ISSN : 0974 - 7435 Volume 10 Issue 24

2014

BioTechnology

An Indian Journal

FULL PAPER

BTAIJ, 10(24), 2014 [15165-15171]

Research on emergency materials grading based on entropy weight and grey associated analysis

Cheng Hu-Biao, Jiang Da-Li*

Institute of Modern Logistics, Logistical Engineering University, Chongqing 401311, (CHINA)

E-mail: jiang2100-2@163.com

ABSTRACT

Emergency materials are the material basis to deal with unexpected events. The emergency materials grading is one of the key issues in optimizing inventory management and improving operational efficiency in emergency system. This paper builds a hierarchical evaluation system through analyzing the influence factors of the grading of emergency materials, then designs the grey associated analysis model combing entropy weight, obtaining the comprehensive priority order and grading of emergency materials. The number experiment analysis proves that this method is effective and provides the mathematics basis for optimizing the decision of emergency materials reserve.

KEYWORDS

Emergency materials; Grading; Inventory management; Entropy weight; The grey associated analysis.

INTRODUCTION

In recent years, various significant sudden disaster events have caused major injury to countries and people involved, such as 9.11 terrorist attack in America in 2011, nuclear leakage in Japan in 2011, SARS sweeping across in China in 2003, freezing rain and snow disaster as well as Wenchuan Earthquake in 2008, Yushu Earthquake and catastrophic debris flow in Zhouqu in 2010 and Lushan Earthquake in 2013 etc. How to establish high-efficiency emergency response mechanism and system has increasingly drawn attention from government all over the world, and emergency material grading and classifying management is a significant research field of emergency system operation decision.

In accordance with standard of classification in Emergency Material Classification and Product Catalogue, National Development and Reform Commission has classified emergency materials as protective articles and life rescue etc. totally 13 categories. Many scholars have made research on emergency material grading and classification: Qin Junchang et al. [1] classified emergency materials as responsive materials and recovery materials in the perspective of the vertical integration of operational process in emergency management; Zhang Xufeng[2] thought to classify emergency materials as four categories: life rescue materials, engineering support materials, engineering construction materials and post-disaster reconstruction materials taking into consideration of relief priority of emergency materials; Guo Zixue and Zhang Qiang[3] adopted fuzzy clustering to classify these 12 kinds of emergency materials based on thought of requirement grading; Xia Ping and Liu Kai[4] adopted PPSVM method to classify emergency materials based on thought of requirement grading; Ding Bin and Wang Peng[5] adopted fuzzy clustering to classify emergency materials in the perspective of reserve; Wang Qingrong et al.[6] classified emergency materials by means of dynamical evolution algorithm. It can be seen from the above research status that there are more researches focusing on qualitative research grading of emergency materials, more researches focusing on quantitative research classification of emergency materials, while fewer researches focusing on quantitative research grading of emergency materials: currently methods for quantitative classification of emergency materials mainly include fuzzy clustering method, neural network method, principal component analysis method and SVM method etc., but there are so few methods used for quantitative grading; traditional ABC grading method which only considers single index can be better applied in goods inventory management, but it is not applicable to emergency material grading, as grading of emergency materials not only needs to think of significance of materials during response to emergency, but also needs to think of purchase difficulty, estimated demand, timeliness of materials and other factors, not only considering economic efficiency, but also involving emergency efficiency etc. In the view of optimization of inventory management, grading management as per degree of significance of materials may greatly improve emergency efficiency and reduce cost. Therefore, the research objective is to seek a scientific and reasonable quantitative grading method concerning emergency materials conforming to actual demand fully taking factors influencing grading of emergency material into consideration and in combination with advantages of inventory grading management, thus providing important basis for subsequent emergency material storage decision.

Grey associated analysis refers to a statistical method by which interaction and correlation among multiple factors in system are studied[7-9], and calculation of grey correlation can determine significant ranking of emergency materials. It provides new ideas for emergency material grading.

EVALUATION INDEX SYSTEM OF EMERGENCY MATERIALS GRADING

In the paper, on the basis of summary of research status on emergency material classification index system[10-15], and in consideration of demand characteristics, timeliness, scarcity and guarantee period etc. factors of emergency materials, evaluation index system of emergency material grading is established, as is shown in Figure 1.

