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Chapter 5

A Simulation and Evaluation System Oriented to the Emergency Response Effectiveness of the Abrupt Earthquake Disaster

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Additional information is available at the end of the chapter

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1. Introduction

The untraditional emergency disasters, like the 2008 Sichuan earthquake of China, break out with nothing indication, no time to prepare for. These emergency events always bring us the catastrophe with much casualty, homeless and immeasurable economic losses.

The emergency disasters response problem is an important thing to be researched all over the world. As we all know that we can not change the breaking out of the untraditional emergency event in present technology level, but it never means that we could do nothing, on the contrary, if we have enough response plans or preparedness, the disasters should be reduced to the minimum level. It requires us to prepare many valid emergency response plans by hands. However, how to get such valid emergency response plans?

Considering the emergency catastrophe like earthquake takes place so abruptly, it is difficult to make decisions to get the most suitable preparedness plan from many emergency response plans. In order to improve the emergency response capability for the abrupt earthquake disasters, it is necessary to build a decision-making support system to evaluate the response plans and to select a most suitable preparedness plans.

In fact, it is difficult to test and evaluate the response plans in the real conditions of a strong earthquake disaster. As far as we know, modeling and simulation methods are fit for evaluating the preparedness plans. Adopting the modeling and simulation methods, there are many advantages such as low cost, safety research, time-space easily convert, and so on.

Many emergency researches, authors in reference [1-3], show that the more preparedness for the emergency event, the less risk we suffer from the uncertainty emergency. As we all know

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that, the emergency plans are oriented to the future event, we have none of the real data and sense. So the modeling and simulation methods are utilized to the decision-make support system.

More researches have discussion about the modeling and simulation method in the emergency response management [4]. At the mean time, Many researcher and experts have noticed the importance of the simulation and evaluation method in the decision-making support system [5,6]. The emergency response needs the decision making support system [7,8].

In China, there are many learners to carry out their researches on the emergency response management, Professor Wang [9] puts forth the parallel simulation method to research the emergency management. Fan Weicheng [10] points to the public incidents, provides some useful suggestion and response methods for the emergency platform system.

In this chapter, we set the research object orient to the emergency earthquake disasters. Design a decision-making support system framework for the emergency response management, and then mainly research the simulation and evaluation methods and their application in the earthquake disasters.

2. Systematic frameworks for simulating and evaluating the emergency preparedness for earthquake

Judging and analyzing the advantage and disadvantages of an emergency response plan needs a good decision making support system. To build up such a decision making system, a serial of technical methods and theory models are required to support the system. In this chapter, the author sums up the research methods for the emergency response plans, and put forth a whole research route map to design and develop the system. Such a research route map is a set of systematic framework which can simulate and evaluate the response plans for the untraditional emergency disaster like earthquake, seeing the Figure 1.

In Figure 1, there are 5 main parts (subsystems) in the set of systematic framework. These subsystems are built to support the whole decision framework. They are including: (A) emergency response effectiveness concept and the evaluation indices, (B) indices weights acquisition,(C)emergency response simulation theory based on OODA-DEVS, (D) simulation system and simulation data acquirement,(E) the integrated evaluation process and decision making support system.

The next research is to describe the related subsystems in the Figure 1. The following research will take emphasis on the main techniques of the simulation and evaluation in emergency response plans.

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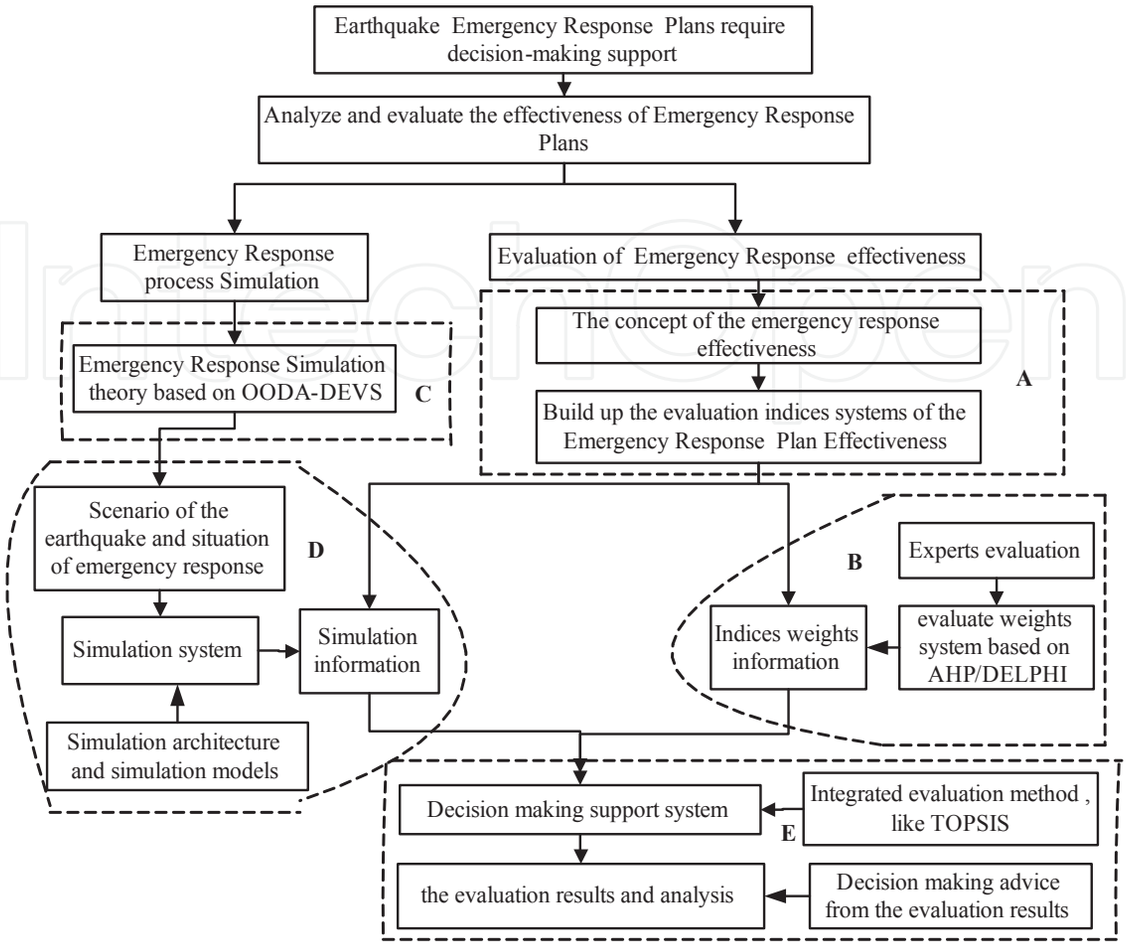


Figure 1. Systematic framework to simulate and evaluate the abrupt earthquake disaster

3. Evaluation indices orient to the emergency response of the earthquake disaster

In order to select a right plan from many emergency response plans, it is necessary to make a good decision to evaluate the emergency response plans. And therefore, build up a set of evaluation indices system is very important.

3.1. Measurements on the effectiveness for emergency response

To evaluate the emergency response plans, we need design a comprehensive evaluation index. Such a complex index is needed to measure what is the degree of an emergency response plan can perform.

The operational effectiveness is widely used in military evaluation. As we know that, a war is very similar to the fight for the earthquake disaster. And thus, we need to give a definition for

the effectiveness. In fact, effectiveness means the degree to which objectives are achieved and the extent to which targeted problems are solved.

And therefore, the effectiveness of emergency response plan can be defined as the degree to which the emergency plans executed right by the decision makers are achieved, or the extent to which the emergency disaster risk to reduce and rapid response rescue.

By means of the definition of the emergency response effectiveness, we can put forth a comprehensive index to measure the degree of the emergency response.

Emergency response effectiveness concept includes: 1) it is a comprehensive index; 2) given a specific emergency conditions and specific mission, which degree does the emergency response plan perform in the mission.

According to the concept of the emergency response effectiveness, we can measure the emergency response plans of the earthquake disaster in some aspects including: rescue speed, capability, safety and cost. As we know that, judge whether a well earthquake emergency plan is valid need comprehensive evaluate the above factors.

3.2. Evaluation indices systems for the emergency response preparedness

As a comprehensive effectiveness index, it needs to decompose into detailed sub indices. Using the top-down analysis methodology of system engineering, we can break up the top effectiveness indices into the different sub-indices, seeing in the Figure 2.

