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Development of carbon emission calculation platform for high-speed rail bridge construction

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Abstract

As the global pressure to combat climate change intensifies, low-carbon policies have become a core driving force for economic development and environmental protection in various countries. The construction industry, as a significant source of carbon emissions, has far-reaching impacts on the environment with every action it takes. High-speed rail has become an essential transportation hub connecting cities, and the construction of high-speed rail bridges is increasing day by day. Given that high-speed rail transportation and construction are major sources of carbon emissions, how to achieve coordinated development under the backdrop of low-carbon policies has become an urgent issue to address. This paper, from a low-carbon perspective, develops a carbon emission calculation platform, providing new ideas for reducing carbon emissions in construction. By combining case studies and practical experience, this paper verifies the effectiveness of coordinated development between road transportation and construction under the impetus of low-carbon policies, offering theoretical support and reference for policy formulation and practice in relevant fields.

Keywords

Building energy efficiency, Carbon emission, Carbon emission calculation platform.

1. Introduction

In the face of the urgent situation of global climate change, controlling carbon emissions has become a critical issue for all humanity. The construction industry, as a significant sector in carbon emissions, has far-reaching impacts on the environment with every action it takes. According to relevant studies, it is estimated that by 2030, greenhouse gases produced by the construction industry will account for 25% of society's total emissions. In this context, bridge engineering, as an essential part of infrastructure construction, faces increasingly urgent needs for low-carbon development. High-speed rail, as a green and low-carbon mode of transportation, plays an increasingly important role in the transportation sector. However, high-speed rail bridge projects face issues such as high resource consumption and significant carbon emissions during construction. Each stage of construction requires substantial energy use, leading to considerable carbon emissions. These emissions not only pollute the surrounding environment but also contradict global efforts to combat climate change. With the proposal of the "dual carbon" goals, exploring effective ways to reduce carbon emissions during high-speed rail bridge construction is imperative. This study will delve into relevant strategies to provide theoretical and practical support for the low-carbon transformation of high-speed rail bridge construction.

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2. System design

2.1. Overall architecture design

The carbon emission calculation platform for high-speed rail bridge construction adopts a layered architecture design, primarily divided into three parts: the data layer (carbon emission factor database), the business logic layer (carbon emission management), and the presentation layer (carbon emission visualization). The data layer is responsible for storing and managing various data required by the platform, including the carbon emission factor database and actual construction carbon emission data. The business logic layer consists of core modules such as carbon emission factor management, carbon emission calculation, evaluation, and analysis. It achieves efficient interaction between modules through API interfaces, ensuring the system has good extensibility and maintainability. The presentation layer mainly focuses on displaying rich user interaction interfaces and visualizing data. Through large screens and user operation interfaces, managers can monitor carbon emissions in real-time during construction, perform data queries and report generation, helping users quickly understand and analyze carbon emission data, supporting decision-making and the implementation of optimization measures.

The carbon emission calculation platform for high-speed rail bridge construction features efficient data processing and data security protection. The front end adopts the Vue 3.x framework, while the back end uses a microservices architecture (Spring Cloud) framework. MySQL is selected as the database, with multiple architectures combined to meet various data storage requirements. Containerization deployment is achieved through Docker and Kubernetes to ensure system usability and scalability. Additionally, the platform includes robust security mechanisms, such as data encryption, role-based access control, and audit logs, ensuring data privacy and system security. The overall architecture design aims to achieve efficient and reliable carbon emission monitoring and management, promoting green and sustainable development in high-speed rail bridge construction

2.2. Overall functional design

The carbon emission calculation platform for high-speed railway bridge construction mainly provides comprehensive carbon emission management solutions for high-speed railway bridge construction projects. The platform realizes the whole-process management from carbon emission estimation, monitoring to optimization through three core functional modules: carbon emission budget, actual carbon emission calculation, and low-carbon construction evaluation and analysis.

3. Design of carbon emission budget function for high-speed rail bridge construction

3.1. Functional objectives

The carbon emission budget for high-speed rail bridge construction estimates the theoretical carbon emissions during the construction process. This function combines uploaded lists of labor, materials, machinery, and other items, using a standard library of carbon emission factors to calculate the carbon emission budget for the construction phase. It also provides a budget report, facilitating early carbon emission control and optimization by project managers.

