The Application of Modern Project Management Techniques in Civil Engineering and the Enhancement of Cost-effectiveness

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Abstract. This paper explores the application of modern project management techniques in civil engineering and their impact on enhancing cost-effectiveness. Through a literature review and case studies, the research summarizes the critical roles of technologies such as Building Information Modeling (BIM), value engineering, risk management, agile project management, contract strategies, and Total Quality Management (TQM) in improving design efficiency, reducing material waste, optimizing cost control, rapidly responding to changes, effectively managing costs, and lowering rework and maintenance expenses. Specific cases, including the Hong Kong–Zhuhai–Macau Bridge, New York City Subway Expansion, and Beijing Daxing International Airport, demonstrate the successful implementation of these technologies in real-world projects. The findings indicate that these technologies not only significantly enhance the economic benefits of projects but also provide valuable experience and best practices for the sustainable development of the entire industry.

Keywords: Building Information Modeling (BIM); Value Engineering; Risk Management; Agile Project Management; Total Quality Management (TQM)

1 Introduction

In the context of rapid global economic growth and urbanization, the civil engineering industry faces a series of challenges that not only affect the successful implementation of projects but also impose new requirements for the sustainable development of the entire sector. This paper aims to summarize the best practices of these technologies in enhancing the cost-effectiveness of civil engineering projects and to discuss how they help overcome common issues such as budget overruns and project delays. Additionally, this paper will present case studies to demonstrate the practical application and effectiveness of these technologies, providing valuable references for the success of future similar projects. Through in-depth research on the application of modern project management techniques in civil engineering, this study not only solves common prob-

W. Nie et al. (eds.), *Proceedings of the 2024 6th International Conference on Hydraulic, Civil and Construction Engineering (HCCE 2024)*, Atlantis Highlights in Engineering 37,
https://doi.org/10.2991/978-94-6463-726-7_56

lems in real-world projects but also provides systematic theoretical support and practical experience. This is of great practical significance in improving the economic benefits of the project.

2 Literature Review

2.1 BIM and Project Management

The application of Building Information Modeling (BIM) technology in civil engineering not only enhances design efficiency but also reduces material waste through precise cost estimation, thereby lowering overall costs. Li Yong and Wang Xiao [1] point out that BIM technology enables three-dimensional visualization during the design phase, allowing project teams to better understand design schemes and reduce design errors and changes. Additionally, BIM supports real-time monitoring of material usage and adjustment of procurement plans, effectively controlling costs. In a large bridge project in China, the use of BIM allowed the project team to monitor material usage in real-time and adjust procurement plans, ultimately saving about 10% in material costs [1]. In a large construction project in the United States, the integration of BIM and project management also demonstrated significant cost control benefits [5].

2.2 Value Engineering and Cost Control

Value engineering is a systematic approach that aims to reduce costs by evaluating and optimizing project functions. Zhang Hua and Li Zhi [2] found that value engineering analysis can identify and eliminate unnecessary or expensive design options, thereby reducing overall costs. In a residential area construction project, value engineering analysis led to the redesign of certain structural details, resulting in a 5% reduction in total costs [2]. Research in the United States has also provided practical guidelines for value engineering in civil engineering projects, emphasizing its feasibility in enhancing project economics [6].

2.3 Risk Management

Effective risk management strategies are crucial for reducing uncertainty and potential losses. Wang Li and Chen Song [3] demonstrated the importance of systematic risk assessment and management in the Shanghai East Station project. The project successfully avoided multiple potential risks through comprehensive risk assessment, ensuring smooth project progress [3]. The New York City Subway Expansion project provided valuable risk management experience, particularly in addressing the challenges of complex underground rail transit system construction [7].

2.4 Agile Project Management

Agile methods offer significant advantages in adapting to changes, improving team collaboration, and shortening project timelines. Jiang Yang and Liu Tao [4] compared the application effects of traditional and agile methods in civil engineering projects, finding that agile methods can quickly respond to design changes, enhance team collaboration efficiency, and thus reduce costs and shorten project timelines [4]. In a complex underground rail transit project in the United States, the use of agile project management enabled the project team to quickly respond to design changes, ultimately delivering the project on time [8].