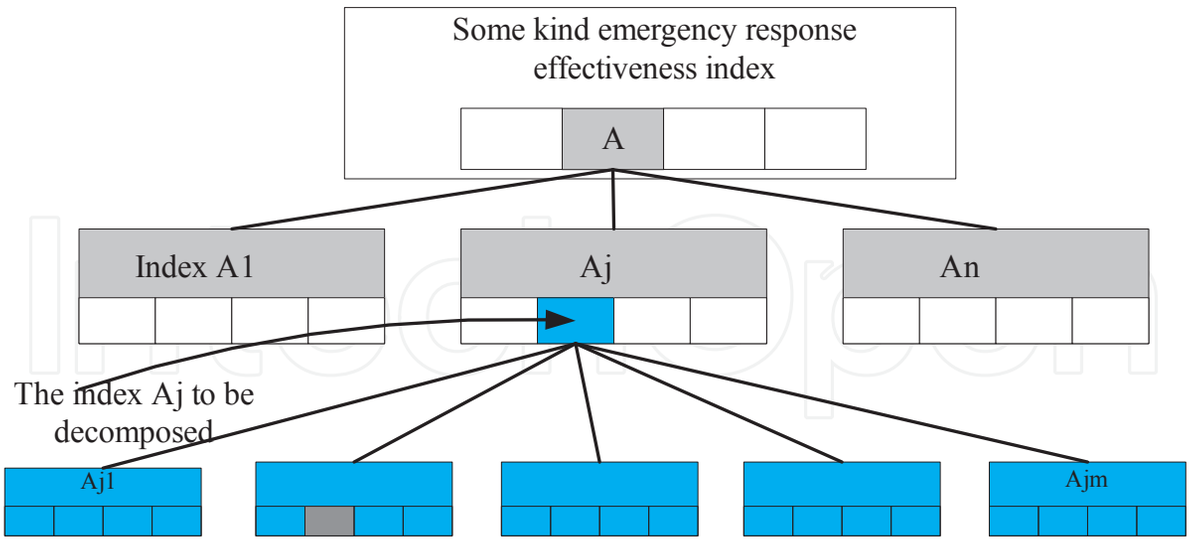


Figure 2. Effectiveness indices decomposed in top-down methodology

With the top-down methodology, we can design the response effectiveness indices system for the untraditional earthquake disaster, for example, seeing Figure 3.

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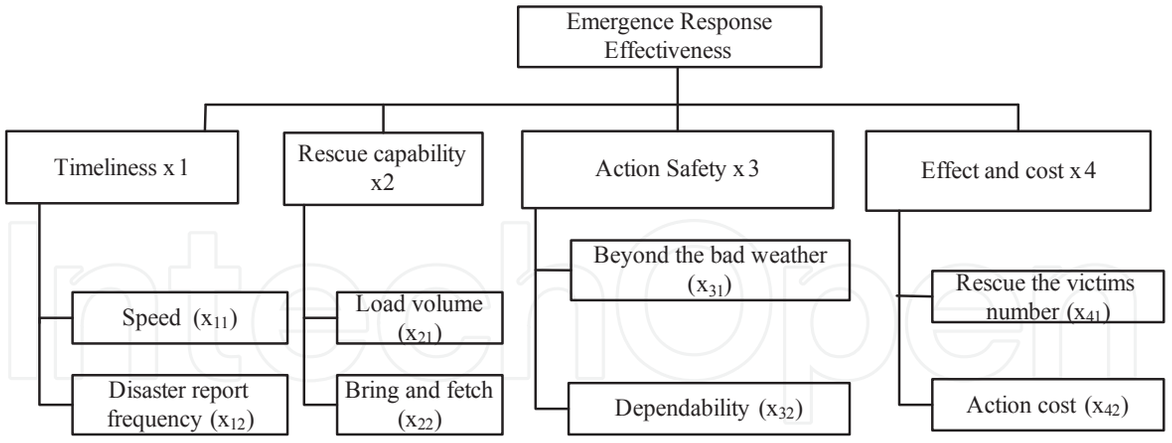


Figure 3. Response effectiveness indices of earthquake disaster

In order to describe the indices clearly and be easy to design for programming, we adopt the XML (Extensible Markup Language) file format to describe the effectiveness indices of the earthquake disaster. The emergency response effectiveness indices system can be written in XML file format as follows:

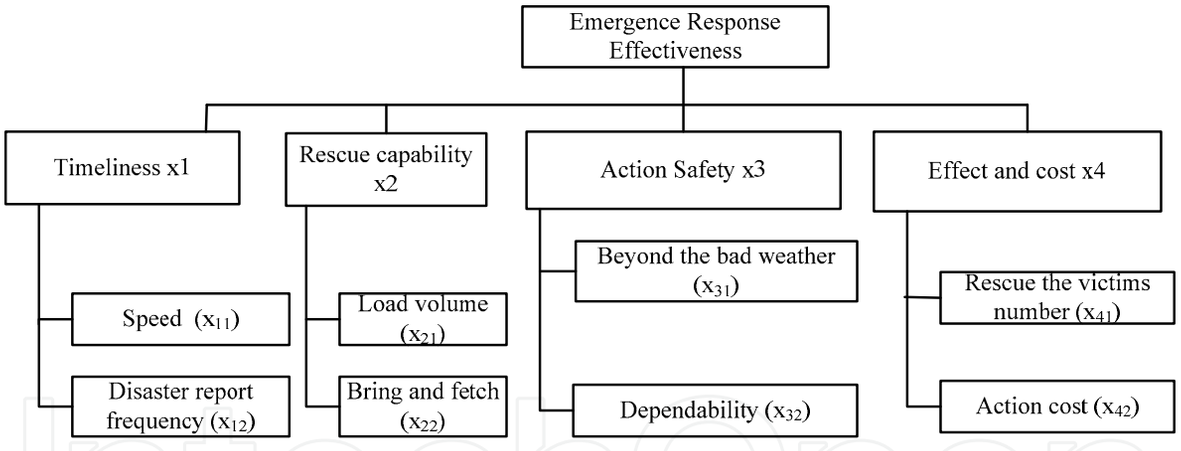


Figure 4. The emergency response effectiveness indices system

3.3. The weights acquirement for the emergency response effectiveness indices

For the evaluation indices system, we have to know how much the sub-indices make role in evaluating the emergency response preparedness. And therefore, it is essential to acquire and calculate the weights of the sub-indices, which support the whole response plans effectiveness. However, it is complicated to acquire the indices weights because the calculation full of experts' interaction with the evaluation systems.

In order to calculate the indices weights smoothly and make such an weights acquirement system reusable, we design a weights evaluation system based on MVC (Model View and

Controller) mode. The MVC mode is a reusability mode in software engineering, seeing the Figure 5. The architecture of the weight evaluation system based on MVC is designed as the Figure 6.

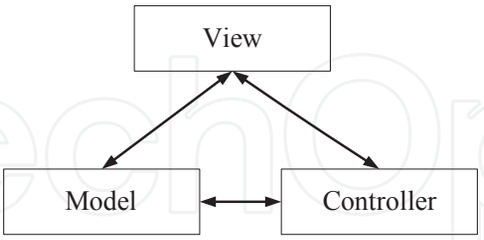


Figure 5. The Model-View-Controller mode in software engineering

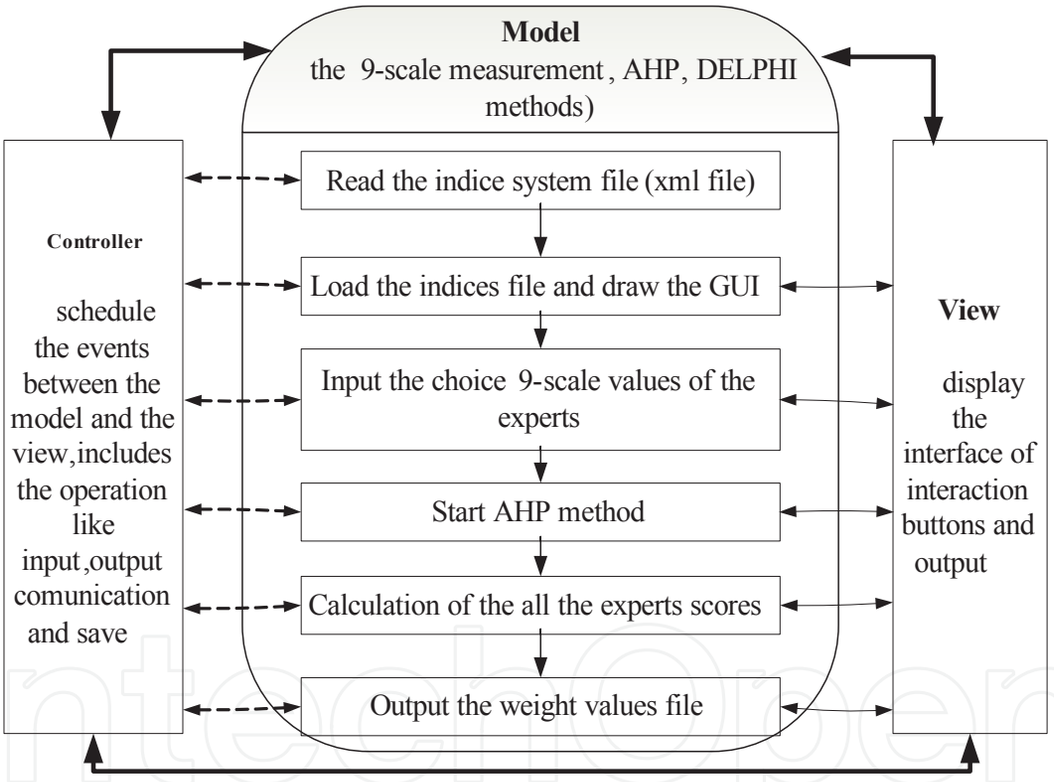


Figure 6. The architecture of the weight acquisition system based on MVC

In the Figure 6,the main parts are described as follows:

Model: it is a process algorithm of expert scoring information based on the idea of AHP (Analytic Hierarchy Process). Before the model starts, the response effectiveness indices system file (xml file) will be loaded in the weights acquisition system.

