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Quantitative Evaluation of the Effect of Presence of Regional BCP on Disaster Response

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ABSTRACT

The 2016 Kumamoto earthquake has caused severe damages on economic activities and livelihood of residents through supply chains. Disruptions on the supply of common resources such as food, water supplies, roads and other infrastructure often render the effectiveness of business recovery in widespread region declined. Therefore, a new concept of region-wide BCP is urgently required, which focuses on collaboration among stakeholders including private corporations, local governments and communities as well as residents, in order to enhance the resilience of the region against disasters. This paper focuses on one of the most important elements of regional BCP, information sharing factor in supply chains of disaster relief goods in order to evaluate the effect of presence of regional BCP on disaster response. Through quantitative analysis using the agent simulation of relief logistics from the distribution center in Tosu City, Saga Prefecture to evacuation centers in Kumamoto Prefecture based on actual state of relief goods supply in Kumamoto earthquake.

Keywords: *regional BCP, emergency relief logistics, quantitative evaluation, agent simulation*

INTRODUCTION

The 2016 Kumamoto earthquake has caused serious damage on economic activities and livelihood of residents in Kumamoto Prefecture. The whole afflicted region was faced with shortages of food, water, and so forth. In the past disasters, some corporations could restore normal operations from disruption quickly due to the effective coordination with other companies in their Business Continuity Plan. However, from what we learned in the recent disasters, when a major earthquake occurs, the disruption also includes food, water supplies, roads and other infrastructure. Damage on the supply of these common resources often render the effectiveness of business recovery in widespread region declined. Therefore, a new concept of region-wide BCP is urgently required. JICA has proposed the new concept as Regional BCP in 2013, which is BCP in collaboration among stakeholders including private corporations, local governments and communities as well as residents, in order to enhance the resilience of the region to disasters.

There are many previous research addressing different aspects of collaboration among relevant organizations. Minear (2002) addressed challenges and complexity associated with collaboration in emergency relief supply [1]. Moore et al. (2003) demonstrated collaboration efforts in previous disaster emergency relief operations and assessed the key factors that leads to the failure or success of these efforts [2]. There are also other studies which elaborately describes the actual state of emergency relief logistics in the 2016 Kumamoto earthquake, and summarized effective methods for role sharing and resource utilization according to the characteristics of various private business operators/organizations [3], [4]. However, quantitative analysis and evaluation on the information sharing factor in emergency relief chain collaboration was missing in the previous approaches.

This paper, therefore, focuses on the effect of presence of regional BCP on disaster response through quantitative analysis through the agent simulation of relief logistics. GIS Network and agent simulation using

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Adopting AnyLogic as a software for agent simulation in this study, the model of emergency relief supply chain is built to predict the performance of relief logistics system under various conditions set up according to the actual state of relief logistics in the 2016 Kumamoto earthquake. In this paper, results of simulation are compared each other according to the conditions in emergency relief chain, and the difference in delivery time and compliance of supplies is shown in order to prove that information sharing factor in emergency relief chain collaboration is indispensable and important in relief operations.

RELIEF GOODS SUPPLY IN THE 2016 KUMAMOTO EARTHQUAKE

A. General state of relief logistics in the Kumamoto earthquake

After the first strike of the killer earthquake, primary deliveries of relief supplies are carried out from municipalities and manufacturers throuout Japan to Tosu distribution center; secondary deliveries are performed from Tosu distribution center to evacuation centers located in Kumamoto prefecture as shown in Figure 1. For municipalities in the affected areas, procurement and transportation of relief supplies such as water, food and blankets is the primary work. Since the work is a special task only during emergency, it is extremely difficult for a afflicted municipality to implement the task alone.

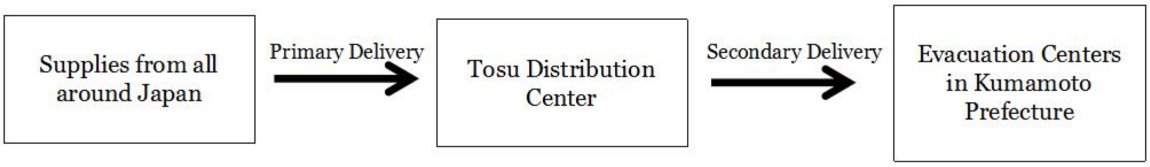

Figure 1: General state of relief logistics in Kumamoto earthquake

B. Actual state on relief goods and provision route

1) About the feature of relief goods: Relief goods are divided largely into "daily delivered food" such as lunch boxes and rice balls that do not have a long-term life and other general merchandise, from the viewpoint of the expiration date and the commercial flow. In the logistics of daily delivered food, temperature control is indispensable for a distribution center and prompt delivery is requested for logistics organizations.

