Reducing Carbon Emissions from Prefabricated Decoration in China

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Since decoration is an essential part of buildings, the carbon emissions generated by decoration work should not be ignored. Prefabricated decoration has attracted much attention as efforts are made to pursue green, low-carbon, and waste-reducing buildings. Prefabricated decoration is characterized by the pre-manufacturing of building decoration elements in the factory, which are later assembled on-site. One of the primary advantages of this method is the utilization of eco-friendly materials that substantially reduce the environmental footprint of construction projects. These materials are selected for their sustainability, durability, and lower carbon emissions, supporting the global shift towards environmentally responsible building practices.

prefabricated decoration | prefabricated buildings | life cycle assessment | carbon emissions reduction | building energy consumption

1. Introduction

Against the backdrop of the country's rapid economic development, China's total carbon emissions and its share of the world's emissions are high and continually rising. As a major greenhouse gas, carbon dioxide not only leads to an increase in surface temperature but also causes degradation of the natural environment [1]. The Chinese government has established several low-carbon strategies to regulate and solve high carbon emissions by actively supporting the "energy saving and carbon reduction" program and encouraging the development of low-carbon cities and economies [2]. However, problems such as carbon inefficiency and high building energy consumption in construction remain a concern [3], and as China's urbanization progresses, its construction industry's share of energy consumption and carbon emissions will continue to increase [4]. The construction industry already represents one of the largest carbon emitters in China [5], is characterized by extensive resource consumption and long operation times, and has become a potential impediment to China achieving its dual-carbon goals [6]. It is therefore necessary to take effective measures to reduce carbon emissions from the construction industry, which can be achieved through technological innovation and low-carbon building development.

The rapid expansion of the real estate industry in China has boosted the construction industry, thus giving rise to many related decorating activities [7]. Building interior decoration as an essential part of buildings requires a large consumption of materials and resources for new building decoration and the refurbishment of existing buildings [8]. Traditional building decoration has concurrently highlighted the industry's detrimental environmental impacts [9].

Traditional decoration can lead to the generation of large quantities of waste and environmental issues due to the work that needs to be conducted on sites [10]. The current practices of traditional interior decoration, with their inadequate quality control, traditional techniques, safety risks, and resource wastage, necessitate a reevaluation and revolution [11]. In response to the shortcomings of traditional decoration, prefabricated decoration has gained popularity in recent years [12]. Prefabricated decoration exhibits four key features: standardized design, cohesive manufacturing, assembly-based construction, and collaborative information integration [13]. Prefabricated decoration offers similar advantages to prefabricated construction, including a cleaner and safer working environment for employees and a reduction in the amount of waste generated during construction [14]. In addition, prefabricated decoration has shown improvements in terms of reduced construction duration, labor savings, and increased material utilization [15]. Prefabricated decoration is a good alternative to traditional decoration in the pursuit of green and low-carbon goals [16]. Moreover, the current public and residential building sector is facing a plethora of existing building refurbishment projects that require the maintenance and upgrading of decoration products with minimal impact on operations [17]. The willingness of migrant workers in the current labor market to choose the construction industry is declining, and there is a gap in employment age, resulting in a continuous increase in labor costs [18]. Prefabricated decoration is helping to address these problems and, in doing so, presents new development opportunities.

With the advancement of prefabricated decoration, the construction industry has increased its attention to this decoration method [19]. However, the adoption of prefabricated decoration is low due to traditional decoration companies’ unwillingness to change as well as the lack of identification of the environmental benefits of prefabricated decoration. Given the efforts to pursue low-carbon and green building practices, it is necessary to quantify the carbon emissions from prefabricated decoration.

2. Reducing Carbon Emissions from Prefabricated Decoration

2.1. Carbon Emissions from the Construction Industry

As a major source of carbon emissions, the construction industry has received extensive research attention, and many different research directions have been generated for construction carbon emissions. Most of the literature analyzes the carbon emissions trend in the construction industry. The studies include global, national, and regional trends and emissions from various buildings [20][21], especially the projections of China’s construction industry carbon emissions and reduction potential by 2060 [22][23][24]. This study’s results can reveal whether carbon emissions are growing, stabilizing, or declining and the main factors contributing to such trends.

