

Construction of Technical Standards and Cost Estimation Model for K12 Education Information Technology Equipment Upgrade

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Abstract

Currently, K12 education information technology (IT) equipment in China has entered a “peak period of renewal and replacement”. However, due to the lack of unified technical standards and a scientific cost estimation model, schools face blind purchasing and significant waste of funds. This study focuses on balancing the “effect of equipment upgrade and funding”. Through literature review, field research (covering 100 K12 schools in 10 provinces across the eastern, central, and western regions), statistical analysis, and case validation, this study conducts research on the formulation of technical standards and the construction of cost estimation models. For the first time, this study establishes differentiated technical standards for “basic equipment” and “smart equipment”, specifying parameters, safety, and compatibility requirements for basic equipment (e.g., resolution of interactive intelligent blackboards $\geq 4K$) and smart equipment (e.g., AI grading accuracy $\geq 98\%$). Based on a three-dimensional framework of “equipment type, school size, and regional economic level”, a cost estimation model is constructed using multiple regression analysis, with a verified error rate of $\leq 5\%$. Ultimately, a “standard + model + toolkit” implementation plan is formed. Practice has shown that this plan can increase equipment utilization to over 80% and achieve a funding savings rate of 25%.

Keywords: K12 education, education information technology equipment, technical standards, cost estimation model, life cycle cost, digital education, basic equipment, smart equipment, regional economic differences, school size, equipment utilization rate

1. Introduction

1.1 Research Background and Significance

Currently, K12 education information technology equipment in China has entered a “peak period of renewal and replacement”. According to statistics from the Ministry of Education in 2023, over 60% of multimedia classroom equipment has been in use for more than 8 years, and 30% of smart classroom equipment is technologically outdated. Due to the lack of unified technical standards, schools face significant blind purchasing (equipment utilization rate is less than 30%) and severe repetitive investment (annual waste exceeds 5 billion yuan). Meanwhile, although policies such as the “Education Information Technology 2.0 Action Plan” have promoted equipment upgrades, the execution shortcomings of “lack of technical standards” and “vague cost estimation” have led to significant regional digital education gaps and insufficient implementation rates of special budgets. Against this backdrop, conducting research on the technical standards and cost estimation model for K12 education information technology equipment upgrades can theoretically fill the research gap in the intersection of educational technology and educational economics. In practice, it can provide support for school procurement and educational department planning, solve the pain point of “balancing upgrade effect and funding”, and promote the transformation of educational information technology investment from “scale expansion” to “quality and efficiency”.

1.2 Domestic and International Research Status

Internationally, research on K12 education information technology equipment has formed a policy and practice linkage system. The U.S. "National Education Technology Plan (NETP)" specifies that equipment should support real-time interaction and comply with child privacy protection standards, emphasizing integration with the curriculum. The EU's "Digital Education Action Plan" focuses on equipment interconnectivity, setting basic parameters such as network bandwidth, while reserving space for new technology upgrades. In terms of cost estimation, the UK's "School Information Technology Cost-Benefit Assessment Framework" disassembles costs over the entire life cycle, combines school size and usage intensity with coefficients, and verifies the rationality of investment through cost-benefit ratios.

Domestic research focuses on technical parameters and cost composition, such as proposing that interactive intelligent blackboards should have a 4K resolution and a touch response delay of 0.3 seconds, and clarifying that procurement costs account for 60%-70% of total investment. However, existing research has shortcomings: technical standards do not distinguish between basic and smart equipment, and cost estimation ignores regional economic levels and differences in school size, leading to results that are disconnected from practice.

1.3 Research Approach and Methods

The research follows a logic of "problem orientation – theoretical support – practical validation". It first identifies core issues through surveys, then constructs standards and models based on relevant theories, and finally optimizes them through practical validation. In terms of methods, the literature review method is used to sort out and organize achievements. Field research is conducted in 100 schools across 10 provinces, with interviews of relevant personnel. SPSS is used for multiple regression analysis to construct the cost model, and case validation is carried out through comparative experiments in 20 schools.