2) About the form of procurement and provision of relief supplies: There are various forms to provide relief goods to affected people through affected local government. They can be roughly classified into the following four categories from the perspective of afflicted local governments as shown in Figure 2 [4]. The first form is that the afflicted municipality provides stockpiled goods having been kept in stockpiling warehouses before the disaster. The second form of "push type support" may be performed in the early stage after the occurrence of disaster. The third form of provision is called "pull type support". Requested items are provided depending on the priority required by the victim. Since the goods required by the affected people change as time passes, temporal matching of supply and demand is effective in this form compared with the push type support. The fourth form is spontaneous donation in which goods are provided by volunteers such as individuals and some private enterprises.

C. About the headquarters system in cooperation with private business operators and organizations

The information processing functions of the department responsible for relief supplies in the disaster headquarters are divided into the following five types (1) through (5):

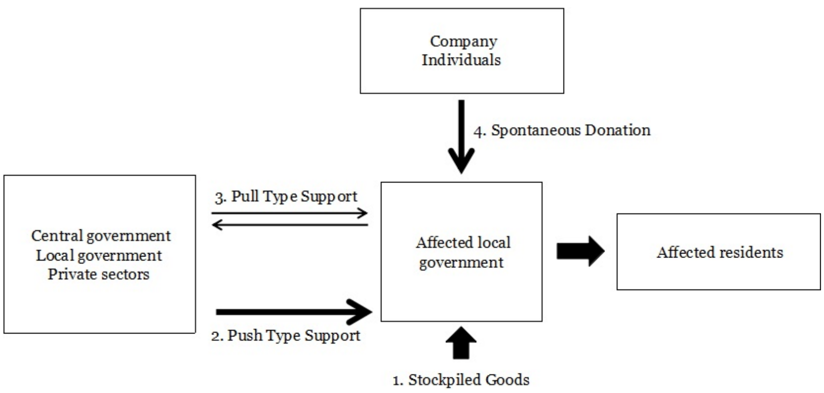

Figure 2: Form of provision of relief goods (after Udagawa [4] corrected by the authors)

(1) information on goods procurement such as items and quantities of relief goods
(2) information on transportation such as the number of vehicles required.
(3) information processing function related to warehouse management
(4) needs information function related to collecting and arranging requests for relief goods.
(5) overall adjustments on planning distribution and delivery of relief goods.

REGIONAL BCP AND CONDITION OF SIMULATION

A. Definition of Regional BCP

Regional BCP designates a direction and outline of collaborated damage mitigation countermeasures and continuation procedures of stakeholders united in the region in order for the effective business recovery.

B. Necessity of Regional BCP

Each enterprise is one of the members of the regional community, and they benefits from external resources such as social infrastructures and environment. The purpose of vital external resources management is to share these resources among stakeholders effectively when a disaster occurs and also to ensure the availability of the resources. Therefore, collaborative efforts are required among the private sector, public sector and the local community to maintain the critical external resources as shown in Figure 3 [5].

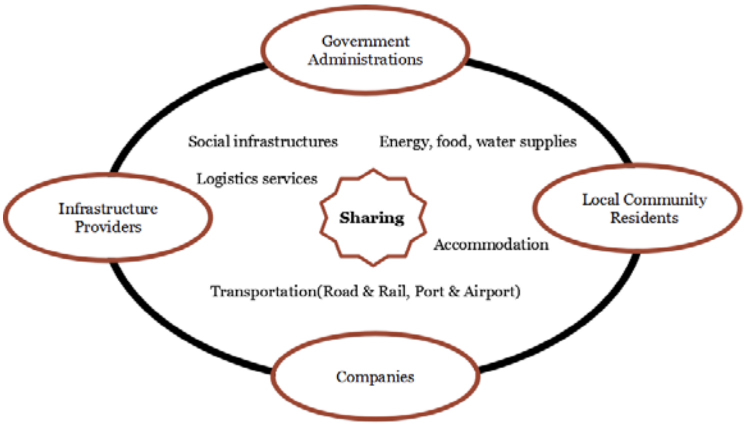

Figure 3: Definition of regional BCP

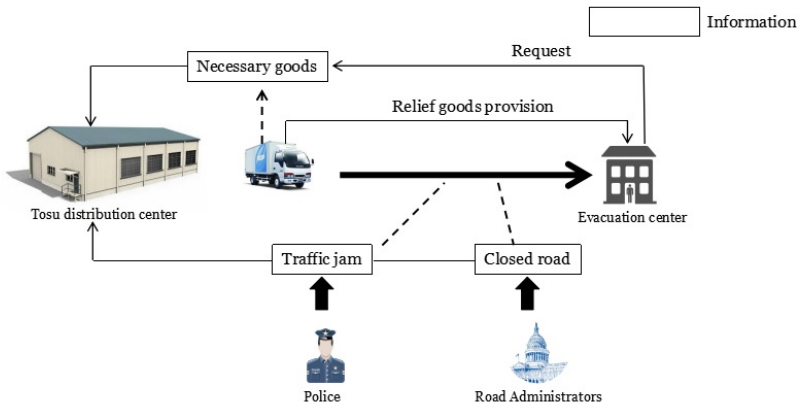

Figure 4: Actual state and condition of simulation for relief supply chain in the Kumamoto earthquake

