Research on Integrated Design of Construction Engineering Cost Management Platform in Cloud Computing Environment

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Abstract: Aiming at the problems existing in the traditional construction project cost management model, such as data island, inefficient collaboration and delayed decision-making, this paper puts forward a design scheme of an integrated platform for construction project cost management based on cloud computing. The platform adopts cloud native micro-service architecture, which is divided into infrastructure layer, platform service layer, application service layer and user access layer, and realizes elastic expansion of resources, unified management of data, rapid iteration of applications and convenient access of users. The core functions of the platform are realized by cost core business module, data integration and exchange module, intelligent forecasting and decision support module and cloud collaborative workflow module. Through the LSTM (Long Short-Term Memory) neural network model, the platform can realize the dynamic prediction of material prices and effectively reduce the risk of cost overruns; Integrate BIM, ERP and other systems through API to break down information barriers and realize data interconnection; Improve collaboration efficiency and reduce communication costs through cloud collaboration space. The platform verification results show that the scheme can effectively solve the problems existing in the traditional cost management mode and improve the efficiency and decision-making level of project cost management.

1. Introduction

As the core of the whole life cycle of a project, construction project cost management is very important for investment benefit and project quality. The traditional model relies on manual and discrete software, which has three major pain points: isolated data island, inefficient collaboration and delayed decision-making. With the development of cloud computing technology, its flexible computing, distributed storage and AI capabilities have brought changes to the industry. Real-time data processing is supported by resource elasticity, information barriers are broken by integrating BIM, ERP and other systems with API, and cost prediction accuracy and cost management efficiency are improved by machine learning. In this context, national policies continue to promote the deep integration of "cloud+construction" [1]. "The 14th Five-Year Plan for Construction Industry Development" clearly puts forward "developing a dynamic monitoring system of project cost based on cloud computing", which requires that the cloud platform coverage rate of large-scale projects will exceed 80% in 2025 [2]. However, the existing research mostly focuses on local technology, lacking systematic design of all-factor integrated platform, which leads to the challenges of "data impassability, algorithm islanding and application fragmentation". This study builds an integrated platform of construction project cost management based on cloud computing, and expands the research boundary of the cross field of cloud computing and project management. Shorten the system response time to the second level through the micro-service architecture, and support the concurrent operation of thousands of users; Using LSTM (Long Short-Term Memory) neural network to realize the dynamic prediction of material price and reduce the risk of overspending; Build a multi-party cloud collaboration space to reduce communication costs.

2. Integrated platform architecture design

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2.1 Overall architecture design

The integrated platform of construction project cost management in cloud computing environment solves three core pain points: data island, inefficient collaboration and delayed decision-making. The platform design follows the principles of "high cohesion, low coupling", "elastic extensibility" and "data-driven" to ensure that it can meet the complex needs of large-scale engineering projects and adapt to future technical iterations [3]. The overall architecture of the platform adopts a cloud-based micro-service architecture, which is divided into four layers: infrastructure layer, platform service layer, application service layer and user access layer. This design ensures the flexibility, reliability and high concurrency of the system. The schematic diagram is shown in Figure 1 below.

