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Application of Soft Systems Methodology in Solving Disaster Emergency Logistics Problems

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***Abstract*—**In recent years, many high intensity earthquakes have occurred around the world, such as the 2011 earthquake in Tohoku, Japan. These large-scale disasters caused huge casualties and losses. In addition, inefficient disaster response operations also caused the second wave of casualties and losses, and expanded the damage. Effective disaster management can be used to respond to the chaotic situation, and reduce the damage; however, some inefficient disaster response operations are still used. Therefore, this case study chose the 921 earthquake for analyzing disaster emergency logistics problems and proposed the Soft Systems Methodology (SSM) to solve disaster emergency logistics problems. Moreover, it analyses the effect of human factors on system operation, and suggests a solution to improve the system.

***Keywords*—**Soft systems methodology, emergency logistics.

I. Introduction

EVERYTIME a natural disaster occurs, many people get killed or injured; moreover, some victims are trapped in collapsed buildings and unable to move. Therefore, the fast rescue operation in the golden 72 hours is the first issue after a disaster. In addition, homeless victims immediately face the four basic livelihood issues: food, clothing, housing, and transportation. Thus, relief supply transportation becomes the second issue after a disaster. If Search and Rescue (SAR) teams and relief supplies cannot rapidly arrive in the affected area, the death toll will rise, and victims will live without enough relief supplies such as food, drinking water, medical supplies, and tents. Therefore, disaster emergency logistics is the key to avoid such consequences. However, if disaster emergency logistics planning is not complete, the SAR team dispatch and relief supply distribution will be chaotic, and efficiency will be greatly reduced. In order to avoid such consequences, this study uses the SSM methodology to build a complete disaster emergency logistics system including SAR team dispatch and relief supply distribution. We also propose to analyze the difficulties faced by disaster victims in Taiwan where natural disasters such as earthquake, typhoons, flood, and so on hit very frequently.

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As of now, Taiwan still needs to conduct good emergency planning to meet the relief needs of the people in the affected zone. People always complain to the government about the poor efficiency of disaster relief. The government has improved disaster relief system after each natural disaster, but still needs to improve the efficiency of operations and people's satisfaction. The objective of this study is to build a complete disaster emergency logistics system by analyzing human factors.SSM methodology was developed by Checkland in the 1980s. SSM is a use of the systems thinking to solve the problem of social-system. It is mainly used to tackle those that contain a large number of social, political, and human factors issues. Obviously, SSM is different from Hard System Methodology, which uses the quantitative and technical methods to solve all kinds of "hard" problem. SSM applies systems thinking in the real practice of human society, and also recognizes that human social organization is a complex system. It is a very effective way to explore the complexities of human society, and resolve its own messy non-technical issues. There are seven steps in the SSM.

II. Literature Review

Emergency logistics is the response to sudden occurrence of a serious natural or man-made disaster, sudden public health incidents, public safety incidents and military conflicts, and to meet the demand of relief materials, human resources and funds. In addition, it can be divided into military emergency logistics and non-military emergency logistics. Emergency logistics is a special case of general logistics activities. It has seven characteristics different from general logistics activities: 1) Sudden and Unpredictable, 2) The Randomness of Demand, 3) The Urgency of Time Constraints, 4) The Peak of Demand, 5) Weak Economy, 6) Unconventional, and 7) The Joint Participation of the Government, NGO, International Government and Agencies. When a major disaster occurs, it always destroys many buildings and structures and kills people. However, some people survive a major disaster but they lose their homes, belongings, jobs and businesses. More serious aftereffect is that a few people still get trapped in damaged buildings, and wait for help. Therefore, quickly rescuing the trapped victims and providing relief supplies to the disaster areas are the most important tasks after a major disaster, and the completion of these tasks is exactly what emergency logisticians do. In other words, a good emergency logistics system will determine the efficiency of disaster relief. The Golden 72 Hours and relief supply distribution are two important factors in natural disaster emergency logistics.