3.2. Core process

The carbon emission budgeting process for high-speed rail bridge construction begins when the business user clicks "Start." The user then uploads a list of construction resources. If the upload is successful, the list will be forwarded to the business supervisor for review. If it fails, the business user must modify or supplement the data and re-upload. The business supervisor

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reviews the list; if it does not pass, it is returned to the business user for modification or supplementation of data. If it passes, the supervisor parses the list data and matches it with carbon emission factors. If the match fails, the business user must again modify or supplement the data. If the match is successful, the business supervisor calculates the carbon emission budget. Once the calculation is complete, the entire process ends.

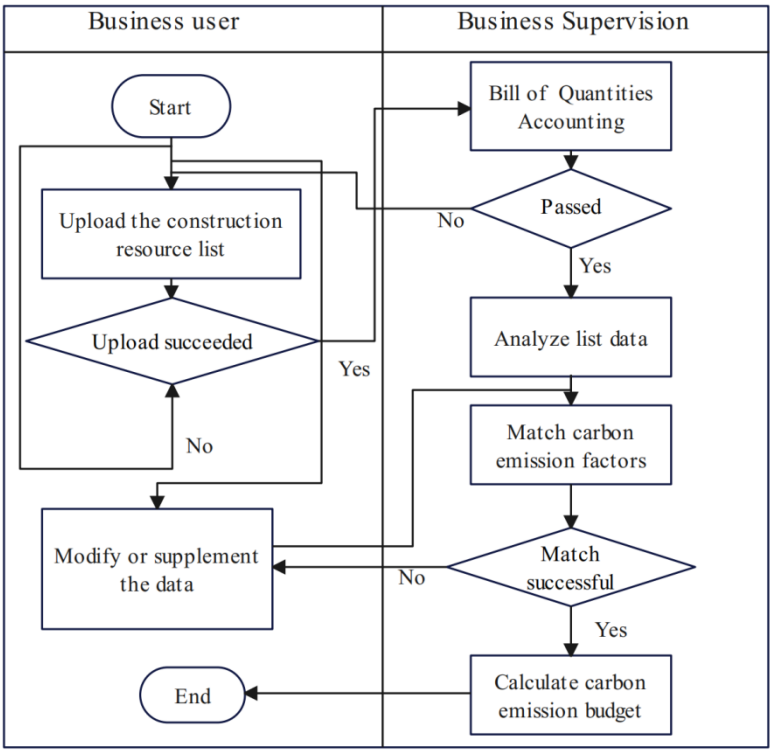

Fig. 1 Core Flowchart of Budget

3.3. Key Elements

List data analysis: in-depth extraction and accurate matching of labor, materials, machinery and other resources. Through systematic data processing, ensure the accurate recording of the use of various resources, and provide a reliable basis for the final carbon emission calculation.

Carbon emission factor database: Based on national standard classification, it contains carbon emission coefficients of various energy sources, materials and processes. The factor database is updated regularly to reflect the latest policies and technological progress, ensuring the authority and consistency of data and supporting the carbon emission assessment needs of different industries.

Budget calculation formula: carbon emission of each resource= consumption×carbon emission factor. This formula is convenient for quick estimation of total carbon emission, identification of high emission links, formulation of effective emission reduction strategies, and realization of accurate carbon footprint analysis to help achieve the sustainable development goals.

4. Design of carbon emission calculation function for high-speed rail bridge construction

4.1. Functional objectives

The calculation of carbon emissions in high-speed rail bridge construction is based on the actual consumption data to calculate the actual carbon emissions of various resources in the process of high-speed rail bridge construction, and generate accurate calculation reports. This function mainly relies on the uploaded cost documents and the carbon emission factor database for accurate calculation

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4.2. .Core process

The process for calculating carbon emissions in high-speed rail bridge construction starts with the business user "beginning" operations. The business user first uploads cost documents. If the upload is successful, the document is submitted to the business supervisor for review; if not, the data needs to be modified or supplemented before re-uploading. Upon receiving the document, the business supervisor conducts an audit. If the audit fails, the process ends; if it passes, the file data is parsed, followed by extracting resource consumption data and matching it with carbon emission factors. If the match fails, the data must be modified and supplemented again before attempting to match the carbon emission factors once more; if the match succeeds, the carbon emissions are calculated, and the process concludes.

