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Research on the Collaborative Development Path of Construction Project Management and Construction Technology

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Abstract: This paper discusses the significance of the collaborative development of construction project management and construction technology. It analyzes issues in their cooperation, especially in waste-to-energy projects, which face technical complexity and management challenges. It also explores technology-driven efficiency opportunities, process re-engineering, and various decision-making models. Case studies illustrate their application, and synergy efficiency indicators and lifecycle impact assessment are used for evaluation. Finally, it proposes implementation roadmaps and intelligent collaboration platforms for future research.

Keywords: Construction project management; Construction technology; Waste-to-energy projects

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1. Introduction

In the construction domain, the symbiotic development of construction project management and construction technology is of paramount importance. This is further emphasized by the "14th Five-Year Plan for the Development of the Construction Industry" issued in 2021, which encourages the integration of management and technology to enhance the industry's competitiveness. The interaction between them, especially in waste-to-energy projects, is complex. Despite challenges like misalignment between conventional management and technical execution, there are numerous opportunities such as technology-driven efficiency improvements and process re-engineering. Recent studies also highlight that integrating digital technologies, such as Building Information Modeling (BIM) and Enterprise Resource Planning (ERP), into construction project management can significantly optimize coordination and improve performance in waste-to-energy plants [1]. Understanding and optimizing this relationship is crucial for improving the overall performance and sustainability of construction projects, especially in the context of the latest policy - driven industry transformation.

2. Characteristics of waste-to-energy power plant construction projects

2.1. Technical complexity in waste-to-energy facility construction

Waste-to-energy power plant construction projects are fraught with technical complexity. For instance:

(1) The emissions control systems in these plants are highly sophisticated. Stringent environmental regulations worldwide demand that waste-to-energy facilities minimize harmful emissions such as dioxins, sulfur dioxide, and particulate matter [2]. To achieve this, advanced pollution control technologies like selective catalytic reduction (SCR) for nitrogen oxide removal, fabric filters for particulate capture, and flue-gas desulfurization systems are required. These systems must be precisely designed, installed, and operated to meet the strict environmental standards;

(2) The waste incineration processes are another area of high-level technicality. Different types of waste have varying calorific values, moisture contents, and chemical compositions. This requires the development of optimized incineration techniques to ensure complete combustion, which is crucial for energy recovery and minimizing the generation of pollutants. Engineers need to carefully control parameters such as combustion temperature, air supply, and residence time to achieve efficient incineration;

(3) The energy conversion mechanisms in waste-to-energy plants are complex. Converting the heat generated from waste incineration into electricity involves multiple steps, including steam generation, steam turbine operation, and power generation. The efficiency of this conversion process depends on the quality of equipment, the design of the system, and the integration of various components. High-efficiency heat exchangers, well-designed turbines, and advanced control systems are necessary to maximize energy output and ensure the stable operation of the power-generation process.

2.2. Management challenges in large-scale environmental projects

Waste-to-energy power plant construction projects, as a part of large-scale environmental projects, face unique management challenges. Multi-stakeholder coordination is a significant issue. These projects involve various parties, including the government, power plant operators, environmental protection agencies, local communities, and construction contractors [3]. Each stakeholder has different interests and goals. For example, the government may focus on achieving environmental and energy-related policy objectives, while local communities might be more concerned about potential environmental impacts such as odor and noise pollution. Coordinating these diverse interests to ensure a smooth construction process is difficult.

Environmental compliance pressures are also prominent. Waste-to-energy projects are under strict environmental regulations. Construction activities must meet standards regarding waste treatment, emissions control, and land use. Failure to comply can result in project delays, heavy fines, and negative public perception. Additionally, any changes in environmental regulations during the project lifecycle can pose new challenges, requiring project managers to stay updated and adjust plans accordingly.

