Chapter 55
Research on Life Circle Environmental and Social Costs of Construction Projects Based on Emergy Analysis: An Example from Xiamen

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Abstract Whether a construction project is a success or not relates to environment, economy, society and other factors. Civil buildings should not only meet the living, but also weigh the impacts on ecological environment and social issues it brings. Environmental and social impacts should have deeply reflected in the construction cost, however, not calculated. The benefits of building energy conservation, new technologies for environmental protection, excellent project management and organizational capacity does not reflect in the construction cost. Therefore, current system of construction cost could not reflect the real price of building products, and we must find a new way which can scientifically reflect the life cycle energy consumption of building products according to the principle of environmental economics, ecology and social economics.

On basis of the emergy analysis method, this article focused on identification and quantitative analysis on environmental and social costs of the single building, and taken an empirical analysis on an example from Xiamen. It has a far-reaching significance for reasonably priced of the construction environmental and social costs, for the sustainable development strategy, and to better reflect the people-oriented concept.

Keywords Emergy analysis • Ecological impacts • Environmental costs • Social cost • Social impacts • Construction project • Construction cost

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55.1 Introduction

Over the years, the price of building products is calculated based on the cost of valuation theory. With the research and application of the theory of building energy consumption and life cycle cost, the environmental costs of the residential building products and the social costs quantitative calculation became a new problem. In the existing system of cost we considered little about the environmental and social costs, even not included. Price of building materials, for example, appears to be relatively cheap raw material for concrete, will be dried up by current exploitation rate 30 years later in China. Existing materials prices were benefited by regression method, and the calculated by use value rather than absolute value. The rise and promote of emergy theory and emergy analysis provides an absolute value metric ideas and methods to solve the above problem. Emergy is the available energy (exergy) of one kind that is used up in transformations directly and indirectly to make a product or service. Emergy is an expression of all the energy used in the work processes that generate a product or service in units of one type of energy. In this paper, we do methods and empirical research by the use of environmental and social costs based on emergy analysis method to calculate the residential building products.

55.2 Literature Review

1. Social evaluation
   Social evaluation of large-scale construction projects were taken seriously by scholars in recent years. World Commission on Dams project gave top priority to social evaluation. Social migration caused by the large-scale projects, and the resulting social costs and social and cultural changes [1]. Their research showed that local people faced the potential risk of being infected schistosomiasis when they migrated because of major projects construction like the Three Gorges Project, South-to-North water diversion project and Returning Land project. The whole life cycle costs of the three major projects included in the health and epidemic prevention and patient cure for healthy expenditure in form of increasing social costs [2].

   As the in-depth research on the Sustainable Development and post-industrial stage of developed countries faced a lot of infrastructure Sustainable operations and maintenance costs (Bouwer 2009), life cycle cost became the project sustainability evaluation tool.
2. Large-scale project cost range
   In recent 20 years, scholars began to pay more attention to the social costs of large-scale construction projects. The calculation of the social cost by summing up generally includes the adverse effects of four aspects: natural environment,

public property, human society and the regional economy (Xiao 2005). Gilchrist [3] made a quantitative study of the social costs.

3. The plight of the cost valuation theory
Current cost valuation theory about calculation on the value of resources is the benefit regression analysis method in China, pursuing economic output. Against the limitations of this method, (Bakshi and Fiksel 2003) Bakshi and Fiksel proposed it is crucial to the development of "eco-centric" approach because environmental issues are a multi-disciplinary and cross-disciplinary interactions.

   Yang followed the social cost is defined in Allouche [2] and made qualitative analysis of social costs of the whole life of the construction projects. Wang came to a conclusion "the social costs of quantitative calculation seem difficult to solve" [4].