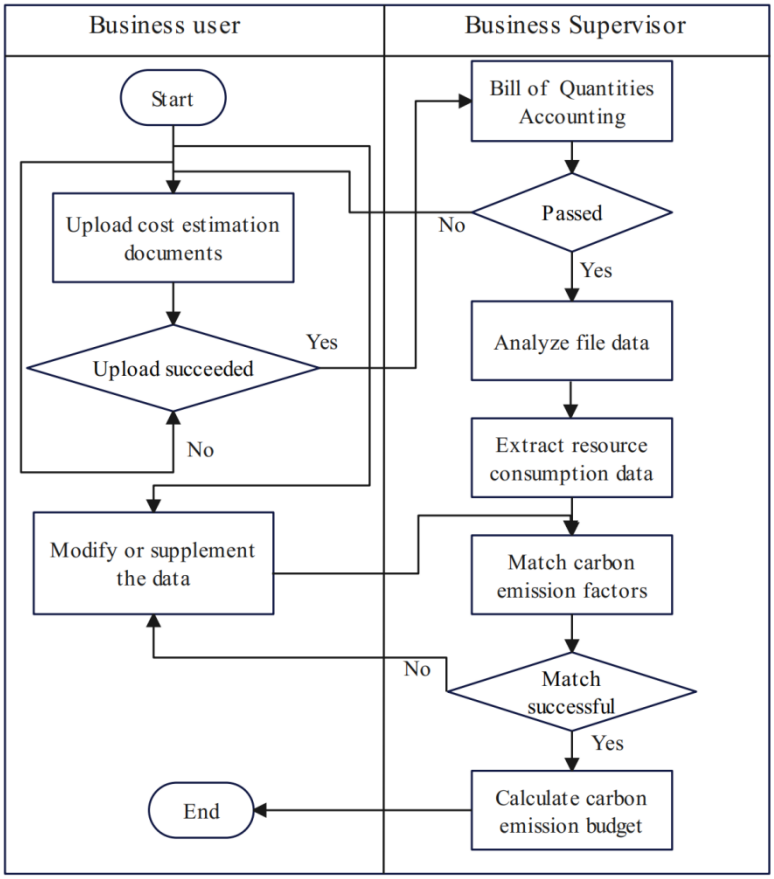

Fig. 2 Core Flowchart of Calculation

4.3. Key elements

Document analysis: Extract consumption data from cost documents, covering detailed information of labor, materials, machinery and other resources. Through systematic analysis methods, ensure the integrity and accuracy of the data, providing a solid foundation for subsequent carbon emission calculation.

Matching of actual consumption with factors: Based on the actual consumption, the carbon emission factor library is used to accurately calculate the carbon emission of various resources according to the correlation coefficient. This process ensures the scientificity and accuracy of the calculation, which helps to fully understand the carbon footprint of the project and provides a basis for optimizing resource allocation.

Compliance analysis: Ensure that the carbon emissions of high-speed rail Bridges comply with industry regulations and national standards. Identify and correct potential compliance risks by comparing the calculation results with relevant regulatory requirements, support the

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sustainable development and environmental protection goals of the project, and enhance the corporate social responsibility image.

5. Design of evaluation and analysis function of low-carbon construction of high-speed railway Bridges

5.1. Functional objectives

Based on the carbon emission budget and actual calculation results, a low-carbon construction evaluation and analysis report of high-speed railway bridge construction is generated to help managers evaluate the effect of carbon emission management, optimize the construction scheme and meet the regulatory needs.

5.2. Core process

The evaluation and analysis process for low-carbon construction of high-speed rail bridges begins with the business user or supervisor "starting." First, files are uploaded, followed by entering the carbon emission budget calculation process and the actual carbon emission calculation process. After the calculations are complete, the carbon emission deviation is calculated, and the results are visualized. Next, the sources of the deviation are analyzed, with the result data also visualized. Then, the effectiveness of low-carbon measures is assessed, followed by generating a low-carbon construction evaluation report, concluding the process.