View: it is the graphic user interface (GUI) and it displays the visual information including the input windows of the experts, and the print of the weight values output.

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Controller: it is the communication and control bridge between the Model and View, and it mainly includes the operations of the input, output, and calculation and saving.

As an application example, we load the xml file of the response effectiveness indices (seeing the response effectiveness indices system, Figure 3.), then the weight evaluation system with the graphic interface view is generated, (seeing the Figure 7). This system is developed in java programming language. Notice, Here the indicators are the same meaning of indices.

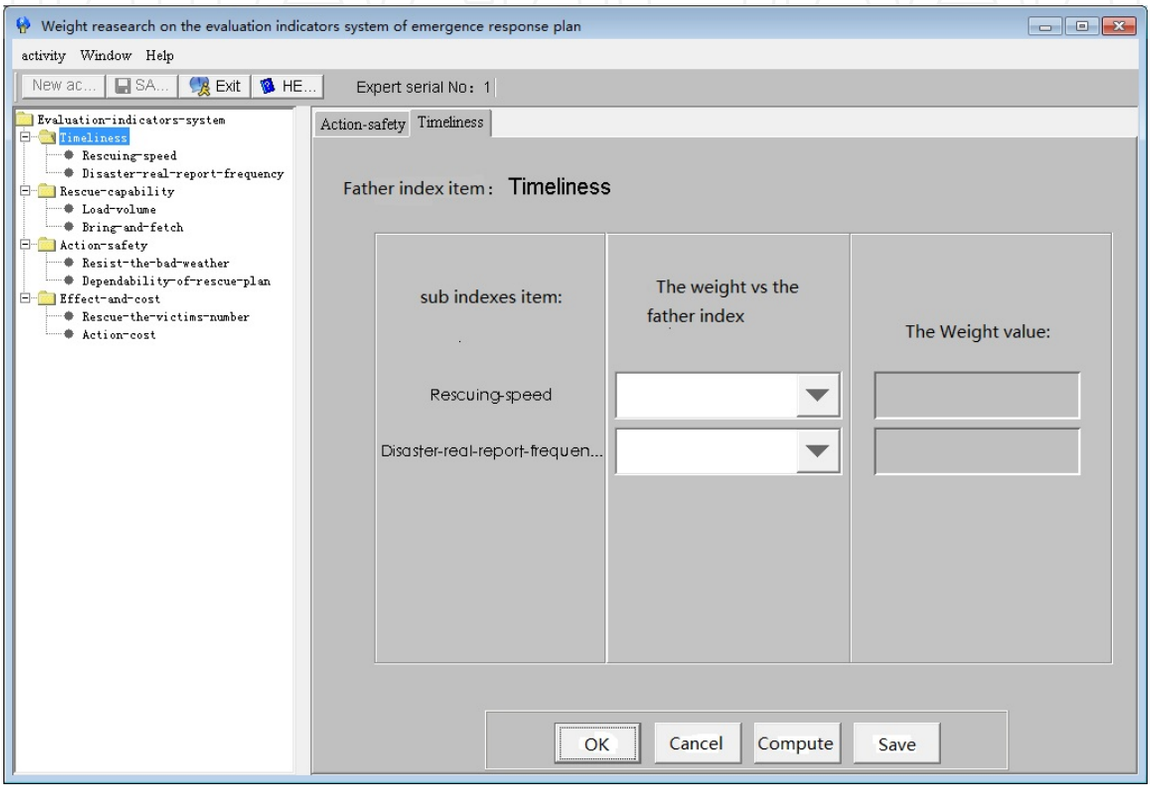


Figure 7. The weights calculation and the visual interaction system

By means of above system, we can get the indices weights W from index x_1 to x_8 : W=(0.142, 0.115, 0.091, 0.10, 0.092, 0.123, 0.159, 0.178). The weights W will be used in the integrated evaluation in later of this chapter.

3.4. The acquirement of the simulation information

The response plans of the emergency event are designed for the future emergency, so that we cannot collect the real data of emergency event, and therefore the simulation method are necessary to evaluate the future emergency plans. However, it is difficult to get the proper information from the simulation system because there is much difference between the simulation and evaluation. As we know that, the simulation system cannot get the proper information without the evaluation indices requirements. So we try to build a bridge between the two subsystems. This bridge is the so-called framework of menu of simulation data collecting, seeing the Figure 8.

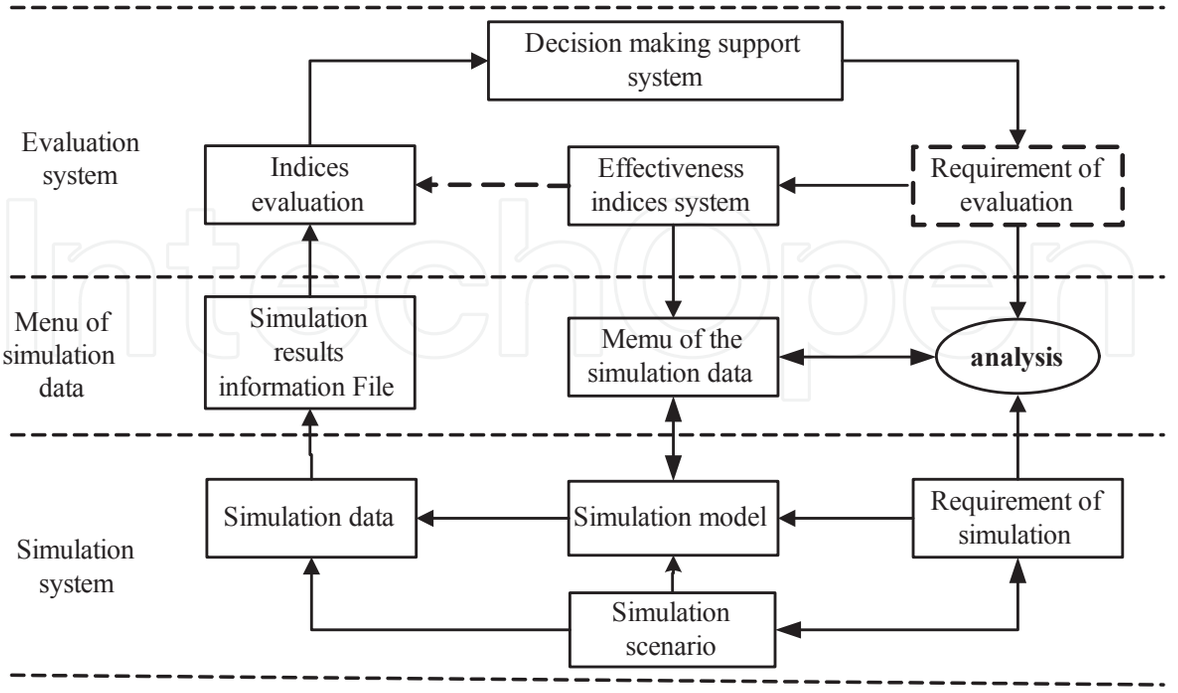


Figure 8. The framework of the menu of the simulation data collecting

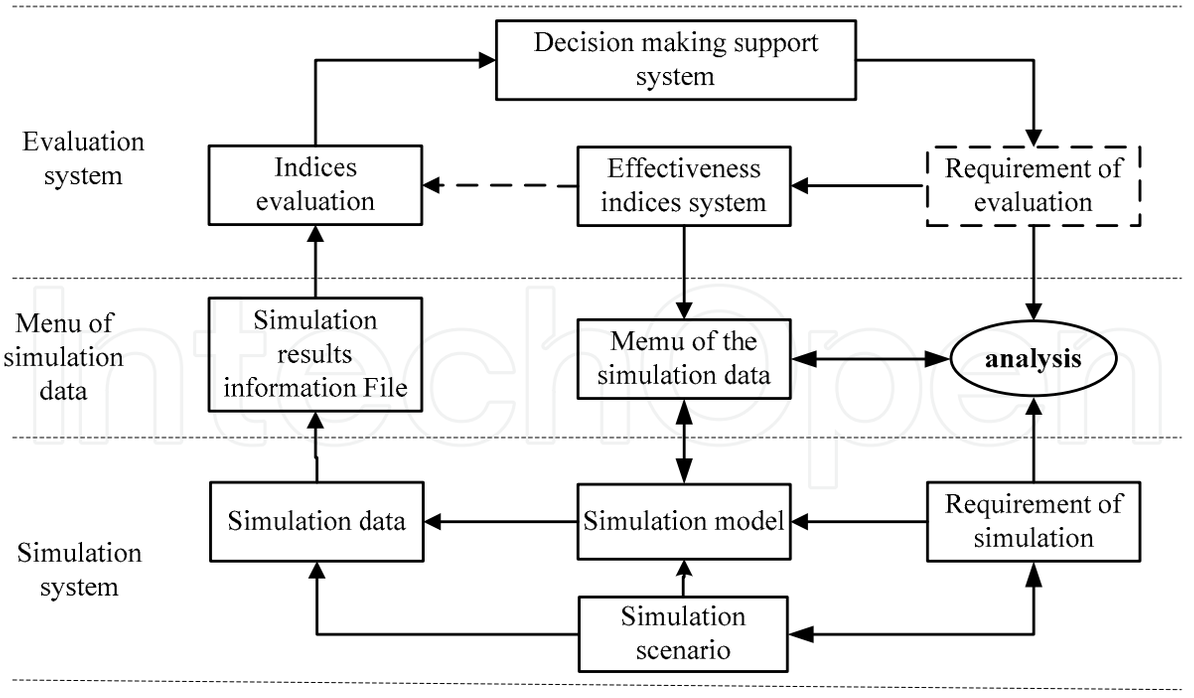


Figure 9. The menu of the simulation data

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Because the simulation data is isomerous, it is difficult to save and transfer in form of the relational database format. In accordance with the format of emergency response effectiveness indices, the proper file format for the menu of the simulation data is the XML file. For the earthquake emergency response scenario, we design the menu of the simulation data to collect the simulation information as follows, seeing in Figure 9.