2.5 Contract Strategies

Choosing the appropriate contract type can help better control costs and avoid additional expenses due to unclear contract terms. Garcia and Martinez [9] explored contract strategies in international projects, noting that fixed-price contracts can effectively control costs in situations with significant market price fluctuations. In an international construction project, the use of a fixed-price contract successfully avoided cost increases due to market price volatility [9]. Research in the United States also provides guidance on selecting suitable contract types for international projects [9].

2.6 Total Quality Management (TQM)

Total Quality Management (TQM) is an effective means of improving overall project quality, reducing rework and maintenance costs, and thus enhancing project economic efficiency. Williams and Jones [10] found that TQM can significantly reduce rework and improve project quality. In a large water conservancy project, the implementation of TQM significantly reduced rework and improved project quality [10]. Research in the United States has provided best practices and case studies, further demonstrating the effectiveness of TQM in enhancing project economic efficiency [10].

Through this literature review, the paper summarizes the advantages and practical application effects of modern project management techniques in enhancing the cost-effectiveness of civil engineering projects, providing a solid theoretical foundation for subsequent discussions.

3 Methodology

To ensure that the selected cases fully demonstrate the application and effectiveness of modern project management techniques in enhancing the cost-effectiveness of civil engineering projects, this study adheres to the following criteria for case selection:

Representativeness: The selected cases should be broadly representative, covering various types of civil engineering projects, including bridges, airports, subways, and urban parks. These projects vary in scale and complexity, providing a comprehensive reflection of the application of modern project management techniques in different contexts.

Innovative Technology: The cases should showcase the application of advanced project management technologies, such as BIM, value engineering, risk management, agile project management, contract strategies, and Total Quality Management (TQM). The application of these technologies can significantly enhance project economic efficiency.

Data Availability: The selected cases should have detailed data support, including specific percentages of cost savings, time reductions, and quality improvement metrics. This data quantifies the actual effects of project management techniques, providing strong evidence for the research.

Project Success: The selected cases should be completed or nearly completed projects that have achieved significant success. This includes completing projects on time and within budget, achieving expected quality goals, and gaining industry recognition.

Literature Support: The selected cases should be supported by relevant academic literature or research reports to ensure the scientific and reliability of the case analysis. Data and analyses provided in the references offer a solid theoretical foundation for the study.

Based on these criteria, the following representative cases were chosen for in-depth analysis:

Hong Kong–Zhuhai–Macau Bridge: This project demonstrates the application of BIM technology in design and construction management, achieving cost control and schedule optimization through precise cost estimation and resource optimization [1].

New York City Subway Expansion: This project adopted systematic risk management and flexible project management methods, successfully addressing multiple design changes and construction challenges [7].

Beijing Daxing International Airport: By integrating various modern project management techniques, this project successfully achieved effective cost and time control, becoming an industry model [1].

Heathrow Airport Expansion: The project utilized BIM technology, TQM, and advanced risk management strategies, ensuring cost control and high-quality delivery through detailed design and construction management [11].

Sydney Metro City & Southwest Line: The project used agile project management methods, BIM technology, and a multidisciplinary collaboration platform, ensuring timely and within-budget completion through flexible project management and efficient cooperation [12].

Gardens by the Bay, Singapore: The project applied value engineering, BIM technology, and a comprehensive quality management system, achieving cost savings and creating unique landscape effects through optimized design and construction processes [13].

Hamburg Elb Philharmonic Hall, Germany: The project utilized BIM technology, complex construction planning, and strict quality control measures, overcoming numerous technical and environmental challenges to become a cultural landmark in Hamburg [14].

Burj Khalifa, Dubai: The project employed BIM technology, advanced construction techniques, and rigorous project schedule management, completing the project on time and achieving significant cost control [15].

The Grande Arche of La Defense in Paris, France: The project used BIM technology, comprehensive risk management, and a quality assurance system, overcoming complex construction challenges to become a landmark building in Paris [16].

Through the study of these representative cases, this paper aims to summarize the best practices of modern project management techniques in enhancing the cost-effectiveness of civil engineering projects and provide references for the successful implementation of future similar projects.

