Research on Carbon Emission Measurement of Construction Products Based on BIM

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Abstract: With global warming, environmental issues have gradually received attention. Surprisingly, the construction industry contributes most of the greenhouse gases. In order to reduce carbon emissions, the construction industry has proposed many energy-saving and emission-reduction methods from the perspectives of construction technology, reverse logistics supply chain optimization, and design optimization. However, problems in the prediction and measurement of carbon emissions have always been the focus and difficulty of the construction industry. Recently, BIM technology has continuously penetrated into the construction industry, which has influenced many scholars to gradually use BIM technology to reduce carbon emissions. Unlike other scholars, this research uses the Revit API to integrate carbon emission measurement functions into the Revit environment. These not only reduce the dependence on third-party software and tedious operations, but also provide architectural designers with reference information for environment optimization during the design stage.

1. Introduction
The "Paris Agreement" signed in 2016 means that most countries in the world have reached a consensus: All countries should take immediate action to reduce greenhouse gas emissions and cultivate awareness of climate change. The long-term goal of the "Paris Agreement" is to limit the increase in global average temperature to within 2°C by 2100 compared to the pre-industrial period. However, according to the "2019 Carbon Emission Gap Report" released by the United Nations Environment Programme (UNEP), if this goal is to be achieved, global carbon emissions need to be reduced by 2.7% each year in the next ten years[1]. According to statistics, the construction industry accounts for 36% of global energy consumption and 39% of global carbon emissions. Therefore, the construction industry has a huge impact in achieving the goal of reducing global carbon emissions. In order to reduce carbon emissions in the construction industry, carbon prediction and carbon accounting have become one of the important methods.

2. Literature review
At present, there are three commonly used carbon emission measurement methods in the world, namely the actual measurement method, the material balance algorithm and the carbon emission coefficient method. The actual measurement method refers to the method of measuring the flow rate, velocity and concentration of exhaust gas through monitoring means or continuous measurement.
equipment approved by relevant national departments. The result of this method is more accurate, but the disadvantage is that the input cost is higher. The material balance algorithm is based on the principle of conservation of quality, and calculates carbon emissions through dynamic data monitoring of the input resources and output in the system at various times. The use of this method requires a detailed understanding of the production process, physical and chemical changes, and mastery of the production and output components, consumption and other data. The carbon emission coefficient method is a method of calculating carbon emissions through the correlation between carbon emission factors and corresponding resource consumption. The carbon emission factor is often selected from the data in the carbon emission database of professional institutions at home and abroad or the data obtained through experiments and monitoring in combination with the product itself. This method is simpler to apply than the previous two methods. This article uses a combination of carbon emission coefficient method and computer model software for calculation.

Building models based on BIM technology not only include geometric information of components and parts, but also non-geometric information such as suppliers and costs. Many scholars use BIM technology to calculate the carbon emissions of building products[2]. Mousa[3] have established carbon emissions estimation models based on BIM technology, and collected building carbon emissions data to help the operation management team find carbon emissions problems. Ding[4] proposed a carbon measurement method for prefabricated houses based on BIM technology. The research established a building product carbon emission measurement system based on BIM and ACCESS, used BIM software to build a building model and obtained a bill of quantities of the model, and then imported the bill of quantities into the ACCESS database to calculate the carbon emissions of prefabricated houses. However, in the current method, the calculation of carbon emissions requires the help of third-party software, and the process is relatively cumbersome. Therefore, this article proposes a BIM-based secondary development, which integrates the carbon emission coefficient method into the Revit environment through the Revit API, so that BIM software has the function of carbon emission calculation to reduce the tedious operation of third-party software.