4. Simulation mechanism of the emergency response process

As we know that, it is difficult to evaluate the emergency response effectiveness of the earthquake disaster in real environments. It is necessary to use simulation method to support the decision making. And therefore, a reasonable simulation method should be based on a scientific mechanism of emergency simulation.

4.1. The mechanism on the emergency response process of an earthquake disaster

In order to deal with the emergency response to the earthquake disasters, the government especial organization such as emergency departments and their executers should keep reconnaissance on the disaster zone, and make actions according to the detail disaster conditions.

How to describe such rules of the emergency process is a big problem. Considering the OODA (Observe, Orient, Decide, Act) loop which is John. Boyd, the famous U.S. captain, first put forth. It tells us the combat rule which runs as a loop, seeing as Figure 10.

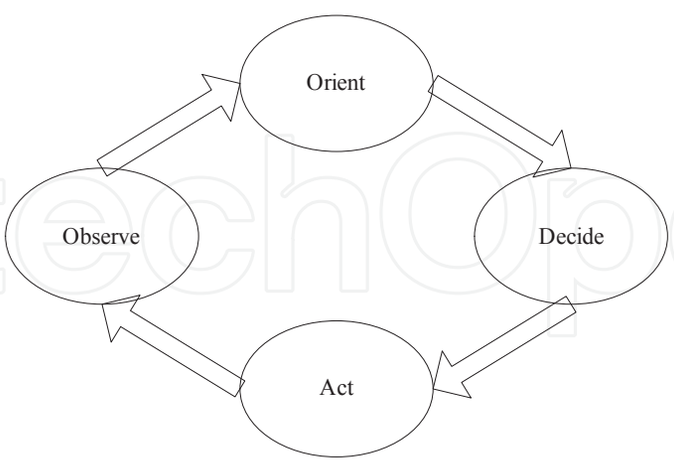


Figure 10. OODA loop diagram

In fact, the rapid response to the earthquake disaster is similar to a combat. And therefore, we should build the emergency response framework based on OODA loop as follows, seeing the Figure 11.

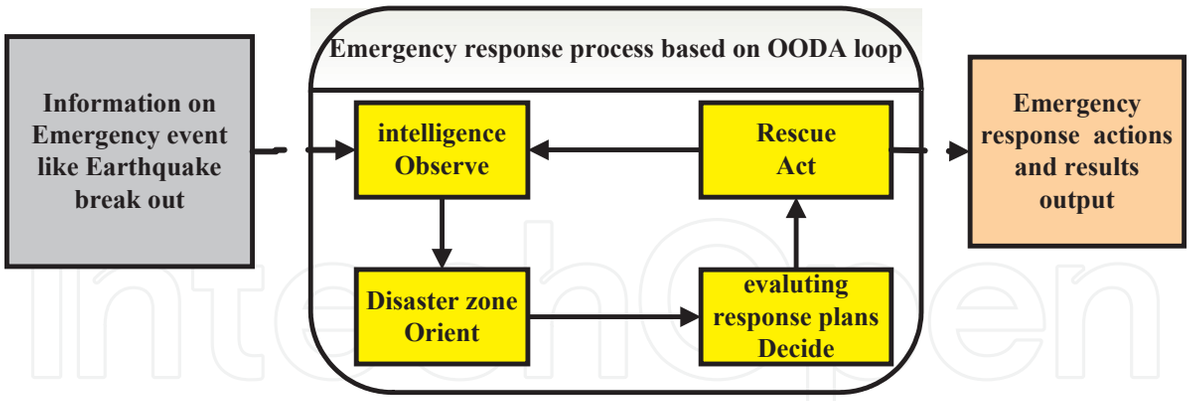


Figure 11. The response framework is based on OODA loop for the earthquake disaster

4.2. Emergency response modeling theory based on OODA

With the emergency response framework for the earthquake disaster, we need build a simulation model in scientific language. DEVS (Discrete Event System Specification) is a formalism language for modeling and analysis of discrete event systems (DESs). The emergency response system just is such a system, so that it is reasonable to using DEVS to describe the simulation process.

4.2.1. The OODA loop and the DEVS theory

The DEVS formalism was invented by Bernard P. Zeigler, who is emeritus professor at the University of Arizona. It is a modular and hierarchical formalism for modeling and analyzing general systems. There are two key models: atomic DEVS and coupled DEVS. *Atomic DEVS* captures the system behavior, while *Coupled DEVS* describes the structure of system.

The atomic DEVS is fit for describing the emergency response system behavior. Combining with the emergency response process framework based on OODA, we can build up the control structure in the DEVS factors, seeing in Figure 12.

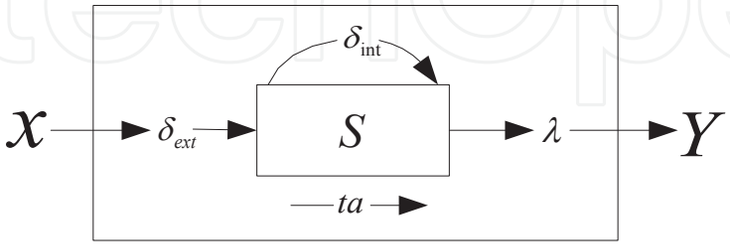


Figure 12. DEVS atomic model diagram

An atomic DEVS model is defined as a 7-tuple

AtomicDEVS= $<S, ta, \delta_{int}, X, \delta_{ext}, Y, \lambda>$

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Where:

S is the set of sequential states (or also called the set of partial states);

X is the set of input events;

Y is the set of output events;

$Q=\{(s,\ t_e)\mid s\in S,\ 0\le t_e\le ta(s)\}$ is the set of total states, and t_e is the elapsed time since the last event;

$\delta_{\text{int}}: S\to S$ is the internal transition function which defines how a state of the system changes internally (when the elapsed time reaches the lifetime of the state);

$\delta_{ext}: Q\times X\to S$ is the external transition function which defines how an input event changes a state of the system.

$\lambda: S\to Y$ is the output function. This function defines how a state of the system generates an output event (when the elapsed time reaches the lifetime of the state);

The output function $\lambda(s)$ is decided by the state s before transition.

$ta: S\to R^{+}_{0,\infty}$ is the time advance function which is used to determine the lifespan of a state, $R^{+}_{0,\infty}$ means Non negative real numbers; when no input events arrive, the state s will maintain the lifetime. When $ta(s)=0$, we call the state s is executing state; while $ta(s)=+\infty$, the state s is called dead state, and the system always waits for the input event.

4.2.2. Describe the emergency response process in OODA-DEVS

The kernel of a simulation system is to the simulation engine. The simulation engine of the emergency response system is required to design based on the DEVS simulation theory. Considering of the emergency response process is an OODA loop, the simulation engine of the emergency response system for disaster is designed as follows, seeing the Figure 13.

In the Figure 13, it tells us the workflow of the system simulation engine. When simulation start at $T_{0,}$ each variable in the simulation system is initiated. Then scan the current simulation time t, and judge whether the t is more than the total simulation time T. If t>T, then the emergency simulation process is terminated, else it requires to judge the emergency events. Before dealing with the messages of the emergency system, it is needed to judge the kinds of the messages. 1) If the received message is the input event message-X-message, what's more, the simulation time t of the input event must meet the requirement of the next event time, we can define such an event as the ex-message; if the simulation time of the input event is wrong, show that the synchronization time is invalid, and the event must be cancelled and to be scanned again.