2. Theoretical Foundations and Core Concept Definition for K12 Education Information Technology Equipment Upgrade

2.1 Definition of Core Concepts

K12 education information technology equipment is designed for primary and secondary school teaching scenarios, integrating hardware and supporting software, and is divided into basic and smart categories. Basic equipment, such as interactive intelligent blackboards and campus network devices, meets the needs of information transmission. Smart equipment, such as smart classroom systems and AI homework grading devices, relies on new technologies to improve teaching efficiency and personalization. Technical standards uniformly regulate performance, safety, and interconnectivity, covering technical parameters, functional requirements, compatibility, and student information protection. The cost estimation model, viewed from the entire life cycle, uses mathematical tools to adjust direct and indirect costs such as procurement and maintenance according to equipment type, school size, and regional economic level coefficients, achieving precise budgeting.

2.2 Theoretical Foundations

The Technology Acceptance Model (TAM) is driven by the dual cores of "perceived usefulness" and "perceived ease of use", incorporating teacher experience into the standards: smart equipment should enable one-click course initiation, and basic equipment parameters should synchronize with teaching habits by default, ensuring a handshake between performance and simplicity. The Life Cycle Cost (LCC) theory integrates the complete bill from procurement to disposal, accounting for hidden expenditures such as maintenance, training, and disposal of obsolete equipment, completely bidding farewell to the pattern of 'buying first and worrying about maintenance later'. The theory of educational equity implants a "regional coefficient" regulator into the cost model: 1.2 for the eastern region and 0.8 for the western region, using differentiated weights to offset regional economic disparities and bridging the digital education gap on the abacus first.

3. Current Status Survey and Problem Analysis of K12 Education Information Technology Equipment Upgrade

3.1 Survey Design and Implementation

The survey selected 100 K12 schools (30 primary schools, 40 junior high schools, and 30 senior high schools, with an urban-rural ratio of 45%:55%) from 10 provinces in the eastern, central, and western regions to ensure sample representativeness. Three types of tools were designed: "Equipment Status Questionnaire", "Person-in-Charge Interview Outline", and "Cost Data Collection Form". The survey was carried out in three stages from March to May 2024: a pilot survey (10 schools to optimize tools), formal survey (online questionnaire response rate of 92%, 120 hours of offline interviews, and 832 documents collected), and validity test (reliability $\alpha = 0.87$, validity KMO = 0.82), ensuring reliable data. (Qi, Z., 2025)

3.2 Current Status Analysis

The current K12 education information technology equipment is characterized by “old, idle, and chaotic” conditions. Basic equipment is operating beyond its intended lifespan; in rural western areas, 75% of interactive intelligent blackboards and switches have been in use for 8 years. Smart equipment also has 30% of AI grading and smart classroom systems surpassing the 4-year threshold. Regardless of whether it is basic or smart equipment, the usage rate of additional functions is less than 30%. Old equipment breaks down an average of 1.2 times per month, and new equipment is often plagued by compatibility errors. In the procurement process, nearly half of the schools rely solely on vendor “recommendations”, and the western region is more dependent on administrative “designations”. The average annual investment per school is 156,000 yuan in the eastern region, 98,000 yuan in the central region, and only 63,000 yuan in the western region. However, there is still 28% redundant purchasing and 35% of equipment remains idle. The sample schools waste an average of 21 million yuan per year, and it is estimated that the national waste exceeds 5 billion yuan annually. In terms of standards, the situation is even more chaotic. More than 30% of schools use corporate standards or “no standards” as criteria, resulting in 42% of equipment being incompatible, 23% of parameters being inflated, and 18% of smart equipment posing data leakage risks, turning “interconnectivity” into “interconnection and blockage”.

3.3 Core Problem Extraction

The triple gaps in technical standards, cost estimation, and implementation amplify each other. On the standards side, there is a lack of classification norms for basic and smart equipment. Key parameters such as bandwidth and resolution are described in a “one-size-fits-all” manner, and requirements for compatibility and security such as data encryption and interface protocols are completely blank. On the cost side, only the purchase price is focused on, while maintenance, training, and disposal are completely ignored. The transportation costs in the western mountainous areas are 3-5 times higher than those in the eastern region, and the differences in school sizes are not calculated, resulting in inherently distorted budgets. In schools, there is a situation of “buying a lot but using little”. In the western region, in order to raise procurement funds, maintenance is even cut, and old equipment is left untreated. New functions are either beyond demand or lack key elements, ultimately falling into a vicious cycle of “the more invested, the more wasted, and the more replaced, the more disconnected”.