Schedule optimization is another major challenge. The construction of waste-to-energy power plants is complex, involving multiple construction phases, from site preparation to equipment installation. Unforeseen factors such as inclement weather, material shortages, or technical difficulties can disrupt the schedule. Moreover, tight deadlines are often set to meet energy demands or environmental targets, making it crucial for project managers to develop robust scheduling strategies that can adapt to changes and ensure timely project completion.

3. Status quo of construction management-technology integration

3.1. Disconnection between conventional management practices and technical execution

In the realm of construction project management, a significant disconnection exists between conventional management practices and technical execution, especially when dealing with advanced construction technologies such as the installation of flue gas treatment systems [4]. Conventional management often adheres to standardized procedures and schedules established based on past experiences. However, these practices may not adequately account for the unique intricacies and requirements of novel construction technologies.

For instance, the installation of flue gas treatment systems demands precise technical know-how regarding gas chemistry, equipment calibration, and environmental compliance. Traditional management approaches might focus more on overall project timelines and cost control, overlooking the technical subtleties. This leads to situations where construction teams are rushed to meet deadlines, potentially compromising the quality of technical execution.

Moreover, conventional management may lack real-time communication channels with technical teams. As a result, technical challenges encountered during the installation of flue gas treatment systems are not promptly relayed to management. This lack of communication can cause delays in decision- making, further widening the gap between management's expectations and the actual technical progress. In essence, the disconnect between conventional management practices and technical execution hampers the efficient and effective implementation of advanced construction technologies in construction projects.

3.2. Technology-driven efficiency opportunities

In the context of construction project management and construction technology collaboration, technology presents numerous efficiency-enhancing opportunities. For instance, BIM is playing a crucial role in plant layout optimization. BIM offers a 3D digital representation of the construction project, enabling project teams to visualize and analyze the spatial relationships within the plant layout. This helps in identifying potential conflicts and inefficiencies in the design stage, thus reducing rework and construction delays [5]. By simulating different scenarios, project managers can select the most optimal layout, which improves the overall functionality of the plant and enhances construction efficiency.

Moreover, the Internet of Things (IoT)-based equipment monitoring systems are revolutionizing the operational synergy aspect. IoT devices can be installed on construction equipment to collect real-time data on parameters such as equipment health, usage patterns, and performance. This data allows for predictive maintenance, which can prevent breakdowns during construction. By proactively addressing equipment issues, the downtime of construction activities is minimized, leading to increased productivity. Additionally, the data from IoT-enabled equipment can be integrated with project management systems, providing project managers with a comprehensive view of the construction process. This integration facilitates better decision-making, ensuring that resources are allocated more effectively and that construction schedules are adhered to more closely.

4. Collaborative development framework

4.1. Integration mechanisms for management-technology convergence

4.1.1. Process re-engineering for technical coordination

Process re-engineering for technical coordination in the collaborative development of construction project management and construction technology is crucial. It aims to establish seamless connections between different technical aspects to ensure smooth project progress. For construction projects, the construction of the boiler system, for instance, requires a series of complex technical operations. Through process re-engineering, new workflows are designed that integrate construction scheduling with quality assurance protocols [6]. This means that while the construction is being carried out according to the schedule, quality control measures are simultaneously implemented at every step. By re-engineering the processes, redundant steps can be eliminated, and bottlenecks can be identified and resolved in advance. It enables better communication and cooperation among different technical teams involved in the project, such as the installation team, the inspection team, and the maintenance-planning team. In this way, the overall efficiency of technical coordination is improved, and potential conflicts between different technical requirements are minimized. The re-engineered processes also provide a clear roadmap for the entire construction process, ensuring that all technical activities are coordinated in a more systematic and efficient manner, ultimately promoting the successful collaborative development of construction project management and construction technology.

4.1.2. Collaborative decision-making models

Matrix-based decision frameworks are developed to achieve a balance between technical feasibility and budget constraints in construction projects. Technical feasibility, such as combustion efficiency in relevant construction systems, is a crucial factor that determines the functionality and long-term performance of the project. On the other hand, budget constraints are equally important as they ensure the economic viability of the project.