After confirm the ex-message, it is required to update the simulation time of last event t_L and the time of the next event t_N, and then output the simulation result information by means of the output function$\lambda(S)$. While the response units like rescuer teams send the simulation information to the top level simulation unit (decision making departments), the response units

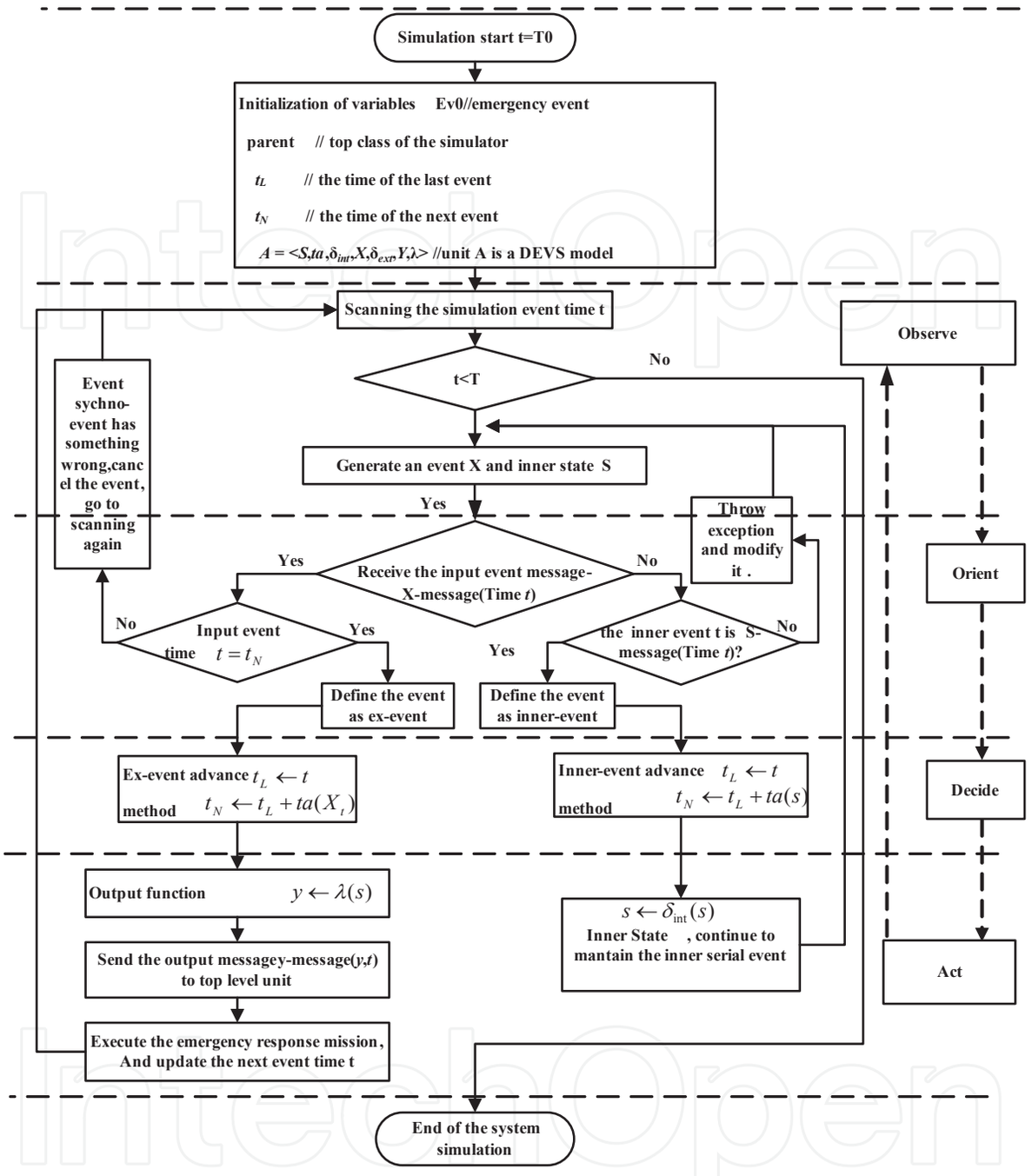


Figure 13. OODA-DEVS simulation engine

themselves will continue to finish their missions. Such units is required to update the simulation time t again, and return to scan the simulation event time t. so far, an external input event is finished dealing with.

2) If the message received is an inner message, then we define it as an inner serial event. Other wise, confirm it as an exceptional message, and it needs to modify in the time management (a simulation service rule). For the inner serial event, the inner state transits, and update the time

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of the last event, and the next event time t. continue to these steps till the ex-message is coming, and transfer to the ex state loop. From above flow chart analysis, it is easy to find out, the simulation engine process just like the OODA four parts loop.

4.3. Simulation system and simulation data list acquisition

4.3.1. The simulation architecture of the emergency response management

As we all know that, the earthquake emergency response system is very complex. The simulation system includes many parts: the emergency scenario, the behaviors of response units, the interaction communications between the rescuer and the refugees. All the parts are based on the OODA loop in the response process.

Considering the emergency response plans need the many interaction operations, so that we build up a simulation system architecture based on the HLA/RTI (High Level Architecture/ Run-time Infrastructure) technology. It is suitable for the modeling developers to use HLA and RTI to describe emergency system with many uncertainty events.

The simulation architecture includes many software nodes: response plan and rescue units, the emergency information like weather and location, situation description, the environment of disaster area, emergency events generator, and rescue command system, and so on.

The simulation architecture of the emergency response for earthquake disaster is shown in Figure 14.

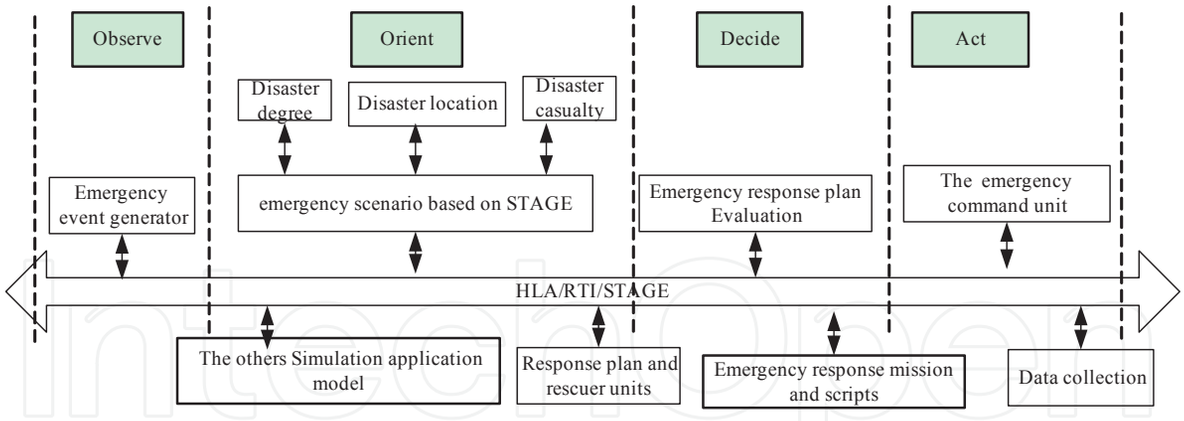


Figure 14. Simulation architecture of the emergency response

4.3.2. Response units behaviors simulation scripts

After we build a simulation system, we need analyze the simulation behaviors. In the simulation toolkit of STAGE (Scenario Toolkit and Generation Environment), we can create the behavior simulation scripts based on the above simulation theory and the simulation engine.

Emergency response unit is the force to execute the rescue mission like troop, emergency medical services, police, and firefighters and so on. For each of the emergency response unit,

there is a script program to describe the unit behavior. The script codes are written in STAGE as follows.

```
(1) The script codes for detection of the emergency response units
    int detect_platforms[500];                          //the numbers of detect platforms
    track.cycle_on(detected_platforms);          //start scanning the detect platforms
      while((track.next()>0)and(track.indentify=danger)and(track.type=land)) do
      detect_platforms[index]=1;     //detected the emergency response units, its value is 1.
    endwhile
(2) The orient script code of the emergency response unit
    Boolean detected[500]; int i=l;boolen identify; //initiating the variables
    enum {best, better, good, worse, worst} Degree;// the enum type about disaster degree
    while(i<500)do
     if (identify)
        detected[i]=1;
      else detected[i]=0;
    while(detected[i]!=0)do
      object.orient(i,Degree);
      data_link.assign_int(i);
      i=i+l;
    endwhile;

(3) The decision and action of the emergency response unit:
    int act_index; //the index which need to rescue
    track.cycle_on(act_index);                          //scan the act_index
    while(track.next()>0)do                    //there are objects required to rescue
    if(boolen rescue==1 and the orient[i]==worse)then
     entity.request_ground_track=1; // require ground tracks to rescue.
     entity.request_speed=entity.actual_speed+entity.max_acceleration*10; //require the speed of the
rescue truck
    endif;
      if(rescue==0)then
        entity.request--speed=0;  //the emergency response unit is stopping
      endif;
    endwhile;
```

5. Earthquake disaster scenario and emergency response simulation

In order to analyze the emergency response plans of earthquake disasters, a typical earthquake disaster is designed as an application scenario. The next emergency response plans are evaluated based on such a scenario.

5.1. Earthquake disaster scenario

Suppose a terrible catastrophe like earthquake breaks out in some uncertainty place, seeing the Figure 15, we should carry out the emergency response plans to quickly rescue the victims. Usually the routes to the disaster zone are far away from city and the disaster conditions are very complicated and uncertainty, so that we are required a decision-making support system to get the best emergency plan from many available plans.

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In this earthquake disaster scenario, the advantages and disadvantages of the emergency response plans can be shown in Table 1.