The Golden 72 Hours

Many emergency disaster experts think that the golden 72 hours after disaster is the period during which human can survive with physical strength without food and water. Fig. 1 shows that the survival rate is 90% within 24 hours, 50%-60% between 25 and 48 hours, and 20%-30% between 49 and 72 hours. After 72 hours, the survival rate is 5%-10% or less. Thus, quickly rescuing more victims within the golden 72 hours is the most important issue.

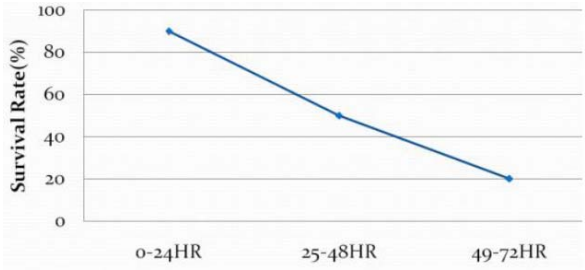

Fig. 1 Statistics of Rescue Time and Survival Rate [5]

III. Relief Supply Distribution

Natural disasters destroy bridges, road, rail lines and other infrastructure interrupting outside communication. Victims face not only life-threatening danger but also shortage of relief supplies; therefore, establishing an emergency logistics network to transport relief supplies to each disaster area is the major process in emergency logistics. The process of emergency logistics network is that the relief suppliers transport supplies to each relief distribution center, and then the relief distribution centers dispatch appropriate relief materials to each disaster area. Thus, in the situation of limited relief supplies availability, dispatching appropriate supplies based on individual needs and overall fairness is the difficult problem for a distribution center. Disaster policy makers must quickly make complex decisions in uncertain dynamic environments. Earthquake scenario is the most difficult case to make decisions because it has characteristics of sudden and multi-hazard. It also causes aftershocks or secondary disaster, and sometimes secondary disaster brings more losses. Thus, the focus of related studies has gradually changed from disaster prevention and mitigation to emergency logistics.

Taiwan is located in the largest and most active circum-Pacific seismic belt; therefore, earthquake activity is very frequent. On September 20, 1999, the 921 earthquake happened, and it highlighted the many problems of Taiwanese disaster emergency logistics. Reference [2] constructed the domestic disaster relief logistics system in order to improve the efficiency of relief supply distribution. He proposed that Taiwanese disaster relief logistics system should use 3PL, cross docking, and supply chain. In order to improve the deficiencies of government and NGOs in the management and distribution of relief supplies, he suggested that the material distribution job should be handled by a professional logistics industry, and the government should use public power to provide supervision or assistance such as land acquisition or collection of vehicle.

Reference [1] interviewed some relief workers who were actually involved in relief material demand side, supply side, and distribution side of the 921 earthquake. He used their experiences and suggestions to analyze the supply locations, transportation and space. In addition, he compared earthquake logistics with general logistics and found that there are similar operating procedures between earthquake logistics and general logistics. Reference [9] introduced the concept of fourth party logistics (4PL) into disaster relief logistics system. It provides logistics planning, consulting, logistics information system, and supply chain management to first-party, second-party, and third-party, but it does not actually assume specific logistics operation activities. In other words, 4PL is a supply chain integrator, a leading force in the supply and demand sides, and the third-party logistics, but not a logistics stakeholder. Based on 4PL, [9] suggested that the government should set up a logistics center, prepare material distribution plan, and integrate non-profit organization (Red Cross, Tzu Chi Foundation, and Volunteer Fire Fighters) for the consistency of logistics administration and command as shown in Fig. 2.

Further, [2] used the concept of Stackelberg equilibrium to solve the post-disaster stockpiles distribution problem. His study focused on how to make a fair distribution between the central government and the county governments. Under the uncoordinated situation, the county governments report demand quantity for seeking their own maximum benefit, the central government guesses the number of the actual need of the county governments to allocate resources, and it constitutes the Stackelberg competition. He recommended that there is a variety of human problems to be considered in the resource distribution.