C. Relationship between actual state and condition of simulation

The form to provide relief goods considered in this study is "pull type support". The disaster-affected municipality, Mashiki Town and Nishihara Village in Kumamoto Prefecture requests necessary supplies to the distribution center in Tosu City, Saga Prefecture. Out of various relief supplies, "daily delivered food" such as lunch boxes and rice balls that do not have a long-term life, should be processed in a short time, and prompt transportation and delivery is critical. Therefore, transportation information on road conditions such as road closure and traffic jam becomes vital.

From the viewpoint of the information processing functions of the department responsible for relief supplies in the disaster management headquarters of relevant organizations, conditions in the following should be taken into consideration in the simulation. The first condition is presence or absence of information sharing on needs for collecting and arranging requests for relief goods. The second condition is presence or absence of traffic information sharing such as closed road and traffic jam information. The third condition is on the propriety on overall adjustment among relevant organizations. Figure 4 demonstrates the actual state and condition of simulation for relief supply chain in the Kumamoto earthquake.

SIMULATION USING ANYLOGIC

A. About agent-based simulation

Agent-based simulation is an effective way for simulating various phenomena in complicated systems. Many tools exist for building agent simulation models in AnyLogic adopted in this study. Anylogic GIS space function allows us to place agents into a geospatial environment defined by an online GIS map, making the agents move at the specified speed from one place to another, executing actions upon agents' arrival, animating the moving or static agents at their locations, establishing links based on layout of the agents, and so on.

B. Conception of simulation model

1) Basic simulation model design: The supply chain model includes one distributor agent located in Tosu City, Saga Prefecture. Two retailer agents are located in Mashiki Town and Nishihara Village, Kumamoto Prefecture, and a fleet of truck agents that deliver the goods from the distributor to retailers. A retailer agent has the function to generate demands and send the order agent to the distributor agent. The order agent is composed of items and quantity of relief goods. The distributor receives orders, and process them and pass them to truck agents. Truck agents receive orders from the distributor and move on the real roads between the origin and the destination of the supply chain on the map. Figure 5 illustrates the frame work of simulation model.

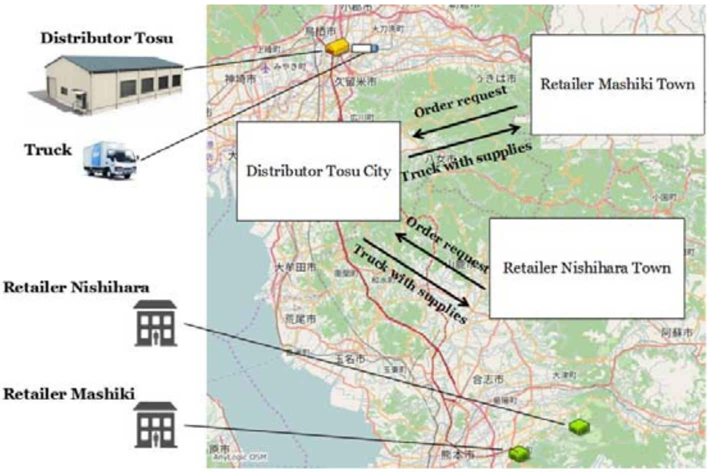

Figure 5: Framework of simulation model

2) Description of simulation process: As the first group of simulation, one destination evacuation center of Mashiki Town was selected. Mashiki Town sends request of relief goods to the distributor in Tosu in this group of simulation. Assuming that the time ordered is 8:00, and that contents of order is 5000 bottles of water and 6500 pieces of confectionary bread. As for traffic situation, traffic jam and closed roads are taken into consideration. Line A-B, E-F, E-G in Figure 6 represents the road route in a normal state, respectively. Truck speed is set as the limit speed for each actual road type; Line C-D shows the road with slight traffic jam where truck speed is reduced slightly lower than the speed limit; Line B-C represents the road with heavy traffic jam where truck speed is greatly reduced. Both the two breakpoints D and F in the figure represent the points where road blockage occurred due to the earthquake.

In terms of order request condition, two scenarios are set up. One is the scenario in which a distributor receives order from a retailer, and the distributor loads right goods on the truck and the truck departs at the right time. Another is the scenario in which a distributor does not receive any request from a retailer. In this case, a distributor has no choice but to load relief goods on the truck and the truck depart at wrong time with the wrong goods until they receive the actual order, because daily delivered foods have to be delivered within an expiration date. Finally, a distributor has to load again at a late time and new truck depart loading the right goods.

