Study on the Carbon Emissions of Construction

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Abstract. This paper is aimed at improving the LCA method of carbon emissions on construction. Because when using the LCA method for computing carbon emissions of the construction, low-load operating time and quitting time of construction machinery are calculated as normal operating time. So we collected 30 groups of construction machinery's operating time data to conduct the simulation based on the K-S test and the queuing theory. Then, we compared the carbon emissions measured by the simulation with them measured by the LCA method. Finally, the results demonstrate that the value of carbon emissions on simulation measurement is closer to the real value of carbon emissions.

Introduction

Global warming is a big challenge faced by human society's development and the problem caused by sea levels' rising and glaciers' melting has directly affect the survival and development of humankind. The main cause of global warming is the emission of greenhouse gases, and the effect of carbon dioxide accounts for more than 65% of all greenhouse gas warming effect. Carbon emissions generated by the construction industry accounts for a considerable proportion in all industries. The IPCC's fourth assessment report indicates that the global construction industry produce the carbon emissions about 8.6 billion tons per year, account for 33% of global carbon emissions in 2004 [1]. Also, it predicts that the number will increase to 156 tons per year by 2030. In developed countries, building carbon emissions account for about 36% of the total emissions. In the building's life cycle, the number of carbon dioxide emissions at construction stage is bigger than it in other phases. Therefore, it has become an important issue that to carry on the accurate measurement of carbon emissions in the process of construction.

In western countries, carbon emissions measurement research was started early and the LCA method was mainly adopted. Leif focused on carbon emissions of building materials, and the building life cycle was divided into five stages (material production, fixed-point construction, operation, dismantling and dealing) [2]. Deepak conducted a simulation research on energy efficiency in buildings, took advantage of the comprehensive evaluation of the network and principal component analysis method to measure the carbon emissions in the different phase [3]. Tove put forward the strict requirements and the bias of data interpretation are the major obstacles to the LCA method [4]. Huberman divided the project on the LCA method into three stages (before using, being using and after using). He also thought that the energy consumption of the whole life period should be considered in building comprehensive energy consumption evaluation. But the energy contained by buildings and the energy consumption on construction were not in deeper study [5]. In China, the LCA method were mainly used. To measure urban residential carbon emissions, Liu Nianxiong divided the project into four different stages (material preparation, construction, operation and remove) [6]. Li Qiming divided the project into three stages (construction, operation and destruction) [7].

The above studies are based on the LCA method. However, when using the LCA method for computing carbon emissions of the construction, low-load operating time and quitting time of construction machinery are regarded as normal operating time. So the carbon emissions of construction machinery on the LCA method are different from the real. For this problem, we took the project of the Guanggu Big Wheel in Wuhan,Hubei province for example, selected truck crane and platform as the research objects and compare carbon emissions between the LCA method and Simulation method.

Method

According to the LCA method, we use mathematical model to express the carbon emissions of building construction:

$$C = C_m + C_t + C_c \tag{1}$$

In this equation, C indicates the total carbon emissions in the process of construction. C_m represents the total carbon emissions of building materials in the process of construction. C_t shows the total carbon emissions in the process of building materials transportation. C_c indicates the total carbon emissions in the process of building energy consumption.

The type of building materials to a certain extent affect the construction site construction technology. The overall principle is to select the materials, which are with energy conservation and low exhaust according to life cycle theory, and the recovery rate of materials should be taken into consideration. So we could get the total carbon emissions in the construction engineering of building materials as follows:

$$C_m = \sum Q_i \alpha_{mi}(1 - \omega_i) \tag{2}$$

In this equation, i indicates the types of building materials, α_{mi} represents carbon emission factor of building materials production and ω_i indicates the recovery coefficient of building materials which can be found in the national statistical yearbook.

The carbon emissions for building materials in the process of transport mainly comes from the mode of transportation, the weight of the materials, types and the transport distance, so its carbon emissions can be represented as:

$$C_t = \sum_{i,j} Q_{ij} \times \alpha_{tj} \times D_{ij} \tag{3}$$

In this equation, i represents the mode of transportation. Q_{ij} indicates the traffic volume of building materials. α_{tj} represents the carbon emission factor on different mode of transportation. D_{ij} shows the transport distance of building materials under different mode of transportation. Due to the amount of energy on the mode of transportation is different, so it's need to be calculated separately. The specific carbon emission factor can be viewed in the statistical yearbook.

The carbon emissions mainly comes from the construction machinery in the construction process. According to the LCA method, the construction machinery quantity, affecting work quantity and the carbon emissions factors can be utilized to calculate the carbon emissions in the process of construction:

$$C_c = \sum_{i,j} n_i \times EC_{ij} \times \alpha_{cj} \times T_i \tag{4}$$

In this equation, i indicates types of construction machinery and j indicates the consumption of mechanical energy types. n_i represents the number of construction machinery. EC_{ij} means the energy consumption of construction machinery's operating. T_i demonstrates the working hours of construction machinery and α_{cj} represents the carbon emissions coefficient of energy. In the traditional carbon emissions calculation, there are two kinds of carbon emission coefficient, one kind is fossil energy, another kind is the power. To get the carbon emission factor of power network, OM and BM calculation methods are utilized.

However,when using the LCA method for computing carbon emissions of the construction, low-load operating time and quitting time of construction machinery are regarded as normal operating time. Therefore, the simulation of time on three different mechanical conditions of construction should be added to the original formula.

The carbon emissions produced by mechanical normal operating:

$$CE_O = \sum_{i,j} n_i \times E_{ij} \times \alpha_{cj} \times t_{Oi}(n) \tag{5}$$

In this equation, E_{ij} indicates the energy consumption of construction machinery's operating. $t_{Oi}(n)$ represents normal operating time of construction machinery and we get it from the simulation.

