African Journal of Business Management Vol. 6(34), pp. 9718-9729, 29 August, 2012
Available online at http://www.academicjournals.org/AJBM
DOI: 10.5897/AJBM11.718
ISSN 1993-8233 ©2012 Academic Journals

Full Length Research Paper

Emergency supply chain management: Case study of Taiwan

Shuo-Yan Chou and Dayjian Chen*

Department of industrial management, National Taiwan University of Science and Technology, No. 43, Keelung Rd, Sec. 4, Taipei, Taiwan.

Accepted 17 May, 2012

Disasters did not happen often, but when they occurred, noticeably, the governor belittled and delayed rescue actions due to poor preparations at peacetime; consequently, all residents suffered huge damages and losses in human lives. The disasters always include tsunamis, volcanic eruptions, hurricanes, terrorism, tornadoes, and earthquakes etc. When the disasters occurred, in order to rescue injured patients on time, supplies must be available at the right time to meet the emergency demands. This is especially true with regard to the difficult and serious process of disaster aftermath recovery management. Consequently, this study is of current importance. To reduce the dangerous impacts and losses from disasters, aftermath rescue recovery problems and effective disaster supply management are vital. The findings of this study are that disaster demand and supply management focuses on three main requirements: (1) Low cost, (2) high-performance and effective-operations, and (3) few risks. The study employed a heuristic algorithm and used computational analysis to demonstrate the power of the algorithm. The results showed that transportation management played the most important role in a successful rescue.

Key words: Emergency demand and supply management, tsunamis, earthquake, epidemic infection, rescue manager.

INTRODUCTION

A large-scale disaster emergency supply chain management is very different from a business supply chain management, which manages the forward and backward supply chain of a manufacturing system. Cowing et al. (2004) main large-scale disasters always include tsunamis, volcanic eruptions, hurricanes, terrorism, tornadoes, and earthquakes etc. However, the large-scale earthquake disaster occurred with shocking frequency and with horrifying results in terms of deaths, injuries, missing people, homelessness and infrastructural damage.

Noticeably, when the disasters occur, the disasters always have the worst impacts which results in quite helpless conditions due to the compound and complex nature of these disasters such as earthquakes, tsunamis, giving rise to nuclear radiation damages. For example China, Japan, South Korea and Taiwan etc. are countries that have these strong chances of compound and complex disasters giving rise to nuclear radiation damages. Therefore, these international disaster and dangerous issues of nuclear radiation damages should be strongly studied by disaster scholars and professionals.

Furthermore, when the disasters occur, in terms of the disaster outgoing demands, urgent execution of rescue actions is required for the dead, patients in danger, the severely injured, the homeless, accident waste, etc. Disaster emergencies require the incoming demands for food, doctors, nurses, drinking water, part time volunteers, and rescue equipment supplies that must be met in a short period of time. Thus, the mechanism for managing these incoming and outgoing accident demands and demand supplies is called disaster supply chain management (DSCM) or aftermath recovery management (ARM).

This study applies effective applications of industrial engineering techniques and management to the real life problem of disaster supply chain management, such as

*Corresponding author. E-mail: d1382@ms77.hinet.net. Tel: +886-2-2737-6327. Fax: +886-2-2737-6344.

an 8.6-strength (Richter scale) earthquake in Taiwan. This study provides valuable solutions to problems concerning disaster supply chain management. According to the empirical reports of a 1999 earthquake in Taiwan, earthquake accident demands and supplies should consist of five important items relating to causes and effects, as follows:

(1) The government sets up permanent or disaster recovery organizations, such as a disaster recovery coordinator in the Ministry of Interior Affairs, disaster recovery distributors at the provincial or state level and/or disaster recovery nodes in districts to manage demands, supplies, and to execute disaster rescue activities. However, temporary disaster organizations should be considered failures in rescue activities because during peacetime, the government's permanent offices must automatically prepare future disaster rescue plans and policies and create the documents necessary for civilian part time volunteer rescue agreements, lists of names of skilled civilian professionals, etc.
(2) A disaster rescue manager plays a key role in district disaster recovery activities, as he has received training in and has become familiar with rescue operations and has the individual characteristics necessary for emergency operations, such as real-time operational abilities and the ability to make competent emergency decisions without delays.
(3) The disaster rescue manager organizes skilled civilian professionals in time for disaster recovery operations from lists of names that are updated daily. These skilled professional civilian part time volunteers support rescue activities on crucial days for one or two days at a time, and include doctors, nurses, paramedics, excavators, bulldozer operators, heavy machine operators, helicopter pilots, etc.
(4) The disaster rescue manager should execute the effective and correct use of limited resources in time (for instance, medical supplies, stretchers, food, rescue equipment etc.). There must be efficient and effective transportation management to get rescue resources to the receivers. The rescue manager ensures that each delivery is documented with the driver's name, time of arrival, and item details to help avoid noncontact with receivers and unloading items in the wrong place.
(5) The district disaster rescue manager ensures that the correct rescue items and the correct quantities of items are moved. The main rescue items include professionals, volunteers, stretchers, ambulances, excavator drivers, bulldozer drivers, helicopter pilots, medical supplies, rescue equipment, food, drinking water and transportation cost etc. They cost us lots of money (Kavalec and Woods, 1999; Jansson, 1994). This work is a part of transportation management.

Thus, the empirical DSCM must fulfill all of the aforementioned five important requirements in a disaster area. Although, the emergency rescue teams and volunteers do not know each other before the disaster occurs, they are required to work together with effective and close co-operation.

Maintaining all of the above factors is extremely difficult for disaster rescue managers. Revelle (1996) was of the opinion that the temporary disasters organizations must have failed in their rescue activities.

