Measurement of Post-earthquake Reconstruction System based on Synergy Theory

X D Liang[1], Q X Xiang[2], C M Liu[3,*] and M Wang[4]

[1,2,3,4] Sichuan University, Sichuan, China

Corresponding author and e-mail: C M Liu,2016225025022@stu.scu.edu.cn

Abstract. This paper considers the post-earthquake restoration and reconstruction as a complex Synergetic system from the perspective of Synergetic theory. In order to measure the coordinated development and orderly evolution trend of the system, a comprehensive and scientific index system is established from the two aspects of economic benefits and social perfection. The information entropy weight method and TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) are used to construct a synthesized estimating model and the restoration and reconstruction in Sichuan Province from 2008 to 2013 is taken as an example to be an empirical analysis. The results show that the restoration and reconstruction after Wenchuan earthquake in 2008 has evolved toward a healthy and orderly direction. The results of the measurement are in agreement with the actual situation, proving the validity of the model in the measurement of post-earthquake development.

1. Introduction

Earthquake is one of the most destructive disasters jeopardizing human survival and development, bringing serious damages to regional economic and social development [1]. Post-earthquake restoration and reconstruction is the first consideration to alleviate the serious losses caused by disasters to the national economy and people's livelihood. Existing researches mainly focus on lessons learned from post-earthquake reconstruction [2], geological structures of earthquake regions[3], earthquake emergency[4], the procedure of restoration and reconstruction[5], planning program[6], policies [7] and so on. However, there have rarely been any study focusing on the actual situation of post-earthquake restoration and reconstruction. This study conducts a research from this perspective.

This article measures the regional development of post-earthquake restoration and reconstruction from an integral angle. The post-earthquake restoration and reconstruction is considered as a complex collaborative system by establishing a comprehensive and scientific index system [8] from the two aspects of economic benefits and social perfection. Coordination of the post-earthquake restoration and reconstruction is quantitatively predicted by using the information entropy weight method[1] and TOPSIS[9] to establish a synthesized estimating model.

This year (2018) is the tenth anniversary of the Wenchuan earthquake. And suffered the severest damages in the year, Sichuan Province, the recovery after the earthquake struck a chord in the hearts of people across the world. Taking Sichuan Province as an example have certain scientific significance to some extent.

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2. Synergetic structure of post-earthquake restoration and reconstruction

Synergetics mainly studies the formation and self-organization of patterns and structures in open systems far from thermodynamic equilibrium. The post-earthquake restoration and reconstruction evaluation system is an open economics-society-resources composite one, featured with the characteristics in Figure 1 in its evolution. Thus, synergetics can well explain the complex evolution of the post-earthquake restoration and reconstruction evaluation system.