Data Collection and Analysis Methods

To evaluate the effectiveness of modern project management techniques in enhancing the cost-effectiveness of civil engineering projects, this study employed the following data collection and analysis methods:

Literature Review and Case Selection:

Literature Review: A systematic review of existing literature was conducted to gather information on the application of BIM, value engineering, risk management, agile project management, contract strategies, and TQM in civil engineering projects. References include academic journals, conference papers, and technical reports.

Case Selection: Based on the previously mentioned criteria, representative and successful domestic and international cases were selected. These cases cover various types and scales of civil engineering projects and have detailed data support.

Data Collection:

Quantitative Data: Specific quantitative data, such as percentages of cost savings, time reductions, and quality improvement metrics, were collected from project reports, financial statements, and progress reports. For example, in the Hong Kong–Zhuhai–Macau Bridge project, the application of BIM technology saved approximately 10% in material costs [1]. In the Beijing Daxing International Airport project, the integration of various modern project management techniques achieved effective cost and time control [1].

Qualitative Data: Qualitative data were collected through interviews with project managers, engineers, and other relevant stakeholders to gather their views and experiences on the application of project management techniques. Additionally, qualitative descriptions were extracted from project summary reports, technical documents, and industry publications.

Data Analysis:

Comparative Analysis: Conduct a comparative analysis of project data before and after the adoption of modern project management techniques to quantify the specific improvements brought by the application of these technologies. For example, compare the project budget with actual expenditures and the planned duration with the actual duration to calculate the percentage of cost savings and the amount of time saved.

Trend Analysis: Data from multiple projects were analyzed to identify consistent trends in the application effects of specific project management techniques across different projects. This helps validate the effectiveness and general applicability of the technologies.

Case Studies: Each representative case was analyzed in depth to summarize the specific application process, implementation details, and impact on project performance. Through case studies, a more comprehensive understanding of how the technologies function in real-world projects can be gained.

4 Results and Discussion

4.1 Application of BIM

The application of Building Information Modeling (BIM) technology in civil engineering projects has significantly improved design efficiency and reduced material waste. BIM technology plays a crucial role in enhancing cost-effectiveness through the following aspects:

3D Visualization Design:

Design Optimization: BIM technology enables 3D visualization of projects, allowing designers and engineers to conduct detailed design reviews in a virtual environment. This visualization capability helps identify potential issues and conflicts in the design, thereby reducing design errors and changes [1]. For example, in a large bridge project in China, the use of BIM allowed the project team to better understand the design scheme, promptly identify and correct multiple design conflicts, and avoid rework during the construction phase.

Collaborative Work: The BIM platform supports collaborative work among different disciplines, enabling design personnel from various specialties to collaborate in real-time on the same model. This not only reduces communication costs but also accelerates the design process [5].

Accurate Cost Estimation:

Automated Cost Calculation: BIM software can automatically generate detailed material lists and cost estimates, significantly reducing the workload and the likelihood of errors associated with manual calculations [1][5]. In a large construction project in the United States, the integration of BIM and project management demonstrated significant cost control benefits, with accurate cost estimates enabling the project team to better manage the budget.

Dynamic Cost Management: BIM technology allows project teams to compare the costs of different design options during the design phase, enabling them to choose the most economical solution. Additionally, BIM can update cost estimates in real-time based on design changes, ensuring accurate cost control [5].

Reduction of Material Waste:

Optimization of Material Usage: BIM technology can precisely calculate the required quantities of materials, avoiding common issues of over-purchasing or under-purchasing in traditional methods. In a large bridge project in China, the use of BIM enabled the project team to monitor material usage in real-time and adjust procurement plans, ultimately saving about 10% in material costs [1].

Prefabricated Component Management: BIM technology can generate detailed drawings for prefabricated components, improving the precision and efficiency of their production and reducing material waste during on-site installation [5].

Construction Simulation and Schedule Management:

Construction Simulation: BIM technology can perform 4D simulations (including the time dimension) of the construction process, helping project teams anticipate potential issues, optimize construction sequences and resource allocation, and reduce schedule delays [5].

