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Study on Environmental Parameters of Urban Renewal and Renovation Based on Life Cycle Assessment (LCA)

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Abstract: Aiming at the phenomenon of "short life" of existing urban buildings and high pollution of construction industry, this paper analyzes the environmental parameters of urban renewal and renovation. Taking the concept of "implied environmental impact factor" as the platform, this paper constructs the calculation model of urban construction implied environmental impact factor, and calculates and analyzes the environmental parameters of urban renewal and renovation in China by this method. The calculation results show that the renewal and renovation conform to the basic requirements of the reduction and reuse of circular economy, and the environmental benefits can be effectively increased.
Keywords: urban buildings, renewal, environmental parameters

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1. INTRODUCTION

The construction of economy-developed countries generally experiences the three stages of large-scale construction, construction combined with maintenance and reconstruction, and old buildings renovation [1]. The new construction cost and quantity of Britain, Sweden, and America in 1970s to 1980s is continuously decreasing, while the construction renewal and renovation projects are increasing year by year. In America, old buildings renewal and renovation industry has become one of the most popular nine industries. China at present is gradually entering the second stage of new construction combined with maintenance and renovation. Chinese urban construction is in high speed expansion from 1990s up to now, almost having completed the European 100-year construction history in 30 years [2]. In the following 20 to 30 years, the urban will produce an astonishing number of old houses. How to deal with non-historic protected existing dwellings? It has become a dilemma for the decision makers whether to carry out simple demolition and reconstruction or to update and reuse.

Foreign research results show that the construction industry directly or indirectly consumes about 32% of global energy, about 12% of fresh water, resulting in 40% of the wastes, discharging 40% of the greenhouse gases. If the construction industry's energy consumption and damage to the environment are reduced by 1%, it will make the global energy consumption and environmental damage reduced by 0.3% ~ 0.4%, whose environmental significance is huge [3].

2. DEFINITION OF CONCEPTS

2.1 Establishment of implied environmental impact factor calculation model

According to the concept of building implied environmental impact factor, the urban building implied environmental impact factor calculation model is seen in (2-1).

$$E_e = E_m + E_t + E_p + E_d + E_c \tag{2-1}$$

In (2-1), E_e refers to the total implied environmental impact factor value of urban buildings; E_m represents the implied environmental impact factor value in the material physical-orientation stage; E_t suggests the implied environmental impact factor value in the construction material transportation process; E_p indicates the implied environmental impact factor value in the construction implementation process; E_d is the implied environmental impact factor value in the dismantling stage; E_c shows the implied environmental impact factor value in the waste disposal stage.

1) The calculation model of E_m

$$E_m = \sum_{i=1}^{n}\left(1+\frac{d_i}{100}\right)Q_{ei}e_{mi} \tag{2-2}$$

In (2-2), n is types of building materials contained in the buildings, Q_{ei} is the total quality or amount of the i building material in the buildings, e_{mi} is the implied environmental impact factor of the i building material in the buildings, namely the implied environmental impact factor of unit quality or amount material, and d_i is the attrition rate of the i building material in the construction process.

2) The calculation model of E_t

$$E_t = \sum_{i=1}^{n} Q_{ti}L_i e_{ti} + \sum_{j=1}^{m} Q_{tj}L_j e_{tj} \tag{2-3}$$

In (2-3), n is similar to that in (2-2); Q_{ti} is the total quality or amount of the i construction material used in the buildings construction; L_i refers to the transport distance of the i construction material from the production place to the construction site; e_{ti} suggests the transportation implied environmental impact factor intensity of the i construction material from the production place to the construction site; Q_{tj} represents the total quality or amount of the j construction material in the buildings dismantling stage; L_j indicates the transportation distance of the j construction material in dismantling part from the construction site to the disposal site; e_{tj} is the transportation implied environmental impact factor intensity of the j construction material in dismantling part from the construction site to the disposal site.