4. Ecological theory and methods in engineering
In recent years, the application of ecology expanded the engineering fields. Emergy analysis about building had just been arisen: Buranakarm evaluated recycling and reuse of building materials by using the emergy analysis method [5]. Jalali used emergy approach to evaluate deconstruction effectiveness including building materials of the concrete walls [6]. Hong Zhou and Wangshu Yang had calculated the emergy in the engineering project [28] and looked upon the engineering system as a subsystem of the ecosystem. Emergy analysis in Civil Engineering is in the ascendant. Emergy analysis method has its advantage to simulate and analyze the natural environment [12], measure the contribution to economic development in any environment, to make up for a monetary standard which cannot measure the defects of nature contributes to the economic development [7]. Huang used emergy analysis method to analyze the material flow of urban infrastructure (Huang 2003). Wang discussed the price system of the sustainable strategy of building products (Wang 2005). Emergy analysis method is also used in the regional labor transfer [8]. Hu-ning Expressway expansion project is to calculated the first large-scale projects example in China [12]. Combination between emergy analysis and emergy life cycle assessment are applied to a target information and technical analysis of complex systems for maximum power and zero emissions (Ulgiati 2007). Integration of Life Cycle Assessment methods, raw material input and the transfer process of environmental systems, and the establishment of environmental management information system were done (Eun 2009).

5. Emergy theory to analyze social problems in large-scale projects

Research in this area needs to be developed. Before this, the emergy theory is applied to the value assessment and history and the development of plans and policies to value analysis and evaluation

1) Assess the energy value of the development plans and policies
Emergy analysis indicated what kind of development plans and programs can contribute up to wealth (emergy) waste at least. In some parts, the early emergy assessment indicated energy measurement can test the following policy: the choice of plan, planning of urban spatial structure, the optimal population

density, scientific research and education, allocation of funds, the net profit of economic growth, labor evaluation and information.

2) The history of value analysis and evaluation
The historical emergy analysis and evaluation is a carried out. Woithe (1994) evaluated the energy flow of the American Civil War in 1860, indicating the status of slaves, resources, external communication and war key factor transformity. On the economic aspects of the paper (Boyles 1975), Boyles pointed out the use of modern monetary evaluation criteria contained in the energy.

3) Emergy analysis of the social cost in the project life cycle
Social costs, hidden, does not direct the performance of quantitative cost and must resort to other means of conversion costs can be directly measured, which makes it difficult to calculate than the economic costs, but these costs are still is there. At present, the practice of engineering construction, we often only emphasis on the management of the economic costs while social costs is considered less. Subjectively because we consider the financial impact of the project itself much more than external effects such as environment, society. We still do not pay enough attention to the national economy evaluation of the project, although the external effect evaluation, but often a mere formality. Social costs are difficult to measure objectively, which has a practical bad effect on its position in practice. According to transformities determined by Odum emergy method, we should add cost elements transformities that have never calculated, mainly including the cost elements of our social transformity in China, which related to the level of social development in China, such as labor, landscape resources and cultural relics such as these factors indicators are very different with the United States. We calculate one by one.

55.3 Methodology

55.3.1 Basic Principles of Emergy Analysis

Traditional project cost calculation does not reflect the project's impact on the surrounding ecological environment, and actually projects affected the surrounding environment and animals and plants in it by dynamic light, heat, noise, electromagnetic radiation, and so forth, especially inevitable impact on human beings society.

Combine life cycle with emergy analysis, we divide the project into five stages: idea, construction, operation, decoration and demolishment to calculate.

During the whole life cycle environmental cost, due to the indicators of each stage of the project impact on the environment is different, according to the theory and the environmental impact of the whole life cycle theory, the construction cost of the project emergy evaluation system will be in phases: project planning, construction engineering, decoration, operations and maintenance and dismantlement. About