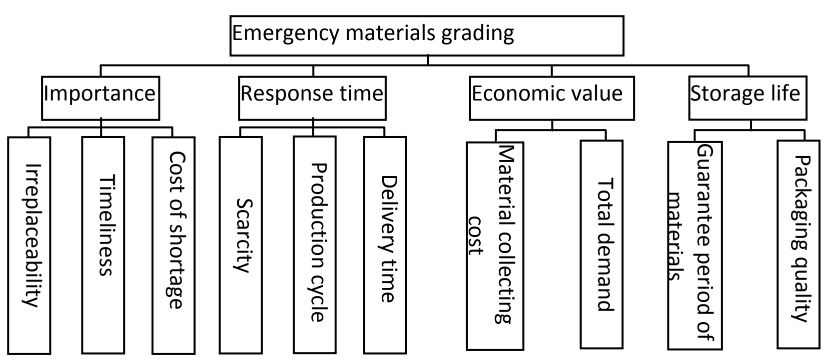

Figure 1: Evaluation index system of emergency material grading

There are many factors involved in emergency material grading, and how to conduct quantitative processing and comprehensive judgment on related information is particularly important, and the quantitative process is shown as follows. Irreplaceability measures whether there are no other materials replacing one material which is scarce to play a role: in case of having uniqueness and complete irreplaceability, assign value of 4; in case of shortage of alternate resource and high cost of utilization, assign value of 3; in case of few varieties of alternate resource and bad effect and partial substitution, assign value of 2; in case of many substitutions and complete substitution, assign value of 1. Timeliness measures urgent degree of material demand after occurrence of disaster, whether it may result in reduction of material effect with time delay, and whether it must reach a certain amount within short period: in case of immediate supply, assign value of 5; in case of supply within 1-2 days, assign value of 4; in case of supply within 3-7 days, assign value of 3; in case of supply in 14 days, assign value of 2; while in case of supply one month later, assign value of 1. Cost of shortage measures losses resulting from untimely provision in case of demand as storage of materials is insufficient: in case of failure of rescue resulting in far-reaching influence, assign value of 5; in case of influence on result of rescue, assign value of 4; in case of directly leading to slow action, assign value of 3; in case of indirect influence which may be made up, assign value of 2; in case of a little economic losses, assign value of 1.

Scarcity measures difficulty degree of purchase and whether domestic storage is sufficient: as to materials having difficulty in production and supply, in case of dependence on production abroad, assign value of 5; in case of materials with not wide productivity source, assign value of 4; in case of production only by a few enterprises and local places, assign value of 3; in case of production by many enterprises and local places, assign value of 2; in case of wide market source and being common in daily life, assign value of 1. Production cycle refers to the whole production and processing time from raw material to finished product, which takes day as the unit. Delivery time mainly refers to interval time from place of departure of materials to place of demand, which takes day as the unit.

Material collecting cost measures price of unit material and cost needed for collection, and it takes yuan as the unit. Total demand measures material demand, with million yuan as the unit.

Guarantee period of materials measures the quality guarantee time of materials under specified storage condition, with month as the unit. Packaging quality measures intact degree of packaging protection performance: in case of good protection, assign value of 3; in case of moderate protection, assign value of 2; and in case of general protection, assign value of 1.

RELATED PRINCIPLE OF EMERGENCY MATERIAL GRADING

Basic principle of emergency material grading management

After grading of emergency material, emergency materials may be reasonably and effectively controlled, the category of great importance, under urgent demand, with great cost of shortage and with large fund occupation is specified as primary material, and the principle of priority and key control in the aspects of order placement and purchase, inventory reserve and machinery allocation etc. is carried out; while minor category with little fund occupation and easily obtained in the market is classified as third-level material, and it is controlled by simple means; and material category between primary and third-level materials is classified as secondary material, which shall be generally controlled. Such method by which materials are under grading management based on different conditions can not only strengthen management and control on key materials, but also can simplify management, being able to achieve good emergency effect and economic effect.

Basic principle of information entropy

Theory of information entropy proposed by Shannon is widely applied in description of system uncertainty[16-17], mainly regarding that the degree of uncertainty of state of certain thing is related to number of state of such thing possibly occurring and probability of occurrence of each state. The description of the definition is shown as follows.