3) The calculation model of E_p and E_d

The energy consumed in urban construction and demolition phase is mainly electric power. According to Adalberth's research, in the construction phase, urban construction electricity and temporary housing electricity consumption are 93.6MJ/m^2 and 50.4MJ/m^2 respectively [4]. The energy consumption of urban construction demolition stage is assumed to be 15% of construction energy consumption. Per 100 square meters of urban construction and the energy consumption in demolition phase see (2-4).

$$(93.6+50.4)\times(1+15\%)\times100=16560MJ=4600kwh,\ 1\text{kwh}=3.6MJ \quad (2\text{-}4)$$

4) The calculation of E_c

Due to the lack of data, this paper assumes that for the main structure of the building, after the demolition, all the metal materials are 90% recycled, and the final waste rate is 10%; brick recycling 50%, the final waste rate is 50%; waste wood recycling 20%, the final recovery rate is 80%; cement recycling 10%, the final waste rate is 90%; the remaining materials are not recycled, eventually the waste rate is 100%. In this way, the total amount of solid waste generated after the demolition of buildings can be calculated [5].

2.2 Quantification of implied environmental impact factor analysis

1) Characterization

The function of characterization lies in transforming the different materials in the influence types for the same standard object, so as to achieve comparability. For example, various greenhouse gases result in global warming, such as CO_2, CH_4, N_2O and CCl_4 can be expressed by CO_2 equivalent [6]. According to the results of relevant scholars, it can obtain the standards for different pollutants conversion.

2) Normalization

Normalization of the results is helpful to quantify the size of various influence types in a comparable standard, providing the basis for the next assessment. In this paper, the total annual social resource consumption and the implied environmental impact factors are used as the standard benchmarks [7]. Potential effects and resource consumption after standardization see (2-5).

3. RESULT

In 2013, compositions of residential demolition commonly used materials are shown in table 1.

Table 1. Compositions of residential demolition commonly used materials

	Clay brick	Cement	Wood lumber	Steels	Glasses	PVC
Nationwide	4413.8 myriad pieces	47.328 million t	3.8802 million m^3	5.8000 million t	30.392 million m^2	0.0754 million t
	116.14 million t	47.328 million t	1.9401 million t	5.8000 million t	0.2291 million t	0.0754 million t

According to the data in table 1 and based on the model introduced in 2.1, the implied environmental impact factor in each stage of urban construction can be calculated. The calculation results are shown in table 2.

Table 2. Sum of residence renewal and renovation implied environmental impact factors

	Energy and resources			Atmospheric emission (t)							
η (%)	Energy (tce)	Mineral resources (t)	Water (ten thousand m^3)	CO_2	CO	CH_4	HC	SO_2	NO_x	Dust	N_2O
95	2.35	1.10	1.19	5.94	5.84	1.79	1.09	1.08E+04	1.25	2.98	2.15
	E+06	E+07	E+04	E+06	E+04	E+04	E+04		E+04	E+05	E+01
85	7.06	3.29	3.58	1.78	1.75	5.36	3.26	3.25	3.75	8.95	6.44
	E+06	E+07	E+04	E+07	E+05	E+04	E+04	E+04	E+04	E+05	E+01
75	1.18	5.48	5.96	2.97	2.92	8.93	5.43	5.42	6.24	1.49	1.07
	E+07	E+07	E+04	E+07	E+05	E+04	E+04	E+04	E+04	E+06	E+02
65	1.65	7.67	8.35	4.16	4.09	1.25	7.61	7.58	8.74	2.09	1.50
	E+07	E+07	E+04	E+07	E+05	E+05	E+04	E+04	E+04	E+06	E+02
50	2.35	1.10	1.19	5.94	5.84	1.79	1.09	1.08	1.25	2.98	2.15
	E+07	E+08	E+05	E+07	E+05	E+05	E+05	E+05	E+05	E+06	E+02
0	4.71	2.19	2.39	1.19	1.17	3.57	2.17	2.17	2.50	5.97	4.29
	E+07	E+08	E+05	E+08	E+06	E+05	E+05	E+05	E+05	E+06	E+02
	Atmospheric emission (t)						Water discharge (t)			Soil emission	
η	SO_x	VOC	Formaldehyde	H_2S	HCL	Ethylene	COD	BOD	NH_4	Solid wastes	
95	3.06	1.57	2.76	2.53	2.54	1.43	1.18	2.52	2.87	6.79E+06	
	E+04	E+01	E-01	E+01	E+02	E+01	E+02	E+00	E+02		
85	9.19	4.70	8.27	7.58	7.62	4.29	3.53	7.55	8.61	2.04E+07	
	E+04	E+01	E-01	E+01	E+02	E+01	E+02	E+00	E+02		
75	1.53	7.83	1.38	1.26	1.27	7.15	5.88	1.26	1.44	3.40E+07	

