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Full Life Cycle Research Based on the Contradiction of Engineering General Objective

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Abstract: *In the management of the entire life cycle of an engineering project, the contradiction of the overall engineering objectives is a complex and important issue. The study of the engineering life cycle based on the contradiction of overall engineering objectives aims to comprehensively analyze each stage of the project life cycle, identify the points of conflict among various objectives, and propose corresponding solutions to optimize the overall engineering objectives. This research on the engineering life cycle based on the contradiction of overall engineering objectives is a complex and significant topic. Through in-depth research and practice, it can promote the continuous improvement and development of engineering life cycle management, providing strong support for the successful implementation of engineering projects.*

Keywords: *Overall Engineering Objectives, Life Cycle, Engineering Project, Objective Control*

1. Introduction

In the engineering field, whole life cycle management has become a key approach to ensuring the successful implementation of projects and maximizing their benefits. The concept of engineering management based on the whole life cycle integrates principles from modern management science, systems theory, cybernetics, and information theory to guide comprehensive project management throughout all stages. Within the framework of construction cost management in China, the life-cycle cost of a construction project can be divided into the following phases: decision-making, design, construction, and operation [1].

However, engineering projects often face various challenges and contradictions while striving to achieve their overall objectives. These contradictions may stem from aspects such as quality, cost, time, and environmental concerns, which interact and constrain one another, making it difficult to achieve an ideal balance throughout the life cycle. To address these contradictions and optimize the overall project objectives, it is particularly important to analyze each phase of the life cycle based on the inherent contradictions among the overall goals. Considering practical conditions, this study proposes effective management strategies and technical measures to resolve the conflicts among project objectives, which holds practical significance for improving the overall efficiency of engineering projects.

2. Analysis of Contradictions in Overall Engineering Objectives

Overall engineering objectives refer to the comprehensive evaluation of the outcomes achieved based on pre-established goals and specific technical requirements. They reflect the basic characteristics of modern engineering technology, the structural system of engineering technology, and the technical features of life cycle engineering. They also reflect the purpose and tasks of the work and embody the working principles. As a multi-dimensional and complex control system, the main contradictions in achieving overall engineering objectives in current project management are as follows: the conflict between the total investment goal of construction and the operating management and technical service fees, the contradiction between the construction and operation of the project and other social costs, and the mismatch between the rigid project management models and the increasing complexity and scale of projects. These contradictions represent the main challenges in achieving overall engineering objectives and are key difficulties in the process.

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2.1 Three Main Contradictions in Achieving Overall Engineering Objectives

2.1.1 Conflict between Total Investment Goal and Operating Management and Technical Service Fees

Key points in project investment control primarily include establishing investment control objectives, breaking down investment targets into manageable components, and implementing proactive pre-control measures. For certain types of engineering projects, increasing the total investment by enhancing quality standards or upgrading technical specifications often results in a reduction in operational and maintenance costs during the project's usage phase. These cost reductions may manifest in areas such as repair expenses, energy consumption, material usage, and labor input. In contrast, significantly lowering quality requirements may lead to higher maintenance costs over time, ultimately increasing the overall operational value of the project. This correlation exists because high-quality projects typically integrate considerations of safety, durability, and opexrational efficiency into the early stages of design and construction, thereby minimizing the need for intensive maintenance in later phases.

In the context of China's engineering sector, there has long been a prevailing tendency to place disproportionate emphasis on reducing construction investment, often at the expense of ignoring future operational and maintenance costs. This short-sighted approach frequently results in projects that suffer from functional shortcomings and quality deficiencies, which in turn lead to elevated energy usage and higher maintenance expenditures during the operational phase. To address this issue, it is essential to adopt a more balanced investment strategy that considers both initial construction costs and long-term operational expenses. By achieving an optimal balance between quality and functionality, it becomes possible to reduce life-cycle costs and enhance the overall sustainability and efficiency of engineering projects.