Disaster supply chain management has become an important field of study due to the damage caused by large-scale emergency accidents, such as earthquakes, hurricanes, terrorism, tsunamis, tornadoes, etc. (Srivastava, 2008; Lee and Kim, 2002; Erenguç et al., 1999). Rescue managers should effectively and efficiently respond to emergency accidents, providing a high volume of supplies and successfully rescuing those who have been injured in time. Well-planned DSCM intensely relies on coordination between the empirical abilities of senior rescue managers and the professionals and part time volunteers of non-profit civilian organizations (Chiu and Zheng, 2007; Min and Zhou, 2002).

According to an empirical analysis, disaster rescue activities strongly depend on civilian individuals and organizations without political and payment considerations. The rescue activities focus on efficient scheduling and demand and supply planning for high performance. In fact, they are the most important factors for success (Larson, 2004; Erkut and Verter, 1995) for example, in peacetime, rescue managers must keep information regarding rescue resource items, suppliers' prices, quantity and quality, delivery time and so on to simulate and empirically revise a disaster relief schedule. Thus, disaster rescue activities have two characteristics, one of which is the temporary supply and the urgent requirements of a few days, and the other of which consists of high volume rescue demands, namely, professionals, volunteers, ambulances, stretchers, excavators, bulldozers, helicopters, food, medical supplies, rescue equipment, and temporary storage spaces (Sheu et al., 2005; Min et al., 2002; Jayaraman et al., 2001; Fleischmann et al., 2000a).

The remainder of this paper is organized as follows. Subsequently, the study presents the disaster background and Taiwan experiences. Thereafter, it addresses the emergency rescue issues. Then, it develops a model of a heuristic algorithm for resolving emergency supply chain problems. Afterward, it computationally analyzes and evaluates the algorithm's efficiency through a case study. Finally, discussion and conclusions were presented.

Background

Chiu and Zheng (2007) use real-time mobilization decisions for multi-priority emergency response resources. Chen and Chern (1999) chose the shortest path algorithm to resolve problems related to supply chain networks configurations, and adopted an algorithm for scheduling problems. Awadh et al. (1995) resolved various types of planning problems in supply chain networks. Jayaraman et al. (2001) used a mixed integer programming (MIP) formula to resolve emergency supply and demand problems. Petrovic (2007) developed problem-solving methods based on genetic algorithms. These studies offer good methods that greatly assisted the present study.

Taiwan earthquake

This disaster study uses strong empirical data from the September 21, 1999, Taiwan earthquake. The earthquake center was on land, Nan-Tau city (the most earthquakes were on sea, and therefore, sea earthquake could give rise to a tsunami). Taiwan earthquake measured 8.6 on the Richter scale. This earthquake left 2,500 dead, 300 missing, 3,000 homeless and 5,200 houses requiring rebuilding. Strong damages and losses were estimated at US$5.8 billion, as a result of the earthquake center being on land, and not in sea. This study uses a mixed integer programming (MIP) formula to resolve emergency supply and demand problems (Jayaraman et al., 2001). The predominant data used in this study was provided by the association of Taiwan disaster supply management.

Taiwan's disaster experience management

Taiwan experiences of disaster demand and supply management focuses on three main requirements: (1) low cost, (2) few risks, and (3) high performance. Thus, using empirical management data and the professional knowledge of disaster rescue volunteers, this study highlights the following five novel findings:

(1) The government sets up three levels of disaster recovery organizations, namely, (a) Disaster recovery coordinators, (b) disaster recovery distributors, and (c) disaster recovery nodes for emergency disaster rescue activities.

(A) Level one, in central government, coordinates disaster recovery operations with the Ministry of Interior Affairs. These officers prepare disaster legislation and regulations, and monitor all regulations of awards for rescue volunteers and professionals, and punish those who steal rescue money or invade and occupy resources. They are also in charge of disaster plans and rescue standard operation procedures for coordinators, distributors, and nodes, including both operations in peacetime and when disasters happen.
(B) Level two sets up disaster recovery distributors at the provincial or state level. These officers are in charge of finances and rescue equipment, helping nodes to execute recovery activities. Few disaster countries can omit this level. Positions are usually given names such as disaster recovery California distributor, disaster recovery Florida distributor, etc.
(C) Level three sets up disaster recovery nodes at the district level. The node leader is a rescue manager who conducts disaster recovery activities at local capacity and is in charge of executing recovery activities following the standard operation procedures (SOP) from a coordinator (Fleischmann et al., 2000b). Examples include disaster recovery Houston node and disaster recovery Austin node. When many nodes exist in the same city, the names can be more granular, such as disaster recovery Houston M012 node, where the M refers to a medical professional group and the number 012 provides a serial number. In the case of disaster recovery Houston V168 node, the V refers to volunteer group, and so on.

(2) The disaster rescue manager and district staffs should be well trained and perform emergency supply activities without delay at high levels of performance.
(3) The transportation management of incoming and outgoing demands is strongly based on low cost, few risks, and high performance. It is the first important task in all successful rescue activities.
(4) In outgoing demands, the first priority is to send dangerously injured patients to outside hospitals. The second priority is to remove vulnerable groups including the poor, women, children, the elderly, the handicapped, and people with pre-existing mental disorders etc.
(5) In peacetime, the district rescue manager effectively conducts supporting plans of morality and justice, for example, rescue manager always visits the general secretary of district medical associations for doctors, and nurse associations for nurses etc., and signs an agreement organizing helicopters from the air force and the army within two or three days of an emergency.

By analyzing the above five novel findings, this study provides more empirically valuable knowledge pertaining to disaster supply chain management, therefore, provides valuable information regarding real-life problems. However, when the disaster occurs, noticeably, the governor belittles and delays rescue actions and poorly prepares at peacetime, all residents have huge damages and losses in human lives.