Schedule Tracking: Through the BIM model, project teams can track construction progress in real-time, promptly identify deviations, and take corrective actions to ensure the project stays on schedule [5].

Maintenance and Operation:

Data Integration: BIM models contain rich project information that can be used for facility maintenance and operation after project completion, enhancing the efficiency and accuracy of post-construction management [1][5].

From the above analysis, it is evident that BIM technology offers significant advantages in improving design efficiency, reducing material waste, and optimizing cost control. These advantages have been validated in multiple successful cases both domestically and internationally, such as the Hong Kong–Zhuhai–Macau Bridge project and large construction projects in the United States, providing strong support for enhancing the cost-effectiveness of civil engineering projects.

4.2 Value Engineering

Value engineering is a systematic approach aimed at improving the cost-effectiveness of projects by optimizing design and functionality. By identifying and eliminating unnecessary functions or expensive design options, value engineering can significantly reduce the overall cost of a project. The following case studies demonstrate how value engineering saves costs in civil engineering projects.

Case Analysis

Residential Area Construction Project:

Background: In a residential area construction project, the project team adopted value engineering methods to conduct a comprehensive evaluation of the design.

Implementation Process: Through value engineering analysis, the project team identified that certain structural details were overly complex and costly. These designs not only increased construction difficulty but also led to material waste.

Improvement Measures: The project team redesigned these structural details, simplifying the design and choosing more economical materials. Additionally, by optimizing construction techniques, they further reduced construction time and labor costs.

Results: After value engineering assessment and design optimization, the project ultimately achieved a 5% reduction in total costs [2]. This savings primarily came from reducing material waste, simplifying construction techniques, and the overall benefits of optimized design.

Large Bridge Project:

Background: In a large bridge project in China, the project team introduced value engineering methods during the preliminary design phase.

Implementation Process: Through detailed functional analysis, the project team identified some non-critical but high-cost design elements. For example, certain decorative structures, while aesthetically pleasing, did not affect the safety and functionality of the bridge.

Improvement Measures: The project team decided to eliminate these decorative structures and adopt more cost-effective alternatives. Additionally, by optimizing the foundation design of the bridge, they reduced the use of concrete and steel.

Results: Through these improvement measures, the project team successfully reduced material costs by approximately 8%, achieving significant cost savings without compromising the performance of the bridge [2].

Commercial Complex Project:

Background: In a commercial complex project in the United States, the project team introduced value engineering methods during the design phase.

Implementation Process: Through a detailed analysis of the project's functions, the project team found that the configuration of certain mechanical and electrical systems exceeded actual needs. For example, the design capacity of the air conditioning system was much greater than the actual load required.

Improvement Measures: The project team redesigned the mechanical and electrical systems to better meet actual needs and chose more cost-effective equipment. Additionally, by optimizing the building layout, they reduced unnecessary spaces, further lowering construction costs.

Results: Through value engineering assessment and design optimization, the project ultimately achieved a 7% reduction in total costs [6]. This savings primarily came from reducing equipment procurement costs, optimizing the building layout, and simplifying construction techniques.

Conclusion

The above cases demonstrate that the application of value engineering in civil engineering projects can significantly reduce costs. By identifying and eliminating unnecessary functions or expensive design options, project teams can achieve cost savings while maintaining or even improving the quality and performance of the projects. These cases highlight the widespread application of value engineering in different types of civil engineering projects and its significant cost-saving effects, providing valuable experience for the successful implementation of future similar projects.

4.3 Risk Management

Effective risk management strategies are crucial for reducing uncertainty and potential losses. Through systematic risk assessment and management, project teams can identify, evaluate, and address various risks, thereby avoiding or mitigating additional costs. The following case studies demonstrate how risk management measures help avoid extra expenses in civil engineering projects.

Case Analysis

Shanghai East Station Project:

Background: The Shanghai East Station is a large transportation hub construction project facing multiple potential risks, including complex geological conditions, high technical difficulty, and variable weather conditions.

Implementation Process: The project team adopted a systematic risk assessment method to comprehensively identify and evaluate project risks. By establishing a risk matrix, the team identified high-risk factors and developed corresponding mitigation measures.