2.1.2 Conflict between Project Construction and Operation and Other Social Costs

The social cost of an engineering project refers to measurable costs borne by the public rather than project participants (i.e., the owner or contractor), which negatively affect people or the environment surrounding the construction site. Other social costs refer to the additional expenses incurred in various sectors of society throughout the entire life cycle of the project as a result of its construction and operation. These costs are typically not directly borne by the project's builders, investors, or enterprises, but rather by government agencies or other social organizations. Therefore, activities such as the emission of waste gases from chemical plants, or the increased fuel consumption and time expenditure caused by highway construction, are considered part of other social activity costs. These costs have a certain impact on the overall development and operation of society and thus must be thoroughly considered during engineering decision-making processes.[2]

2.1.3 Mismatch between Rigid Project Management Models and Increasing Project Complexity and Scale

Since the implementation of the reform and opening-up policy, China has achieved remarkable and widely recognized success in the field of major infrastructure and project construction, attracting global attention for its engineering capabilities. From the early development of the "Five Vertical and Seven Horizontal" national highway trunk line system to the current formation of the "Eight Vertical and Eight Horizontal" high-speed railway network, as well as the completion of iconic mega-projects such as Beijing Daxing International Airport and the Baihetan Hydropower Station, these initiatives not only demonstrate China's exceptional prowess in engineering and construction but also contribute to the creation of numerous world-class engineering benchmarks. These large-scale projects are emblematic of China's growing technological confidence and its ability to deliver complex infrastructure within challenging timelines and conditions.

Moreover, with the widespread adoption of advanced project delivery models such as Public-Private Partnerships (PPP) and Engineering, Procurement, and Construction (EPC) contracts, project management in China is increasingly characterized by trends of expanding scale, heightened complexity, and integrated coordination across various domains. This evolution has significantly accelerated the modernization, specialization, and innovation of China's engineering and construction sectors, further positioning the country as a global leader in infrastructure development.

However, in many cases, effective and targeted management models that align with the growing scale and complexity of such mega-projects have not yet been successfully developed or implemented. A common pitfall is the simplistic transplantation of conventional project management methodologies—originally designed for smaller or less complex projects—into large-scale project

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environments. Another frequent issue is the proportional expansion of standard management frameworks, assuming that simply scaling up these methods will suffice for managing mega-projects. This oversimplified and linear approach not only weakens the unique characteristics and inherent demands of complex projects but also overlooks the multi-dimensional challenges associated with size, coordination, risk, and integration. Critically, underestimating the degree of scale and complexity remains the primary factor leading to difficulties in achieving core engineering objectives and performance outcomes. Addressing this challenge requires a more nuanced, flexible, and system-oriented management paradigm tailored to the realities of large-scale project delivery.

2.2 Balancing Stakeholder Needs in the Value System

Balancing the diverse needs of stakeholders within the value system of an engineering project presents inherent contradictions and complexities. The overall engineering objectives—such as time, cost, and quality—are closely interconnected and often mutually restrictive. For instance, efforts to shorten the project duration frequently result in increased costs or a decline in construction quality. Conversely, striving for higher quality standards may lead to longer timelines or additional financial investment. These trade-offs underscore the challenge of achieving an optimal balance among competing priorities.

To effectively manage these contradictions and ensure that stakeholder needs are adequately addressed, project management must adopt a holistic and adaptive approach. This involves decomposing overarching project goals into more manageable sub-objectives, strategically leveraging the technical strengths of various engineering disciplines, conducting thorough and rational project planning, and applying dynamic management techniques throughout the project lifecycle. Such an approach enables the coordinated optimization of functional performance, quality assurance, economic efficiency, adherence to schedule, and environmental sustainability.

Only by integrating these dimensions can a project truly balance the interests and expectations of all stakeholders within a coherent and sustainable value system. This requires continuous monitoring, adjustment, and cross-disciplinary collaboration to maintain alignment between project execution and stakeholder value realization[3].

2.2.1 Strengthening Quality Management and Controlling Quality Costs

Juran and others suggest a positive relationship between total quality cost and internal and external failure costs, and an inverse relationship with prevention and appraisal costs. This relationship reaches equilibrium at the intersection of the failure cost curve and the prevention and appraisal cost curve, representing the lowest total quality cost, also considered the optimal quality cost.