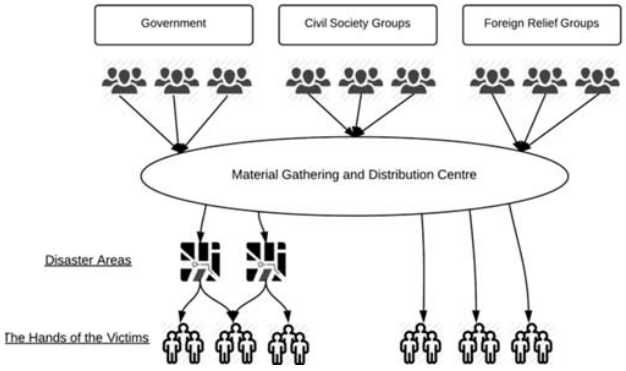

Fig. 2 The Proposed Disaster Relief Logistics System [9]

Reference [3] studied the implementation of natural disaster relief system in Northern Song Dynasty (960AD-1127AD) of China. He found that the government already had the complete administrative system and institutions for natural disaster relief in place. However, the effectiveness of disaster relief did not have the desired effect. According to his analysis, there were three key problems in the disaster relief system. First, there were too many institutions responsible for one disaster, no one coordinated them, and that caused each institution

having different opinion with others in relief execution. The second problem was centralization, where all requests had to be submitted to the top, and a final decision was made by the highest ranking minister and emperor. Third, some local administrators were corrupt and the central government could not get the correct information about local disaster situation. Reference [3] concluded that the human factors affected relief execution in Song Dynasty of China; otherwise, it was actually a perfect relief system when compared to modern systems. Reference [7] studied the role, function and organization of SAR team in the light of 921 earthquake disaster and highlighted that a good SAR team depends on excellent equipment, personnel, and organizational structure. However, without a complete system, a good SAR team is still unable to do its best in disaster relief work. Based on the review of above literatures, natural disaster emergency logistics has more uncertainties than general logistics, with insufficient information. The present disaster relief logistics system in Taiwan is totally controlled by the government, and it is difficult to achieve the ideal system by combining the government with professional logistics companies. Therefore, this study tries to build the complete disaster emergency logistics system which is fully controlled by the government and combines the SAR team dispatch with relief supply distribution. As most studies have used mathematical approaches to analyze the relief distribution in the past, this study focused on human factors, and used Checkland's SSM to analyze the problems in the 921 earthquake.

IV. Case Study

The 921 earthquake, also known as Jiji earthquake was a reverse fault earthquake in the mountains of central Taiwan. The tremor measured 7.6 on the Moment magnitude scale, 7.3 on the Richter scale, and the focal depth was 8.0km. It was the deadliest earthquake after the World War II and the entire island of Taiwan felt severe shaking. It lasted 102 seconds, and killed 2,415 people, injured 11,305 and 29 missing. There were several aftershocks of intensity 6.8 on Richter scale and the greatest impact occurred at 2:16 am. Moreover, 57,711 buildings were destroyed, 53,768 damaged, and caused NT$300 billion worth of economic loss. The aftershocks were the main reason why the 921 earthquake damaged more buildings than any other earthquake. Subsequently, many countries around the world contributed to disaster relief and sent SAR teams and working dogs to Taiwan. They were stationed in different disaster zones after landing in Taiwan. According to National Fire Agency (NFA), a total of 21 countries, 38 foreign emergency SAR teams, 728 people, and 103 SAR dogs arrived to assist the rescue work. These international SAR teams had participated in many earthquake rescue works of the world, so they had rich experience in on-site relief and carried a number of advanced SAR equipment. They were helpful to disaster area building security monitoring, initial exploration of disaster scene and information collection, establishment of command system, arrangement of personnel and security maintenance, rescue and establishment of medical concepts.

V. A Problem

The 921 earthquake had two typical problems: SAR team dispatch and relief supply distribution.