	E+05	E+01	E+00	E+02	E+03	E+01	E+02	E+01	E+03	
65	2.14	1.10	1.93	1.77	1.78	1.00	8.23	1.76	2.01	4.76E+07
	E+05	E+02	E+00	E+02	E+03	E+02	E+02	E+01	E+03	
50	3.06	1.57	2.76	2.53	2.54	1.43	1.18	2.52	2.87	6.79E+07
	E+05	E+02	E+00	E+02	E+03	E+02	E+03	E+01	E+03	
0	6.13	3.13	5.51	5.05	5.08	2.86	2.35	5.03	5.74	1.36E+08
	E+05	E+02	E+00	E+02	E+03	E+02	E+03	E+01	E+03	

Table 3. Characterization of residence renewal and renovation implied environmental impact factor

Factors \ η (%)	95	85	75	65	50	0
Global warming (tCO_2eq)	6.32E+06	1.89E+07	3.16E+07	4.43E+07	6.32E+07	1.27E+08
Ozone depletion effect (tCFC-11eq)	0	0	0	0	0	0
Fossil energy consumption (t.ce)	2.35E+06	7.06E+06	1.18E+07	1.65E+07	2.35E+07	4.71E+07
Mineral resource consumption (t)	1.10E+07	3.29E+07	5.48E+07	7.67E+07	1.10E+08	2.19E+08
Acidification (tSO_2eq)	2.28E+06	6.83E+06	1.14E+07	1.59E+07	2.28E+07	4.55E+07
Photo-chemical smog (tC_2H_4eq)	4.48E+03	1.34E+04	2.23E+04	3.13E+04	4.48E+04	8.93E+04
Eutrophication of water body ($tPO_4^{3+}eq$)	1.73E+03	5.18E+03	8.62E+03	1.21E+04	1.73E+04	3.45E+04
Consumption of fresh water resources (ten thousand m^3)	1.19E+04	3.58E+04	5.96E+04	8.35E+04	1.19E+05	2.39E+05
Wood resource consumption (ten thousand m^3)	21.94	65.82	109.70	153.58	219.39	438.79
Dust (t)	2.98E+05	8.95E+05	1.49E+06	2.09E+06	2.98E+06	5.97E+06
Solid wastes (t)	6.79E+06	2.04E+07	3.40E+07	4.76E+07	6.79E+07	1.36E+08

From the calculation results in table 3, it can be seen that, based on reserving most of the original structure of the existing urban buildings, to carry out renovation on it, not simply dismantling [9]. It has significant environmental ecological benefits in CO_2, CO, SO_2 solid wastes and so on material emission reductions, in accordance with the basic requirements of recycling economy reduction and reuse.

The normalization calculation results are shown in table 4.

Table 4. The normalization calculation results (unit: standard equivalent/100m^2)