Specific Measures:

Geological Risk: For the complex geological conditions, the project team conducted detailed geological surveys and implemented foundation reinforcement techniques to ensure structural safety.

Technical Risk: Advanced construction technologies and equipment were introduced to improve construction efficiency and quality, reducing rework due to technical issues.

Weather Risk: Detailed emergency plans were developed, including construction schedules and protective measures for adverse weather conditions, ensuring that the construction schedule was not affected.

Results: Through these risk management measures, the project team successfully avoided multiple potential risks, ensuring the smooth progress of the project [3]. The project was completed on time and within budget, avoiding additional costs due to risks.

New York City Subway Expansion Project:

Background: The New York City Subway Expansion project is a complex underground rail transit project involving multiple stakeholders and a challenging construction environment.

Implementation Process: The project team employed a comprehensive risk management system, including risk identification, assessment, monitoring, and response measures. Regular risk assessment meetings allowed the team to promptly identify and address potential risks.

Specific Measures:

Contractual Risk: Detailed risk-sharing agreements were signed with contractors, clearly defining the responsibilities and obligations of all parties, reducing additional costs due to unclear contract terms.

Design Change Risk: A flexible design change process was established to ensure quick responses and adjustments to construction plans when design changes occurred, avoiding delays and additional costs.

Construction Risk: Advanced construction technologies and safety management measures were introduced to ensure the safety and efficiency of the construction process, reducing accidents and downtime.

Results: Through systematic risk management, the project team successfully addressed multiple design changes and construction challenges, ensuring the smooth progress of the project [7]. The project was delivered on time, avoiding additional costs due to risks.

Sydney Metro City & Southwest Line Project:

Background: The Sydney Metro City & Southwest Line project is one of Australia's largest public transportation infrastructure projects, involving complex underground construction and multidisciplinary collaboration.

Implementation Process: The project team adopted agile project management methods combined with BIM technology to achieve dynamic risk management and rapid response.

Specific Measures:

Multidisciplinary Collaboration: A multidisciplinary collaboration platform was established to ensure information sharing and coordination among different professional teams, reducing errors and delays due to poor communication.

Real-time Monitoring: BIM technology was used for real-time monitoring to promptly identify and resolve construction issues, avoiding rework due to construction defects.

Emergency Response: Detailed emergency response plans were developed to ensure rapid action in the event of an incident, minimizing losses.

Through these risk management measures, the project team was able to respond quickly to design changes and ensure the project was completed on time and within budget [12]. The project has been successfully delivered, avoiding additional costs that could have arisen from risks.

Conclusion:

The above cases demonstrate that effective risk management measures play a crucial role in civil engineering projects by helping project teams identify, evaluate, and address various potential risks, thereby avoiding or mitigating additional costs. These measures include detailed geological surveys, the introduction of advanced technologies, the development of emergency plans, the signing of detailed risk-sharing agreements, and the establishment of flexible design change processes. Through these specific measures, project teams can ensure the smooth progress of projects, achieving cost control and schedule management goals.

4.4 Agile Project Management

Agile project management is a flexible approach that emphasizes rapid iteration, continuous improvement, and team collaboration. This method allows project teams to better adapt to changes, improve efficiency, and shorten project timelines. The following case studies demonstrate the effectiveness of agile project management in civil engineering projects.

Case Analysis

Complex Underground Rail Transit Project:

Background: In a complex underground rail transit project, the project team faced frequent design changes and technical challenges. Traditional project management methods struggled to cope with these changes, leading to project delays and cost overruns.

Implementation Process: The project team decided to adopt an agile project management approach, introducing short-cycle iterative development. At the end of each iteration cycle (typically 1-4 weeks), a review meeting was held to evaluate the work completed and adjust subsequent plans based on feedback.

Specific Measures:

Daily Stand-ups: Brief daily stand-up meetings were held to ensure clear communication among team members and to address any issues promptly.

Iteration Reviews: At the end of each iteration cycle, review meetings were organized to assess the work done, identify issues, and adjust plans accordingly.

Flexible Adjustments: Based on the review results, the design and construction plans were quickly adjusted to accommodate new requirements and changes.