Quality costs encompass all expenses incurred to ensure and improve product quality and losses due to not meeting quality standards. These costs mainly include two aspects: control costs and failure costs,corresponding to expenses for preventing and correcting quality issues. Appraisal costs, including prevention and appraisal costs, fall under quality assurance costs, proportional to the product quality level—higher quality leads to higher appraisal and prevention costs. Failure costs, including internal and external failure costs, are loss costs, inversely related to quality—higher quality reduces failure costs. To manage quality costs reasonably, construction processes should first ensure the accuracy of construction drawings, minimizing cost increases due to design errors. Second, scientific construction methods and techniques should be adopted to improve efficiency and quality, reducing waste and rework. Lastly, quality education and training should be emphasized to enhance construction personnel's quality awareness and skills, ensuring project quality standards are met and reducing quality costs.[4]

2.2.2 Prioritizing a User-Centric Approach

Among all stakeholders related to engineering projects, users are undoubtedly the most critical. Regardless of the project's purpose and outcomes, the ultimate goal is to meet user needs. User satisfaction is the core criterion for measuring project success, only by genuinely winning user approval can the project demonstrate its practical value. Therefore, in goal setting, feasibility studies, planning, and design processes, it is essential to think from the user's perspective, ensuring accurate market positioning, user-friendly design, and reasonable sales volume and pricing strategies to maximize user expectations and demands.

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2.2.3 Investment Balancing Strategies for Mutual Benefit

To ensure investment benefits, investors must balance investment amounts, return rates, and risk reduction. They need to comprehensively assess project resources to establish reasonable investment expectations and make investment decisions through market research and risk management strategies. Contractors and suppliers focus more on factors like value, quality, corporate image, and relationships (reputation). These aspects not only affect the construction party's immediate interests but also their overall competitiveness in the industry. Thus, they must ensure project quality and safety, strive to complete projects on time within reasonable costs, and focus on building a good corporate image to maintain cooperation and reputation.

3. The Antagonism between Overall Engineering Objectives and life cycle Management

While there is a synergistic relationship between overall engineering objectives and life cycle management, certain antagonisms exist in practice.

3.1 Difficulty in Setting and Achieving Objectives

Overall engineering objectives are often idealistic and comprehensive. However, during life cycle management, various unforeseen risks and challenges may arise, making these objectives difficult to achieve. The contradiction between objective setting and the difficulty of achievement can lead to confusion and frustration within the project management team during project execution.[5]

3.2 Resource Allocation and Optimization

Life cycle management emphasizes the optimized allocation and management of resources throughout the project's life cycle. However, in practice, due to limited resources, the project management team may need to make trade-offs between quality, schedule, and investment objectives. This contradiction in resource allocation and optimization can present challenges in balancing various interests.

3.3 Information Asymmetry During the Decision-Making Stage

Life cycle management requires consideration of the entire project life cycle starting from the decision-making stage. However, at this stage, the project management team may struggle to obtain comprehensive and accurate information to support decisions. Common decision-making errors include investing in unnecessary projects, selecting inappropriate construction sites, or determining unreasonable investment plans. These errors often result in unnecessary financial, human, material, and financial resource waste, and may cause irreparable losses. Thus, ensuring correct project decisions is a prerequisite for rational project cost estimation and control. Only by avoiding decision-making errors can project costs be effectively controlled and project success ensured. This information asymmetry can lead to difficulties in the decision-making stage, impacting the overall implementation of the project.

3.4 Conflicts and Coordination of Interests

Stakeholders in engineering projects often have different goals and expectations, potentially leading to conflicts of interest during life cycle management. The project management team must coordinate and balance these interests to achieve the overall project benefit. However, this contradiction between conflicts and coordination of interests can increase the complexity and difficulty of project management. To address these antagonisms, the project management team must enhance communication, collaboration, and risk management at all stages of life cycle management to ensure the project progresses according to planned objectives and requirements. Additionally, the project management team should continually learn and summarize experiences to improve their life cycle management capabilities and better address potential conflicts and challenges.[6]

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4. Synergistic Analysis of Contradictions in Overall Engineering Objectives and life cycle Management

The contradictions in overall engineering objectives and life cycle management have a close synergistic relationship. This synergy mainly manifests in how life cycle management balances and optimizes quality, schedule, and investment objectives at various stages of the project.