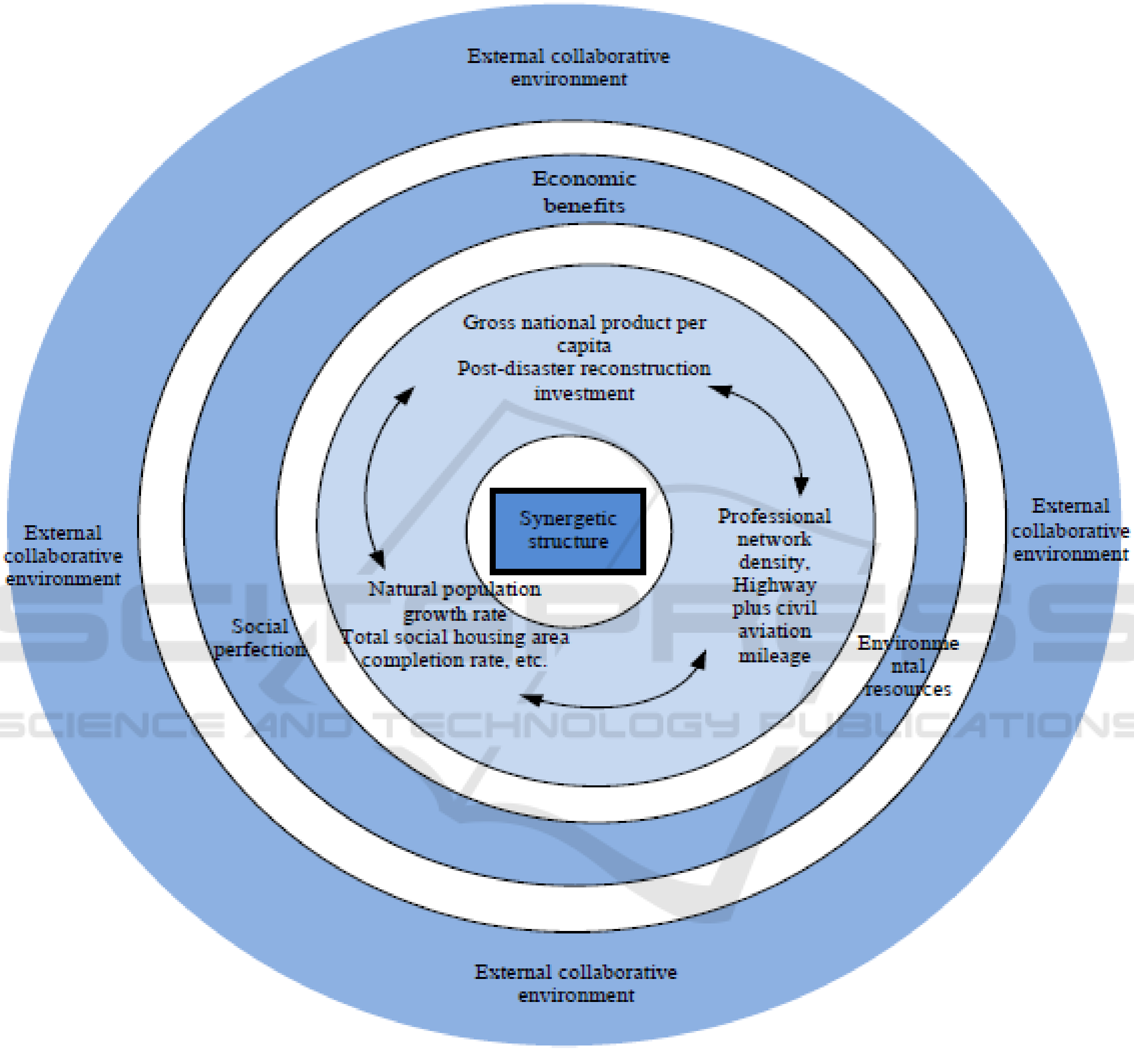

Figure 1. Post-earthquake restoration and reconstruction evaluation system synergetic structure.

3. Index selection of the post-earthquake reconstruction system

Post-earthquake restoration and reconstruction evaluation system is quite complex system. Selection of the evaluation indexes directly affects the eventual establishment of the evaluation index system.

This paper strictly following the principles of representative, comprehensive, systematic, scientific, related, quantifiable, accessible, maneuverable, error-reducing, and efficient, and with reference to previous papers' index selection, this paper divides the post-earthquake recovery evaluation system into the target layer, i.e., the post-earthquake restoration and reconstruction evaluation system, and the principle layer, i.e., economic benefit and social improvement, and the index layer, namely, the fourteen indexes including per capita gross national product (GNP), reconstruction investment, the whole society completion rate of housing areas, and health institution, etc. (refer to Table 1).

Table 1. Post-earthquake Recovery and Reconstruction index set.

Target	Standard	Index	unit	property
Regional development measurement system of Post-earthquake Recovery and Reconstruction A	Economic B1	Per Capita GNP---C10	yuan	Benefit
		Proportion of Investment in Fixed Assets to GDP--C11	%	Benefit
		Expenditure for Post-earthquake Recovery and Reconstruction ---C12	yuan	Benefit
		Taxes Revenue ---C13	yuan	Benefit
	Society B2	Natural Growth Rate---C20	%	Benefit
		Unemployment Rate in Urban Areas---C21	%	Cost
		Rate of Total Floor Space of Buildings Completed in Construction ---C22	%	Benefit
		Release information from Sichuan earthquake preparedness and disaster reduction information network---C23	piece	Benefit
		Number of Health Care Institutions---C24	unit	Benefit
		Number of Beds in Health Care Center---C25	unit	Benefit
		Number of Fixed and mobile Telephone Subscribers at Year-end---C26	10 000 subscribers	Benefit
		Highways and Total Civil Aviation Routes ---C27	10 000 km	Benefit
		Professional network density---C28	km/unit	Benefit
		Per Capita Public Green Areas---C29	(sq.m)	Benefit