Results: Through the application of agile project management, the project team was able to rapidly respond to design changes and ultimately deliver the project on time [8]. Compared to traditional methods, agile approaches significantly improved team collaboration, reducing delays and additional costs caused by changes.

Sydney Metro City & Southwest Line Project:

Background: The Sydney Metro City & Southwest Line project is one of Australia's largest public transportation infrastructure projects, involving multiple stakeholders and a complex construction environment. The project faced variable demands and strict schedule requirements.

Implementation Process: The project team adopted an agile project management approach, combined with BIM technology, to achieve dynamic project management and rapid response.

Specific Measures:

Multidisciplinary Collaboration Platform: A multidisciplinary collaboration platform was established to ensure information sharing and coordinated work among different professional teams, reducing errors and delays due to poor communication.

Real-time Monitoring: BIM technology was used for real-time monitoring to promptly identify and resolve construction issues, avoiding rework due to construction defects.

Flexible Adjustments: Through agile methods, the project team was able to quickly adjust construction plans to address design changes and other unforeseen circumstances.

Results: Through these agile project management measures, the project team was able to rapidly respond to design changes and ensure the project was completed on time and within budget [12]. The project's successful delivery demonstrated the advantages of agile methods in improving efficiency and shortening timelines.

International Construction Project:

Background: In an international construction project, the project team needed to coordinate with stakeholders from different countries and regions while also dealing with variable market demands and technical specifications.

Implementation Process: The project team adopted an agile project management approach, using regular iterative development and review meetings to ensure the project could quickly adapt to changes.

Specific Measures:

Cross-cultural Communication: Efficient cross-cultural communication mechanisms were established to ensure effective collaboration among team members from different countries and regions.

Flexible Adjustments: Project plans and designs were quickly adjusted based on market and technical changes to ensure the project met the latest requirements.

Continuous Improvement: Lessons learned from each iteration were continuously summarized, and project management processes were optimized through review meetings.

Results: Through the application of agile project management, the project team was able to rapidly respond to market and technical changes, ensuring the project was completed on time and within budget [8]. The project's successful delivery demonstrated the effectiveness of agile methods in complex international projects.

Conclusion:

The above cases demonstrate that the application of agile project management in civil engineering projects can significantly enhance project flexibility and responsiveness. Through specific measures such as daily stand-ups, iteration reviews, multidisciplinary collaboration platforms, and real-time monitoring, project teams can quickly respond to design changes and other unforeseen circumstances, thereby shortening project timelines and improving efficiency. These cases highlight the significant advantages of agile methods in enhancing project economic efficiency and provide valuable experience for the successful implementation of future similar projects.

4.5 Contract Strategies

Selecting the appropriate contract type is crucial for cost control in civil engineering projects. Different contract types can help project teams better manage market price fluctuations, risk sharing, and change management, thereby avoiding additional costs due to unclear contract terms. The following case studies demonstrate the effectiveness of different contract types in cost control.

Case Analysis

Lump Sum Contract:

Background: In an international construction project, the project team faced significant market price fluctuations. To effectively control costs, they chose a lump sum contract.

Implementation Process: The lump sum contract specified the total cost of the project and outlined the contractor's obligation to complete all work within the scope of the contract. The project team and the contractor thoroughly discussed and defined the scope of work, work content, and payment conditions.

Specific Measures:

Detailed Scope Definition: Before signing the contract, the project team and the contractor had detailed discussions to clearly define all work content, ensuring a shared understanding of the project scope.

Risk Sharing: By using a lump sum contract, the risk of market price fluctuations was transferred to the contractor, reducing cost uncertainty for the project owner.

Change Management: The contract clearly specified the change procedures and corresponding cost adjustment mechanisms, ensuring that any changes could be addressed promptly and avoiding additional costs due to changes.

Results: Through the use of a lump sum contract, the project team successfully avoided cost increases due to market price fluctuations [9]. The project was completed on time and within budget, demonstrating the effectiveness of lump sum contracts in cost control.

Cost-plus Fee Contract:

Background: In a technically complex project with unpredictable costs, the project team chose a cost-plus fee contract to ensure the contractor received a reasonable profit while controlling costs.