Figure 6: Traffic situation of simulation model

In terms of traffic condition, the truck departs from Tosu distribution center, Saga Prefecture to the affected area. Traffic jam usually occurs along the road route. While the closed blockage are concentrated in the earthquake affected area. Thus, the priority of route selection by the driver is as follows:

(1) select the shortest route.
(2) select the route without traffic jam
(3) select the route without road closure

Conditions of relief supply chain simulation on presence and absent of traffic information are classified into four types. They are organized as the principle according to the type of truck as shown in Table 1.

Table 1: Principle of priority for route selection

Type of truck	The first Priority	The second Priority	The third priority
a	○	○	○
b	○	○	×
c	○	×	○
d	○	×	×
Necessary Traffic Information	Shortest Route	Traffic Jam	Closed Road

3) Simulation results: From the viewpoint of the information processing functions of the department responsible for relief supplies of the disaster headquarters, ten cases of simulation were conducted. Case 1 through 8 in the first group of simulation are set up in terms of information on needs for collecting and arranging requests of relief goods, and on presence or absence of traffic information sharing such as traffic jam information and closed roads information. Case 9 and 10 in the second group are set up on the propriety on overall adjustment among relevant organizations. All of these cases and results are summarized in Table 1 and 2 in the following:

Table 2: Results of case group 1

CASE	Supply Request Received? (Y/N)	Traffic Jam Situation known?(Y/N)	Closed Road Situation known?(Y/N)	Compliance of supplies	Departure Time	Time taken to arrive
1	Y	N	N	Right	9:06	11h 29min
2	Y	N	Y	Right	9:06	7h 50min
3	Y	Y	N	Right	9:06	2h 30min
4	Y	Y	Y	Right	9:06	2h 21min
5	N	Y	Y	Right	12:06	2h 21min
6	N	Y	N	Right	12:06	2h 30min
7	N	N	Y	Right	12:06	7h 50min
8	N	N	N	Right	12:06	11h 29min

Table 3: Results of case group 2

CASE	Mashiki Town Supply Request received? (Y/N)	Nishihara Village Supply Request received? (Y/N)	Traffic Jam Closed Road known?(Y/N)	Supply for Mashiki Town	Supply for Nishihara Village	Mashiki Town Departure Time Time required	Nishihara Village Departure Time Time required
9	Y	N	Y	Right	Wrong	9:06 2h 21min	unloading 4h 34min
10	Y	Y	Y	Right	Right	9:06 2h 21min	9:06 2h 47min

As shown in Table 2, there is extremely large time difference is recognized among 8 cases. For example, the truck arrived the destination with right supply in only 2 hours and 20 minutes in case 4. On the other hand, the truck departed three hours later than optimum timing and took 11 hours and 29 minutes to reach the destination in case 8. The time difference between two cases is more than 12 hours, from the viewpoint of the expiration date of the relief goods, prompt transportation and delivery is critical.

Case 9 and 10 in Table 2 are set up under the premise that the truck drivers has possessed the traffic information in both cases. As for Case 9, the distributor only possesses needs information from Mashiki Town, while the distributor possesses needs information from both Mashiki Town and Nishihara Village in case 10. Correct goods were loaded on trucks for Mashiki Town, while wrong goods were loaded on trucks for Nishihara Village in case 9. In case 9, a tuck arrived Mashiki Town and unloaded the goods once there. Then, the truck left for Nishihara Village with the wrong goods. In case 10, on the other hand, two trucks departed separately. One truck left for Mashiki Town directly and another left for Nishihara Village without stopping and unloading at Mashiki Town. As a result, it took almost 2 hours longer to complete the task in case 10 than that in case 9. Furthermore, the wrong goods which had not been requested were delivered to Nishihara Village in case 9. Therefore, the result in Table 3 revealed that overall adjustment carried out by smooth information sharing among relevant organizations in charge of relief supply was extremely important.

CONCLUDING REMARK

This paper focuses on one of the most important elements of regional BCP, information sharing factor in supply chains of disaster relief goods in order to evaluate the effect of presence of regional BCP on disaster response. Through quantitative analysis using the agent simulation of relief logistics from the distribution center in Tosu City, Saga Prefecture to evacuation centers in Kumamoto prefecture based on actual state of relief goods supply in Kumamoto earthquake. Conclusions obtained in this paper are summarized as follows:

(1) The time difference with and without information sharing among relevant organization in charge of relief supply is more than 12 hours, from the viewpoint of the expiration date of the relief goods, prompt transportation and delivery is critical.

(2) Overall adjustment carried out by smooth information sharing among relevant organizations in charge of relief supply was extremely important.

(3) The effect of presence of regional BCP which enhances smooth information sharing was proved to be critical in relief supply chain as the countermeasure against large disasters.

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