A. Search and Rescue (SAR) Team Dispatch

The operations efficiency of a SAR team depends on its well-trained members, the appropriate relief tools, equipment, and logistical support. However, Taiwan did not have the domestic SAR teams equipped with human life necessary equipment, satellite communications equipment, global positioning system (GPS), geographic information system (GIS), life detector, infrared finder, and other high-tech rescue equipment and apparatus in year 1999. In addition, there were no professional and technical personnel in SAR teams to assist in rescuing human life. In this condition of congenital deficiency and acquired disorder (lack of high-tech equipment and apparatus), the effectiveness of earthquake rescue operation was inevitably reduced. The domestic SAR teams could not rescue victims immediately who were trapped in collapsed buildings. They had to wait for the arrival of international SAR teams. However, the trapped victims could not wait for delayed rescue efforts. Although the international SAR teams had arrived in Taiwan immediately after the disaster, they could not use their experienced professionals and equipment to enhance rescue efficiency due to some problems. The following are three real cases that can describe the difficulties the international SAT teams encountered in the rescue operations.

1. Bureaucratic SAR Team Dispatch

When the Czech SAR team arrived in Puli disaster area, they immediately asked the staff of the local town hall, fire department, and military where to start rescuing. However, they did not get the proper reply and were directed to the Ministry of Foreign Affairs which contacted the NFA, and NFA further contacted the local command center to operate. The local command center did not have enough power to dispatch international SAR team, and had to wait for permission from the central government.

2. No Unified Management

As per the French SAR team, each international SAR team lacked communication with other teams and had disagreement with each other. This affected the opportunity of SAR teams to find survivors.

3. Same Place Was Detected by THREE Different SAR Teams

The Spanish SAR team began to detect signs of life under collapsed buildings and could not find any survivors because that area had been detected by the Japanese SAR earlier. After the Spanish SAR team left, the South Korean SAR team came to the same spot and repeated the same operation [4].

These three real cases highlighted the bottleneck in the rescue operation due to bureaucracy, and each international SAR team did their own work independently without communicating with other teams. If the local command center could dispatch international SAR teams to disaster areas

without waiting for permission from the central government, the international SAR teams could quickly enter the disaster area, to rescue more victims. Moreover, the chance of finding survivors could be greatly increased if the relief center could build the communication bridge to link each international team.

B. Relief Supply Distribution

After the 921 earthquake, the government set up the central processing centre to coordinate and command relief efforts and immediately informed each city and county to set up a disaster management for relief work within 20 minutes. However, the central command system did not master the immediate and complete information, and lacked ability to integrate. This resulted into rescue effectiveness greatly reduced. The following are three main problems of relief supply distribution.

1. A Few People Monopolized Relief Supplies

There was an influx of nearly 2000 victims in one of asylum centers of Taichung, which included eight communities. Although there was a steady stream of supplies from all social circles, the supplies distribution was controlled by one of the communities and the other seven communities could not get any relief supply. The reason was the biased treatment by the community which controlled the distribution of supplies. Moreover, some village chiefs monopolized the supplies, and different factions of the villagers could not get any relief supply. The government did not coordinate it [5].

2. The Conflict between Central Government and County Government

After the disaster, the local government should set up disaster response centre in charge of local disaster prevention and rescue service and the central government should set up a central disaster response centre to oversee and coordinate the local disaster prevention and rescue service. However, homeless victims immediately faced four basic livelihood issues: food, clothing, shelter, and transportation. Subsequently, the county government urgently asked the central disaster response centre for basic livelihood supplies to ensure the survival of the victims. But the top decision-making unit faced problem of allocating relief resources and fair measures. The county government used the largest efficacy of way to submit the required relief quantity to the central government after estimating the victims' needs. However, some county governments overstated their demand when they noticed that the central government was discounting their demand volume. In the end, victims were the worst losers in this conflict.

3. No Complete Control over the Flow of Relief Supplies

After the disaster, not only the government provided relief supplies to victims but also some generous people actively donated supplies to the disaster areas. However, the government did not control them and let them directly enter the disaster areas. Moreover, there was no administrator to handle the relief supplies from the donors. It resulted in repeated issuance and leftover of relief supplies.

These three problems caused the unbalanced distribution of relief supplies to each area, and as a result some areas did not have enough relief supplies. The relief supplies distribution had a serious problem.