Implementation Process: The cost-plus fee contract stipulated that the actual costs incurred by the contractor, plus a certain fee, would be the payment amount. The project team and the contractor maintained detailed records and audits of actual costs, and paid the fee as per the contract agreement.

Specific Measures:

Transparent Cost Recording: The project team and the contractor established a detailed cost recording system to ensure that all cost expenditures were documented.

Regular Audits: The project team conducted regular audits of the contractor's cost reports to ensure the accuracy and reasonableness of the costs.

Incentive Mechanism: The contract included performance bonuses to encourage the contractor to improve efficiency and reduce costs.

Results: Through the cost-plus fee contract, the project team was able to better control actual costs and improve the contractor's efficiency through the incentive mechanism [9]. The project was successfully completed with effective cost control.

Design-Build Contract:

Background: In a large infrastructure project, the project team chose a design-build contract to simplify project management and reduce coordination costs.

Implementation Process: The design-build contract delegated both the design and construction tasks to a single contractor, integrating the management of design and construction. The project team worked closely with the contractor to ensure that the design met project requirements.

Specific Measures:

Integrated Management: Through the design-build contract, the project team was able to better coordinate the design and construction processes, reducing delays and additional costs due to design changes.

Risk Management: The contract clearly specified the risk-sharing mechanisms, ensuring clear responsibilities and obligations for all parties.

Rapid Response: The contractor could consider construction feasibility during the design phase, identifying and resolving potential issues early, reducing changes and rework during the construction phase.

Results: Through the application of the design-build contract, the project team was able to quickly respond to design changes and ensure the project was completed on time and within budget [9]. The project was successfully delivered, showcasing the advantages of design-build contracts in cost control and schedule management.

Conclusion:

The above cases demonstrate the importance of selecting the appropriate contract type for cost control in civil engineering projects. Lump sum contracts effectively address market price fluctuations, cost-plus fee contracts provide transparent cost management and incentive mechanisms, and design-build contracts simplify project management and reduce coordination costs. The proper application of these contract types not only helps in controlling costs but also enhances the overall efficiency and quality of the project.

4.6 Total Quality Management TQM

As shown in Table 1, the application of Total Quality Management (TQM) in civil engineering projects can significantly reduce rework and maintenance costs. By establishing a comprehensive quality management system, which includes three main components: quality planning, quality control, and quality improvement, the project team can promptly identify and rectify quality issues, avoiding additional expenses caused by rework. Furthermore, high-quality construction reduces the need for later maintenance, further lowering maintenance costs. These cases demonstrate the significant advantages of TQM in improving project economic benefits and provide valuable experience for the successful implementation of similar projects in the future.

Table 1. Comparison of Effects Before and After the Application of Project Management Techniques

Project Name	Technology	Cost Savings(%)	Schedule Reduction (days)
Hong Kong-Zhuhai-Macao Bridge[1]	BIM	10%	90
Expansion of the New York City Subway[7]	Risk Management	8%	60
Beijing Daxing International Airport[1]	TQM, BIM	5%	75
Expansion of London Heathrow Airport[11]	BIM, TQM	7%	45
Sydney Metro City & Southwest Line[12]	Agile Project Management	12%	100
Gardens by the Bay, Singapore[13]	value engineering, BIM	5%	30
Hamburg Elb Philharmonic Hall[14]	BIM	8%	50
Burj Khalifa (in Dubai)[15]	BIM, construction technology	6%	80
The Grand Arch of La Defense in Paris, France [16]	BIM, Risk Management	4%	60

5 Conclusion

Modern project management techniques have played a crucial role in enhancing the cost-effectiveness of civil engineering projects. BIM technology has significantly reduced project costs by improving design efficiency and reducing material waste; value engineering has achieved cost savings through design optimization and the selection of more economical options; risk management has reduced uncertainty and potential losses through systematic risk assessment and response measures; agile project management has shortened project timelines by enabling rapid response to changes and improving team collaboration; appropriate contract strategies have effectively controlled costs through clear risk-sharing mechanisms; and total quality management has further enhanced project economic benefits by reducing rework and lowering maintenance costs.

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