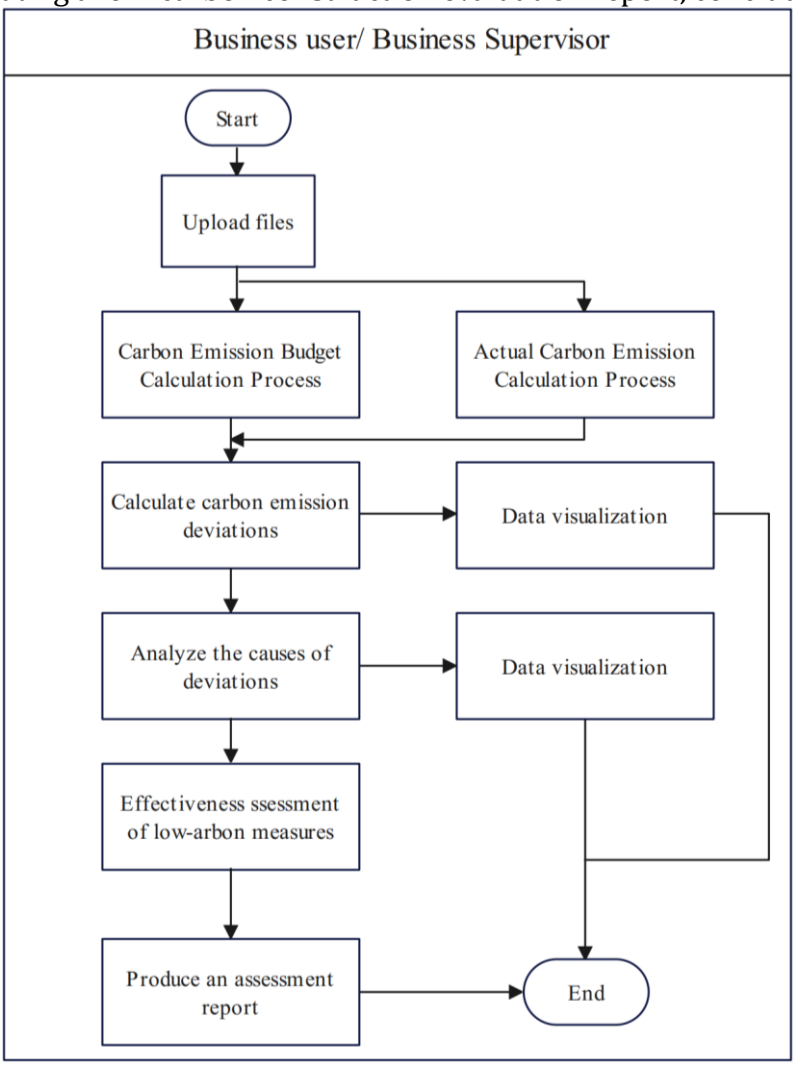

Fig. 3 Flowchart of Evaluation and Analysis Functions

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5.3. Key Elements

Carbon Emission Comparison: By conducting a detailed comparative analysis of budgeted and actual carbon emission data, identify the differences between them. Possible reasons for discrepancies may include resource utilization efficiency, changes in construction techniques, or external environmental factors. This process helps understand the carbon emission performance during project execution, providing data support for subsequent optimization to ensure the achievement of carbon management goals.

Evaluation of Low-Carbon Measures: Conduct a systematic assessment of implemented low-carbon measures, such as energy-saving technology applications, material optimization, and waste management, to measure their actual emission reduction effects. Through data analysis and on-site inspections, determine the effectiveness of these measures and propose improvement suggestions based on the evaluation results. This will further enhance the implementation effectiveness of low-carbon measures and overall carbon reduction levels, supporting sustainable development goals.

Visual Presentation: Utilize large screens and data visualization tools to present carbon emission data and analysis results in the form of charts, trend graphs, and ratio diagrams. This method facilitates quick understanding of carbon emission status and the effectiveness of low-carbon measures by managers, supports scientific decision-making on issues and strategic planning for projects, promotes transparency and efficiency in carbon management, and enhances overall management efficiency and accuracy.

6. Conclusion

This article provides a detailed explanation of the design and implementation of a carbon emission calculation system, as well as its functions and features. The system's design includes the budgeting function for carbon emissions in high-speed rail bridge construction, the calculation function, and the evaluation and analysis function for low-carbon construction. It is a targeted computing platform. In the future, with continuous technological advancements and the widespread adoption of this platform, low-carbon collaborative development will see more opportunities. Further developing transportation industry technologies under the "dual carbon" policy background is not only an important measure to align with the low-carbon green development strategy and support modernization and sustainable development, but also a critical step in enhancing the environmental friendliness, efficiency, operational stability, and long-term sustainability of the transportation industry. This has significant implications for promoting innovation and development in the transportation sector.

Acknowledgements

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