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Research on the Optimization of Engineering Cost Curriculum System Under the Diversified Investment and Financing Model of Free Trade Port

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Abstract: The development of free trade ports has fostered diversified investment and financing vehicles represented by cross-border capital, Public-Private Partnerships (PPP) and Infrastructure Real Estate Investment Trusts (REITs), which have profoundly reshaped the connotation and extension of engineering cost management. Traditional engineering cost curriculum systems center on construction drawing budget and bill quantity pricing, failing to meet the demand for composite competencies including investment and financing planning, international contract administration, full-process consulting and digital tools under new financing models. Based on a systematic analysis of the characteristics of free trade port investment and financing models and the new requirements for cost management, this paper examines prominent drawbacks of existing curriculum systems, such as fragmented knowledge frameworks, insufficient international vision and inadequate practical training. It proposes optimization strategies from four dimensions: restructuring curriculum modules, integrating international competency training, embedding digital technologies and building practical training platforms. A supporting system coordinated by teaching staff, institutional mechanisms and educational resources is also constructed, providing references for cultivating high-caliber engineering cost professionals capable of supporting free trade port development.

Keywords: Free Trade Port; Diversified Investment and Financing; Engineering Cost; Curriculum System; Optimization

1. Introduction

Free trade ports represent the most advanced form of opening-up worldwide, and their development entails large-scale infrastructure investment and the development of complex commercial projects. Under the institutional framework of "liberal access at the frontline and controlled management at the second line", free trade ports implement liberalized and facilitated investment policies, forming a landscape with coexisting investment and financing approaches including government investment, private capital participation, foreign investment, franchising and public infrastructure REITs. Diversified financing channels have transformed the pricing basis, risk structure and management logic of engineering cost management. Instead of merely controlling construction-stage costs, cost management now extends forward to investment and financing decision-making, financial scheme comparison and full-lifecycle cost optimization, and stretches backward to asset operation and investment exit arrangements. Practitioners also need to address brand-new challenges such as cross-border capital flows, exchange rate fluctuations and alignment with international regulatory standards.

Talents constitute the primary driver of industrial transformation. Universities offering engineering cost and related majors shoulder the core responsibility of supplying frontline management professionals to the industry. Nevertheless, most current engineering cost curricula revolve around conventional construction pricing, focusing on quota principles, bill quantity measurement and budget compilation. Courses barely cover project financing, contract laws, international cost standards and digital measurement technologies, leading to a structural mismatch between graduate competency and the practical demands of free trade port construction. A core challenge for curriculum optimization emerges: while consolidating students' fundamental skills in engineering measurement and pricing, higher education must incorporate investment-financing

perspectives, international awareness and digital capabilities. Centered on this challenge, this paper develops a targeted curriculum optimization framework tailored to the diversified investment and financing environment of free trade ports[1].

2. Diversified Investment and Financing Models of Free Trade Ports and New Requirements for Engineering Cost Management

2.1 Multidimensional Characteristics of Free Trade Port Investment and Financing Models

Three distinct characteristics define financing models in free trade ports. First, globally sourced capital. Investment access is fully liberalized for sectors outside the negative list, allowing foreign investors to participate in infrastructure and public service projects through greenfield investment, mergers and acquisitions, or equity participation. Cross-border financing, offshore bonds and Qualified Foreign Limited Partnerships (QFLP) are widely adopted financial instruments. Second, diversified implementation mechanisms. Variants of PPP such as Build-Operate-Transfer (BOT), Transfer-Operate-Transfer (TOT) and Design-Build-Finance-Operate-Transfer (DBFOT), alongside hybrid models including "investment plus Engineering, Procurement and Construction (EPC)" and "equity investment plus general construction contracting", are commonly deployed. Risk allocation and return mechanisms differ drastically across these models. Third, financialized exit channels. Infrastructure REITs, asset securitization and equity transfers provide liquidity for investors, requiring cost management to cover the entire investment lifecycle from capital injection to exit[2].