4. Establishment of evaluation model

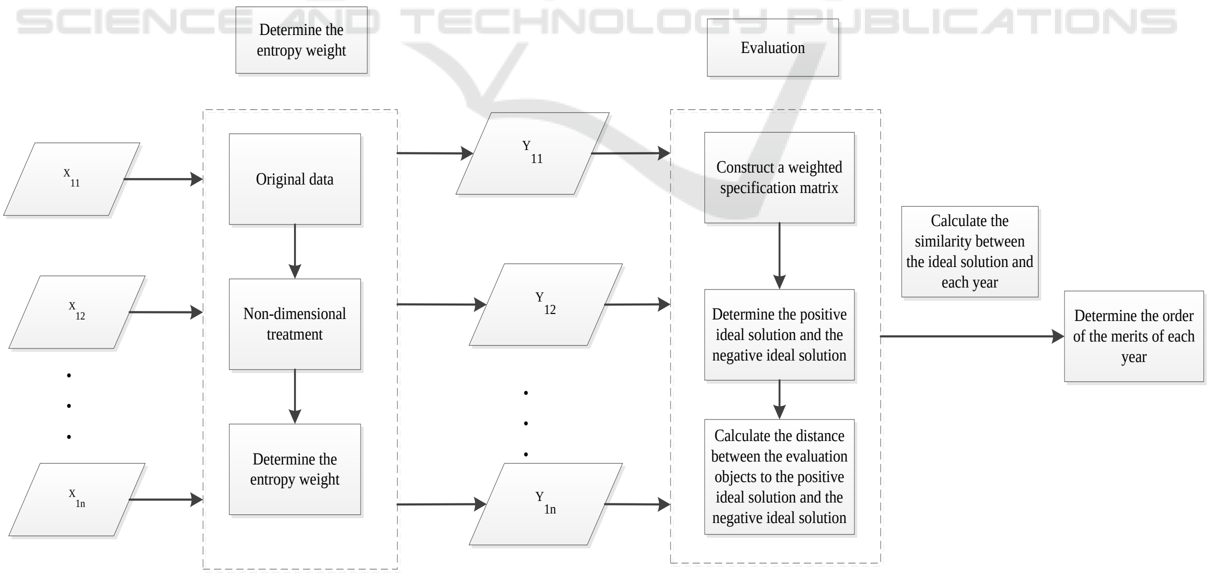

Figure 2. Measurement of post-earthquake reconstruction system based on synergy theory.

Common weighting methods include entropy weight method, standard deviation method, CRITIC method and expert estimation method. Common evaluation methods include analytic hierarchy process, index synthesis method, efficiency coefficient method, optimization distance method, fuzzy comprehensive evaluation method, grey correlation method, etc. Entropy weight method is an objective weighting method. In the entropy weight method, the entropy weight of each index is calculated according to its information entropy and variation, and is then modified according to the entropy in order to obtain an objective weight. Based on the double base point method, the TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) detects the distance between the object and the optimal and worst solutions. The object is deemed as best if it is closest to the optimal solution and farthest from the worst solution; otherwise it is deemed as worst. The TOPSIS method can objectively evaluate the plans with multiple indexes. The evaluation process in this article is shown in Figure 2.