4.1 Core Concept Analysis

The core concept of life cycle management is to ensure the project progresses according to expected objectives and requirements from planning to operation and maintenance. This requires the project management team to comprehensively consider and balance quality, schedule, and investment at each project stage. For example, during the planning stage, the management team must establish the project's quality, schedule, and investment objectives and develop corresponding strategies and plans. These objectives and plans should consider the overall project benefits and long-term operational needs, avoiding the one-sided pursuit of a single objective at the expense of others.

4.2 Analysis of Different Management Stages

Life cycle management requires monitoring and adjusting the project's quality, schedule, and investment at all stages. During the execution stage, the project management team must implement the project plan, ensuring it progresses according to the established quality, schedule, and investment objectives. The team must continuously monitor and evaluate the project's actual progress, promptly identifying and resolving any issues. If deviations occur, the project plan and resource allocation must be adjusted to ensure the project meets its established objectives and requirements.

4.3 Quality Control and Risk Management During the Monitoring Stage

The project management team must formulate and implement a comprehensive set of strict quality control measures to ensure that the quality of the project consistently meets the predetermined standards and performance requirements throughout all phases of construction. In parallel, the team must conduct thorough and systematic identification, assessment, and control of potential risks, ensuring that the project can effectively respond to various uncertainties and challenges that may arise during its lifecycle. The adoption of these measures not only mitigates risks and reduces associated costs but also significantly enhances the overall operational efficiency, safety, and reliability of the project.

The core task of quality control throughout the entire life cycle of a construction project lies in maintaining a coherent, integrated, and all-encompassing framework of supervision and quality management. This ensures that every stage and aspect of project quality is carefully monitored and that no gaps or blind spots exist in the quality assurance process. Achieving this objective requires all involved responsible parties to fully assume their respective quality supervision duties and remain accountable not only for their own actions but also for the quality behavior and output of both upstream and downstream units within the supply and construction chains [6]. This necessitates the adoption of a systematic, macro-level perspective in managing overall project quality to ensure that the final construction outcomes align with and fulfill the expected quality targets.

Currently, uncontrolled investment remains a prevalent issue in engineering projects across China. This problem arises not only from ineffective management practices and outdated implementation methods, but more critically, from the insufficient estimation and underappreciation of risk factors that directly influence and constrain project outcomes. The lack of foresight in risk identification and mitigation strategies often leads to significant and avoidable losses during project execution. As such, the tasks of identifying, analyzing, evaluating, and proactively controlling project risks have become increasingly urgent and essential [7]. Addressing these challenges requires improved risk management systems, greater strategic foresight, and the integration of modern project governance mechanisms.

4.4 Analysis of the Project Closure Stage in life cycle Management

The project closure stage in life cycle management emphasizes project conclusion and summarization. The project management team must finalize delivery to the client, ensuring it meets the client's requirements. Additionally, the team must review and summarize the project's objectives, plans,

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execution, and monitoring. These summaries help the project management team gain insights and improve future project management capabilities.

5. Conclusion and Outlook

Based on the contradictions in overall engineering objectives, this study explores life cycle process management and derives the following main conclusions:

The contradictions in overall engineering objectives, such as the interrelationship between quality, schedule, and investment, are pervasive. These contradictions exist not only at different stages of the project but also throughout the entire life cycle of the project.

To balance and optimize these conflicting objectives, life cycle management is particularly important. By comprehensively considering various stages and aspects of the project, life cycle management helps achieve the overall optimal benefits of the project. Although there is a synergistic relationship between life cycle management and overall engineering objectives, contradictions may also arise in practice. This requires the project management team to focus on coordination and properly handle these contradictions throughout the project's life cycle.[8]

As the scale and complexity of engineering projects continue to increase, life cycle management will play an increasingly important role. Future research can further explore the root causes and influencing factors of contradictions in overall engineering objectives, optimize methods and technologies for life cycle management, and promote interdisciplinary research collaboration to advance project management theory and practice. In conclusion, overall engineering objectives and life cycle management are complementary and inseparable. By applying the principles and methods of life cycle management, we can better balance and optimize overall engineering objectives, achieving long-term benefits and sustainable development for projects.

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