2.2 Competency Restructuring Requirements for Engineering Cost Management

Under such financing frameworks, engineering cost management faces four major updated competency demands: First, investment and financing planning becomes a core upstream competency for cost management. Cost engineers must analyze how different financing structures affect total project investment, capital costs and expected returns. During project proposal and feasibility study phases, they need to participate in technical-economic comparison of financing schemes and calculate key indicators such as full investment internal rate of return, equity internal rate of return and debt service coverage ratio.

Second, full-process cost management must be deeply integrated with contract and risk management. International standard contract suites such as the FIDIC Silver Book and Red Book are extensively applied in free trade port projects. Cost practitioners must interpret clauses concerning price adjustment, force majeure, claims and dispute adjudication, and conduct quantitative assessment and allocation design for risks stemming from exchange rates, interest rates and policy shifts[3].

Third, coordination competency for international cost standards and industry practices gains prominence. Projects involving foreign capital or international consultants often adopt parallel standards, including China's national bill quantity specifications, the Royal Institution of Chartered Surveyors (RICS) New Rules of Measurement and the United States Construction Specifications Institute (CSI) format. Professionals must master cross-standard measurement and conversion techniques.

Fourth, digital and intelligent tools become essential efficiency enablers. Technologies such as 5D Building Information Modeling (BIM), enterprise-level cost databases, artificial intelligence-assisted quantity takeoff and blockchain-based measurement and payment systems are rapidly adopted in large free trade port projects. Graduates are expected to advance from basic software operation to data governance and model-driven decision-making.

These interwoven competency requirements form a composite capability matrix covering "cost technology, investment-financing analysis, contract law, international standards and digital skills", which establishes clear guidance for curriculum system optimization[4].

3. Deficiencies in the Current Engineering Cost Curriculum System

3.1 Disconnect Between Curriculum Content and Investment-Financing Industry Practice

Core courses for engineering cost majors in most universities remain concentrated on measurement and pricing of architectural, decorative and municipal works, supplemented by foundational courses in engineering economics and project management.

Engineering economics courses mostly cover classical content such as the time value of money and single-scheme economic comparison, with almost no coverage of cutting-edge topics including project financing structure design, value-for-money assessment and fiscal capacity demonstration for PPP projects, and underlying asset valuation for infrastructure REITs. Budgeting courses are compiled around domestic quotas and bill quantity standards, rarely introducing how capital costs and weighted average cost of capital (WACC) affect overall project costs. They also fail to link cost control with financing schedules and payment clauses. After graduation, students lack sufficient theoretical support when engaging with real-world projects involving funds, loans and tax planning[5].

3.2 Weak Teaching of International Engineering and Contract Administration

Although several universities offer selective courses titled International Engineering Management or International Engineering Contract Administration, these courses have limited class hours and only provide general introductory content without in-depth clause-by-clause interpretation and scenario simulation of the 2017 FIDIC suite. Systematic instruction on global cost standard systems, such as standards issued by the International Cost Engineering Council (ICEC) and the RICS International Measurement Standards, is nearly absent. Consequently, graduates struggle to deliver professional solutions when encountering back-to-back contract clauses, bill of quantities compilation for international competitive bidding and cross-border dispute resolution in free trade port projects[6].

3.3 Practical Training Lacks Investment-Financing Scenario Simulation

Current practical teaching relies on curriculum and graduation design assignments following a fixed workflow: students receive construction drawings, conduct manual or software-based quantity takeoff, apply quota pricing and aggregate total costs, with no variables related to investment and financing incorporated. Teaching cases mainly involve conventional residential and public buildings, lacking complex project types characteristic of free trade ports such as comprehensive zone development, Transit-Oriented Development (TOD) and customized industrial parks. No comparative cost analysis across alternative financing schemes is included in case studies. While training software supports BIM quantity takeoff and cloud pricing platforms, simulations merely focus on quantity and price calculation without integrated virtual environments covering financing, design, cost control and operation.

3.4 Interdisciplinary Integration Remains Superficial

Engineering cost is inherently interdisciplinary, yet courses covering engineering, economics, management and law are administered by separate academic departments with minimal coordination between modules. Students complete accounting courses without the ability to analyze project financial statements; they study economic law but cannot interpret property rights and guarantee clauses in PPP agreements; they master BIM modeling yet fail to leverage models for cost simulation and financing parameter optimization. Siloed curriculum modules create fragmented knowledge frameworks, preventing students from building integrated knowledge networks to resolve complex cost challenges.