These matrix-based decision frameworks provide a systematic approach. They enable project managers and technical experts to comprehensively assess different options. For example, when considering different construction materials or technologies, the matrix can clearly show how each option fares in terms of technical feasibility and cost. If a new, high-efficiency construction technology is proposed, the matrix can help evaluate whether it can be implemented within the given budget.

By using these models, stakeholders can make more informed decisions. They can identify trade-offs between technical superiority and cost-effectiveness. This not only helps in optimizing the overall project outcome but also promotes the integration of construction project management and construction technology. It serves as a practical tool for collaborative decision-making, ensuring that both management and technical aspects are considered simultaneously throughout the project lifecycle [7].

4.2. Digital enablers for synergistic development

4.2.1. BIM-ERP system integration

BIM-ERP system integration plays a crucial role in the collaborative development of construction project management and construction technology. It effectively demonstrates cross-platform data interoperability between 3D modeling, such as chimney structure design, and resource allocation systems.

BIM, with its 3D-based information-rich models, provides detailed geometric and non-geometric data about the construction project. This includes aspects like the precise design of the chimney structure, enabling stakeholders to visualize and understand the project in a more intuitive way. On the other hand, ERP systems are focused on resource management, covering areas such as human resources, materials, and cost.

When integrating BIM and ERP, the data from BIM models can be shared with ERP systems. For example, the quantity of materials required for the chimney construction calculated from the BIM model can be directly fed into the ERP system for procurement planning. This integration ensures that the resource allocation in the

ERP system is based on accurate project-specific data from the BIM model. It also allows for real-time updates. If there are design changes in the BIM model, the relevant resource requirements can be adjusted in the ERP system accordingly. In this way, the seamless integration of BIM and ERP promotes the synergy between construction project management and construction technology, enhancing overall project efficiency and performance [8].

4.2.2. Predictive analytics for technical risk management

Predictive analytics for technical risk management is a crucial aspect within the collaborative development framework of construction project management and construction technology. By formulating machine learning models based on historical project data patterns, it enables the anticipation of equipment installation risks. These models can analyze a vast amount of historical data, including information about equipment types, installation environments, past risk occurrences, and the corresponding resolutions [9]. This analysis helps in identifying hidden patterns and relationships that might not be apparent through traditional methods. Once these patterns are recognized, the models can predict potential technical risks during equipment installation in current and future projects. For instance, they can forecast whether a particular type of equipment might encounter difficulties due to site-specific conditions, such as limited space or complex geological structures. By leveraging predictive analytics, project managers can take proactive measures. They can allocate resources more effectively, plan for additional support or alternative installation methods in advance, and thus reduce the negative impacts of technical risks on the overall project schedule, cost, and quality. This not only enhances the efficiency of construction projects but also promotes a more seamless collaboration between construction project management and construction technology, as both sides can work together more purposefully to address predicted risks.

5. Case implementation in waste-to-energy projects

5.1. Synergy practice in civil engineering phases

5.1.1. Foundation construction coordination

This part presents a case study on the collaborative management of reinforced concrete works for high-load incinerator foundations in waste-to-energy projects. In waste-to-energy projects, the construction of high-load incinerator foundations is a critical task. The synergy in foundation construction coordination plays a decisive role in the overall project quality and progress.

During the construction of reinforced concrete works for these foundations, various aspects need to be carefully coordinated. For instance, the design of the reinforcement layout should be closely integrated with the construction technology. The engineers need to ensure that the reinforcement can effectively bear the high loads from the incinerator. At the same time, the construction sequence of concrete pouring also requires precise planning. Incorrect pouring sequences may lead to problems such as uneven stress distribution in the foundation.

Collaborative management here involves communication and cooperation among multiple parties. Architects, structural engineers, and construction workers need to work together. The architects provide the overall design concept, the structural engineers calculate and design the load-bearing structure, and the construction workers implement the construction according to the plans. Through this collaborative approach, potential problems can be identified and resolved in a timely manner. This kind of collaborative management in foundation construction coordination not only improves the construction efficiency but also ensures the long-term stability and safety of the waste-to-energy facilities, as proven by relevant research [10].