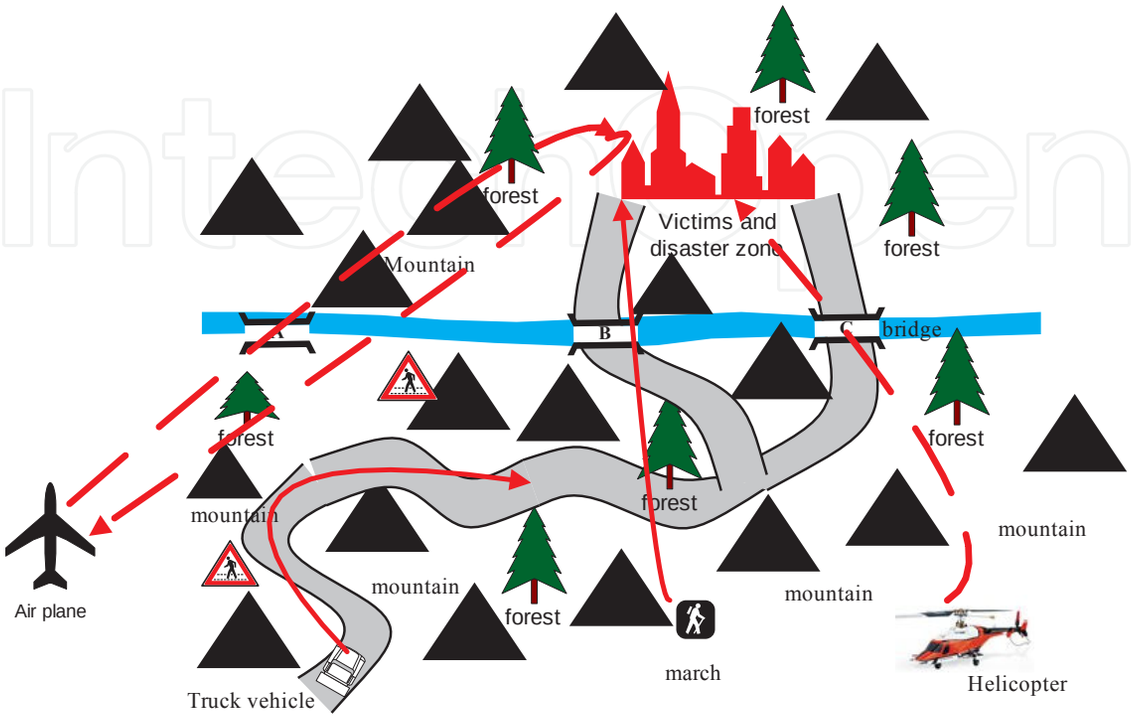


Figure 15. The Earthquake disaster scenario and some emergency response plans

Id	response plans	Advantage	Disadvantage
1	Truck Vehicle	Less relied on weather, fast and land easily.	More relied on highway traffic, less safety.
2	Air- plane	Less relied on highway, high speed and large loading capacity	More relied on weather, hard to land on disaster area and high cost.
3	Helicopter	Less relied on highway, high speed, good flexibility, take off and land easily.	More relied on weather, less safety and high cost.
4	March	Less relied on highway, good flexibility, flexible route	Carry less and move slowly.
m	Plan M	……	……

Table 1. The advantages and disadvantages of some emergency response plans

5.2. The acquisition of the simulation data

For example, we select the emergency response plan by truck vehicle to simulate. In this plan simulation, first to arrange vehicles direction to the disaster zone, and then to design the routes with the random disasters conditions based on the discrete event simulation method (see Figure.16). During the simulation time, it is possible that the rescue trucks are hit by roll rock

or mudslide from the secondary disasters, and it will spend much time to deal with the breakdown. We can simulate the trucks rescue action in different routes in the STAGE (see Figure.17).

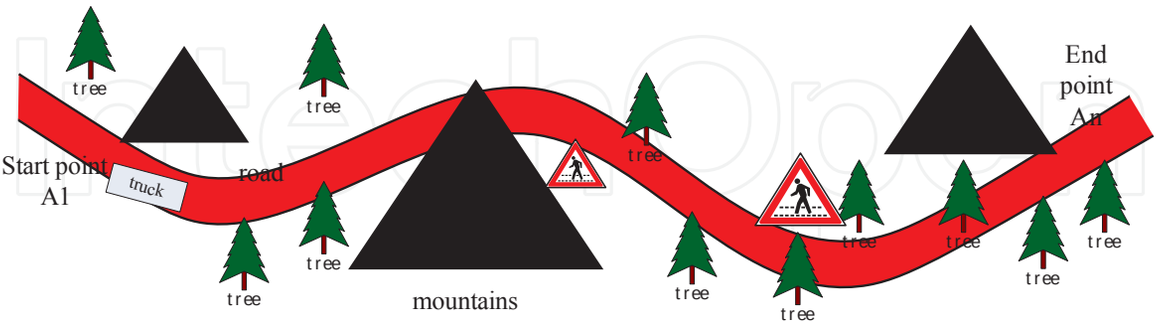


Figure 16. Simulation of the breakdown of the truck plan

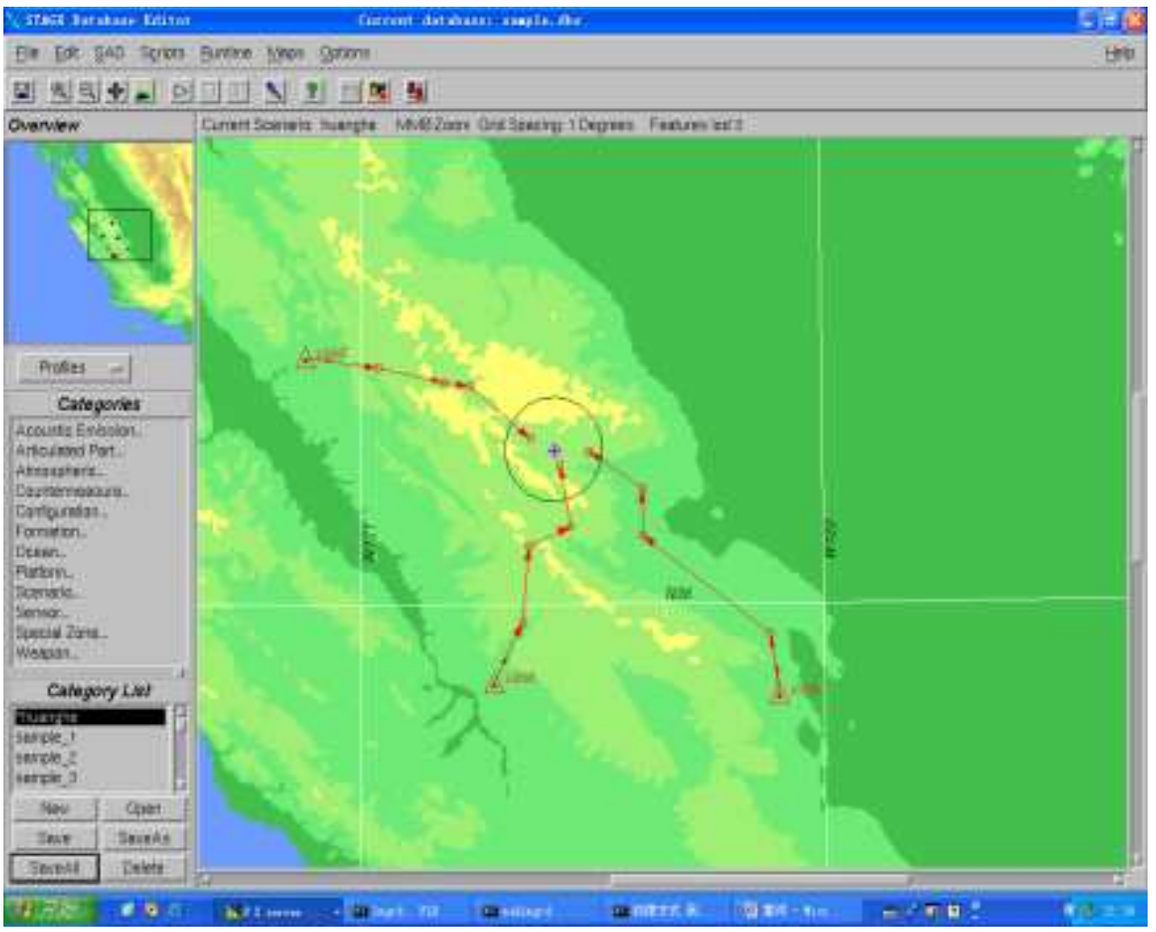


Figure 17. Simulation on the process of truck plan

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Through the simulation system, we can collect the needed simulation information and save it as Xml file. The simulation information file (Truck.xml) is written in the format of the menu of simulation data as follows, seeing Figure 18:

```
<?xml version="1.0" encoding="UTF-8" ?>
< Evaluation-indices-system-of-emergency-response-plan >
      <Timeliness >
          < Rescuing-speed start-time=" 0" arrival time="4" distance=" 300.0"/>
          < Disaster–realtime-report frequency report –times-about-the-disaster="15"/>
      </ Timeliness >
      < Rescue-capability >
          < Load-volume available-weight-to-carry -and-fetch="12"/>
          < Bring-and -fetch equipment-capability-to-carry-and-fetch="0.6" />
       </ Rescue-capability >
          < Action-safety >
                < Beyond-the-bad-weather Level-of-last-bad-weather="6"/>
                < Dependability-of-rescue plan Dependability-probability="0.7"/>
      </ Action-safety >
      < Effect-and-cost >
                < Rescue-the-victims number Number-being-rescued="10"/>
      < Action-cost Cost-of–the-rescue-plan="10"/>
      </ Effect-and-cost >
</ Evaluation-indices-system-of-emergency-response-plan >
```

Figure 18. Simulation information in Xml file

The Truck.xml file is the simulation results information about adopting the truck plan in the emergency response. The simulation and data collection of the other response plans are similar to the plan of the truck. Here it is not necessary to repeat the other emergency plans.