4. Optimization Paths for the Curriculum System

Following demand-driven and problem-oriented principles, this paper proposes four optimization paths guided by the philosophy of "solid foundational knowledge, enhanced interdisciplinary integration, expanded international vision and intensive practical training".

4.1 Establish Composite Core Curriculum Modules Integrating Engineering Cost and Investment-Financing

While retaining foundational engineering courses covering mechanics, structural engineering and construction technology, universities shall restructure and upgrade economics and management course clusters. (1) Add a compulsory course titled Project Financing and Infrastructure Investment & Financing Course content covers fundamental project financing models, PPP transaction structure design, core franchising agreement clauses, value-for-money evaluation, fiscal capacity analysis and asset valuation logic for infrastructure REITs. Extensive practical cases

from free trade port projects help students identify shifts in total investment composition under different financing frameworks and master cost scheme preparation and review from a financing perspective.

(2) Revise Engineering Economics into Engineering Investment Analysis and Decision-Making Based on existing modules on the time value of money and economic benefit evaluation, the revised course incorporates portfolio theory for multi-project decision-making, sensitivity analysis, Monte Carlo simulation and real options for investment timing assessment. Hands-on training with Excel and @Risk software is prioritized to cultivate data-supported investment analysis capabilities.

(3) Launch a thematic course on Free Trade Port Fiscal & Tax Policies and Engineering Cost Centered on the unique zero-tariff, low-tax-rate and simplified taxation regimes of free trade ports, this course analyzes how corporate income tax, value-added tax, customs duties and stamp duty impact construction costs, material and equipment prices, and financing expenses. Case exercises train students to calculate taxable and tax-exclusive construction costs under various material supply modes.

4.2 Integrate Training for International Competencies and Full-Process Consulting Capabilities

(1) Develop an International Engineering Cost curriculum module The course International Engineering Contract Management (In-depth FIDIC Interpretation) compares general and special contract conditions clause by clause, and simulates full workflows including contractor claim submission, engineer's determinations and Dispute Adjudication Board (DAB) rulings. A supplementary course International Engineering Cost Standard Comparison systematically contrasts China's GB 50500 specifications with RICS NRM and the US MasterFormat system, reinforced by cross-border quantity takeoff and pricing exercises to strengthen standard conversion proficiency.

(2) Incorporate full-process engineering consulting perspectives The core course Construction Engineering Cost Management integrates official guidelines for full-process cost consulting, clarifying key cost control objectives across investment decision, design, bidding, construction, completion and operation phases. Special emphasis is placed on the timing and deliverables of investment-financing planning within the decision stage. The integrated concept of "design management paired with cost control" is introduced, requiring students to conduct value engineering analysis during design scheme comparison while accounting for financing cost constraints.

4.3 Deeply Integrate Digital Technologies into Instruction

A standalone compulsory course Digital Cost Management and Intelligent Construction covers 5D BIM cost management platforms, engineering measurement using unmanned aerial vehicles and 3D laser scanning, construction cost big data analysis and indicator database development, and the application logic of blockchain in measurement, payment and supply chain finance. Relevant software modules are embedded within traditional courses such as Installation Engineering Measurement and Pricing for collaborative instruction, eliminating disconnection between digital tool training and core cost theory.

4.4 Develop Multi-Level Scenario-Based Practical Training Systems

(1) Develop immersive virtual simulation projects Universities shall cooperate with software developers to build a virtual simulation platform for comprehensive free trade port development projects, covering mixed-use formats including hotels, office towers, commercial complexes and underground utility tunnels. The platform embeds multiple financing schemes (fiscal direct investment, PPP, foreign fund participation), international contract templates and differentiated tax environments. Students assume roles as cost consulting teams to complete full-cycle tasks from investment estimation, design budget and tender control price compilation to interim payment verification, variation claim settlement and final account auditing, allowing them to observe how changes in financing parameters alter cost management outcomes.