4. Formulation of Technical Standards for K12 Education Information Technology Equipment Upgrade

4.1 Principles and Basis for Standard Formulation

The principle of practicality focuses on K12 teaching scenarios to ensure that equipment functions match classroom interaction, after-school service, and other needs. The principle of foresight combines 5G and AI technology trends to reserve space for technological iteration. The principle of security strictly complies with the “Personal Information Protection Law” and “Data Security Law” to safeguard student information security. The principle of compatibility requires equipment to be able to interface with existing school systems and provincial educational resource platforms across different platforms.

The basis includes three aspects: Policy basis is guided by the “Education Information Technology 2.0 Action Plan” and the “14th Five-Year Education Information Technology Development Plan”, in line with national education digitalization requirements. Practice basis is derived from the survey results of 100 schools, targeting equipment aging and functional waste to set standards. Technical basis refers to the mainstream industry levels to ensure that parameter settings are neither overly advanced nor lag behind existing technologies.

4.2 Technical Standards for Basic Equipment

In multimedia classroom equipment, interactive intelligent blackboards should meet the resolution $\geq 4K$, touch response time ≤ 0.3 seconds, and have a blue light filtering eye protection mode. Projectors should have a brightness ≥ 3500 lumens and a contrast ratio $\geq 10000:1$ to adapt to classrooms with different lighting conditions. In campus networks, the core switch bandwidth should be $\geq 10Gbps$, the access layer bandwidth $\geq 100Mbps$, the wireless network coverage rate $\geq 98\%$, and the delay $\leq 20ms$ to ensure stable operation of multiple terminals online simultaneously. In addition, the suggested service life for basic equipment is 6-8 years, with no less than two annual maintenance sessions and a fault response time not exceeding 24 hours.

Table 1.

Category	Sub-item	Configuration Requirements
Interactive Smart Blackboard	Resolution	$\geq 4K (3840 \times 2160)$
	Touch Response Time	≤ 0.3 s
Projector	Brightness	≥ 3500 lumens
Contrast Ratio		$\geq 10000:1$

Campus Network	Core Switch Bandwidth	≥ 10 Gbps
	Access Layer Bandwidth	≥ 100 Mbps

4.3 Technical Standards for Smart Equipment

The interactive response delay of the smart classroom system should be ≤ 0.5 seconds, supporting simultaneous online users ≥ 50 . The classroom data storage capacity should be $\geq 1\text{TB}$ to meet the needs of student performance data retention. For AI homework grading devices, the grading accuracy for Chinese and mathematics should be $\geq 98\%$, and for English compositions $\geq 95\%$, with the ability to recognize multiple question types such as multiple-choice, fill-in-the-blank, and subjective questions. In terms of data security and compatibility, the data encryption level of smart equipment should be \geq AES-256 (Li, W., 2025), supporting integration with provincial educational resource public service platforms, and being compatible with mainstream teaching software such as Seewo Whiteboard and DingTalk Education Edition.

4.4 Grading of Technical Standards and Applicable Scenarios

Standards are set according to school size: For small schools (student number < 1000), the smart classroom system should support simultaneous online users ≥ 50 ; for medium-sized schools (1000-2000 students), ≥ 65 ; and for large schools (> 2000 students), ≥ 80 . This approach accommodates the different teaching needs of schools of various sizes, avoiding a “one-size-fits-all” standard.

5. Construction of Cost Estimation Model for K12 Education Information Technology Equipment Upgrade

5.1 Analysis of Cost Composition Elements

Direct costs center around equipment procurement fees, complemented by installation and commissioning fees (5%-8% of equipment cost), and transportation fees priced according to regional distance. Indirect costs include annual equipment maintenance fees (10%-12% of equipment cost, discounted over 5 years), teacher training fees (average 800-1200 yuan per person \times number of trainees), and equipment disposal fees (2% of equipment cost, averaged over equipment life). Through correlation analysis, “equipment type (basic/smart), school size (number of students), and regional economic level (east/central/west)” are identified as the three core influencing factors.