6. The integrated evaluation and decision making for the emergency plans

As a decision-making system for the emergency response plans, it is necessary to integrate the above simulation data and the weights information of the evaluation indices system from the experts.

As for the evaluation method, because the evaluation indices are the isomer information which has different attributes. Therefore, in this paper, a good general evaluation model is adopted to build the decision-making method.

The detail evaluation method is researched as follows.

6.1. Build the evaluation indices system

The effectiveness evaluation indices system is built in Figure 19. A_i is the index i, which describes the system attributes of the alternatives. Among the indices, there are three different

types of indices: one type is the effective index, which value is the more, the better; while the second type is the cost index, which value is the more, the worse; and the third type is the proper index, which characteristic is between the two indices.

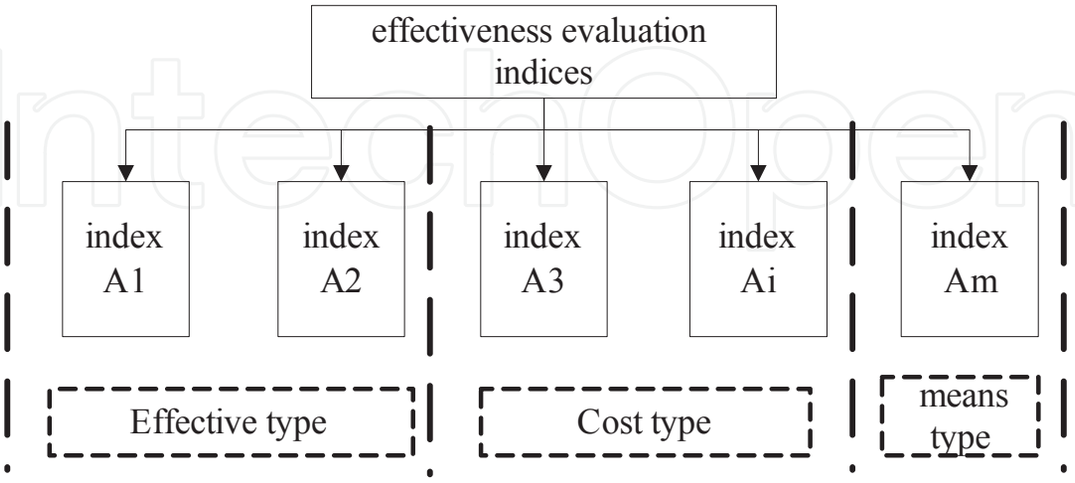


Figure 19. The general evaluation indices system on the emergency effectiveness

6.2. Effectiveness evaluation model based on TOPSIS

TOPSIS is for short of the Technique for Order Preference by Similarity to Ideal Solution. Its main idea is to evaluate the alternatives by means of the measurement scale named Euclidean distance. It is fit for evaluating many alternatives, which have different kinds of attributes.

The evaluation method based on the TOPSIS is very suitable for evaluating the effect of the alternatives, which have many heterogeneous indices. In fact, this method is built on a decision-making matrix, which different rows in the same column index have the same attribute. This is the reason that the heterogeneous data from different plans can also be compared in this evaluation model.

First all, it is necessary to collect the related evaluation data. Combining with the evaluation indices system, get the data or attribute values from the different evaluation indices. Using such data or attributes values, we can build the evaluation matrix C, seeing the Table 2. In this table, the row denotes the alternatives, and the column name stands for the attributes values of the indices. Here the attributes data is from simulation information.

alternative	**attribute 1**	**attribute 2**	**…**	**attribute n**
alternative1	C_{11}	C_{21}	…	C_{1n}
…	…	…	…	…
alternative m	C_{n1}	C_{22}	…	C_{mn}

Table 2. Alternative-attribute information

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C_{ij} means the j-th attribute of the i-th alternative or emergency plan. Where i=1,2,…,m; j=1,2, …,n.

The evaluation method based on the TOPSIS is describes as follows.

Firstly, convert the attributes in table 2 into the decision matrix C.

$$C = \begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ c_{m1} & c_{m2} & \cdots & c_{mn} \end{pmatrix}$$
$$r_{ij} = w_j c_{ij} \Big/ \sqrt{\sum_{i=1}^{n} c_{ij}^2} \quad (1)$$

For the data from the matrix C, the attributes from the same column can be compared with different rows. In order to be convenient to evaluate the different alternatives, we need to standardize the matrix C into matrix R with the unit r_{ij} in formula (1). For w_j, it is the j-th weight of the indices. The matrix R becomes a normalization matrix which also adds the related weights from the evaluation indices, and R will be the foundation of the next evaluation steps.

Secondly, analyze the ideal point and negative-ideal point from the alternatives.

To get the ideal alternative and negative-ideal alternative, it depends on the type of the indices. Different type indices have different modes of process. The ideal alternative vector point is x* in the formula (2). At the same time, the negative-ideal alternative vector point is x-in the formula (3):

$$\{(\max_i r_{ij} \mid j \in J), (\min_i r_{ij} \mid j \in J') \mid i \in M\} = [r_1^*, r_2^*, ..., r_n^*] \quad (2)$$

$$\{(\min_i r_{ij} \mid j \in J), (\max_i r_{ij} \mid j \in J') \mid i \in M\} = [r_1^-, r_2^-, ..., r_n^-] \quad (3)$$

In the formula (2) (3), M is the set of the alternatives, J and J′ is the effective type and cost type respectively.

Thirdly, calculate Euclidean distance of each alternative to the ideal alternative or the negative-ideal alternative.

The Euclidean distance of the i-th alternative to the ideal vector point.

$$S_i^* = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^*)^2} \quad (i \in M) \quad (4)$$

The Euclidean distance of the i-th alternative to the negative-ideal vector point.

$$S_i^- = \sqrt{\sum_{j=1}^{n} (r_{ij} - r_j^{-*})^2} \quad (i \in M) \tag{5}$$

Fourthly, calculate the degree of each alternative approaching the ideal alternative C_i in formula (6).

$$C_i = S_i^- / (S_i^- + S_i^*) \tag{6}$$

According to the formula (6), if the degree C_i is larger, means that i-th alternative is better.

6.3. Response effectiveness indices system and evaluation information acquisition

In this application example, the effectiveness of several emergency response alternatives for the earthquake is evaluated based on the above evaluation model. The evaluation process is carried out as follows:

First, set up the evaluation indices system for the earthquake emergency response effectiveness, seeing the Figure 20.

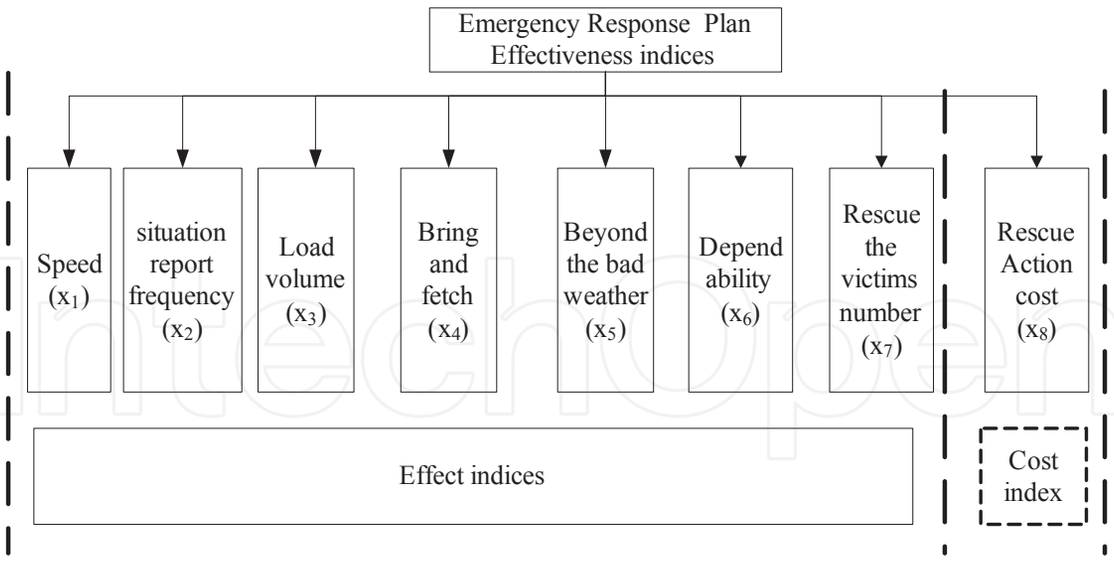


Figure 20. The effectiveness evaluation indices system

Second, there are two kinds of important information to be ready: indices weights and the indices simulation data.

According to the weights acquisition system, get the weights values from x_1 to x_8 as follows:

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W=0.142, 0.115, 0.091, 0.10, 0.092, 0.123, 0.159, 0.178.

The simulation values of the indices from x_1 to x_8 are filled in the table 3, where, x_8 is the cost type index, means the less the better. The indices except x_8 are the effect indices.

