

Applying DEA to analyze the performance evaluation of local governments' crisis responses : An example of 2014 Kaohsiung gas explosions

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Abstract

There are constant crises and disasters in Taiwan every year. For example, aircraft crash in Penghu and Kaohsiung gas explosions recently, SARS in 2003, Typhoon Morakot in 2009, and 921 Earthquakes in 1999 harshly inspected existing crisis management systems. The follow-up processing also examined the appropriateness of crisis management mechanisms established by local governments when encountering crises. To measure local governments' crisis response performance on Kaohsiung gas explosions with DEA, proper input and output factors should be selected to efficiently evaluate local governments' crisis response efficiency. The fuzzy Delphi method is used to select input and output factors to combine expert opinions, reduce input costs, and avoid ambiguity in the investigation process. All variable data used in this study are acquired from the government's public statement. The empirical results show that the two local governments of Tainan City and Kaohsiung City are relatively efficient, with efficiency = 1, which means that the crisis response efficiency of the two local governments has reached an ideal state. The rest 10 local governments present relatively worse crisis response efficiency. It is expected that local governments with better relative efficiency in the DEA result could be the goal and lesson for other local governments.

Subject Classification: 62P25, 91B15, 91B55.

Keywords: Local government, Crisis response, Performance evaluation, Crisis management.

Introduction

In such an era when information industry is advanced, including information, network, computers, video, and electronic media, global disasters or major incidents would be real-time transmitted to the world. Such crises examine the responses and management capability of local governments, business organizations, or institutions. In 1999, more than 2400 people died in the 921 (Jiji) Earthquakes in Taiwan, and the paralysis caused by water, electricity, and communication cut-off occurred after the disaster. The government and the management team rescued victims and proceeded systematic evacuation at the first time. The government's crisis response experiences were worthy of learning. In 2011, the fourth largest earthquake and tsunami in history occurred in Japan. The official statistics a year later revealed total 15,854 people died, 3,203 missing, and 26,992 injured; and, the total disaster loss was 207 trillion Yen. Later on, the globally highlighted nuclear disaster occurred, which was highly emphasized and concerned by countries with nuclear power plants. The follow-up processing also examined the proper operation of Japanese government's crisis management mechanism. The above crises occurred without any warnings, and the effects and harm were broad, serious, and unpredictable. Improper crisis responses resulting in tangible or intangible damage to the citizens would be hard to make up. Local governments therefore have to be well prepared for crisis responses.

In 2014, Kaohsiung gas explosions occurred in early morning when several petrochemical gas explosions happened in Cianjhen District and Lingya District in Kaohsiung City, Taiwan. The citizens reported suspected gas leaks, and then serial explosions happened in the areas few hours later and resulted in 32 people died and 321 injured as well as serious damage of several major roads. The investigation afterwards proved the cause of propene explosion. The gas explosions seriously damaged local power supply equipment, communication wires, water pipes, and gas pipelines and resulted in electricity, gas, water, and communication cut-off. The damaged roads were recovered few months later. Central Emergency Operation Center dispatched 5 members and 2 cars from Special Search and Rescue Team of National Fire Agency, Ministry of the Interior, 15 firemen from Kaohsiung Harbor Fire Brigade, 11 members from the environmental accident response team of Environmental Protection Administration and coordinated 45 firemen and 22 fire engines from Tainan City Government Fire Bureau, 9 firemen and 4 fire engines from Pingtung County Fire Department. Total 1392 people and 84 cars supported

for the rescue. Furthermore, fire departments in Taitung County, Chiayi City, Taipei City, New Taipei City, Taoyuan County, and Taichung City successively dispatched people to assist in the disaster relief. The accumulative total of 764 person-times of firefighters, 240 car-times, 45 life detectors, and 21 search and rescue dogs were dispatched for the rescue.

Literature review

I. Crisis management

Crisis management is a statement about how to deal with crises and reduce crisis losses. Crisis management aims to avoid or reduce the negative consequences of crises and protect institutions, individuals or companies from damage. Albert and Kenneth [1] believe that effective crisis management should include: predicting crises, formulating crisis response measures, early detection of crises, avoiding crises, facing and responding to crises, and good interaction with the media. According to Bastidas [2], crisis management is a continuous and dynamic response process that emphasizes active management and continuous learning mechanisms.