4.1. Determine the weight-entropy method

(1) Build a matrix

Use m year , n measurement indicators to build the initial measure matrix in Regional development measurement system for Post-Earthquake reconstruction R .

$$R = \begin{bmatrix} x_{11} & x_{12} & k & x_{1n} \\ x_{21} & x_{22} & k & x_{2n} \\ k & k & k & k \\ x_{m1} & x_{m2} & k & x_{mn} \end{bmatrix}_{m\times n} \tag{1}$$

(2) Non-dimension treatment

Data non-dimension treatment is the first step in the comprehensive evaluation step. in consideration of Natural Growth Rate may be negative number in the indexes,0-1 standard transformation is selected to deal with the original data. Add 0.00001 to translate the non-dimension data. The processing formula is as follows:

Benefit type: $$y_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}} \tag{2}$$

Cost type: $$y_{ij} = \frac{x_j^{max} - x_{ij}}{x_j^{max} - x_j^{min}} \tag{3}$$

(3) Determine the entropy weight

According to the definition of entropy value, the smaller entropy value is, the grater variation of the index value is, provided amount of information ,play a greater role of the index in the comprehensive evaluation, and get the higher entropy weight in the index.

On the contrary, the greater entropy value is, the smaller variation of the index value is, provided a relatively small amount of information ,play a smaller role of the index in the comprehensive evaluation, the lower entropy weight should be got in the index.

Calculate the entropy value e_j of the j index：

$$e_j = -k \sum_{i=1}^{m} p_{ij} \cdot \ln p_{ij} \tag{4}$$

In the formula:

$$k = 1/\ln m \tag{5}$$

Calculate the entropy weight w_j of the j index:

$$w_j = (1 - e_j)/\sum_{j=1}^{n}(1 - e_j) \tag{6}$$

4.2. Calculate the score of a particular year -- TOPSIS Algorithm model

TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) The double base point method is to rank the distances between the evaluation objects to the positive ideal solution and the negative ideal solution, If the evaluation object is closest to the optimal solution and meanwhile is farthest away from he worst solution, It Shows the evaluation object is the best one. otherwise it is the worst one. The TOPSIS algorithm model can evaluate the plans in multiple indicators objectively.

(1) Construct a weighted specification matrix

Considering the different weight of evaluation indexes to the Post-Earthquake reconstruction measurement system, weight the evaluation indexes via information entropy and get the weighted evaluation matrix.

$$y'_{ij} = w_j \cdot y_{ij} \tag{7}$$

$$R' = \begin{bmatrix} y'_{11} & y'_{12} & k' & y'_{1n} \\ y'_{21} & y'_{22} & k' & y'_{2n} \\ k' & k' & k' & k' \\ y'_{m1} & y'_{m2} & k' & y'_{mn} \end{bmatrix}_{m\times n} \tag{8}$$

(2) Determine the positive ideal solution and the negative ideal solution

Positive ideal solution:

$$y_j^* = \begin{cases} \max_i y'_{ij} & \text{Benefit attribute} \\ \min_i y'_{ij} & \text{Cost attribute} \end{cases} \tag{9}$$

Negative ideal solution:

$$y_j^0 = \begin{cases} \min_i y'_{ij} & \text{Benefit attribute} \\ \max_i y'_{ij} & \text{Cost attribute} \end{cases} \tag{10}$$

When determine the positive ideal solution, Take the maximum value of the benefit indicator, and take the minimum value in cost type. We should take the minimum value of the benefit indicator, and take the maximum value in cost type if we determine the negative ideal solution.

(3) Calculate the distance between the evaluation objects to the positive ideal solution and the negative ideal solution

Calculate the distance from i year to the positive ideal solution.

$$d_i^* = \sqrt{\sum_{j=1}^{n}\left(y'_{ij} - y_j^*\right)^2} \tag{11}$$

Calculate the distance from i year to the negative ideal solution.

$$d_i^0 = \sqrt{\sum_{j=1}^{n}\left(y'_{ij} - y_j^0\right)^2} \tag{12}$$

(4) Calculate the similarity between the ideal solution and each year.

$$c_i^* = d_i^0 / (d_i^0 + d_i^*) \tag{13}$$

(5) Determine the order of the merits of each year

According to the TOPSIS model principle, the closer to the positive ideal solution and farther away from the negative ideal solution, the better of the evaluation year is.

Sort the c* from big to small, the bigger of the c* is, it indicate this year got the better results than other years in the Regional sustainable development measurement system for Post-Earthquake reconstruction.