The carbon emissions produced by mechanical low-load operating:

$$CE_I = \beta \sum_{i,j} n_i \times E_{ij} \times \alpha_{cj} \times t_{Ii}(n) \tag{6}$$

In this equation, E_{ij} indicates the energy consumption of construction machinery's low-load working. $t_{Ii}(n)$ represents low-load operating time of construction machinery and we get it from the simulation. β means sabotage and carbon emissions coefficient ratio is about 0.2 in the process of operation.

The quitting time of construction machinery:

$$T_i(n) = \frac{t_i(n)}{80\% \times 60 \times 8} \tag{7}$$

In this equation, $T_i(n)$ represents the quitting time of construction machinery. $t_i(n)$ indicates the total worked hours of construction machinery.

So we can get the carbon emissions in the process of construction:

$$CE(n,t) = \sum_{i=1} n_i E_i \times \alpha_j \times \left[t_{Oi}(n) + \beta t_{Ii}(n)\right] \tag{8}$$

Results

There are two kinds of activity duration of simulation, they're certain type and random type. Random activity duration, depending on the type of activity the random distribution of the inverse function transform method and the conversion method to generate random variables, the random variable is required by the random search activity duration. We studied the project of the Guanggu Big Wheel in Wuhan,Hubei province and selected truck crane and platform as the research objects. The simulation of their total working time is random type. Each event's time of machinery activity was collected through the questionnaire survey and field observations. In order to determine the time distribution of event action accurately, the reciprocating records on every movement were not less than 30 times, as it's shown in Table 1:

Table 1: The observation of construction time

Observed Frequency	Platform Lorry			
	Loading	Transportation		Returning
1	14.1	39.6		37.0
2	14.5	41.4		38.0
3	16.1	38.0		37.5
4	12.8	39.5		38.4
⋮	⋮	⋮		⋮
30	16.0	41.1		39.5
Observed Frequency	Truck Crane			
	Loading	Lifting	Unloading	Moving
1	9.0	6.8	4.4	8.6
2	10.0	6.4	4.6	9.0
3	10.4	6.8	5.0	7.6
4	9.6	6.4	5.6	6.4
⋮	⋮	⋮	⋮	⋮
30	10.4	6.4	4.5	9.0

First of all, we used SPSS for data fitting to determine the time distribution parameters of each movement. Then kolmogorov-smirnov test was conducted for event time fitting results, as it's shown in Table 2:

Table 2: The distribution of time for discrete event

	Platform Lorry			
	Loading	Transportation		Returning
N	30	30		30
Mean	15.19	39.98		38.63
Standard Deviation	1.30	1.20		1.25
K-S Z	0.44	0.56		0.58
The Progressive Significance	0.99	0.92		0.89
	Truck Crane			
	Loading	Lifting	Unloading	Moving
N	30	30	30	30
Mean	9.18	6.63	4.79	7.86
Standard Deviation	1.00	0.72	0.53	1.06
K-S Z	0.71	0.60	0.62	0.70
The Progressive Significance	0.70	0.86	0.83	0.71

The K-S test threshold is bigger than 0.05, so the distribution of time for each event action is acceptable. Then we used Matlab to adopt case step method for carrying out the simulation. The original construction scheme was equipped with two electric platform lorries, two sets of 25 tons of truck crane and a 50 tons of truck crane. The parameters (weight and volume) of each device were input in the model. According to the predetermined quantity, we could estimate mechanical completion, if it's completed, end the simulation, as it's shown in Fig. 1:

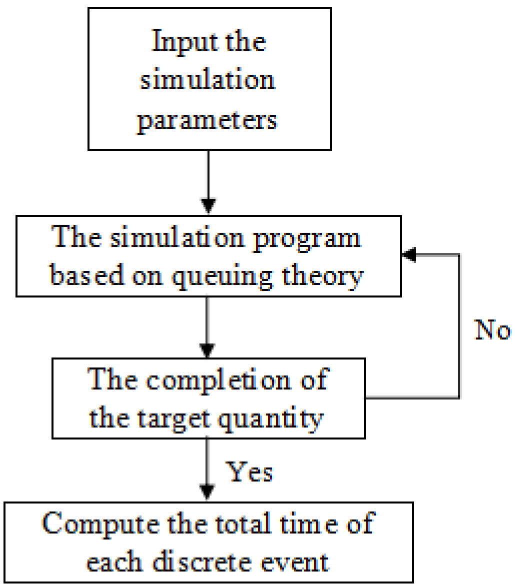

Fig.1. The flow of simulation

The sum of the total time is 14.8 machine-team is close to the actual 15 machine-team, all kinds of the mechanical carbon emissions are shown as a result of Table 3:

Table 3: The carbon emissions of different measurements (/tons)

Measurement	Platform Lorry	Truck Crane (25 tons)	Truck Crane (50 tons)
Simulation	0.8	1.2	1.0
LCA	1.7	3.0	1.9

For construction machinery measurement of carbon emissions, the measured carbon emissions on the LCA method is about double that on simulation measurement. Because when using the LCA method for computing carbon emissions of the construction, low-load operating time and quitting time of construction machinery are calculated as normal operating time. So the value of carbon emissions on simulation measurement is close to the real value of carbon emissions.

Conclusions

According to the observation on the construction of the Guanggu Big Wheel in Wuhan, we obtained data about operating hours of the construction machinery to conduct the simulation. Because when using the LCA method for computing carbon emissions of the construction, low-load operating time and quitting time of construction machinery are calculated as normal operating time. So the value of carbon emissions on simulation measurement is close to the real value of carbon emissions.

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