Taiwan experiences of disaster rescue activities

In the event of a large-scale disaster, issuing supplies has the following requirements: First, urgent provisions of temporary supplies within a few days of the disaster; second, heavy transportation requirements responding to a high volume of rescue demands, resources, and accident waste; third, a strong demand for skilled rescue managers; fourth, aftermath recovery management, the success of which saves lives and reduces the disaster

Victims' losses. This study analyzes and focuses on four key points and offers the solution of a heuristic algorithm via a computer model (Awadh et al., 1995; Chern et al., 2008; Pati et al., 2008; Min et al., 2002; Lee and Kim, 2002).

Main rescue actions

There are two main rescue actions in disaster supply chain management, incoming demand and outgoing demand rescue actions consecutively.

Incoming demand rescue actions

Incoming demand rescue actions include sending skilled medical professionals and needed supplies to disaster areas as soon as possible. These include male and female volunteers, doctors, nurses, food, drinking water, medicine, medical supplies, bulldozers, excavators, trucks, ambulances, helicopters, drivers and pilots, fuel suppliers and mechanics and rescue equipment such as patient stretchers, oxygen and masks, tents, patient clothes, and covers, all of which are immediately needed at demand nodes. Therefore, incoming rescue demands should be shipped into the appropriate nodes by their due dates.

Outgoing demand rescue actions

Outgoing demands involve immediately sending out patients, the severely injured, the dead, the homeless and disaster waste materials from disaster areas. The outgoing rescue demands should be performed in time to send the dangerously injured to nearby hospitals as soon as possible to save more human lives. However, the appropriate node is extremely important because all the dangerously injured patients in a disaster have very short golden rescue time and if they are transferred to the wrong hospitals, they will likely die. Thus, transportation managers and intellectual drivers should send dangerously injured patients to suitable hospitals.

Hospital information is very important for ambulance drivers. For instance, AA hospitals have surgery professionals, BB hospitals have orthopedic professionals and CC hospitals have heart and lung internal medicine professionals. Ambulance drivers should know this information from their drivers' manuals, which are provided by district disaster recovery nodes to prevent drivers from going the wrong way. The manager of transportation management conducts these tasks. However, what if the ambulance drivers from disaster areas have questions regarding the transport of one, two, or three patients to the same hospital in one trip, which patient can be transported in the next trip (Chiu and Zheng, 2007; Kara et al., 2003). Outgoing rescue demands have a very strong impact on successful rescue activities because outgoing rescue demands sending out dangerously injured patients to nearby hospitals where they can obtain good care and more safety. Therefore, sufficient available transportation resources and effective management are necessary (for example, the number of helicopters urgently sent to the scene of an accident, the number of container trucks for high-volume incoming and outgoing demands, etc.). Thus transportation management should be efficiently managed so that rescue actions can more easily approach success (Erkut and Verter, 1995; Button, 1990). For this reason, during the first two days of a disaster rescue, the heroes are always helicopters.

Process of disaster occurrence

When the disaster is occurring, the rescue coordinators and managers can easily find all suitable volunteers from their name lists. Therefore, this permanent rescue organization can conduct and show strong competitiveness while working at a high level of performance, dependent on effective training and preparation in peacetime.

This study emphasizes that international professional volunteers should also be welcomed, as they are highly experienced rescue professionals. Therefore, disaster recovery coordinators should give them a one-hour orientation, provide mobile phones for international attendees, show information related to dormitory arrangements, and offer the name lists of corresponding personnel in English or other international languages. The purpose of this orientation is to provide support and resources, for instance, food, water and the corresponding group leaders from name lists. This orientation refreshes their abilities, allowing them to effectively and efficiently complete their high-performance rescue activities, which is especially important because patients injured in a disaster area have very short golden rescue time.

International volunteers are highly skilled in professional rescue tasks and will provide excellent rescue performances when they are fully supported. Thus, when the disaster occurs, noticeably, the governor belittles and delays rescue actions and poorly prepares in peacetime, all residents suffer huge damages and losses in human lives.

Aftermath for relief operations

The empirical analysis performed by this study shows how the aftermath for relief operations has not achieved important rescue tasks for the government service thus far. The uncompleted lists of government continuous servicing are as follows:

(1) The most affected sectors required intense recovery, in the area of housing, agriculture, fisheries, infrastructure, and a healthy environment relating to epidemics and public health care;

(2) There was no outbreak of infectious diseases, but public health care department especially has to prevent infectious diseases and epidemic infection;
(3) Vulnerable groups should continuously be taken care of without social issues, including the poor, women, children, the handicapped, the elderly, the homeless, and people with pre-existing mental disorders;
(4) Emergency rescue medical supplies, food, drinking water resources, etc. were distributed to virtually all affected disaster recovery nodes;
(5) All disaster rescue staffs and assistant managers always monitored and prevented stealing, invading and occupying rescue resources;
(6) Temporary shelters, such as tents, sleeping bag and covers, were availably transferred to all homeless;
(7) Hundreds of thousands of tons of disaster debris were cleaned.

Aftermath for epidemic infection and public health care

This study stresses epidemic and public health care issues where urban areas were particularly hard-hit by the disasters. When the disaster is happening, epidemic infections and public health care concerns impact the disaster areas because epidemics from huge numbers of dead bodies of humans, fish, pigs, domestic animals and fowl can occur. For this reason, these dead humans and animals should be incinerated.

As demonstrated by this study, epidemics can be the second disaster for humans. The second disaster from epidemic infection always happens in areas with temperatures over 32℃. Since this temperature is very suitable for epidemic infection. Chern et al. (2008), for the purpose of preventing epidemics and providing public health care to reduce morbidity and mortality, this study outlines six necessary preventive tasks for the government services:

(1) The reconstruction phases should be highly efficient for epidemics and public health care. The partial destruction of urban infrastructure can provide a good opportunity to build modern exhaust water and garbage disposal systems.
(2) The modern urban exhaust water system infrastructures should be redesigned to accommodate the huge volume of flood and typhoon disasters, with the safety exhaust factors (for water infrastructures) at a minimum of three times the suitable volume to allow for the high flexibility inherent in disaster flooding.
(3) The safety codes and regulations of buildings and infrastructure should be updated, and earthquake-resistant construction techniques should be used as prescribed by double safety policies.
(4) Disaster recovery should improve urban planning with regard to pollution reduction and efficient transportation systems (for example, spatial planning, city development strategies, etc).
(5) Cities may receive a disproportionate share of recovery resources because they must be better-equipped than remoter rural areas.
(6) Public health, the lives of disaster victims, and health care system issues are strongly impacted by disasters.