While gaining a deeper understanding of carbon emissions trends in the construction industry, focusing on how building design and technological innovations affect carbon emissions can help develop practical measures to reduce emissions. Yang et al. studied how digital technology affects construction carbon emissions, and the findings indicated that using digital technology and building a digital city can greatly decrease carbon emissions intensity [25]. In another study, digital infrastructure development was also shown to control carbon emissions effectively [26]. Karlsson et al. explored the potential of combining existing technologies and abatement measures in reducing carbon emissions by analyzing different building designs and the actual level of reduction of different abatement measures from a supply chain perspective and concluded that increasing the recycling rate of materials is the reduction measure that deserves the most attention in the short term [27]. Xu et al. demonstrated in a case study that sustainable material applications can effectively reduce carbon emissions [28]. Xu et al. also explored the use of bamboo as a building material, and the results have shown that bamboo buildings provide a valuable way to extend carbon storage and realize carbon emissions reductions [29]. In addition, the application of intelligent technologies can also greatly contribute to reducing carbon emissions, including artificial intelligence, robotics learning, artificial neural networks, and other technologies [30][31]. Fang et al. constructed a carbon emissions prediction model for the building construction stage based on the robot learning method, which provides great help for designers to clarify the relationship between carbon emissions and design parameters during the construction stage [32]. In summary, measures such as adopting efficient building design, improving building materials, and integrating intelligent technologies can be influential measures for controlling carbon emissions.

Quantifying carbon emissions from construction projects is necessary for more targeted development and implementation of emission reduction strategies and to clarify the effects of emission reduction. Also, in analyzing carbon emissions trends, accurate quantification of carbon emissions allows for a more precise identification of the influencing factors. Li and Chen measured the construction carbon emissions of a residential community project based on the Life Cycle Assessment (LCA) theory. Their results showed that among the different buildings in the project, tall buildings and villas produce the most carbon emissions per unit [33]. Zhang et al. specifically assessed the implied carbon emissions of tall residential buildings with a dataset of up to 403 buildings and explored cascading carbon reduction strategies according to the statistical data [34]. Yang et al. analyzed the carbon emissions and reduction potentials of thirty provinces in China from an urban construction land use perspective and discussed how energy structure, energy efficiency, and economic level affect carbon emissions [35]. Hung et al. quantified the carbon emissions from Hong Kong's construction industry and found that a significant amount of carbon emissions was generated by cross-boundary construction activities and proposed measures such as using low-carbon materials and fuels to minimize indirect construction carbon emissions [36]. Kang et al. illustrated the importance of embodied carbon assessment in the construction sector and developed a computational model based on probabilistic analysis for assessing embodied carbon emissions [37]. Typically, building-implied carbon assessments are based on the specific implementation of the particular project [38]. To assess the implied carbon emissions at the design stage, Cang et al. used Building Information Modeling (BIM) technology and the "building element" as the fundamental unit of measurement to provide a novel carbon emissions calculation method for the design optimization process [39]. In addition to BIM, the Internet of Things (IoT), blockchain, and other digital technologies can also improve carbon quantification [40]. Effective carbon emissions measurement can help the construction industry and stakeholders better understand the carbon emissions characteristics of construction activities and help construction projects set clear carbon reduction targets.