Aiming at the characteristics of crises, Ide et al. [3] divided crises into sudden of incident, urgency for time response, crisis with mechanical threatening, chance of crisis response, and universality of crisis. Yarmohammadian et al. [4] positively affirmed crisis responses that crises would result in learning, education, and training for business organizations or institutions as well as the growth space for the advance of an enterprise [5]. From a comparatively negative aspect, Young, Flowers, and Ren [6] considered that crises would threaten and harm the government or business organizations and affect the image of the government and enterprises. Meacham [7] contained five steps for crisis management, namely detection of crisis message, preparation and prevention of crisis, control and response of crisis damage, engagement in crisis recovery, and review and learning afterwards.

McGrattan et al. [8] indicated that crises might occur on international political stages (e.g. Egyptian coup d'état, European debt crisis encountered by the world), national highest policy making level (e.g. arms purchase of Taiwan, disputes of US beef imports, cross-strait economic compromise, and benefits of Mainland China tourists visiting Taiwan), governmental technocracy department (e.g. opening to Mainland Chinese investors, promotion of medical tourism, impact of Mainland Chinese students in Taiwan, corruption of officials, levy of capital tax in Taiwan stock market

and windfall profits tax, natural disasters, typhoons, earthquakes, debris flow, and fire), business organizations and institutions (e.g. harmful additives, plasticizer in food, action of smart phone patent, safety and environment protection incidents, fire), various profit and non-profit organizations (sweat hospitals, overwork of medical personnel, shortage in hospitals), different levels in societies (e.g. an actor beating up a taxi driver, bad behaviors of actors/actresses or politicians, actor/actress taking drugs), as well as family and individuals (e.g. affairs, suicides, domestic violence, sexual violence). The better understanding of crisis properties would have the stronger capability to cope with crises that the loss would be reduced. Seyle, Widyatmoko, and Silver [9] divided the characteristics of crises as phases for the formation of crises, threatening of crises, uncertainty of crises, and time urgency of crises. Huang mentioned that the phases for the formation of crises could be divided into crisis warning phase, crisis prevention (preparation) phase, crisis stopping phase, crisis recovery phase, and phase of crisis learning afterwards. When crises or various disasters occur, either governmental departmenta, business organizations, institutions, or individuals could not get out. Bad responses of governmental departments, enterprises, institutions, and individuals would cause harms or affect the image. However, when crises are properly responded, the harm or the loss could be reduced. Werner [10] regarded crisis management as the response process that the government, institutions, or business organizations effectively solved hazard factors, with plans, methods, organization, and systems before crisis outburst and rapidly and effectively turned the danger of the government, enterprises & institutions, or individuals to safety within the shortest time.

II. *Crisis management strategy*

After the establishment of Federal Emergency Management Agent (FEMA) in 1979, the crisis management process was divided into four phases of (1) release, (2) preparation, (3) response, and (4) recovery. Tony [11] proposed three strategies which decision-makers should take into account when planning crisis policies, including (1) change strategy, (2) integration strategy, and (3) continuation strategy.

- (1) Change strategy: Jaques [12] mentioned that the overall goal of crisis management could be easily understood by general people, but it tended to become abstract and vague. Decision-makers therefore had to consider the characteristics of departments and

the external environments to set more specific secondary goals for the departments designing the action standards. Furthermore, the coordination among departments should be paid attention to so that the departments could make proper adjustment according to objective environmental changes [13]. Moreover, the learning capability of departments could be promoted through (1) danger assessment, (2) control analysis, and (3) information feedback and action adjustment to enhance the interaction [14].

- (2) Integration strategy: Kim [15] indicated that integrating different departments in a crisis management system to achieve the consistent goal was a great challenge. For many departments, crisis management was merely a part of numerous responsibilities that the staff merely focused on the completion of daily tasks, but ignored the environmental changes or the improvement of the lack of work. In this situation, the function of integration strategy had to be developed. On one hand, the explanation of policy purposes could have the departments understand the reasons for various measures. On the other hand, it could re-collect information and adjust the step to set new goals. Accordingly, the departments could have the common value to enhance the cooperation. In other words, integration strategy aimed to link individuals, organizations, and resources in a crisis system through effective communications [16].
- (3) Continuation strategy: Meacham [17] mentioned that there must be various types of organizations or groups in a crisis management system; in this case, a decision-maker would face the dilemma of well arranging and utilizing existing resources and capability under uncertain and complicated situations to have an organization, when encountering sudden crises, be able to continuously develop the basic functions. The solution lied in the flexible structure and operation process for the departments in the organization timely adjusting the strategies to cope with any changes as well as ensuring and maintaining the stability and security of the organization [18].