Therefore, to establish health care as the first priority, the government should set up detection and response systems for epidemic prevention. Assessing the quality of health care should focus on the public health care of humans, domestic animals and fowl, with efforts aimed at avoiding cross-infection. Humans, domestic animals and fowl will accumulate large numbers of deaths due to poor aftermath recovery without effective solutions for public health care related to epidemic prevention.

This study shows the empirical operations and real rescue problems of a 1999 earthquake in Taiwan. Figure 1 shows the disaster supply chain framework including coordinators, distributors, and district nodes.

This study used a heuristic algorithmic model to solve the emergency supply chain of real rescue problems subsequently.

Model

A model of heuristic algorithm was developed to solve emergency supply chain problems and to define important parameters and notations of the model as described (Chern et al., 2008; Pati et al. (2008); Min and Zhou (2002); Awadh et al. (1995). The notations of the model indicate the following:

『ST』: The shortest transportation traveling-time.

The transportation from district demand node to distributor is shown by round robin shortest path algorithm in which the best transportation movement is the fastest traveling time from demand node to distributor.

『LC』: The lowest cost of transportation planning.

Distributor to district demand node shown by minimum cost path algorithm, in which the best transportation movement is the minimum unit cost from distributor to district demand node. Note the three costs, namely, transportation costs, traveling costs, and flexible supply storage costs.

『*THijml*』: The transportation threshold of the supplies.

The supplies storage periods using transportation equipment from district demand node *i* to distributor *j* for suppliers *m*:

Assumptions

The disaster supply chain operations and management

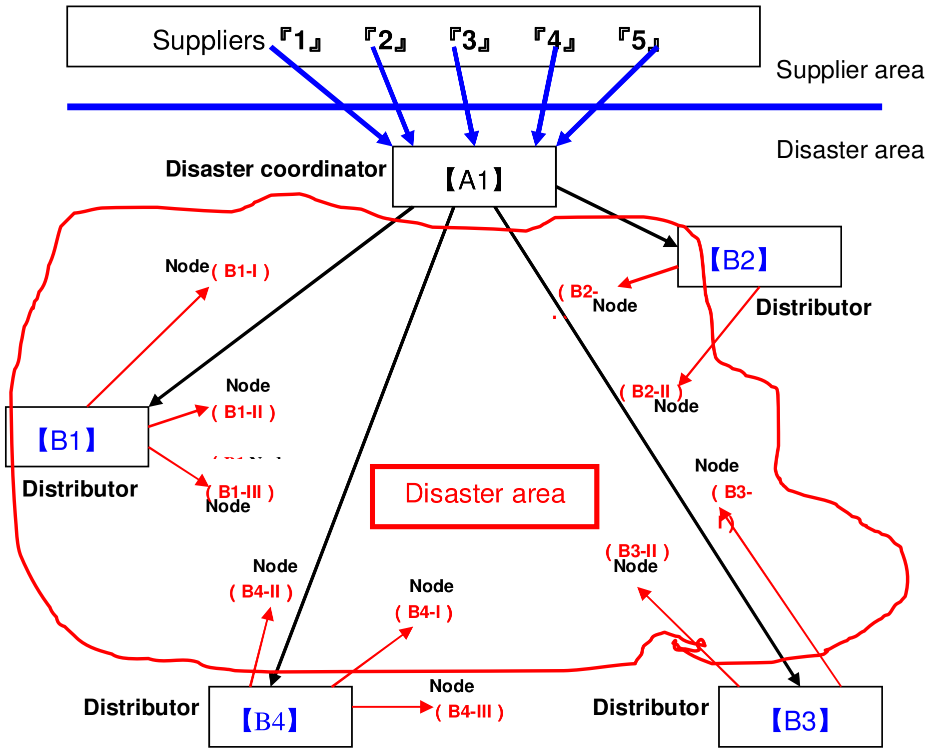

Figure 1. Disaster supply chain framework and nodes. 『1』『2』『3』『4』『5』 Suppliers from disaster outside; 【A1】 disaster coordinator 【B1】 - 【B2】【B3】【B4】 Disaster distributors and temporary storage space; **(B1-I)-(B4-III)** Disaster emergency demand and supply certain nodes; **(B4-III)**Disaster non-emergency node for less patients and homeless; ⟶ Supply and demand control line.

are incredibly effective in responding to the incoming demands and outgoing demands in emergency disaster areas and are able to fill them in a short period of time.

Given: Disaster rescue managers have extensive experience. They professionally conduct disaster supply chain management with high performance. These performances are always without delay for incoming demands, such as doctors, nurses, drinking water, food, and volunteers. Outgoing demands are all complete and on time.

Find: The operations of the disaster supply chain require high performance in terms of the shortest traveling-time and the lowest cost; the cost is important in determining the impact of the rescuing emergency supply chain.

Therefore, the formula with parameters is shown in Equation (1) and includes transportation costs, operation costs, storage costs, and transportation time from district demand node to distributor. Transportation costs are the main cost factor because they significantly affect the total system costs (that is operation costs and storage costs). These significant impacts can be seen in the results of the computational sensitive analysis. The formula with parameters is shown in Equation (1) including transportation costs, operation costs and storage costs.

$$THijml = [(OCl + TCl \times Tijl) / \mathrm{Min}\{RCaj, RCtl\}] / SCnj, \quad (1)$$

Where, *OCl* is the operation cost for equipment *l*; *TCl*, the transportation cost for equipment *l*; *Tijl*, the time needed for equipment *l* to be transported from district demand node *i* to distributor *j*; *RCaj*, the remaining capacity of distributor *j*; *RCtl*, the remaining capacity of transportation equipment *l*; *SCnj*, the units supply storage costs of item *n* at distributor *j*.