η (%) / Factors	95	85	75	65	50	0
Global warming	2.50E-01	7.49E-01	1.25E+00	1.76E+00	2.50E+00	5.03E+00
Ozone depletion effect	0	0	0	0	0	0
Fossil energy consumption	9.95E-01	2.99E+00	5.00E+00	6.99E+00	9.95E+00	1.99E+01
Mineral resource consumption	4.36E+00	1.31E+01	2.17E+01	3.04E+01	4.36E+01	8.69E+01
Acidification	2.18E+01	6.54E+01	1.09E+02	1.52E+02	2.18E+02	4.36E+02
Photo-chemical smog	2.38E+00	7.11E+00	1.18E+01	1.66E+01	2.38E+01	4.74E+01
Eutrophication of water body	9.62E-03	2.88E-02	4.79E-02	6.73E-02	9.62E-02	1.92E-01
Consumption of fresh water resources	8.69E-02	2.62E-01	4.35E-01	6.10E-01	8.69E-01	1.75E+00
Wood resource consumption	5.04E-01	1.51E+00	2.52E+00	3.53E+00	5.04E+00	1.01E+01
Dust	5.71E+00	1.71E+01	2.85E+01	4.00E+01	5.71E+01	1.14E+02
Solid wastes	9.33E+00	2.80E+01	4.67E+01	6.54E+01	9.33E+01	1.87E+02

Table 5. The quantification calculation weights results (unit: standard equivalent/100m^2)

η (%) / Factors	95	85	75	65	50	0
Global warming	2.70E-02	8.08E-02	1.35E-01	1.90E-01	2.70E-01	5.43E-01
Ozone depletion effect	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Fossil energy consumption	2.39E-01	7.18E-01	1.20E+00	1.68E+00	2.39E+00	4.78E+00
Mineral resource consumption	7.13E-01	2.14E+00	3.55E+00	4.97E+00	7.13E+00	1.42E+01
Acidification	5.52E-01	1.65E+00	2.76E+00	3.85E+00	5.52E+00	1.10E+01
Photo-chemical smog	1.20E-01	3.60E-01	5.97E-01	8.40E-01	1.20E+00	2.40E+00

Eutrophication of water body	7.02E-04	2.10E-03	3.50E-03	4.91E-03	7.02E-03	1.40E-02
Consumption of fresh water resources	1.42E-02	4.28E-02	7.11E-02	9.97E-02	1.42E-01	2.86E-01
Wood resource consumption	5.44E-02	1.63E-01	2.72E-01	3.81E-01	5.44E-01	1.09E+00
Dust	2.03E-01	6.07E-01	1.01E+00	1.42E+00	2.03E+00	4.05E+00
Solid wastes	1.73E-01	5.18E-01	8.64E-01	1.21E+00	1.73E+00	3.46E+00
The total	2.10E+00	6.29E+00	1.05E+01	1.46E+01	2.10E+01	4.19E+01

The environmental impact assessment results show that, when the solid retention rate η=0 (i.e. the demolition and reconstruction), the comprehensive environmental impact index caused by the average per 100 square meters of urban building is 41.9 standard equivalent. When η=95%, the comprehensive environmental impact index caused by the average per 100 square meters of urban building is 2.1 standard equivalent. Compared with η=0, the difference is nearly 20 times, as shown in figure 1. When η=0, the effect of different types of environmental impact is shown in figure 2.