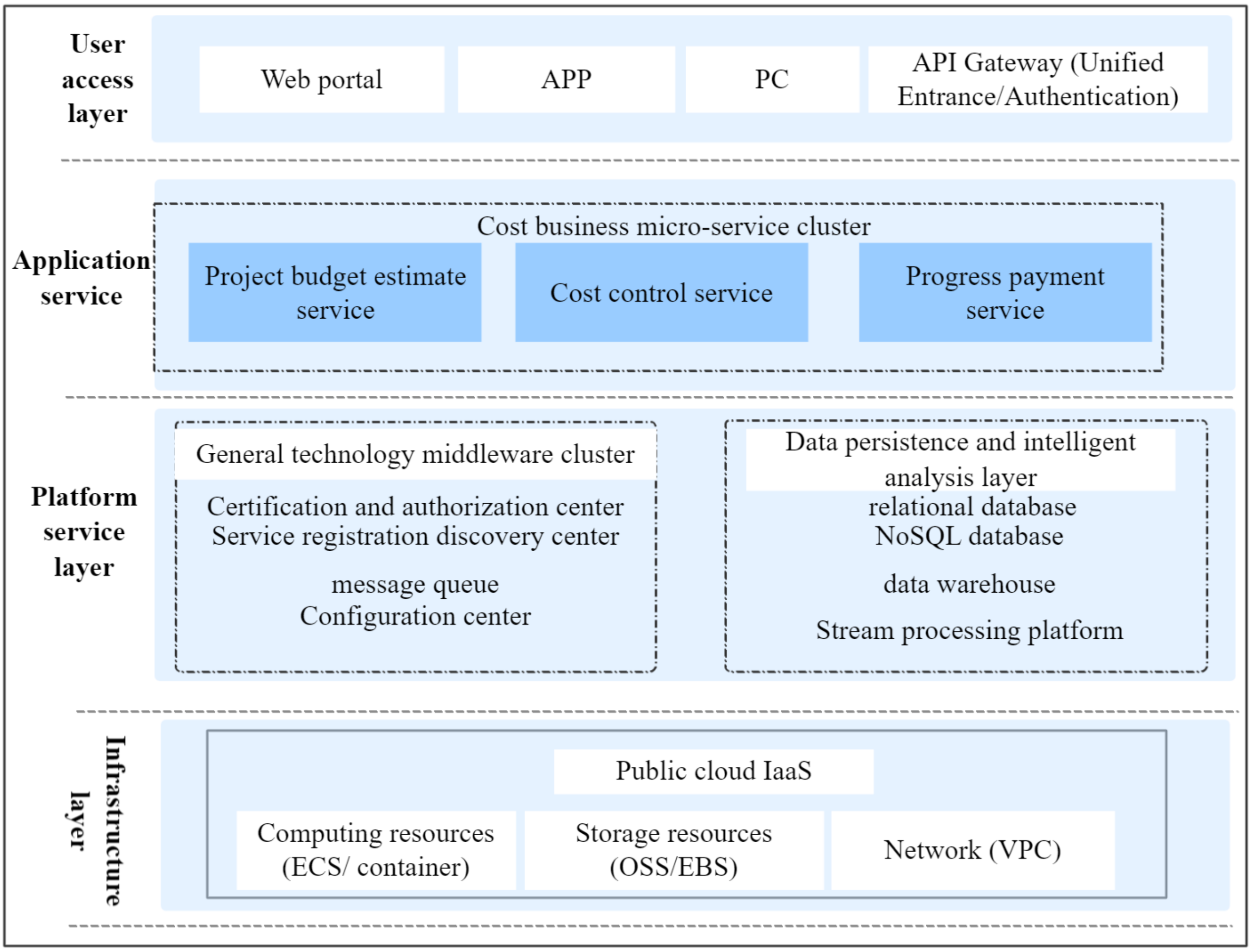

Figure 1 Integrated platform architecture of construction engineering cost management

2.1.1 Infrastructure as a Service (IaaS)

Deploy using a hybrid cloud model. Core business data is stored in private clouds or financial grade cloud services to ensure data security and compliance; And functions such as high concurrency computing, big data analysis, and backup archiving utilize the elastic resources of public clouds (AWS, Alibaba Cloud). Through virtual private cloud (VPC) and dedicated line connections, seamless integration and unified management of public and private cloud resources are achieved, balancing security and resilience [4].

2.1.2 Platform service layer (PaaS)

General technology middleware is the "central nervous system" of micro-service architecture. Spring Cloud Alibaba suite is adopted, including Nacos (Service Registration and Discovery Center, Configuration Center), Sentinel (Traffic Guard, which realizes service fuse and degradation) and RocketMQ (Message Queue, which is used for asynchronous decoupling and peak clipping and valley filling). These components ensure the coordination, high availability and observability among microservices. Multi-mode database strategy is adopted for data persistence and intelligent analysis. The core business data adopts relational database to ensure transaction consistency. Unstructured data is stored in the object store. High-frequency access to cached data uses Redis. In order to support the analysis and machine learning of massive historical cost data and time series data, a data lake warehouse based on Hadoop or cloud native data warehouse is constructed to provide a unified and clean data source for the LSTM model.

2.1.3 Application service layer (SaaS)

Split the traditional monomer application into a set of fine-grained micro-services. Each service focuses on a business field, such as project basic data service, engineering quantity calculation service, quota management service, cost analysis service, progress payment management service, collaborative approval service, etc. Services communicate through lightweight RESTful API or gRPC [5]. This design enables each service to be independently developed, deployed and scaled, which greatly improves the iterative efficiency and stability of the system. As the only entrance to all external services, API gateway handles authentication, authentication, routing, current limiting and logging in a unified way to ensure the security of back-end services.

2.1.4 User access layer

Provide a variety of access methods such as Web (main operation interface), mobile APP (on-site reporting, approval and inquiry) and open API to meet the use needs of different roles (cost engineer, project manager, owner and supervisor) in different scenarios.

2.2 Key module design

The core functions of the platform are realized by the following four key modules as shown in Figure 2.