As to a discrete random variable $X=\left(x_1,x_2,\cdots,x_n\right)$, probability space may be described as:

$$\begin{bmatrix} X \\ P(X) \end{bmatrix} = \begin{bmatrix} x_1 & x_2 & \cdots & x_n \\ p(x_1) & p(x_2) & \cdots & p(x_n) \end{bmatrix} \qquad (1)$$

Where $p\left(x_i\right)$ is corresponding probability of x_i, and it is given that, $0 \le p\left(x_i\right) \le 1$, $i=1,2,\cdots,n$, $\sum_{i=1}^{n} p(x_i)=1$, so corresponding information amount of x_i is defined as: $I\left(x_i\right)=\log_2 \frac{1}{p\left(x_i\right)}=-\log_2 p\left(x_i\right)$, Shannon got information entropy of X through defining mathematical expectation of information amount corresponding to x_i: $H(X)=E\left[I(x_i)\right]=-\sum_{i=1}^{n} p(x_i)\log_2 p(x_i)$. The principle of information entropy can be applied in calculation of entropy weight.

Grey associated analysis model of emergency material

Grey correlation degree gotten through grey associated analysis can be applied to describe sequence of evaluation object. Original grey correlation method adopts equal weight processing when calculation of correlation degree, and adoption of subjective weighting method can’t eliminate the subjectivity of each factor weight. As entropy evaluation method determines index weight with judgment matrix constituted by evaluation index values under objective condition, and it can eliminate subjectivity of each factor weight, making evaluation result more greatly conforming to reality, thus improving evaluation precision of grey associated analysis method, therefore, in the paper, entropy method is introduced to weight calculation in grey associated analysis method to establish grey associated analysis model, and specific technical framework is shown in Figure 2.

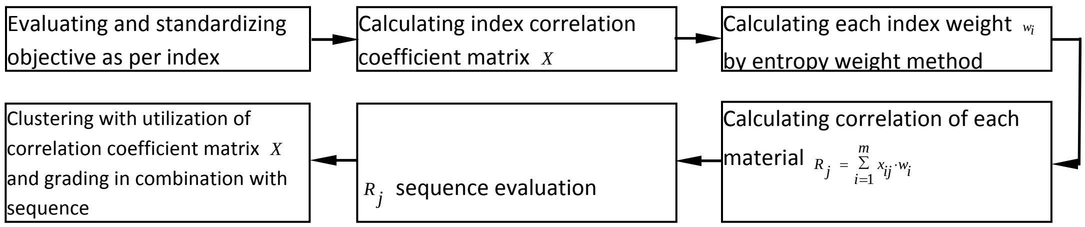

Figure 2: Technical framework of grey associated analysis of emergency material grading

(1)Determine evaluation object, index and dimensionless index value and determine reference series. Assume that evaluated material is $x_1, x_2, \cdots, x_n$; evaluated index is $u_1, u_2, \cdots, u_m$; a_{ij} is element evaluation datum of the jth material and the ith index $(i = 1, 2, \cdots, m; j = 1, 2, \cdots, n)$. The evaluation matrix is

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{21} & \cdots & a_{2n} \\ a_{31} & a_{32} & \cdots & a_{3n} \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix} \qquad (2)$$

All index data with dimensional difference are made dimensionless to transform to value within interval of $[0,1]$. Generally index is divided into two kinds, referring to positive index of which the greater the value is, the better it is; and negative index of which the less the value is, the better it is. With regard to positive index, adopt $e_{ij} = \dfrac{a_{ij} - \min\limits_j(a_{ij})}{\max\limits_j(a_{ij}) - \min\limits_j(a_{ij})}$, while with regard to negative index, adopt $e_{ij} = \dfrac{\max\limits_j(a_{ij}) - a_{ij}}{\max\limits_j(a_{ij}) - \min\limits_j(a_{ij})}$, then standardized data matrix of the evaluated value can be obtained

$$E = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1n} \\ e_{21} & e_{21} & \cdots & e_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ e_{m1} & e_{m2} & \cdots & e_{mn} \end{bmatrix} \qquad (3)$$

Add reference series e_{i0} at the right side of matrix E, just being the index value of most important material sample, generally take the maximum value for positive index, while take minimum value for reverse index. Matrix E' may be obtained.