2.2. Prefabricated Construction Carbon Emissions

As an essential approach to the industrialization of construction, prefabricated buildings have seen an increasing level of application in recent years, bringing new directions for research on construction industry carbon monitoring and assessment. Regarding carbon emissions monitoring, prefabricated constructions offer opportunities for real-time monitoring and visualization of carbon emissions [41]. Tao et al. provided builders with a real-time system for monitoring building construction carbon emissions and enabled visualization and analysis of the monitoring results based on IoT technology [42]. Xu et al. also used IoT and integrated BIM technology to develop a prefabricated construction-embodied carbon detection system [43]. Yevu et al. presented a comprehensive view of digital twin technology in the prefabricated building's full supply chain, enabling carbon emissions monitoring through intelligent technology [44]. Integrating prefabrication technology and a new generation of digital technology can effectively realize the dynamic monitoring of prefabricated building carbon emissions, creating a novel paradigm for the construction industry to control carbon emissions.

Studies on the carbon emissions assessment of prefabricated buildings can be categorized into two main areas. The first topic of research is the carbon emissions generated by prefabricated buildings. Li et al. used BIM, LCA, and the Geographical Information System (GIS) to construct a carbon footprint accounting model for precast concrete composite panels in the materialization stage [45]. By integrating BIM and LCA, automated models can be developed for embodied carbon assessment of prefabricated constructions at various spatial scales [46]. It is also possible to assess the potential of prefabricated constructions to reduce carbon emissions throughout their life cycle without the need to construct physical facilities [47]. According to a study of previous research, BIM technology and LCA methodology are directly related to the assessment of prefabricated projects' carbon emissions. BIM technology can create detailed building models that provide material and quantity information, and these data can be used for LCA analysis, which can then be used to evaluate prefabricated buildings' carbon emissions [48]. BIM and LCA are the most popular and mature methods used in carbon assessment for prefabricated buildings.

The second area of research is comparative analyses of carbon emissions from prefabricated and traditional buildings. Luo et al. compared the carbon emissions of precast piles and cast-in-place piles based on a quantitative model of the process and two case studies and have explored the impact of transportation distance, sustainable materials, and equipment idle time on pile construction carbon emissions [49]. Zhao et al. included green materials in buildings based on comparing carbon emissions between prefabricated and traditional buildings. The results showed that prefabricated buildings are better at reducing environmental loads [50]. Research in both directions of carbon assessment provides important information for the construction industry's carbon management and sustainable development. Meanwhile, comparative analyses can help decision-makers and owners make more informed choices during the project selection and building design stages to reduce carbon emissions and support sustainable development goals.

2.3. Prefabricated Decoration

Prefabricated decoration is characterized by the pre-manufacturing of building decoration elements in the factory, which are later assembled on-site. One of the primary advantages of this method is the utilization of eco-friendly materials that substantially reduce the environmental footprint of construction projects. These materials are selected for their sustainability, durability, and lower carbon emissions, supporting the global shift towards environmentally responsible building practices [51]. Another significant benefit of prefabricated decoration is the reduction in construction time. By streamlining the decoration process through prefabrication, the time required for on-site work is considerably decreased. This efficiency not only expedites project completion but also results in notable savings in labor costs [52]. The construction industry, faced with challenges such as increasing labor costs and a shortage of skilled labor, finds a viable solution in prefabricated decoration. Furthermore, the method plays a crucial role in mitigating overall carbon emissions in the construction process [16]. By manufacturing decoration components in a controlled factory setting and minimizing on-site work, prefabricated decoration significantly reduces the carbon footprint associated with building projects [53]. Prefabricated decoration represents a significant advancement in construction methodologies. It aligns with contemporary environmental and economic demands, offering an efficient, sustainable, and cost-effective solution [54]. Embracing such innovative practices is indicative of the construction industry's commitment to environmental stewardship and operational efficiency, positioning prefabricated decoration as a key player in the future of sustainable building practices.

Through the comprehensive literature review, it is known that research on quantifying carbon emissions from prefabricated buildings has focused on the structural aspect of such buildings, with little attention paid to the specific field of prefabricated decoration. There is no unified and efficient carbon emission evaluation model applicable to prefabricated decoration, which affects the exploration of carbon emissions influencing factors and the quantitative expression of the carbon emissions change trend for prefabricated decoration.

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