VI. Construction of Model

The following seven steps of Checkland's SSM were used in the model construction and solution.

A. Identification of the Problem

As described above, the disaster emergency logistics system was not efficient due to two important factors: SAR team dispatch and relief supply distribution. The first response should be saving human lives. The job of SAR teams is to fast search survivors within the golden 72 hours. However, the emergency logistics system in the 921 earthquake had some problems during this stage of rescue operation. One of the problems was that Taiwan could not find any local SAR team with special equipment and trained personnel at that time and they had to wait for help from international SAR teams. Even after the arrival of international SAR teams in Taiwan, the local command centre did not have authority to dispatch international SAR teams which came under the central government's jurisdiction. Moreover, the local command centre did not coordinate with international SAR teams who were new to the place, which resulted into repeated search effort by international SAR teams. The second response after disaster is to provide relief supplies to victims. However, the disaster logistics system was inefficient in this case, and faced serious supply side and demand side problems. a. Supply Side problems. Although the relief supply distribution was controlled by the government, it did not manage the relief supplies donated by the public. This resulted into some disaster areas having more supplies than other disaster areas. In addition, some county governments submitted inflated demand quantity requests assuming that the central government supplied less than the requested quantity. Consequently, the unbalanced distribution of supplies occurred and some county governments received more supplies [6]–[10].

B. Demand Side

With the unbalanced distribution of relief supplies, some disaster areas had excess relief supplies and the government did not redistribute the excess relief supplies to other areas which had shortages. The excess relief supplies were left on the ground to perish, and the government did not completely control the demand side. This caused a few people monopolizing relief supplies, and other people could not share. Thus, the emergency logistics system had many shortcomings [7].

C. Expression of the Problem Situation

1. SAR Team Dispatch

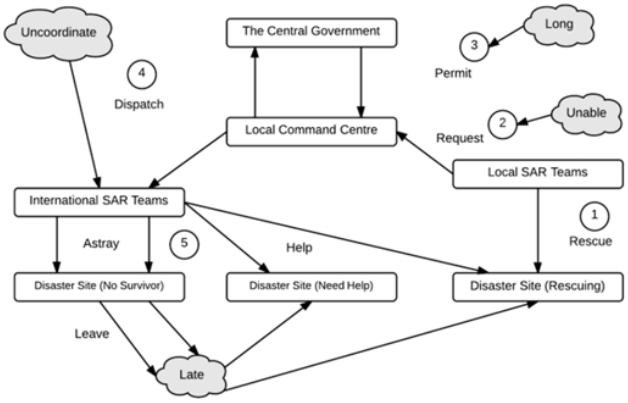

Fig. 3 The Rich Picture of Problem Situation of SAR Team Dispatch

Referring to Fig. 3, the disaster rescue system can be divided into five steps: 1) after disaster, local SAR teams immediately come to the disaster site to rescue people, 2) if some survivors are trapped in the difficult condition which local SAR teams cannot handle, then local SAR teams will ask for dispatching international SAR teams, 3) local command centre forwards the request from local SAR team to the central government, and after examination, the central government permits local command centre to dispatch international SAR teams, 4) local command centre dispatches international SAR teams, and 5) international SAR teams leave for each disaster area for rescue operation. As the rich picture shows, domestic SAR teams obviously did not have enough ability to rescue all survivors by themselves, and had to ask international SAR teams for help. However, international SAR teams could not immediately come to disaster site because local command centre must get permission from the central government prior to dispatching them to the disaster site. Therefore, the time spent was too long from request to dispatch, and some survivors might have died during that period. Moreover, international SAR teams could not arrive on time due to poor guidance, coordination and assistance.

Referring to Fig. 4, the system of relief supply distribution had problems from start to finish. Firstly, all county governments submitted the relief materials demand quantity requests to the central government. However, some of them overstated the demand quantity in order to get more relief supplies. This resulted into some county governments receiving more than what they needed and the rest of the counties faced shortages. After receiving the relief supplies, county governments transport them to each township district office, and then each township district office transports relief supplies to each disaster area. According to the rich picture, there are two problems in disaster areas: i) the mountains of relief supplies due to civil society groups, and their relief supplies not included in supply quantity, and ii) government not controlling the flow of relief supplies after distribution. These result in unbalanced distribution of relief supply.