Emergency response plan A	**Rescuing speed x1**	**Disaster real time report frequency x2**	**Load volume x3**	**Bring and fetch capability x4**	**Beyond the bad weather x5**	**Dependability of rescue plan x6**	**Rescue the victims number x7**	**Action cost x8**
Truck	75	15	12	0.6	6	0.7	10	10
Air plane	500	10	40	0.4	3	0.5	0.1*	40
Helicopter	300	25	20	0.9	8	0.7	20	20
march	6	20	0.5	0.6	9	0.8	1	2

Notice * : For the airplane can not carry anything back from disaster zone, here use 0.1 stands for carrying few.

Table 3. The indices simulation data of emergency response plan

6.4. Process of the evaluation

With the method, we can get the original matrix C from the information in Table 3.

$$C = \begin{bmatrix} 75.0 & 15.0 & 12.0 & 0.6 & 6.0 & 0.7 & 10.0 & 10.0 \\ 500.0 & 10.0 & 40.0 & 0.4 & 3.0 & 0.5 & 0.1 & 40.0 \\ 300.0 & 25.0 & 20.0 & 0.9 & 8.0 & 0.7 & 20.0 & 20.0 \\ 6.0 & 20.0 & 0.5 & 0.6 & 9.0 & 0.8 & 1.0 & 2.0 \end{bmatrix}$$

Due to each of the index has different weight, it is necessary to think about the indices weights for the original matrix. In this paper, the weights values for the indices from x_1 to x_8 is W=0.142, 0.115, 0.091, 0.10, 0.092, 0.123, 0.159, 0.178. Using the formula (1), we can get the standard matrix P.

$$P = \begin{bmatrix} 0.018 & 0.047 & 0.0236 & 0.0462 & 0.04 & 0.063 & 0.071 & 0.0388 \\ 0.121 & 0.0313 & 0.0786 & 0.031 & 0.02 & 0.045 & 0.0007 & 0.155 \\ 0.025 & 0.078 & 0.0393 & 0.0692 & 0.0534 & 0.063 & 0.1421 & 0.0776 \\ 0.0015 & 0.0625 & 0.001 & 0.0462 & 0.06 & 0.072 & 0.0071 & 0.0078 \end{bmatrix}$$

From the matrix P, the Ideal alternative vector point can be selected as IdealPt=(0.121, 0.078, 0.0786,0.069,0.0601, 0.072, 0.142,0.0078). Notice that X_8 is the cost index, the less the better.

At the same time, the most negative alternative point can be chosen as NegativePt=(0.0015, 0.0313, 0.0010, 0.031, 0.020, 0.045,0.00071, 0.155)

By means of the formula (4), get the Euclidean distance of each alternative to the ideal alternative vector point as follows: IdealDis=(18.93,432.2, 232.1, 67.83).

Get the Euclidean distance of each alternative to the most negative alternative vector point as follows: anti-idealDis=(77.87, 502.41, 302.18, 21.53).

Combined with the idealDis and anti-dealDis, we can get the approaching degree F which stands for any alternative approaching the ideal alternative vector point, By the meantime, far way from the most negative alternative vector point, F=(0.4932 0.3946 0.6726 0.4451).

According to the approaching degree F, rank all the response plans in descending order as follows:

Plan 3-helicopter> Plan 1-truck > Plan 4-march > Plan 2-air plane. The diagram is described in Figure 21.

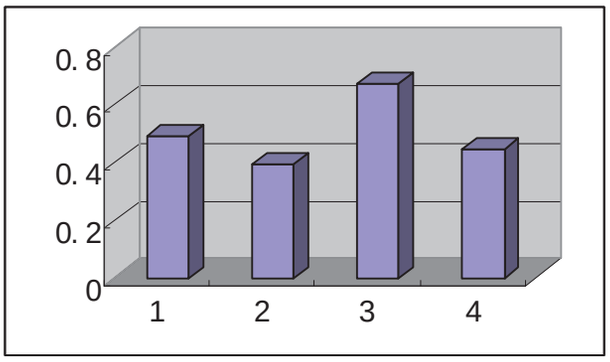


Figure 21. The effectiveness rank of the four Response plans

Based on the evaluation results, the plan 3(Helicopter rescue plan) is the first rank of all the plans, and the truck vehicle plan is the second. However, the last is the airplane response plan because it could not make its function to the maximum for example the plane can not land on the damage airport and pick up nothing back.

6.5. Future work

In this chapter, we develop a robust decision making support system, what's more, make valid application for evaluation and simulation the emergency response to the earthquake. As far as the future work concerned, there are several points to be done:

Firstly, improve the visual system of decision making system. A good visual system is welcome because we prefer the diagram to text or formulas. The future work will enforce the visual modular in the decision making system.

Secondly, improve the simulation technology for analyzing the emergency response plan, especially for the interaction simulation. There are many interactions in the simulation of the emergency response plans, and thus, it is necessary to enforce the Distributed interaction simulation technology like HLA/RTI.

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Thirdly, improve the evaluation method. As we know, the evaluation method is the core of the decision-making support system. in this chapter, we adopt the experts judge method and the multi-attributes decision making method –TOPSIS. In the future work, we should adopt more evaluation methods to support the evaluation of the emergency response plans for the catastrophes.

7. Highlights

In this paper, there are some highlights as follows:

a. Put forth a set of systematic framework to simulate and evaluate the emergency response plans.

b. Define the concept of the emergency response effectiveness, and build up a set of the evaluation indices systems for emergency response plans.

c. Build the emergency response simulation model based on OODA, and describe it in DEVS theory.

d. Build up simulation system architecture based on HLA/RTI; collect simulation information by means of the simulation data list in XML format.

e. Build an evaluation method of emergency response effectiveness based on TOPSIS.

8. Conclusions

In this paper, put forth the concept of the emergency response effectiveness, and center on the methods of response effectiveness simulation and evaluation. A decision-making support system is built to evaluate the emergency response plans. The system is made up of several parts: indices weights acquirement subsystem, simulation mechanism of emergency response process, simulation data acquirement and the integrated evaluation method based on TOPSIS.

By means of the decision-making support system, several response plans in some earthquake disasters are evaluated for their response effectiveness. The evaluation results demonstrate that the simulation and evaluation system is available and reasonable.

9. Summary

It is difficult to judge the most suitable preparedness plan from many emergency response plans. And therefore, it is necessary to build a decision-making support system to evaluate the response plans and to select the most suitable preparedness plan.

In fact, we face with the challenge to test and evaluate the response plans under the **real conditions** of a strong earthquake disaster. Modeling and simulation methods are adopted to

evaluate and demonstrate the preparedness plans for their advantages such as low cost, safety research, time-space easily converting, and so on.

In this chapter, pointing to the strong earthquake disasters, a decision-making support system framework is designed to manage the emergency response plans, and this framework includes the simulation and evaluation methods. In detail, a whole research route map is designed and developed to simulate and evaluate the response plans for the untraditional emergency disaster like earthquake. As a result, a serial of technical methods and theory models are included in the systematic framework. There are 5 main parts (subsystems) in this framework. They are including: (A) emergency response effectiveness concept and the evaluation indices, (B) indices weights acquisition,(C)emergency response simulation theory based on OODA-DEVS, (D) simulation system and simulation data acquirement,(E) the integrated evaluation process and decision making support system.

In this chapter, the concept of the emergency response effectiveness is defined, and it can use as a comprehensive index to measure the degree of the emergency response plan. What's more, the evaluation indices of the emergency response plans are built up in systems engineering method.

In order to describe the evaluation indices clearly and be easy to design for programming, we adopt the XML (Extensible Markup Language) file format to describe the response effectiveness indices of the earthquake disaster.

To get the weights of the evaluation indices, the weights evaluation system based on MVC (Model View and Controller) mode is built.

Referring as the similar process of combat, the emergency response process framework based on OODA loop is built, and put forth a simulation model in DEVS theory. By means of the simulation model, we design the flowchart of the system simulation engines.

For many interaction operations in the emergency response simulation, we build up a simulation system architecture based on the HLA/RTI (High Level Architecture/Run-time Infrastructure) technology. It is suitable for the developers to use HLA and RTI to describe emergency response systems full of interactions and interoperability.

A typical earthquake disaster is designed as an application scenario. The following emergency response plans are evaluated based on such a scenario.

It is necessary to integrate the above simulation data and the weights information of the evaluation indices system from the experts.

As for the evaluation method, because the evaluation indices are the isomer information which has different attributes. A general evaluation model based on TOPSIS is adopted to build the decision-making method.

Taking the emergency simulation scenario of the strong earthquake disaster as example, apply with the simulation and evaluation methods in this chapter, and get the evaluation results of emergency response plans. The evaluation results show feasible. In this example, the Helicopter rescue plan is evaluated as the best plan among the response plans, and the truck vehicle

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plan is the second. However, the last is the airplane response plan for it can not land on the damage airport and pick up nothing back.

Nomenclatures

AHP—Analytic Hierarchy Process

DEVS—Discrete Event System Specification

GUI—Graphic user Interface

HLA—High Level Architecture

MVC—Model View and Controller

M&S—Modeling and Simulation

OODA—Observe, Orient, Decide, Act

RTI—Run-time Infrastructure

STAGE—Scenario Toolkit and Generation Environment)

TOPSIS—Technique for Order Preference by Similarity to Ideal Solution

XML—Extensible Markup Language

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