Table 2.

Detailed Items	Cost Logic / Industry Experience Range
1. Equipment Procurement Cost	Winning Bid Price A
2. Installation and Commissioning Cost	(5%-8%) \times A
3. Transportation Cost	Based on Mileage Tiers + Base Price per Unit
4. Annual Operation and Maintenance Cost	(10%-12%) \times A, Discounted over 5 Years
5. Teacher Training Cost	Per Capita 800-1200 Yuan \times Number of Trainees
6. Disposal Cost	2% \times A, Averaged over Years

5.2 Construction Process of Cost Estimation Model

The dependent variable is the total upgrade cost Y, with independent variables being school size X1 (number of students), regional coefficient X2 (eastern = 1.2, central = 1.0, western = 0.8), and equipment type coefficient X3 (basic = 1, smart = 2). The cost data from the survey of 100 schools are then cleaned (removing outliers) and standardized. Finally, multiple regression analysis is performed using SPSS to derive the core equations: Basic equipment cost $Y_1 = 150 \times X_1 + X_2 \times 40000 + 5000 \times X_3$; Smart equipment cost $Y_2 = 200 \times X_1 + X_2 \times 50000 + 8000 \times X_3$. (Zhong, Y., 2025)

5.3 Model Verification and Optimization

The model's fit is verified through the R^2 test (requirement ≥ 0.85) to ensure its explanatory power over cost data. The F test and t test ($P < 0.05$) confirm the significant impact of independent variables. The estimation error is calculated and coefficients are adjusted to ensure an error rate of $\leq 5\%$, completing model optimization.

6. Practical Validation of Technical Standards and Cost Estimation Model

6.1 Validation Scheme Design

The validation targets 20 differentiated K12 schools, covering urban and rural areas (10 each) and all school

stages (6 primary schools, 8 junior high schools, and 6 senior high schools) to ensure results are applicable to different scenarios. A comparative group design is adopted: the experimental group of 10 schools strictly purchases equipment according to the established technical standards and budgets using the cost estimation model; the control group of 10 schools continues with the traditional procurement model (no unified standards, cost estimation based on experience). Both groups maintain consistency in core conditions such as school size and initial funding basis to eliminate interfering factors. Validation indicators focus on four core aspects: equipment utilization rate (measuring practical value of equipment), funding savings rate (assessing cost control effectiveness), teaching effectiveness (quantified through classroom interaction frequency and remote teaching coverage), and teacher satisfaction (obtained through questionnaire surveys), forming a complete evaluation system.

6.2 Validation Process Implementation

In the experimental group's implementation phase, schools are first provided with technical standard manuals and cost estimation toolkits to assist them in determining equipment parameters and budgets based on their size (number of students) and region (east/central/west). After procurement, a three-month follow-up is conducted to record equipment installation progress, daily usage frequency, fault repair situations, and actual funding expenditure. The control group simultaneously collects corresponding data, including equipment parameter lists, funding investment details, equipment idle time, and classroom application records, ensuring that the data collection cycle and dimensions match those of the experimental group to ensure comparison validity.

6.3 Validation Result Analysis

Data comparison shows that the experimental group's core indicators significantly outperform the control group: equipment utilization rate reaches $\geq 80\%$, more than 50 percentage points higher than the control group ($\leq 30\%$); the average funding savings rate is 25%, with some eastern large schools achieving up to 32%, while the control group experiences 15%-20% funding waste (Haoyang Huang, 2025); in terms of teaching effectiveness, the experimental group's classroom interaction frequency (average 12-15 times per day) is more than three times that of the control group (average 3-5 times per day), and remote teaching coverage (95%) is higher than the control group (60%); teacher satisfaction scores (4.2/5) also lead the control group (2.8/5).

Table 3.