The disaster transportation management planning algorithm, DTMPA's four steps E1, E2, E3, and E4, of computer operations are provided in definitions as follows:

(E1): In transportation planning, convert multi-function distributor into demand, single-function. Compute *THijml* for each distributor *j*, district demand node *i,* based on the feasible use of each piece of transportation equipment.
(E2): Group and sort demands using the Disaster Transportation Management Planning Algorithm (DTMPA) these demands base on rule based mechanism.
(E3): If there is any super-group of unplanned demands, retrieve the next super-group of demands and go to (E4).

Table 1. Taiwan 1999 earthquake main demands.

Items	Quantity	Time	Items	Quantity	Time
Truck drivers	900 h	In time	Medical supplies	150 kg	In time
Excavator drivers	850 h	In time	Medicine drugs	100 kg	In time
Ambulance drivers	33 h	In time	Patient stretcher	200 sets	In time
Doctors	500 h	In time	Tents	30 sets	In day
Nurses	1,100 h	In time	Sleeping bags	300 sets	In day
Volunteers	1,250 h	In time	Garbage place	20 sets	In day
Bulldozer drivers	700 h	In time	Waste materials	800 Kg	In day
Helicopters	19 h	In time	Disinfect	600 m^2	In day
Drinking water	380 Kg	In time	Temporary house	50 sets	In day
Food	280 Kg	In time	Storage space	2,000 m^2	In day

Quantity data are in 10 days on an average. The quantity column's hour meaning is working hours x people/day. Data from the association of Taiwan disaster supply management.

Otherwise, stop and output the final plan.
(E4): Activate Round Robin Shortest Path Algorithm (RRSPA) and Minimum Cost Path Algorithm (MCPA) to find the delivery plan, *LC* and *ST*, for the super-group of demands. Go to (E3).

In transportation planning the first step (E1), all multi-function distributors of the disaster supply chain network is converted to single-function nodes. In the second step (E2), DTMPA groups and sorts demands base on a rule-based mechanism. DTMPA then checks the stopping condition and retrieves the next unplanned super-group of demands in the third step (E3).

In the last step (E4), DTMPA activates RRSPA to look for the shortest traveling-time movement, *ST*, based on the traveling time to move from distributor to district demand node. DTMPA activates MCPA to find the lowest cost, *LC*, based on the cost of moving the available equipment from the district demand node to distributor. The DTMPA iterates (E3) and (E4) until all demands have been planned. Though DTMPA seems straightforward, there are several challenges.

METHODOLOGY

Data collection

This study focuses on Taiwan's earthquake disaster research regarding experimental disaster demand and supply management because the Taiwanese earthquake had a strong impact on the government. Therefore, the demand and supply data collection is supported by the association of Taiwan disaster supply management, and the data error is less than ±2%. These sample data are from Taiwan 1999 earthquake, which measured 8.6 on the Richter scale. This valuable data is presented in Table 1, Figure 1, Figures 2, 3 and 4.

As shown in the large experimental sample shown in Figure 1, a disaster supply chain network (with nodes) consisting of one coordinator【A1】, four distributors from 【B1】 to【B2】, 【B3】, 【B4】, and ten demand nodes from (B1-I), (B2-I), (B3-I), to (B4-III) series was also tested. The major disaster demands from certain nodes are presented in Table 1. Figure 2 shows main professional demands; Figure 3 indicates food and medical drug demands, and Figure 4 illustrates the emergency demand for helicopters and ambulances.

RESULTS

This study provides an example of a computational analysis. The disaster transportation management planning algorithm (DTMPA) took 168 min to plan all 3800 demands and the results were very close to the actual data, assuming that unlimited capacity was resolved by DTMPA in the disaster. Finally, it was found that DTMPA can easily resolve this kind of problem, as demonstrated in the foregoing. The value of parameters such as transportation costs, operation costs, storage costs, and the capability of facilities are known. In order to resolve this problem, Giannikos (1998) mathematical programming language (MPL) software was used.

Resolving the above problems, the objective value obtained was 1,195,479.3. A sensitivity analysis was used to determine how sensitive the model is to changes in the value of the parameters of the model, and to changes in the structure of the model. This study uses Jayaraman et al. (2001) mixed integer programming (MIP) formula to resolve emergency supply and demand problems. In this study, there was difficulty in data acquisition and parameter estimation of disaster demand and supply management.

Sensitive analysis of parameters

This study focuses on analyzing parameter sensitivity, which is the cost of recycling the system network. This means changing the value of transportation costs, operation costs, and storage costs by multiple change rates from -30 to 30%.

Table 2 indicates that the total costs reduces from 1,195,479.3 to 515,879.5 when the unit costs of