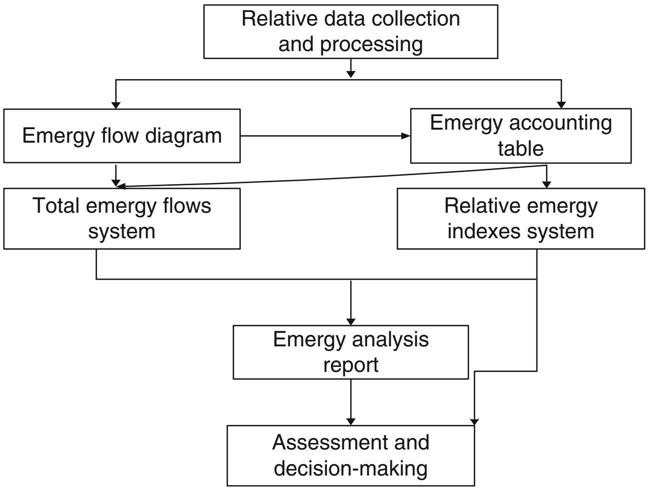

Fig. 55.1 Emergy-based analysis sustainability assessment of a construction project ecosystem

calculations and formulas details follow odum method. Figure 55.1 presents the flowchart with the previously mentioned intermediate products.

55.3.2 Emergy of Animal Reduction

Species emergy: genetic information emergy is the product of geological evolution. For an eco-economic system, it both embodied in biodiversity and rare species. System biodiversity emergy is multiplied by the transformity of the bits of system biodiversity Shannao Weaver index H bits.

$$H = \sum_{i=1}^{s} \frac{N_i}{N} \log_2 \frac{N_i}{N}$$

Ni – number of individuals of species
N – S species overall.

According to the principle of "disappear when the information carrier, the information disappears" shows that when a species disappears, this species, genetic information also disappeared. The rare species emergy are geological emergy consumed by the evolution of the species. Ager estimated 2×10^9 years of geological evolutionary history, and there are 1.5×10^9 mineral species (Lan 2002). Therefore, the energy of each species should be:

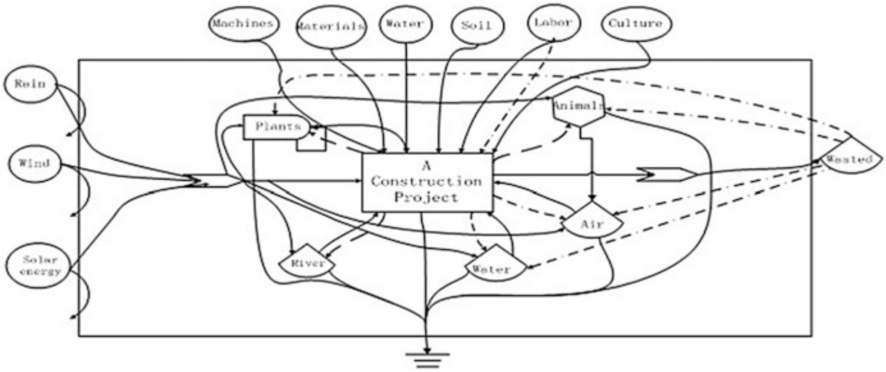

Fig. 55.2 Emergy system diagram in a construction project

$$\left(9.44 \times 10^{24}\text{Jsej/year}\right)\left(2 \times 10^{9}\right)/1.5 \times 10^{9} = 1.26 \times 10^{25}\text{sej/SP}$$

For the rare animals emergy of a specific system is the product of this system on a rare species of support for the species. The support rate (P) is a contribution to the survival of a species, the following formula is: $p = (m/M)(t/12)(s/S)$.

m - number of individuals of the species in the system, M: total number of individuals of the species living on Earth, t: the year/month of the species in the system life time, S: area of the system, s: the area of the actual activities of the individuals of the species within the time t. (Fig. 55.2).

55.4 Case Study

55.4.1 Basic Indicators of the Project

The project is located in A3 # Building at Hubian Lake in the Xiamen Island. The annual average wind density on Xiamen Island east coast is 170w/m^2. The average annual precipitation in Xiamen is 1.14 m/y. The project covers an area of 4226.02 m^2, construction and installation period is 300 days, Total cost is 33 million. In the construction that consumed 2,900 t cement, 2,900 t concrete, 12,500 m^2 wood template, 1600m^{3}cement later. Main material of the above items together accounted for 90 % of the total project cost. Operation period are 30 years, and both decoration and demolition duration are 6 months.