5. Example analysis

To ensure objectivity and comprehensiveness, the raw data is obtained from Sichuan Statistical Yearbook, Annual Report on Government Information Disclosure of Sichuan Earthquake Administration and expert estimation. China News Service Chengdu Jan. 10, 2012 report (Liu Xian) Jiang Jufeng, of Sichuan Province, said on Jan. 10 in the Fifth Session of the 11th Sichuan Provincial People's Congress that the post-earthquake restoration

In the Fifth Session of the 11th Sichuan Provincial People's Congress that the post-earthquake restoration and reconstruction has successfully concluded. Since the restoration is a long-term process, and suffers from secondary disasters without a definite concluding point, this paper selects the 6 years data from 2008 to 2013 for analysis, and arrives at a conclusion

5.1. Comprehensive evaluation

According to formula (1) to (6), we get the entropy and entropy weight of the index. (Reference table 2).

Table 2. Sichuan development measurement system for Post-Earthquake reconstruction entropy value and entropy weight.

Target	Standard	Index	entropy weight in index system	entropy value
Regional development measurement system of Post-earthquake Recovery and Reconstruction A	Economic B1	C10	0.595494665	0.06941247
		C11	0.585568589	0.071115769
		C12	0.483378048	0.088651503
		C13	0.619444425	0.065302729
	society B2	C20	0.354316435	0.110798269
		C21	0.362337034	0.109421947
		C22	0.724367844	0.047298038
		C23	0.509207337	0.084219238
		C24	0.657976843	0.058690628
		C25	0.66838624	0.056904392
		C26	0.672634726	0.056175359
		C27	0.586045558	0.071033922
		C28	0.659325567	0.058459189
		C29	0.693956667	0.052516548

According to formula (1) to (13), we get the comprehensive evaluation value and comprehensive ranking from 2008 to 2013. (Reference table 3)

Table 3. Sichuan sustainable development measurement system for Post-Earthquake reconstruction result.

	year	Comprehensive evaluation value	Rank result
Regional development measurement system of Post-earthquake Recovery and Reconstruction A	2008	0.415266719	6
	2009	0.497085743	5
	2010	0.658781636	1
	2011	0.502235321	4
	2012	0.541540086	2
	2013	0.529082342	3

5.2. Result analysis

It is known from the basic principles of entropy weight method that an index with a greater information entropy weight provides more effective information for decision-makers, and one with a smaller weight provides less effective information.

Table 2 shows that the Rate of Total Floor Space of Buildings Completed in Construction occupies the biggest proportion (weight 0.724367844), as is described by Wang Yanru that the housing reconstruction involving people's fundamental requirement is especially important [10]. The completion of basic facilities such as the Per Capita Public Green Areas (weight 0.693956667), Number of Fixed and mobile Telephone Subscribers at Year-end (weight 0.672634726), Number of Beds in Health Care Center (weight 0.66838624) are relatively important for post-earthquake restoration and reconstruction. The Natural Growth Rate (with a proportion of 0.354316435) and the Unemployment Rate in Urban Areas (with a proportion of 0.362337034) are relatively weaker impacts on post-earthquake restoration and reconstruction. This is because post-earthquake restoration and reconstruction must be fully considered on the basis of an appropriate population size [11]. In general, the improvement of social functions is more important to post-earthquake economic development.

As shown in Table 3, the 2nd to 3rd years after the earthquake is a critical period. During this period, the sufficient investment and whole society housing completion make year 2010 the highest ranking one.

The results reflect the importance of local government's strategy on post-earthquake restoration and reconstruction, providing scientific reference to other places with similar situations.

6. Conclusions and prospects

Based on the sustainable development evaluation method of TOPSIS (double base point), this paper further explores the evaluation methods and ideas of the sustainable development of post-earthquake restoration and reconstruction. With the advantages of TOPSIS in association vector relation and proximity inherited, the objective entropy weigh method is adopted to determine weights for each index, avoiding the shortcomings of evaluation methods in index weight. Government yearbook data is also utilized to validate the feasibility and universalness of the method, which proves to be a scientific one. The effective measurement of post-earthquake restoration evaluation system shows that the two to three years after the earthquake is the critical period, during which local advantages should be fully made use of to boost economy by integrating regional location and facilities and guaranteeing people's livelihood.

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