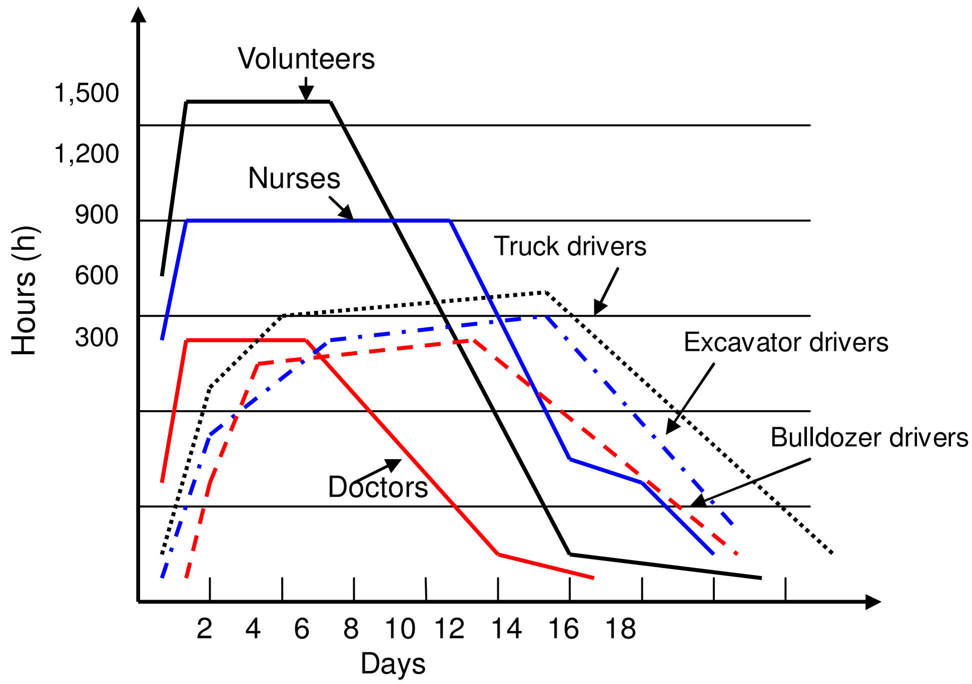

Figure 2. Main professional demands.

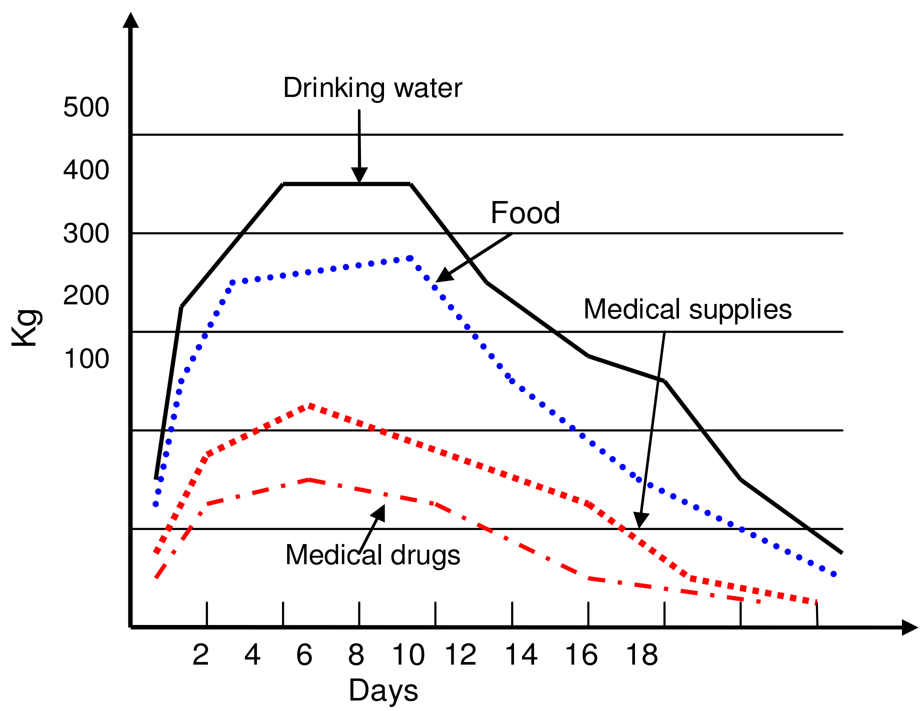

Figure 3. Food and medical drug demands.

transportation decrease 30%, otherwise the total costs rises as the transportation costs increases. The total costs ratio changes 0.1894 (1-0.8106 = 0.1894) for unit transportation costs increases each 18.94%. Table 3 shows the operation costs' decrease of 30% that leads to the total costs of 1,195,479.3, which later reduced to

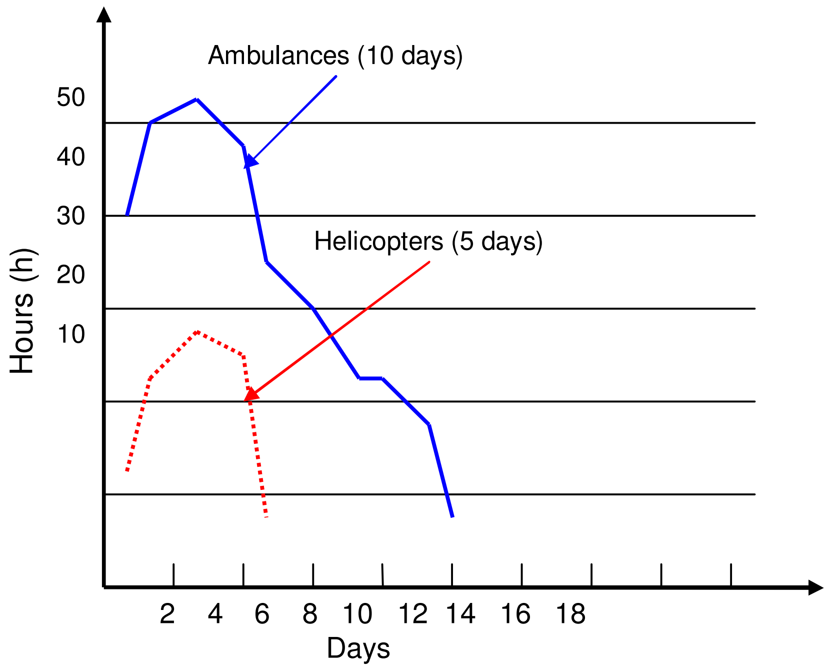

Figure 4. Helicopter and ambulance demands.

Table 2. Differences between transportation costs and total costs.