Surrounding the lake reservoir area is 0.9092E + 6 m^2. Average water depth is 9 m. Around the project the number of species 784 kinds of species, and rare species is the national second class protection animal egrets, after the construction we found 20 healthy adult egrets were lost. This monomer is Shimao A3#, designed by Zhongyuan Construction Design and Research Institute. Wastewater, waste gas, solid waste and other indicators are the valuation of the construction department of Xiamen.

55.4.2 *Engineering Ecosystem and Emergy*

55.4.2.1 Some Assumptions

1. All the formula comes from [9] The sources for and equivalence of transformities used in this report. Transformities used in this paper are given to three significant figures and shown for the 9.44, 9.26 and 15.83 E + 24 sej/y baselines. Units are sej/j except where mass (g) is noted, thus the units are sej/g. An exception is that the emergy per unit of education level is sej per individual and the emergy to dollar ratio (sej/$) is used for services. The 9.44 baseline was used by Odum [9]. It has since been superseded by the 9.26 baseline, but it is reported here because many transformities in the older literature are given relative to this baseline. All the Transformity baseline 15.83 E + 24 sej/y. Tidal energy, earth cycle and wave energy do not change.
2. Emergy-monetary value: 2012 Xiamen total emergy estimate in accordance with the estimate method (Huang 2005). Xiamen's total energy value is 5.696×10^{23} sej, and divided by the total GDP of Xiamen in 2011 (169 billion yuan), then emergy-currency ratio of 2.72×10^{12} sej / $.
3. In general the impact of the lake and surrounding buildings, such as the population to reduce equally the method the average total impact to the single building, the lake has more than 500 buildings similar monomer for the calculation of convenience, we assume that there are 500. Then the single building affection is 1/500 of the overall impact.
4. Engineering data source is from the Zhongyuan Construction Design and Research Institute prepared project documents. Estimation is the approximate estimate of the project through the instance of similar projects, and other projects can be based on this case mode sets of raw data into the appropriate project calculations.
5. The society emergy cost in this case should be included in the labor force (respectively in the Table 55.2) and the demolition of the arrival of the demographic changes (the original residents in the site are 85, all been relocated to other placed. The new owners are 506, who are mostly strangers. While due to the demolition the cultural emergy original residents of is broken, cultural emergy lost is about 8.42×10^{20}sej [9] (Table 55.1).

55.5 Conclusions

Because these values are basically the annual average for the unit of measurement in accordance with the duration of these stages, we conducted a simple sum of the following findings:

I =763.51million

Table 55.1 Species emergy in this project area

Category	Species	Emergy/10^{18}sej	Em value/10^6\$
Plant	245	13.54	4.98
Invertebrate	380	35.72	13.13
Amphibian	40	4.04	1.49
Reptile	21	1.97	0.72
Bird	58	27.17	9.98
Mammal	17	1.60	0.59
Total	761	84.03	30.89

According to Xiamen in 2011 GDP: 169 billion yuan, Em means Emergy-monetary

In accordance with the traditional cost calculations as a year as follows: J =33million and a bit

Clearly: $I \geq \geq J$.

The difference of the I and J are mainly flora and fauna loss (especially rare species) to reduce the ecological costs and society impacts cost, also operation cost, while the reason is uncontrolled sound, light, heat, wasted air, water and soil pollution and other factors as well as too much cost of social costs. We should take a green ecological design in the planning and design, take seriously into account the concept of people-oriented. In construction, green construction techniques and protective measures must be taken. In the operation green energy and low carbon way of life also must be taken, which no doubt greatly reduce our and developers' the ecological inputs.