2. Relief Supply Distribution

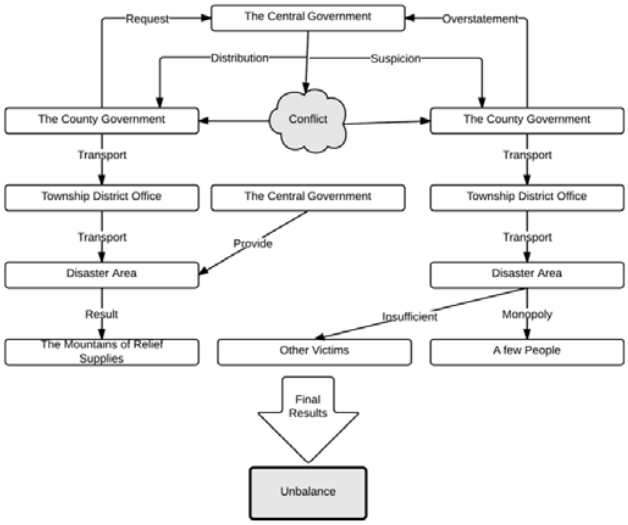

Fig. 4 The Rich Picture of Problem Situation of Relief Supply Distribution

D. Formulation of the Root Definition

1. SAR Team Dispatch

Customer: The job of SAR team is to search more survivors under rubble and rescue them as soon as possible. Therefore, the number of persons rescued depends on rescue efficiency. If a system is good, more survivors will be rescued. If a system is bad, the death toll will rise.

C: The customers are survivors.

Actor: Local command centre is responsible for SAR team dispatch. SAR teams cannot go into action without permission from local command centre.

A: The actor is local command centre.

Transformation Process: The system changes focus on the principles of the golden 72 hours.

T: The SAR team dispatch will be more efficient and quick.

Weltanschauung: Although SAR teams have high-tech equipment and talented people, they cannot work without a good system. The quality of a system will affect rescue efficiency.

W: Improve the efficiency of SAR team dispatch so that more survivors can be rescued.

Owner: The central government controls all rescue operations and the international SAR teams. The local command centre must follow central government's orders and ask for its consent to dispatch international SAR teams.

O: The owner is the central government

Environmental Constraints: The related laws will affect the efficiency of SAR team dispatch.

E: The environmental constraint is related laws.

2. Relief Supply Distribution

Customer: The function of system is to provide relief supplies to victims, thus victims place demand orders for relief supplies. In other words, they are beneficiaries in the system.

C: The customers are victims.

Actor: The county governments submit demand request to the central government to receive relief supplies and to transport relief supplies to each township district office. The township district offices are responsible for distributing relief supplies to each affected area.

A: The actors are the county governments and township district offices.

Transformation Process: The system changes focus on the principles of balance and equity.

T: The distribution of relief supplies will be more balanced and fair.

Weltanschauung: After a disaster, the major mission is to handle the lives of victims, thus distribution of relief supplies becomes a key to reduce the damage. Once the lives of victims are stable, post-disaster reconstruction work will be completed smoothly.

W: Improve the efficiency of distribution of supplies to let every victim get enough relief supplies.

Owner: The central government controls all the relief resources and distribution of relief supplies. Therefore, its decision will affect the result.

O: The owner is the central government

Environmental Constraints: As the civil societies groups are not subject to the government control, they provide relief supplies in the disaster areas independently. However, their relief supplies are not counted in the total supply. Thus, supply quantity exceeds demand in some disaster areas resulting in surplus supplies. In addition, a few people monopolize the relief supplies after distribution.

E: The environmental constraint is civil societies groups and a few people.