$$E' = \begin{bmatrix} e_{11} & e_{12} & \cdots & e_{1n} & e_{10} \\ e_{21} & e_{21} & \cdots & e_{2n} & e_{20} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ e_{m1} & e_{m2} & \cdots & e_{mn} & e_{m0} \end{bmatrix} \qquad (4)$$

(2) Calculate index grey relational coefficient on the basis of matrix E'. Assume that x_{ij} is the correlation coefficient between the ith index of the jth emergency material and most important material, and the formula is

$$x_{ij} = \frac{\min\limits_i \min\limits_j \left|e_{i0} - e_{ij}\right| + \rho \max\limits_i \max\limits_j \left|e_{i0} - e_{ij}\right|}{\left|e_{i0} - e_{ij}\right| + \rho \max\limits_i \max\limits_j \left|e_{i0} - e_{ij}\right|} \qquad (5)$$

Where $\rho \in [0,1]$ is resolution coefficient, and the greater the resolution coefficient is, the greater the resolution ratio is; while the less the resolution coefficient is, the less the resolution ratio is. Take $\rho = 0.5$ in the paper. Index correlation coefficient matrix obtained through calculation is

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{21} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \quad (6)$$

(3) Calculate index entropy weight w_i on the basis of matrix E. Adopt entropy method to evaluate index weight, and entropy value is calculated as per the following formula.

$$p_{ij} = \frac{e_{ij}+1}{\sum_{j=1}^{n}(e_{ij}+1)} \quad (7)$$

$$H_i = -\frac{1}{\log_2 n}\left(\sum_{j=1}^{n} p_{ij}\log_2 p_{ij}\right) \quad (8)$$

$$i = 1,2,\cdots,m; \quad j = 1,2,\cdots,n$$

Then entropy weight is

$$w_i = \frac{1-H_i}{m-\sum_{i=1}^{m} H_i} \quad (9)$$

(4) Calculate degree of correlation among all materials on the basis of the matrix X and index entropy weight w_i and conduct evaluation analysis.

$$R_j = \sum_{i=1}^{m} x_{ij}\cdot w_i \quad (10)$$

According to degree of grey weighted correlation, sequence each evaluation object, and correlation sequence of evaluation object can be established, and the greater the correlation is, the stronger the significance is.

(5) Apply SPSS software to make cluster and conduct grading in combination of material property and correlation sequence on the basis of the matrix X.

CASE ANALYSIS

In the paper, 16 kinds of emergency materials for life rescue in Literature [5] are selected, respectively being: 1, compressed food, 2, bottled water, 3, cotton quilt, 4, tent, 5, first-aid medicine, 6, tourniquet bandage, 7, stretcher, 8, protective clothing, 9, infrared detector, 10, transfusion equipment, 11, helmet, 12, oxygen delivery equipment, 13, canvas, 14, disinfectant sterilizing drugs, 15, storage battery, 16, searchlight. Grey correlation degree is calculated through established index system and model. When evaluation of each material, data are obtained through issuing of questionnaires, consultation from experts, manufacturers and staff for emergency material storage, refer to Table 1.

TABLE 1: Comprehensive evaluation of influencing factor on emergency material grading

Evaluation index	Sequence number of emergency material															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
u_1	1	4	1	3	4	4	2	4	4	4	2	4	2	4	4	4
u_2	4	5	3	5	5	5	5	5	5	5	4	5	4	5	5	5
u_3	4	4	1	4	5	4	3	5	5	5	2	5	3	3	4	4
u_4	1	1	1	3	2	1	2	3	3	2	1	1	1	1	1	1
u_5	4	1	5	10	10	4	4	9	11	8	4	2	4	15	15	15
u_6	2	2	2	4	2	2	2	3	3	2	2	2	2	2	2	2
u_7	10	3	100	300	400	10	300	400	500	100	30	50	30	150	200	50
u_8	300	400	500	700	800	100	450	600	550	900	200	200	150	450	160	100
u_9	18	24	20	36	20	30	48	36	38	26	50	26	36	19	38	38
u_{10}	3	1	1	2	3	3	1	3	3	3	1	3	1	2	1	1