In this paper the main stages which is inquired and calculated does not include the construction project planning and design stage, because we believe that does not involve the emergy loss, but the results of our study is precisely served for this idea stage. Whether a successful project or not is mainly related to the planning and design, the most important stage, thus we can use emergy analysis to the planning ideas comparison, to determine the pros and cons of the project. Simulate each plan for each emergy situations, and analyze the selected total energy consumption (especially non-updatable emergy), and the ecological costs caused by the system will be the best option.

To sum up:

A. This article provided a feasibility study stage can be used to filter the optimal solution to various factors (especially from the ecological environment and social costs point of view) of the building program evaluation;
B. This article established a simple ecological price evaluation system, and this system can be used to distinguish between the eco-residential buildings and residential construction;
C. To a certain extent, methods and ideas used in this paper filled the blank situation emergy theory research in the construction in China;
D. This project is a single building, smaller social cost, mainly about the social costs of labor and demolition. The overall Xiamen original residents were moved out also undermined the cultural structure of the project site in the demolition, thus which were the social costs.

Table 55.2 Life cycle emergy analysis in single residential microsystem (all calculations accord to Odum method)

Item	Item value/sej	Em/$
All input (I)	2261.82E+18	831.55E+6
1. Solar energy	1.55E+13	5.70
2. Wind energy (max)	5.70 E+16	2.10 E+4
3. Rain, chemical potential	4.09 E+14	150.37
4. Rain, geopotential	2.34 E+15	860.29
Indigenous non-renewable energy		
5. Lakes, chemical energy	6.57 E+9	2.4 E-3
6. Soil losses	2.37 E+20	8.71 E+7
7. Erosion, topsoil losses	2.66 E+15	465.03
8. Main rare animals losses (Egretta garzetta)	1.51E+20	5.56 E+7
9. Live biomass (trees)	3.52 E+19	1.29 E+7
10. Biodiversity	5.82 E+20	2.14 E+8
11. Main building materials	50.773E+18	1.87 E+7
12. Electricity Energy	2.76 E+15	1.01 E+3
13. Water use	5.43 E+12	1.996
14. Physical labor service	5.37 E+19	1.97 E+7
15. Management labor service	5.75 E+19	2.11 E+7
16. Machine	5.2E+19	1.91 E+7
17. Equipment and facility in the operation (30 years)	2.86 E+19	1.05 E+7
18. Solar energy	4.65 E+14	170.96
19. Wind energy	1.71 E+18	6.28 E+5
20. Rain, chemical	1.23 E+16	4.52 E+3
21. Rain, geopotential	7.02 E+16	2.58 E+4
22. Electricity Energy	1.93 E+17	7.10 E+4
23. other maintaining	1.57 E+19	5.77 E+6
24. Management labor service	8.40 E+19	3.09 E+7
25. Water	2.15 E+18	7.9 E+5
26. Maintain (10yrs one time) in demolition	3.24 E+19	1.19 E+7
27. Physical labor service	1.53 E+13	5.625
28. machine and transportation	4.42 E+19	1.63 E+7
29. Social cost (culture lost)	8.42 E+20	3.10 E+8
All output (O)	185.08E+18	6.8 E+7
30. Solid waste (construction)	1.10 E+20	4.04 E+7
31. Solid waste (decoration,70d)	1.28 E+19	4.71 E+6
32. Living rubbish (operation)	1.40 E+18	5.15 E+5
33. Solid waste (demolition,70d)	9.03 E+18	3.31 E+6
34 . Industrial wasted water	4.93E+19	1.81 E+7
35. Living sewage (construction)	1.03 E+16	3.79 E+3
36. Living sewage (operation)	2.55 E+18	9.38 E+5
37. Wasted gas (construction)	7.34 E+13	26.99
38. Wasted gas (decoration)	1.44 E+15	529.41
39. Wasted gas (operation) CO_2	3.08E+16	1.13 E+4
Building real value=I-O	2076.73764E+18	763.51E+6

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