III. *Crisis response assessment*

Ferguson, Wallace, and Chandler, [19] proposed a complete crisis management model, or the basic theory for the crisis management principles, as below.

- (1) Preparation before crisis: Setting plans, establishing mechanisms, and simulation and practice.

- (2) Crisis prevention: Early warning, risk management (including risk assessment), and information delivery.
- (3) Crisis response: From crisis cognition, action taking to crisis solving when crises occur.
- (4) Management after crisis: Management afterwards, impact recovery, review afterwards, and experience learning.

Kanel [20] regarded crisis management as the essential knowledge and tactic for crisis decision-makers. A principle to follow was necessary for making correct decisions in order to avoid panic when encountering crises. Lin pointed out the key points of crisis response principles, including goal, strategy, organization, and instrument [2].

- (1) Goal: The overall goal should be set for crisis responses, and then the secondary goal. The overall goal should take national tactics and national benefits into considerations.
- (2) Strategy: It could be divided into offensive and defensive strategies. Offensive strategies preset the measures of 1. taking preemptive actions, 2. punitive attack, 3. resulting in established facts, 4. military menace, and 5. blockade and war of attrition. The above strategies do not aim to acquire complete victory, but to solve crises.
- (3) Organization: The achievement of goals and the administrative execution are practiced in organizations, and strategies could develop the function by organizations.
- (4) Instrument: The selection of instrument reveals the determination and attitudes of responses. Instrument could be divided into military and non-military ones.

Research design

To use data envelopment analysis (DEA) to measure the crisis response performance of local governments in the Kaohsiung gas explosion incident, appropriate input and output factors must be selected to effectively evaluate the crisis response performance of local governments. In order to combine expert opinions, reduce input costs, and avoid ambiguity in the investigation process, this study uses the Fuzzy Delphi Method to select input and output factors. A total of 24 questionnaires were distributed, and 17 valid questionnaires were collected, with a recovery rate of 71%.

After the fuzzy Delphi method is calculated, the geometric mean is regarded as the consensus of experts on the input and output factors, and the median of the evaluation score is used as the selection standard to select input and output factors that can measure the crisis response performance of local governments in the Kaohsiung gas explosion incident. This study selected a total of 14 input/output variables and 12 DMUs are strictly screened

All variable data used in this study are acquired from the government's public statement.

Definition of variable:

I. Input variable:

1. Number of people for disaster relief: Total number of people joining in the disaster relief of Kaohsiung gas explosions.
2. Resources for disaster relief (amount of money): Materials input to the disaster relief for Kaohsiung gas explosions.

II. Output variable:

1. Evacuation and rescue: Containing victim evacuation and victim rescue and care.
2. Crisis response: The period from the cognition of crisis, action taking, to solving crisis.

Empirical analysis of local governments' crisis response efficiency

I. Local governments' crisis response efficiency analysis

Using DEA to evaluate efficiency help understand the relative efficiency of the local government's crisis response in the Kaohsiung gas explosion. Efficiency=1 stands for the DMU achieving the relative efficiency, while efficiency<1 represents a relatively inefficient DMU. The results in Table 1 show that the two local governments, Tainan City and Kaohsiung City, are relatively efficient, with efficiency=1, revealing that such 2 local governments achieve ideal crisis response efficiency. The rest 10 local governments show relatively worse crisis response efficiency.

II. Slack Variable Analysis

In terms of the analysis of returns to scale, Table 2 shows that two local governments showed fixed scale returns in crisis response, and their operating efficiency was optimal; the other 10 local governments showed

Table 1
Relative efficiency of local governments' crisis responses to Kaohsiung gas explosions

Local government	Overall efficiency	Pure technical efficiency	Scale efficiency
Taoyuan County	0.84	0.82	0.83
Taitung County	0.76	0.78	0.74
Hsinchu City	0.63	0.62	0.61
Tainan City	1.00	1.00	1.00
Chiayi City	0.96	0.95	0.97
Chiayi County	0.92	0.93	0.92
Taipei City	0.88	0.86	0.89
New Taipei City	0.90	0.90	0.90
Changhua County	0.90	0.92	0.86
Yunlin County	0.82	0.83	0.80
Kaohsiung City	1.00	1.00	1.00
Pingtung County	0.97	0.96	0.97

increasing scale returns, indicating that they could increase marginal returns by expanding their scale, thereby further improving efficiency.

In terms of slack variable analysis, Table 2 shows that when local governments have sufficient investment, their efficiency improves. Local governments can achieve efficient management by streamlining investment units and concentrating investment on projects with sufficient investment. In addition, the crisis response of the local government of Tainan City showed efficiency, and the investment resources were optimally utilized.