(2) Build real-world case databases and university-enterprise collaborative mechanisms Through industry-university cooperation, desensitized data from representative free trade port projects are compiled into teaching case libraries. Industry mentors with experience in international projects—including chartered cost engineers, legal counsels and

investment-financing specialists—participate in setting assessment tasks and conducting defenses for project financing curriculum design. Senior undergraduates engage in project-based internships at partner enterprises, directly participating in financing calculation, contract planning and cost review of ongoing projects to realize iterative learning through professional practice.

(3) Organize interdisciplinary joint graduation design Cross-major teams consisting of students majoring in engineering cost, engineering management, finance and law are formed to complete a full-cycle development planning and cost scheme for free trade port zone projects. Finance students are responsible for financing structure design and return calculation; law students draft core contract frameworks; engineering cost students conduct quantity-price compilation and quantitative risk allocation analysis. The final comprehensive report breaks disciplinary barriers and cultivates collaborative problem-solving skills.

5. Supporting Mechanisms and Implementation Recommendations

5.1 Cultivate a Multi-Disciplinary Teaching Team

Special training programs for dual-qualified faculty shall be established to support engineering cost teachers in secondments at key free trade port enterprises and international consulting firms for participation in live projects. Short-term workshops led by senior industry experts fill gaps in faculty knowledge of cutting-edge investment-financing practices. Teachers are encouraged to obtain professional certifications including RICS membership, Certified Investment Consultants and legal professional qualifications, enabling them to serve as educators, practicing engineers and financial analysts simultaneously.

5.2 Form an Industry-Education Integration Consortium

Led by universities, a talent cultivation alliance for free trade port engineering economics shall be established, bringing together free trade port administrative authorities, large construction investment groups, international cost consulting firms and industry associations. The alliance undertakes curriculum syllabus review, shared case resource development, internship position provision and real-time alignment with industrial standards, ensuring consistent matching between curriculum content and evolving industry demands.

5.3 Establish Dynamic Curriculum Adjustment and Modular Credit Systems

A sub-committee for engineering economics teaching guidance shall be set up to review and fine-tune course outlines annually. A hybrid credit model combining core compulsory courses, specialized electives and micro-majors is adopted: core compulsory courses consolidate foundational measurement and pricing skills; three elective modules (International Cost Management, Investment-Financing Analysis and Intelligent Construction) allow students to tailor learning to career trajectories. A cross-disciplinary micro-major titled Free Trade Port Engineering Economics is jointly offered with finance and law departments, requiring 10–12 credits to strengthen interdisciplinary competencies; students completing the program receive joint certification from participating departments.

5.4 Improve Assessment Systems and Build Feedback Loops

Single closed-book written examinations are replaced with diversified evaluation methods for core courses, including case study reports, simulated contract negotiations and scheme defenses. Assessment prioritizes comprehensive decision-making ability for cost and investment-financing analysis under uncertain conditions. A graduate career tracking database is developed to collect employer feedback, which is used to iteratively adjust curriculum objectives and content, forming a closed-loop improvement cycle of "demand identification – talent cultivation – feedback collection – curriculum optimization".

6. Conclusion

Free trade port construction represents not only an institutional innovation initiative but also a testbed for conceptual and operational transformation in engineering cost management. Diversified investment and financing models shift the core function of cost management from isolated quantity takeoff and pricing to integrated responsibilities covering investment-financing planning, contract governance, risk control and data-driven

decision-making. Only by dismantling disciplinary barriers and embedding investment-financing theories, international standards and digital technologies throughout engineering cost education can universities cultivate composite professionals capable of supporting high-quality free trade port development.

The curriculum optimization framework proposed in this paper delivers a systematic solution covering curriculum module restructuring, international competency integration, practical training upgrading and supporting mechanism construction. It balances the consolidation of fundamental engineering measurement and pricing capabilities with targeted expansion of emerging competencies such as investment-financing analysis, full-process consulting and international standard application. Looking ahead, as free trade port policies mature and digital technologies advance rapidly, the curriculum system shall proactively incorporate emerging fields including green finance, carbon asset management and Environmental, Social and Governance (ESG) investment evaluation to maintain forward-looking educational standards.

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