Indicator	Experimental Group	Control Group
Equipment Utilization Rate	$\geq 80\%$	$\leq 30\%$
Funding Savings Rate	Average 25%, up to 32% in large schools in the east	Funding Waste 15%-20%
Classroom Interaction Frequency (Daily Average)	12-15 times	3-5 times
Remote Teaching Coverage Rate	95%	60%
Teacher Satisfaction Score	4.2/5	2.8/5

Based on the validation results, the standards and model are optimized accordingly: in terms of technical standards, considering the network conditions of rural schools, the response delay for rural smart equipment is relaxed from 0.5 seconds to 0.8 seconds; in terms of cost estimation model, combining the actual maintenance costs of western schools, the regional coefficient for the western region is slightly adjusted from 0.8 to 0.75 to further enhance the model's adaptability to regional realities.

7. Conclusions and Future Work

7.1 Research Conclusions

This study, focusing on the core pain points of K12 education information technology equipment upgrade, has achieved three key outcomes. Firstly, it has clarified the core content of the "Technical Standards for K12 Education Information Technology Equipment Upgrade". By categorizing the standards, it defines the performance parameters for basic equipment (e.g., resolution $\geq 4K$ for interactive intelligent blackboards, bandwidth $\geq 100Mbps$ for campus networks) and smart indicators for smart equipment (e.g., response delay ≤ 0.5 seconds for smart classroom systems, grading accuracy $\geq 98\%$ for AI grading devices), while incorporating data security (encryption level $\geq AES-256$) and cross-platform compatibility requirements, filling the gap of the absence of unified industry standards. Secondly, a multi-dimensional cost estimation model has been constructed, with "equipment type, school size, and regional economic level" as core variables. The estimation equations are derived through regression analysis of data from 100 schools. After validation with 20 schools, the

model error rate is $\leq 5\%$ (Xiaoying Yang, 2025), capable of accurately calculating upgrade costs in different scenarios, breaking through the limitations of traditional “single unit price estimation”. Thirdly, a “standard + model + toolkit” implementation plan has been proposed. An Excel estimation template and standard query manual have been developed to provide full-process support for school procurement decisions and educational department planning, effectively resolving the issues of “blind procurement” and “funding waste”.

7.2 Research Limitations and Future Work

The study has two limitations: Firstly, the survey sample coverage is limited, involving only 10 provinces in mainland China, excluding the Hong Kong, Macao, and Taiwan regions, which may lead to insufficient adaptability of the model to special regions. Secondly, the cost estimation model does not fully consider the impact of future technological iterations. For example, 6G and more mature AI technologies may change the cost structure of equipment, and the current model parameters may not fully meet long-term needs.

Future research can be advanced in three directions: Firstly, expand the sample scope to include the Hong Kong, Macao, and Taiwan regions and schools in different levels of educational development across cities and counties to further optimize model coefficients and enhance universality. Secondly, track technological trends to regularly update technical standards (e.g., adding 6G compatibility parameters) and cost models (e.g., adjusting the maintenance cost ratio of AI equipment) to maintain the timeliness of research findings. Finally, explore an “equipment upgrade + teaching quality assessment” integrated system, linking equipment usage effectiveness with improvements in student performance and teacher teaching efficiency to form a “investment – effect” closed-loop evaluation, making equipment upgrades more aligned with the core goal of improving educational quality.

7.3 Practical Recommendations

For educational administrative departments, it is recommended to incorporate the established technical standards into regional education information technology plans, allocate special funds based on the cost estimation model, prioritize funding for western rural schools to narrow the digital education gap, and establish a standard implementation supervision mechanism to regularly verify the compliance of school procurement equipment parameters to prevent “pseudo-smart equipment” from entering campuses. For K12 schools, it is suggested to use the accompanying toolkit before procurement to calculate budgets based on their size (number of students) and regional coefficients, select suitable equipment according to standards, and avoid pursuing “high configurations”. After equipment use, regularly collect data on equipment utilization and teaching effectiveness to provide data references for future upgrades. For equipment suppliers, it is recommended to develop products in accordance with technical standards, focus on “teaching adaptability” to optimize functions (e.g., simplify teacher operation processes), and provide “equipment + maintenance + training” integrated services to reduce subsequent costs for schools, promoting the transformation of K12 education information technology equipment upgrades towards a “quality and efficiency” model.

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