VII. Construction of the Conceptual Model

A. SAR Team Dispatch

1) Deploy excellent equipment and personnel in domestic SAR teams
2) Identify information of disaster situation in each disaster area
3) Dispatch local SAR teams to each disaster area
4) Identify how many disaster areas need assistance of international SAR teams
5) Identify how many international SAR teams each disaster area needs
6) Allocate international SAR teams to assist each local SAR team
7) Coordinate and control

Each international SAR team comes from a different country. Thus, they have different languages, cultures and operations. Decision-maker has to build a communication bridge between them, and coordinate them to finish rescue operations without repetition of work.

B. Relief Supply Distribution

1. Reserve Adequate Relief Resources in Peacetime

- Identify information of disaster situation in each disaster area
- Identify all the relief resources to be used for relief distribution.

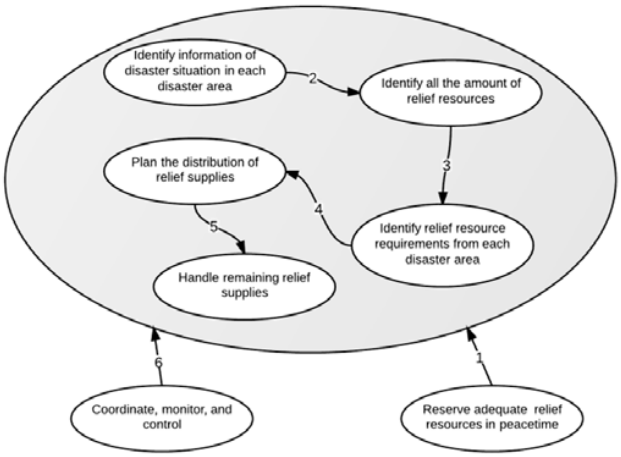

Fig. 5 Conceptual Model of Relief Supply Distribution

2. Identify Relief Resource Requirements from Each Disaster Area

3. Plan the Distribution of Relief Supplies

Based on the disaster situation information and reserve quantity, decision-maker plans the distribution of relief supplies as per the relief resource requirements from each disaster area.

4. Handle Remaining Relief Supplies

If relief supplies exceed demand, relief distribution centre will have leftover supplies.

5. Coordinate, Monitor, and Control

Some victims complain about the relief distribution; thus, decision-maker has to coordinate, monitor flow of relief resources and control whole process to avoid any arising conflict.

C. Comparison of the Model with Reality

1. SAR Team Dispatch

TABLE I
COMPARISON OF THE MODEL WITH REALITY

Conceptual Model	Reality
Deploy excellent equipment and personnel in domestic SAR teams	Domestic SAR teams did not have high-tech equipment and apparatus. Moreover, team members were inexperienced in disaster relief
Identify disaster situation information in each disaster area	The government did not understand information of disaster situation clearly
Dispatch local SAR teams to each disaster area	The government immediately dispatches local SAR teams to disaster areas after disaster
Identify how many disaster areas need assistance of international SAR teams	The government did not know which disaster area needs assistance of international SAR teams
Identify how many international SAR teams each disaster area need	The government did not know the number of international SAR teams they should dispatch to each disaster area
Allocate international SAR teams to assist each local SAR team	The government did not allocate international SAR teams to disaster areas
Coordinate and control	The government did not coordinate international SAR teams. Its control system was bureaucratic

2. Relief Supply Distribution

TABLE II
COMPARISON OF CONCEPTUAL MODEL AND REALITY

Conceptual Model	Reality
Reserve adequate relief resources in peacetime	Reserve was not enough for relief
Identify information of disaster situation in each disaster area	The central government did not understand information of disaster situation clearly
Identify all the amount of relief resources	The central government understood how many relief resources they can use
Identify relief resource requirements from each disaster area	The central government did not know the correct demand requests from county governments
Plan the distribution of relief supplies	The central government had planned the distribution of relief supplies
Handle remaining relief supplies	The government did not handle leftover supplies
Coordinate, monitor, and control	The government did not coordinate conflicts, strictly monitor flow of relief supplies, and control whole process.

VIII. DEFINITION OF CHANGES

A. SAR Team Dispatch

1) The government must build the standard SAR teams

The standard SAR team has not only members who undergo a rigorous physical training and special SAR techniques training but also high-tech special disaster precise rescue equipment.