5.1.2. Structural-electromechanical interface optimization

In waste-to-energy projects, the optimization of the structural-electromechanical interface is crucial for the seamless operation of the entire system. When dealing with the clash detection resolution between building structures and waste heat recovery pipeline networks, several aspects as follows need to be considered.

(1) Accurate 3D modeling of both the building structure and the pipeline network is essential. By creating detailed models, potential clashes can be identified in the virtual environment. This allows engineers to visualize the spatial relationship between the two systems and anticipate any interference points. For example, the height, width, and routing of the pipeline network should be carefully designed to avoid colliding with the load-bearing components of the building structure [11];

(2) During the design phase, close communication between the structural and electromechanical engineering teams is necessary. The structural engineers need to provide information about the structural layout, load-bearing capacity, and any restrictions in the building design. Meanwhile, the electromechanical engineers should share details about the pipeline requirements, such as flow rates, pressure drops, and insulation needs. Through this cross-disciplinary communication, solutions can be developed to optimize the interface. This could involve adjusting the pipeline route, modifying the structural design in a non-critical area, or using flexible connections in the pipeline system to accommodate any minor misalignments;

(3) Continuous monitoring and adjustment during the construction process are also important. As the project progresses, unforeseen circumstances may arise, and real-time adjustments need to be made to ensure that the structural-electromechanical interface remains optimized. This collaborative approach throughout the civil engineering phases in waste-to-energy projects can enhance the overall efficiency and functionality of the project.

5.2. Equipment installation synergy effects

5.2.1. Turbine-generator alignment management

In waste-to-energy projects, turbine-generator alignment management is crucial for achieving equipment installation synergy effects. Precision installation protocols that integrate laser alignment technologies with project scheduling play a vital role. Laser alignment technologies provide highly accurate measurements, enabling precise adjustment of the turbine-generator components. By using lasers, the alignment of shafts, couplings, and other key parts can be monitored and corrected to ensure minimal misalignment, which is essential for reducing vibration, enhancing efficiency, and prolonging the service life of the equipment [12].

When integrating with project scheduling, it's necessary to consider the sequence of tasks. For instance, during the early stages of installation, laser alignment can be used to initially position the turbine-generator components. As the project progresses, regular checks using laser alignment are carried out to ensure that the alignment remains within the allowable tolerance range. This not only helps in timely detection and correction of any misalignment issues but also coordinates well with other construction activities. For example, if a misalignment is detected, the subsequent tasks such as pipe connection and electrical wiring can be paused to address the alignment problem, preventing potential problems in the overall system operation. Overall, this integrated approach in turbine-generator alignment management optimizes the installation process in waste-to-energy projects, promoting the collaborative development of construction project management and construction technology.

5.2.2. Emission control system commissioning workflow

In waste-to-energy projects, the commissioning workflow of the emission control system is of great significance. It is essential to develop phased testing procedures that coordinate the installation of the SCR system with environmental compliance documentation [13].

During the pre-installation phase, a comprehensive inspection of all components of the SCR system should be carried out. Check for any potential damage during transportation and storage, and ensure that all parts meet the design specifications. Simultaneously, start the preparation of environmental compliance documentation, which includes obtaining relevant permits, recording pollutant emission standards, and formulating monitoring plans.

Once the inspection is completed, the installation of the SCR system can commence. The installation process should be carried out in strict accordance with the technical requirements and safety regulations. During this period, the installation team needs to work closely with the environmental management team. As the SCR system is installed, real-time updates of the environmental compliance documentation should be made, documenting the progress of the installation and its impact on emission control.