Change rate	**-30%**	**-20%**	**-10%**	**0%**	**10%**	**20%**	**30%**
Total cost	515,879.5	742,412.7	968,945.9	1,195,479.3	1,428,337.8	1,648,545.9	1,874,037.5
Cost ratio	0.4316	0.6211	0.8106	1	1.1948	1.3789	1.5677

Table 3. Differences between operation costs and total costs.

Change rate	**-30%**	**-20%**	**-10%**	**0%**	**10%**	**20%**	**30%**
Total cost	1,175,965.9	1,182,247.9	1,188,948.9	1,195,479.3	1,201,986.9	1,208,437.5	1,215,005.1
Cost ratio	0.9837	0.9889	0.9945	1	1.0163	1.0108	1.0055

1,175,965.9.

As stated in the contract, if the operation costs increases, the total costs will be increased. The total costs change rate is 0.0055 (1-0.9945 = 0.0055) for unit operation costs increase each 0.55%. Table 4 presents the total costs at 1,195,479.3 which increase by 30% until 1,177,688.1 when the storage costs increases by 30%. Otherwise, the total cost reduces when the storage cost increases. The cost ratio changes, 0.0052, (1-0.9948 = 0.0052) when the storage costs decrease each 0.52%.

Figure 5 shows that transportation costs are the main cost factor because they significantly affect the total system costs. The change rate of operation costs and storage costs impact the total costs. It can be seen from the result of the computational sensitive analysis; the results of numerical studies have indicated that transportation costs play the first important role in this model.

As a result, the efficient way to reduce the disaster supply management total costs is to effectively reduce the transportation costs. Therefore, a very important perspective of successful disaster supply chain management is efficient planning and conducting of transportation management.

DISCUSSION AND CONCLUSIONS

Incentive society justice strategy is the main finding

This study addresses the findings as follows. First, an incentive society justice strategy is strongly required for

Table 4. Differences between storage costs and total costs.

Change rate	-30%	-20%	-10%	0%	10%	20%	30%
Total cost	1,213,426.9	1,207,282.9	1,201,538.7	1,195,479.3	1,189,320.8	1,183513.6	1,177,688.1
Cost ratio	1.0150	1.0098	1.0050	1	0.9948	0.9899	0.9848

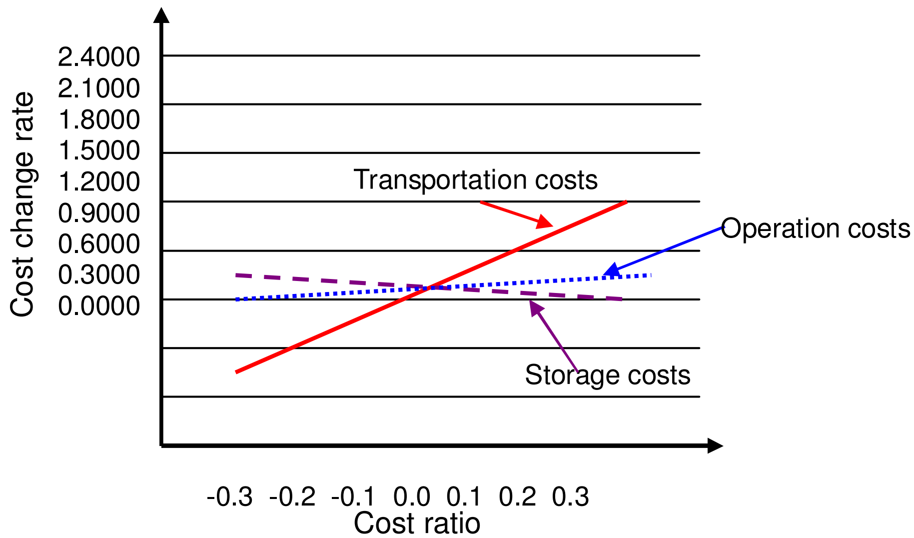

Figure 5. The results of sensitive analysis.

rescue activities. The Governor or the Minister of Interior Affairs grants an award to the volunteers in the aftermath of rescue activities. The honorable ceremony associated with granting an award provides an excellent incentive to excite societal justice and consciousness.

Second, the principle of successful disaster recovery operation and management should be planned during peacetime. Disaster recovery planning is predominantly conducted by intellective and high performance rescue managers. Their knowledge and experience are of vital importance to building up and maintaining the disaster standard operation procedures (SOP).

Third, strategies for rescue activities must not be changed during rescue operations and should follow disaster SOP. Fourth, the successful rescue activities are based on both complete preparations during peacetime and effective communication regarding rescue resources when the disaster is happening. Fifth, substantial rescue failures and losses are due to poor communication between groups. To maintain high performance, the group name lists are necessary.

Aftermath recovery tasks

This study stresses that successful rescue activities must be completely prepared in peacetime and diligently executed by the district rescue manager. Therefore, it is very important to set up permanent disaster recovery departments, to approach success in rescue recovery management, and to conduct four main operations; these include (A) to fully prepare in peacetime, (B) to effectively implement the planned disaster rescue operations while a disaster is happening, (C) to properly manage the aftermath of relief operations and (D) to properly manage the aftermath regarding epidemic infection and public health care as follows:

Peacetime

This study recommends that the rescue manager of each district disaster recovery node prepares seven main tasks at peacetime. First, the rescue manager should invite civilian qualified volunteers and enthusiastic volunteers to join the rescue project. Second, the rescue manager should collect civilian volunteers' professional skills and their related rescue fields. District rescue managers should invite different skilled volunteers to practice rescue recovery simulations to create team cohesiveness and effectiveness.

Third, all rescue volunteers should sign a volunteer agreement confirming their participation in the disaster recovery project; they should also be involved in evaluations of group leaders. The rescue manager should further assign leaders of different skills and related fields. Fourth, the rescue manager should prepare rescue lists of professional names and associated skills in related fields from district medical associations for doctors, from nurse associations for nurses, and from general associations for volunteers. Additionally, the rescue manager must keep the lists of names up-to-date. Fifth, the rescue manager should use documents to contact the corresponding officers or staff personnel of the air force and army for helicopter support.