2) The government must understand information from each disaster area clearly

Before dispatching SAR teams, government has to know the following information clearly: how many people trapped, in which disaster area, and how many SAR teams the area needs?

3) The government must make a plan for international SAR teams
4) The government understands details of disaster situation better than the international SAR teams. They can plan for international SAR teams, and the teams can follow plan to perform rescue operations. Each area will get reasonable relief to avoid the waste of human resources.
5) The government must coordinate international SAR teams, and change control system

Each international SAR team has different work style. Thus, the government should build a communication bridge between them, and coordinate them to work together. In addition, the government must change their control type.

B. Relief Supply Distribution

1) The government must prepare enough reserve for relief in peacetime.
2) The central government must understand information of disaster situation in each disaster area.
3) The government must handle remaining relief supplies.
4) The central government must coordinate conflicts, strictly monitor flow of relief supplies, and control whole process.

IX. ACTION TO SOLVE OR IMPROVE

After a disaster, the central government must set up a central command centre to control disaster relief process, and inform each local government to set up local command centers. After establishing the local command centers, local command will immediately dispatch local SAR teams to each disaster area for rescuing victims. Before international SAR teams arrive, domestic SAR teams should rescue survivors as soon as they can. In addition, they must share all the information with local centers.

So far, the new system is almost like old system. However, the process of international SAR team dispatch is changed in the new system. After international SAR teams arrive, the central command centre will combine them, and then allocate them to each local command centre according to criticality of disaster situation. Subsequently, international SAR teams will follow the order from local command centers to assist local SAR teams in rescue operations.

In the new system, local command centers have authority to control relief operations. The job of central government is to coordinate international SAR teams and legitimately allocate them to each disaster area based on the degree of disaster situation. In addition, the domestic SAR teams are able to rescue more survivors because the government has established the standard SAR teams. Thus, minor damage can be handled by local SAR teams, and the central command centre only needs to dispatch a few international SAR teams to such disaster areas. SAR team dispatch is just the first and the second step is to distribute relief supplies to victims.

After a disaster, each county government immediately submits the request for relief supplies to the central government according to its disaster situation. Inevitably, a few county governments exaggerate the quantity due to biasedness. However, the central government has the details of disaster situation when it dispatches SAR teams; thus, it can plan for distribution of relief supplies. If there is a conflict between the county governments, the central government must coordinate them, and solidify them to solve the problem. After

the county government receives relief supplies from the central government, it transports supplies to each township district office. However, the process is changed in the new system. The government sets up distribution centre for distribution of relief supplies, and all relief supplies will be transported there. Distribution centre is responsible for collection and distribution of relief supplies. In addition, the relief supplies which were provided from civil society groups also have to be transported to the distribution centre and the government can easily monitor the flow of relief supplies. The process becomes orderly, not chaotic like the old system. Each distribution centre has to contact others. It is important to reserve relief material in peacetime rather than preparing relief supplies after a disaster occurs. The government must build a certain number of warehouses for relief material reserve, and store adequate quantity of material in these warehouses. After relief period ends, the government must replenish the relief materials, and handle the leftover materials for the next disaster relief project.

X. Conclusion

The main contribution of this paper is to apply SSM to construct the model of disaster emergency logistics system including SAR team dispatch and relief supply distribution based on the analysis of problems in the 921 earthquake. This study used the seven steps of SSM to find the human factors affecting the whole system operation, and the solution for improved rescue efficiency and balanced distribution. The scope of emergency logistics includes not only materials but also human resources. Moreover, the success of disaster emergency logistics system depends on prior preparation and complete structure. Information is a key factor in disaster emergency logistics. Decision-maker must clearly understand disaster situation information before making a decision. Furthermore, centralization can allow the central government to control the whole system easily, but efficiency is very low. Thus, the central government should give local units authority to execute process decisions. Controller must coordinate all units to ensure system operation. If there is any conflict at any unit, controller must jump in and avoid the paralysis of the system. Any disaster emergency logistics plan must consider all human factors.

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