Programme by matlab, and solve as per grey correlation analysis model steps, and calculated results are $R_9 = 0.8419$, $R_8 = 0.8040$, $R_5 = 0.7161$, $R_4 = 0.7033$, $R_{10} = 0.6969$, $R_{12} = 0.5981$, $R_6 = 0.5828$, $R_{14} = 0.5494$, $R_{15} = 0.5409$, $R_{16} = 0.5294$, $R_7 = 0.4979$, $R_1 = 0.4912$, $R_2 = 0.4616$, $R_{11} = 0.4190$, $R_{13} = 0.3839$, $R_3 = 0.3613$, and sequence reflects degree of significance of materials. Sequence of each index weight is shown as $w_{10} > w_4 > w_7 > w_6 > w_1 > w_5 > w_8 > w_9 > w_3 > w_2$.

Conduct clustering analysis on correlation coefficient matrix X by application of SPSS software, and clustering method refers to Ward square sum of deviations, and Euclidean distance square method is selected for distance measurement, and clustering objective is divided into 3 types, finally clustering results shown in Figure 3 are obtained.

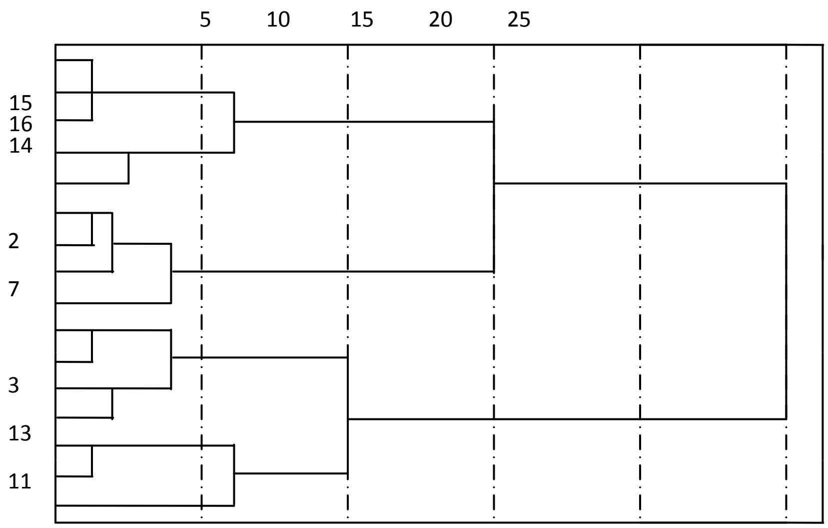

Figure 3: Tree diagram of clustering analysis

Make moderate adjustment taking sequence of grey correlation, in accordance with clustering results in the tree diagram and in combination with grading management principle, material property and possible storage management body, and divide these 16 kinds of emergency materials for life rescue into three levels, refer to Table 2. The research and analysis results not only can reach classification effect in Literature [5] and [6], but also the obtained grading results are clear, and degree of significance of emergency materials is also clear, being more favorable for inventory management of materials.

TABLE 2: Results of emergency material grading

Primary material: badly needed materials for life rescue with fast response and high storage requirement	9 infrared detector	Secondary material: high-cost low-storage materials	15 storage battery
	8 protective clothing		16 searchlight
	5 first-aid medicine		7 stretcher
	4 tent	Third-level material: low-cost short-production-cycle easily-purchased materials	1 compressed food
	10 transfusion equipment		2 bottled water
	12 oxygen delivery equipment		11 helmet
	6 tourniquet bandage		13 canvas
	14 disinfectant sterilizing drugs		3 cotton quilt

Primary materials are badly needed materials for life rescue with fast response and high storage requirement. Features of such materials refer to that cost of materials is high and response speed is required fast. Among them, the requirement of drug materials on environmental protection is high, and they must be under key control. With regard to such type of emergency materials, overall level of storage shall be improved in the aspect of management, and they may be stored instead by medical institutions legally by means of economic or administrative methods to reasonably reduce cost of materials.

Secondary materials belong to high-cost low-storage materials. Features of such materials refer to that cost of materials is relatively high, but response speed is required lower than that of primary materials, and material production cycle and purchase difficulty degree are between that of primary and third-level materials, and with regard to such emergency materials, moderate storage shall be emphasized in aspect of management, and they may be stored instead by manufacturers and suppliers legally by means of economic or administrative methods.