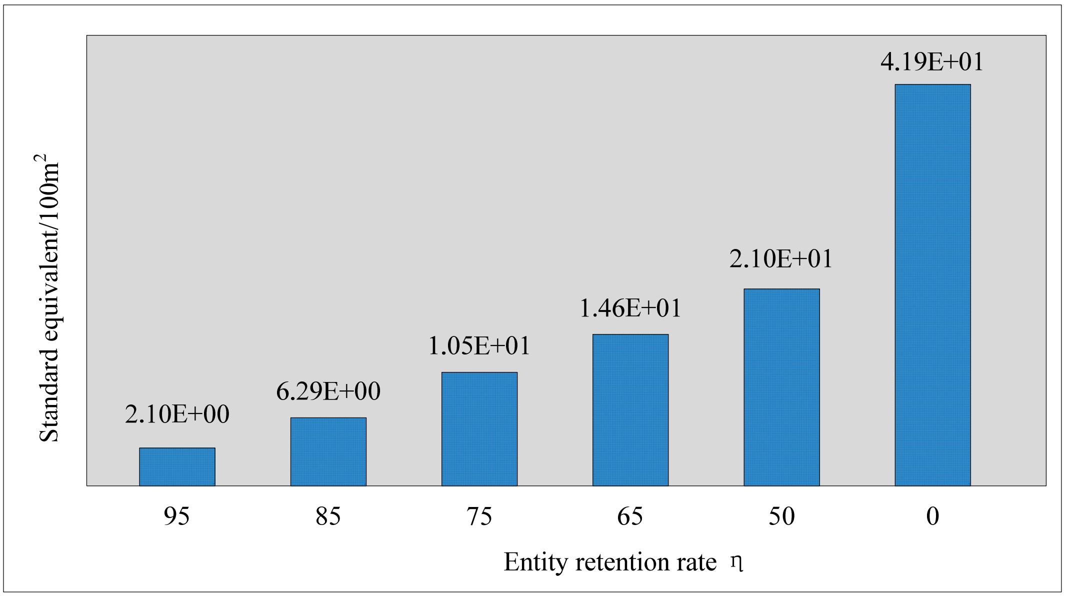

Figure 1. Comprehensive environmental impact under different entity retention rates

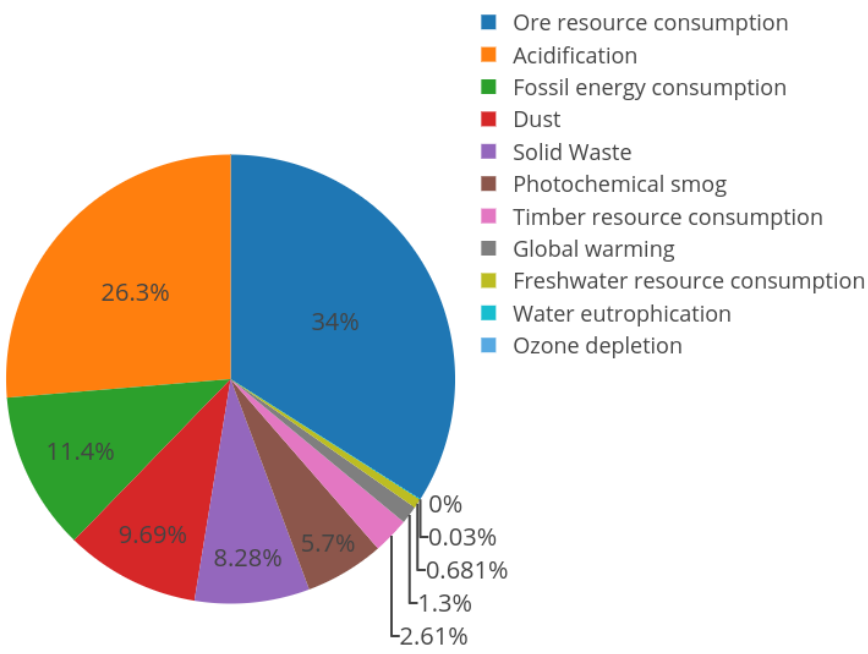

Figure 2. Impact of different influence types on the environment when η=0

From figure 2, it can be seen that, when demolishing and reconstructing the existing urban buildings, in 11 items of environmental impact types, the various resource consumptions are amounted to 48.64%, close to half of the total effect amount, in which the consumption of mineral resources and fossil resources have accounted for 45.35% of the total consumption of resources, indicating that the consumption of demolition and reconstruction of the buildings, especially the consumption of mineral and fossil energy is very large, and this kind of resources is non-renewable resources [10], therefore, the update mode of demolition reconstruction does not comply with the requirements of circular economy and sustainable development. In consequence, if possible, the renewal and renovation of existing urban buildings is an effective way to reduce the impact of building environment.

4. CONCLUSION

Based on the concept of "implied environmental impact factor", this paper constructs a calculation model of environmental impact factor, and uses this method to calculate and analyze the environmental parameters of urban renewal and renovation in China. The calculation results show that it is necessary to make the renewal and renovation of existing urban building, rather than simply demolition. It has significant environmental and ecological benefits in CO_2, CO, SO_2, solid wastes and so on materials emission reduction, in accordance with the basic requirements of the recycling economy emission reduction and reusing, and the environmental benefits increase with the increase of construction entity retention rate in the urban building renewal and renovation.

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