3. Methodology
This research is to integrate the building carbon emission measurement function into the Revit environment through the development of API. This function provides a reference for building designers to save energy and reduce emissions during the BIM design phase, and eliminates the need for third-party software to reduce manual operations by designers. This function is compiled into Revit's custom buttons as external commands, and these are implemented by using Microsoft C# as the programming language and Revit API as the development tool. The working principle of the button with carbon emission measurement is shown in a flowchart (Figure 1). According to the flowchart Fig.1, the starting point of the process is to load the Revit file to calculate the carbon emissions. Then, the building model file is connected with the external command program "carbon emission measurement". Figure 2 represents a screenshot of the API program button that has been developed. The user can click the button to call the Revit API, thereby enabling the compiled external command regarding "carbon emission measurement". In addition, the "External Command" program not only performs parameter data calculation, but also imports the calculated parameter data and corresponding building material information into the designated Excel file.
"Carbon emission measurement" mainly depends on two parts. The first part is to extract parameter information of various materials in building components. The second part is to determine the carbon emission factors of the corresponding building materials. For parameter extraction, the Revit API can
be used to access the graphic data and parameter data of the model, create plug-ins to complete the UI enhancement, and integrate third-party applications to complete such as connecting to external databases. The parameters of various materials in building components originate from the Revit model. Therefore, the initial parameter data is extracted in the Revit software through the BIM model under consideration. According to Table 1, different building materials in buildings have different situation factors, which are also called carbon emission factors. Algorithm 1 is an "external command" program where the button is associated with the BIM model. The algorithm is used to extract the consumption parameter information of the building materials in the BIM model according to the type of building components, and to match the carbon emission function with the corresponding carbon emission factor to calculate the carbon emission result of this category. Then, the total carbon emissions of each building material of the same category are accumulated. Finally, the categories and total results are automatically exported to generate an Excel file with specific information.

Table 1 Building materials carbon emission factor

| Building material category       | Carbon emission factor |
|---------------------------------|------------------------|
| Ordinary Portland Cement        | 735 kg CO₂e/t          |
| C30 concrete                    | 295 kg CO₂e/m³         |
| C50 concrete                    | 385 kg CO₂e/m³         |
| Concrete brick (240mm×115mm×90mm) | 336 kg CO₂e/m³       |
| Steelmaking iron               | 1700 kg CO₂e/t         |
| Cast iron                      | 2280 kg CO₂e/t         |
| Plastic steel window           | 121 kg CO₂e/m²         |
| Polystyrene foam board         | 5020 kg CO₂e/t         |
| Tap water                      | 0.168 kg CO₂e/t        |

Carbon emission in the building materials production stage refers to the mining of raw materials, transportation to processing plants for prefabrication, and the building materials production stage until the building materials leave the factory. According to the "Building Carbon Emission Calculation Standard GB/T51366-2019"[5], the carbon emission calculation function in the building materials production stage is expressed as:

\[ P = \sum_{i=1}^{n} (Q_i \times C_i) \]  

where \( P \) is the carbon emissions during the production stage of construction products and building materials, \( Q \) is the consumption of building materials, \( C \) is the carbon emission factor of building material.

Algorithm 1: Carbon Emission Measurement Algorithm

1. Get all “Elements” (AutoDesk.Revit.DB.Element) in the model
2. For each Element …
   a. Get the list of “Materials” (AutoDesk.Revit.DB.Material) in the element
   b. For each Material …
      i. Identify the class (or category) of the material (Material.MaterialClass)
      ii. If that Class is in the list of materials we are interested in
         1. Use the Material’s ID (Material.Id) to interrogate the Element for its volume (Element.GetMaterialVolume())
         2. Input the Material’s parameter into the function we have set
         3. Add this result to the collection of volumes we are compiling
         4. Output the collection of volumes into Excel file (Microsoft.Office.Interop.Excel)

Compared with other carbon emission measurement methods, this calculation method avoids tedious operations that uses the revit software's detailed list to manually import third-party software to
calculate statistics and then generate statistically complete Excel files. The button is completely integrated into the Revit environment, which will facilitate users to understand the environmental protection information predicted by the designed building model, so that users can reflect on their design in time.

4. Conclusions
In the construction industry, greenhouse gas emissions have always accounted for the majority of emissions in all fields. This phenomenon has caused a serious environmental impact. In order to reduce greenhouse gas emissions, the author proposes a method to integrate the carbon emission measurement function into the Revit environment through the Revit API, which is to provide Revit users with some actual carbon emission parameter information during the design stage. The parameter information can provide useful information for environmental protection reference for experienced designers. Therefore, architects can avoid unnecessary carbon emissions during the design stage. In addition, this method also reduces Revit users’ reliance on third-party software and tedious operations.

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