Third-level materials are low-cost short-production-cycle and easily-purchased materials. The greatest feature of such materials refers to that production cycle is short, cost of materials is low and they are easily purchased. For instance, cost of bottled water is low, and production cycle is short, market supply is sufficient and there are many manufacturers, so even if storage is insufficient in case of occurrence of disaster, it is easily acquired in the market. With regard to such materials, storage shall be reduced as much as possible in aspect of management, and they can be temporarily collected taking full advantage of market storage.

CONCLUSION

Grading management concerning emergency materials is of great significance on copping with damages resulting from disaster. In the paper, influence of emergency material index on grading is fully taken into consideration, and thus emergency material grading method is established based on entropy weight and grey associated analysis. The model quantitatively describes grading of emergency materials and degree of significance of all materials, and improves the deficiency that traditional grading method can only conduct qualitative description or only take single index into consideration, reaching better grading results, and providing mathematical basis for optimizing emergency material storage decision, and in the meantime finds that clustering with utilization of grey correlation coefficient matrix may get better clustering effect.

ACKNOWLEDGEMENTS

This work is supported by the the Natural Science Foundation Project of CQ CSTC (Grant# cstc2011bb0045), and the Natural Science Foundation Project of CQ CSTC (Grant# cstc2010bb9200).

REFERENCES

[1] Qin Jun-chang; Wang Kan-liang.An intertemoral integrated inventory model for emergency materials and its analytic based simulation algorithm.Operations Research and Management Science,17(4):45-50,(2008).

[2] Zhang Xu-feng; Analysis of classify system for contigency materials and purchase Strategy.China Market, (32):110-111, (2007).

[3] Guo Zi-xue,Zhang Qiang; Application of fuzzy clustering analysis in classification of emergency materials[J].Computer Engineering and Applications,45(35):208-211,(2009).

[4] Xia Ping,Liu Kai; Emergency materials classification method based on posterior probability support vector machine.Journal of Transportation Systems Engineering and Information Technology,10(2):174-177,(2010).

[5] Ding Bin,Wang Peng; A method of reserve classification on emergency materials based on clustering analysis. Journal of Beijing Institute of Technology,12(4):10-13,(2010).

[6] Wang Qing-rong,Zhao Xiao-ning,Yang Jing; Emergency materials classification of dynamical evolutionary algorithm based vague entrony weight projection pursuit model.Statistics & Decision,17(3):113-116,(2012).

[7] Liu Si-feng, Dang Yao-guo; Grey System Theory and Application. Science Press:Beijing,(2010).

[8] He Yi-qing,Weng Yi-jing; Evaluation and analysis on city financial ecology environment in poyang lake area in iiangxi province. Journal of Nanchang University,36(3):291-295,(2012).

[9] Cen Yong-ting; The travel agency clustering research based on grey associated degree and entropy weight analysis.Industrial Engineering and Management,17(3):113-116,(2012).

[10] Zhang Yong-ling; Research on classified reserve of emergency materials based on fuzzy clustering analysis.Journal of Catastrophology,27(1):130-134,(2012).

[11] Sun Jing-xia; Research on Design of Emergency Logistics Quick Response System and Optimization of Branch Layout. Master's thesis, Gansu: Lanzhou Jiaotong University,(2013).

[12] Zhang Na; Storage Management and Inventory Optimization of Hazardous Materials in Military Logistics Center.Master's thesis, Tianjin: Tianjin University,(2012).

[13] Hou Ling-xia,Li Kun-yin; Classification of emergency supplies on fuzzy clustering. Logistics Engineering and Management,2013,35(3):74-75.

[14] Dong Quan-zhou,Zhao Qi-lan; Research on classification of emergency materials. Logistics System and Intelligent Management, (2):664-668,(2010).

[15] Jiang Da-li, Zhao Zhen-hua,Zhang Li; A study on the reserve mode of emergency materials based on fuzzy clustering and multi-support vector machine.Advanced Materials and Information Technology Processing, (87):812-818,(2013).

[16] Fu Zu-yun; Information Theory:Basic Theory and Application.Electronic Industry Press:Beijing, (2001).

[17] Shi Feng, Mo Zhong-xi; Basis of Information Theory Wuhan University Press: Wuhan, (2002).