Table 2
Improvement of local governments' crisis responses to Kaohsiung gas explosions

Decision making unit (DMU)	Improvement of input		Improvement of output		returns to scale
	Number of people for disaster relief	Resources for disaster relief	evacuation and resettlement	crisis response	
Taoyuan County	2	2	1	1	IRS
Taitung County	0	1	3	0	IRS

Contd...

Hsinchu City	3	3	2	1	IRS
Tainan City	0	0	0	0	CRS
Chiayi City	2	4	3	0	IRS
Chiayi County	1	3	3	0	IRS
Taipei City	0	1	0	0	IRS
New Taipei City	0	1	2	1	IRS
Changhua County	0	2	4	0	IRS
Yunlin County	5	4	3	0	IRS
Kaohsiung City	0	0	5	8	CRS
Pingtung County	2	3	1	0	IRS

Data source: Self-organized in this study.

Conclusion

According to the efficiency values and variable data obtained by DEA, as shown in Table 1, two local governments (16% of all DMUs) showed strong efficiency, with efficiency = 1, indicating that their crisis response efficiency was relatively good; five local governments (about 42% of all DMUs) had operating efficiency between 0.9 and 1, which was marginal inefficiency, indicating that these local governments could easily improve their crisis response efficiency; another five local governments (42% of all DMUs) had a crisis response efficiency lower than 0.9, which was obviously inefficient, among which the Hsinchu City Government had the lowest crisis response efficiency of 0.63. Constant crises and disasters in Taiwan, such as recent aircraft crash in Penghu and Kaohsiung gas explosions, SARS in 2003, Typhoon Morakot in 2009, and 921 Earthquakes in 1999, harshly inspect existing crisis management systems. Although governmental departments invest enormous manpower, objects, and finance in disaster prevention and rescue, they receive lots of blame for not getting the message, improper processing, and even helpless. The disaster responses to the 921 Earthquake were much more difficult than those to Kaohsiung gas explosions. The DEA evaluation results reveal that the relative crisis response efficiency of Kaohsiung City and Tainan City could be the goal of other local governments.

Suggestion

Aiming at the results and the actual situations of Kaohsiung gas explosions, the following suggestions are proposed in this study for local governments' crisis responses.

1. **To establish mutual support systems of counties and cities for disasters:** It is necessary for a cooperative disaster relief mechanism of local disaster response centers with the same level, which is ruled in advance about the unified command for support from other counties and cities, and disaster prevention and response plans for the cooperative areas should be established and regularly discussed. Such a mechanism allows local governments support and cooperate with each other when encountering disasters. It is therefore suggested that local governments in Taiwan should include cross-region cooperation in the disaster prevention plan in order to enhance local governments' disaster prevention energy. Besides, the evacuation process should be reviewed by having the departments, which are more professionally trained and present richer resources, assist local heads in establishing perfect disaster alert systems and reinforcing the monitoring capability to effectively master the actual situations. Local heads have to understand the evacuation standards for making the evacuation decision.
2. **To establish a coordination and management mechanism for non-profit organizations in resettlement centers:** In addition to members from departments of social welfare, household, and civil affairs, people and volunteers of various non-profit organizations would station in resettlement centers. The lack of coordination and management mechanism results in lots of volunteers flooding in resettlement centers that the multiplication effect is not developed and even result in manpower waster and lack of efficiency. Accordingly, it is suggested to establish a coordination and response center for coordinating the stationing of non-profit organizations in resettlement centers and the management of rescue materials, including the interaction among non-profit organizations and the improvement of the interaction between non-profit organizations and victims in the process, to promote the management efficacy.
3. **To reinforce local community residents' disaster prevention and relief energy:** Disaster prevention and relief do not specially depend on governmental groups, but on all residents in the community. For this reason, it is suggested that local governments should regularly hold relevant disaster prevention courses for the learning of citizens and actively encourage community residents participating in the education and training courses so as to present basic disaster prevention knowledge. Besides, community participants are grouped

for training and reinforced the crisis awareness through actual sand table inference, aiming at possible situations after the occurrence of disasters, e.g. evacuation, principles of firefighter rescue, and locations of resettlement centers. It could have the citizens well prepare for possible disasters and save themselves before external support. The disaster relief energy of civil groups could be effectively combined with community residents to reduce the adjustment in the disaster relief process. As a result, citizens could help themselves as well as help other trapped people to slightly release the inadequate firefighters for rescuing other citizens who are more in need.

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