After the installation is finished, phased testing procedures come into play. Conduct performance tests on the SCR system to check its efficiency in reducing harmful emissions such as nitrogen oxides. These tests should be carried out under different operating conditions to simulate real-world scenarios. Throughout the testing process, compare the test results with the environmental compliance standards set in the documentation. If there are any deviations, timely adjustments and improvements should be made to ensure that the emission control system can operate effectively and meet environmental requirements.

5.3. Performance evaluation metrics

5.3.1. Synergy efficiency indicators

Synergy efficiency indicators in waste-to-energy projects play a crucial role in assessing the collaborative performance between construction project management and construction technology. Defining key performance indicators (KPIs) such as time savings in integrated design-review processes and reduction in technical rework rates is of great significance [14].

Time savings in integrated design-review processes reflect how well project management and construction technology teams collaborate. A more efficient synergy allows for quicker identification and resolution of design-related issues. For example, when project managers can effectively communicate with construction technologists during the design-review stage, potential problems that could cause delays in construction can be spotted earlier. This could involve aspects like conflicts in the building structure design or inefficiencies in the energy-conversion system design. By promptly rectifying these issues, the overall project schedule can be optimized, leading to significant time savings.

The reduction in technical rework rates is another vital synergy efficiency indicator. High rework rates often indicate a lack of coordination between project management and construction technology. If construction technologists are not fully informed about the project management's requirements, or vice versa, it can result in work that does not meet the project's standards. However, a well-coordinated synergy ensures that the work carried out is in line with the overall project goals from the start, reducing the need for rework and thus saving resources, time, and cost.

5.3.2. Lifecycle impact assessment

Lifecycle impact assessment is employed to evaluate the long-term operational benefits of collaborative approaches within the context of waste-to-energy projects. By conducting an LCA of plant maintenance cycles, a comprehensive understanding of the environmental, economic, and social impacts throughout the entire lifespan of the project can be obtained.

In terms of environmental impact, it examines factors such as greenhouse gas emissions during waste incineration, energy consumption in different stages of plant operation and maintenance, and the potential pollution from waste residue treatment. For instance, through accurate quantification of these impacts, it can be determined whether the collaborative approach between construction project management and construction technology effectively reduces the overall environmental footprint compared to traditional methods.

Economically, LCA assesses the costs associated with each stage of the plant's lifecycle, including construction, operation, and maintenance. It analyzes how the collaborative approach influences cost-effectiveness, such as whether it can optimize resource allocation, reduce energy costs, or cut down on unexpected repair expenses.

Socially, the assessment considers aspects like the impact on local communities, including noise pollution during construction, job creation during different project phases, and the contribution to the local energy supply. By integrating these multiple dimensions, Lifecycle Impact Assessment provides a holistic view of the long-term operational benefits of the collaborative development between construction project management and construction technology in waste-to-energy projects. This helps decision-makers make more informed choices and promotes sustainable development in the waste-to-energy industry.

6. Conclusion

In conclusion, the integration of construction project management and construction technology in waste-to-energy construction is of great significance for synergistic value creation. By effectively combining management strategies and technological innovations, projects can achieve better economic, environmental, and social benefits. The proposed implementation roadmaps tailored to different project scales provide practical guidance. For small-scale projects, a more streamlined and cost-efficient approach can be adopted, focusing on basic management-technology integration. Medium-scale projects can expand on this by introducing more advanced management models and construction techniques. Large-scale projects, on the other hand, require comprehensive and sophisticated integration, leveraging the latest in both management and technology. Moreover, the emphasis on intelligent collaboration platforms as a future research direction is well-founded. In an era of rapid digital transformation, such platforms can break down information silos between management and technology teams. They enable real-time communication, data sharing, and coordinated decision-making. Through intelligent algorithms and analytics, these platforms can optimize project processes, predict potential problems, and enhance overall project performance. Future research should explore in-depth how to develop and implement these intelligent collaboration platforms, taking into account aspects such as data security, user-friendliness, and adaptability to different project environments. This will further promote the collaborative development of construction project management and construction technology in waste-to-energy and other construction fields.

Disclosure statement

The author declares no conflict of interest.

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