Furthermore, when the aftermath is completed, the Governor or the Minister of Interior Affairs should grant awards to all attendees. Sixth, district disaster recovery professional senior managers and assistant managers should be recommended as instructors of training programs for new volunteers, and district assistant managers should be well trained in the regulations and operations of the five main rescue tasks listed above.

Seventh, the rescue managers should conduct high-performance transportation operations, since the excellent transportation management model derived from our computational analysis has a strong cost impact on a successful rescuing activity.

Furthermore, the rescue organizations should prepare simple uniforms, such as sleeveless jackets or vests with the name of the permanent governmental rescue organization, for all rescue volunteers to avoid false volunteers blending in and stealing vital rescue resources in disaster areas. The disaster recovery rescue nodes should prepare emergent articles in peacetime, such as patient stretchers, oxygen and masks, tents, sleeping covers, thousands of corpse bags, injured emergent medical supplies, etc., since these high volume demands cannot be acquired during emergencies. In addition, the rescue organizations should compile secret lists of volunteers' names, phone numbers, email addresses, and professional data.

The rescue organizations offer advanced rescue training courses over a few days. These courses are not basic courses but focus on cooperation with other volunteers via crosswise and transverse assistance as well as ways to effectively transfer demand resources with correct personnel and leaders in urgent disasters to avoid regrettable losses.

This study aims to successfully provide effective solutions for real rescue problems using valuable methods to generate the optimal aftermath demand and provide effective disaster management to satisfy all aftermath recovery demands. Rescue managers should have extensive experience and high-performance, with efficiency in transportation management based on the shortest time cycle and the lowest transportation costs to effectively conduct demand and supply management.

The novel and vital findings for successful rescue activities were as follows: first, outgoing demands were of higher priority than incoming demands; second, high volume demands and supplies must be on time; third, transportation management in high performance rescues is vital; fourth, rescue plans, regulations and simulative activities should be practiced; fifth, the golden rescue time (the time starting from disaster occurrence) should be conducted within two days; sixth, the rescue managers should prepare rescue agreements and lists of names of skilled civilian professionals in peacetime, should conduct high-performance transportation operations.

This study emphasizes that high-performance transport-tation management derived from a computation sensitive analysis has a strong cost impact on the success of the rescuing activity. Transportation management very clearly plays an important role in the successful rescue of disaster victims. Thus, a substantial number of difficult rescue activities can be effectively and efficiently completed in high-performance.

Noticeably, when the disasters occur, the disasters always have the worst impacts which results in quite helpless conditions due to the compound and complex nature of these disasters such as earthquakes, tsunamis and giving rise to nuclear radiation damages. The severely strong damages and losses from nuclear radiations are dangerously impacted to local country and nearby countries. However, starting from earthquakes and tsunamis to compound nuclear radiation damages is not a simple local country issues, nuclear radiation damages are an international disaster issues. These international dangerous disaster issues should be strongly monitored by disaster scholars and professionals.

REFERENCES

Awadh B, Hawaleshka O, Sepehri N (1995). A computer-aided process planning model based on genetic algorithms. Compu. Oper. Res., 22(8):841-856.

Button K (1990). Environmental externality and transport policy. Oxford Rev. Eco. Poli. 6:61-75.

Chen SY, Chern CC (1999). Shortest path for a supply chain network. Proceedings of the Asian pacific decision sciences institute conference, Shanghai, China, pp. 579-582.

Chern CC, Chien PS, Chen SY (2008). A heuristic algorithm for the hospital health examination scheduling problem. Eur. J. Oper. Resear. 186(11):1137-1157.

Chiu YC, Zheng H (2007). Real-time mobilization decisions for multi-priority emergency response resources and evacuation groups: model formulation and solution. Transpor. Res. part E, 43:710-736.

Erenguç SS, Simpson NC, Vakharia AJ (1999) Integrated production and distribution planning in supply chains: An invited review, Euro. J. Oper. Res. 115(2):219-236.

Erkut E, Verter V (1995). A framework for hazardous materials transport risk assessment. Risk Anal. 15(5):589-601.

Fleischmann M, Krikke HR, Dekker R, Flapper SDP (2000a). A characterization of logistics networks for product recovery. Omega 28:653-666.

Fleischmann M, Beullens P, Bloemhof-Ruwaard, JM, Wassenhove LN, (2000b). The impact of product recovery on logistics network design, Prod. Oper. Manag. 10(2):156-173.

Jayaraman V, Pirkul H (2001). Planning and coordination of production and distribution for multiple commodities. Eur. J. Oper. Res. 133:394-408.

Giannikos L (1998). A multi-objective programming model for locating treatment sites and routing hazardous wastes. Eur. J. Oper. Res. 104:333-342.

Jansson JO (1994). Accident externality charges. J. Trans. Econ. Policy 28:31-43.

Lee YH, Kim SH (2002) Production distribution planning in supply chain considering capacity constraints, Comp. Ind. Eng. 43:169-190.

Kara BY, Erkut E, Verter V (2003). Accurate calculation of hazardous materials transport risks. Oper. Res. Lett. 31:285-292.

Kavalec C, Woods J (1999). Toward marginal cost pricing of accident risk: the energy and welfare impacts of pay-at-the-pump auto insurance. Energy policy 27:331-342.

Min H, Zhou G (2002). Supply Chain Modeling: Past, Present and Future, Comp. Ind. Eng. 43:231-249.

Pati RK, Vart,P, Kumar P (2008). A goal programming model for paper recycling system. Omega 36(3):405-417.

Srivastava SK (2008). Network design for reverse logistic. Omega 36(4):535-548.

Sheu JB, Chou YH, Hu JJ (2005). An integrated logistics operational model for green supply chain management. Transpor. Res. part E, 41(4):287-313.