensure the necessary functions independently for both L1 and L2 earthquakes. In particular, shelters, temporary housing sites, and temporary storage of debris sites are in short supply.
- In particular, temporary housing sites will be insufficient even if they cooperate with neighbouring areas.
- Current plans for temporary housing, shelters, waste disposal etc. are not based on this data and need to be corrected.
- It is necessary to be consistent with the future recovery plan in setting the temporary housing construction site.
- Aggregated resources are only facilities and land, etc. People, goods, and economic resources are not aggregated yet.

Table 1. Part of the totalized result of the necessary functions for future Nankai megathrust earthquakes and existing resources of each municipal government.

| District/Municipality | A City (Coastal area) | B City (Coastal) | C City | D town | E town | F town |
|-----------------------|----------------------|-----------------|--------|--------|--------|--------|
| **Basic Information** |                      |                 |        |        |        |        |
| Population (person)   | 50,000               | 34,000          | 29,000 | 4,000  | 5,000  | 4,000  |
| Area (km²)            | 130                  | 130             | 540    | 130    | 320    | 210    |
| Number of death       | 980                  | 540             | 300    | 40     | 100    | 30     |
| Number of injured     | 3,400                | 2,000           | 2,000  | 280    | 740    | 280    |
| Number of evacuees    | 15,630               | 12,120          | 4,850  | 816    | 690    | 350    |
| Number of evacuees    | 14,660               | 12,120          | 5,420  | 1,219  | 720    | 500    |
| 1 day after death     | 9,770                | 7,070           | 4,560  | 1,782  | 560    | 480    |
| 1 week after death    |                     |                 |        |        |        |        |
| Estimated Disaster damage |          |                 |        |        |        |        |
| Disaster debris       | 1,789,000            | 1,427,000       | 337,000| 3,300  | 92,000 | 24,000 |
| Temporary house       | 5,446                | 3,538           | 1,396  | 1,720  | 56     | 127    |
| Medical aid station   |                      |                 |        |        |        |        |
| Storage of relief supplies |            |                 |        |        |        |        |
| Mortuary              | 1,911                | 1,063           | 585    | 131    | 245    | 109    |
| District/Municipality                     | L2 Requirement | A City (Coastal area) | B City (Coastal) | C City | D town | E town | F town |
|-----------------------------------------|----------------|----------------------|------------------|--------|--------|--------|--------|
| Temporary burial area                   |                | 6,248                | 3,443            | 1,913  | 0      | 638    | 0      |
| Temporary debris storage                |                | 379,713              | 304,915          | 86,190 | 8,640  | 24,059 | 6,122  |
| Temporary housing                       |                | 501,700              | 337,200          | 103,500| 15,471 | 18,300 | 12,700 |
| Number of evacuees                      |                | 35,545               | 10,351           | 7,013  | 2,347  | 6,279  | 20,814 |
| (Number of person)                      |                | 27,776               | 13,351           | 6,996  | 2,347  | 20,814 |
| 1 day after                             |                | 7,510                | 4,004            | 5,207  | 2,347  | 20,814 |
| 1 week after                            |                |                      |                  |        |        |        |
| 1 month after                           |                |                      |                  |        |        |        |
| Medical aid station                     |                | 5,592                | 6,132            | 3,178  | 3,030  | 11,533 | 6,892  |
| Storage of relief supplies              |                | 14,926               | 11,489           | 4,706  | 620    | 4,341  | 990    |
| Mortuary                                |                | 5,110                | 2,673            | 0      | 681    | 477    | 471    |
| Temporary burial area                   |                | 20,000               | 28,023           | 0      | -      | 1,400  | 0      |
| Temporary debris storage                |                | 166,484              | 110,498          | 50,986 | 12,768 | 25,740 | 16,471 |
| Temporary housing                       |                | 429                  | 166              | 361    | 15     | 9      | 11     |
| Mortuary                                |                |                      |                  |        |        |        |
| Temporary burial area                   |                |                      |                  |        |        |        |
| Temporary debris storage                |                |                      |                  |        |        |        |
| Temporary housing                       |                |                      |                  |        |        |        |

**Figure 11.** Amount of land for temporary housing toward L2 earthquake and amount of secured land.

5.2. **Present and future activities in Kochi**

The Konan municipal government has requested that the subcommittee implements a concrete management system as an extension of the activities so far. The subcommittees also have researchers from regional universities (Kochi University of Technology), and plan to have support from university organizations. Specifically, in consideration of resource restriction information in the prefecture as described in Chapter 3 and Section 5.1, we aim to implement a management system that can identify measures to shorten the project period as described in Section 4.2. The most important measure of the government is the promotion of relocation to a higher elevation. The relocation of public facilities is being considered in specific areas. Plans for relocation of housing in this area will also be discussed. The subcommittee has also been asked to support the development of a relocation plan to a higher
elevation. The subcommittee will take advantage of this opportunity to attempt to implement LGDMS on a small scale, aiming for deployment across the city and the whole prefecture.

6. Conclusion

We have started an initiative for early recovery from future disasters by implementing LGDMS at the municipality level. There are also problems that the basic municipality can solve independently, problems that require wide area cooperation, and problems that require revision of the legal system. In the future, regional cooperation promotion and recommendations to the central government will be necessary. From the experience of the reconstruction project of the GEJE, it is vital to respond flexibly to social conditions such as population decline and changes in industrial structure. It is also important that the municipal government and residents devise a disaster management system.

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