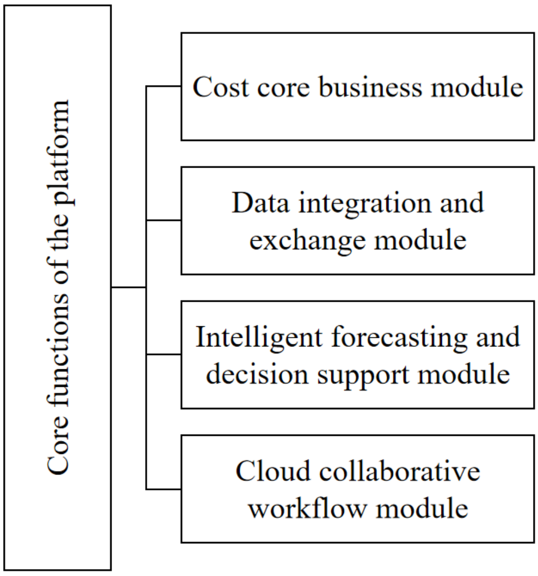

Figure 2 Four key modules of the platform

2.2.1 Cost core business module

Taking the bill of quantities as the core, it runs through the whole process of investment estimation, design budget estimation, construction drawing budget and final accounts [6]. This module provides online editing, version management, change tracing and other functions. Through the micro-service architecture, the editing process can realize multi-person real-time collaboration, avoid version conflict, and shorten the traditional editing cycle from several days to hours.

2.2.2 Data integration and exchange module

This is the key to break the "data island". Design a unified data bus to connect heterogeneous systems with different formats and standards through configurable adapters and APIs. IFC standard parser is developed to automatically extract the geometric attributes and engineering quantity information of components in BIM model and push them to the cost business module, so as to realize the integration of BIM quantity and price and reduce the manual calculation error [7]. Through the API docking material procurement and financial payment modules, the actual purchase price and expenditure data can be obtained in real time, and compared with the budget dynamically to form a cost closed loop. Write a web crawler service, regularly grab external data such as official building materials price platform and freight index, and provide data support for the forecasting module.

2.2.3 Intelligent forecasting and decision support module

This module is the embodiment of intelligent platform. The LSTM neural network model is adopted because it is good at dealing with the long-term dependence of time series data. Taking historical material prices, macroeconomic indicators and seasonal factors as input characteristics, the short-term material prices in the future are dynamically predicted. Historical data in data warehouse-> feature engineering-> model training-> generating prediction model-> deploying for model service-> providing prediction results to business modules through REST API. The forecast results can be directly used to adjust the material price difference in cost calculation, which can warn the risk of price fluctuation in advance, assist managers to formulate better purchasing strategies and effectively reduce the risk of cost overruns.

2.2.4 Cloud collaborative workflow module

Based on open source workflow engines such as Activiti/Flowable, a flexible and customized approval process is constructed. Combined with WebSocket technology, online annotation, instant communication, task reminder and push notification of cost documents are realized, and a multi-party real-time collaboration space is constructed. All communication records and operations leave traces, forming a project knowledge base, greatly reducing communication costs and management internal friction.

2.3 Technology selection

Technology selection focuses on efficiency, stability and scalability. Alibaba Cloud is adopted as the cloud infrastructure to provide compliant and stable full-stack cloud native services and support hybrid cloud deployment to ensure data security; The micro-service framework selects Spring Cloud Alibaba, which is deeply integrated with Java ecology, and integrates Nacos, Sentinel and other components to improve system stability and development efficiency. The database combination uses PolarDB (high performance MySQL compatibility), Redis (high concurrency cache), MongoDB (unstructured data) and Apache Doris (real-time analysis) to meet the diverse data processing needs; Machine learning builds an LSTM model based on TensorFlow/PyTorch, and uses its powerful ecology to realize accurate cost prediction; The front end adopts Vue 3 or React with TypeScript, which supports component development and complex single-page application. Real-time communication between systems is realized through WebSocket, and flexible integration and data conversion are realized by combining RESTful API and Apache Camel, so as to ensure efficient interconnection inside and outside the platform.

3. Platform verification

In order to evaluate the actual efficiency of this integrated platform, a test environment is built, and the historical data of a large-scale residential project under construction is used for simulation operation and comparative analysis. The test simulates the key operations under different concurrent users, and the results are shown in Table 1 below, which proves that the platform meets the design objectives. With thousands of concurrent users, the average response time of the platform is kept at millisecond level, the system throughput is high and the error rate is extremely low, and the performance is stable, which fully meets the concurrent use needs of large project teams.

Table 1 Platform performance test results

Number of concurrent users	Average response time (ms)	95% request response time (ms)	Throughput (Requests/sec)	Error rate (%)
500	380	650	1250	0.01%
1000	550	980	2100	0.05%
1500	850	1500	2800	0.12%

Select rebar as a representative material, use the historical price data of the past 24 months to train the LSTM model, and predict the price trend in the next three months. Compare the forecast result with the actual market price (as shown in Figure 3). The prediction error is measured by the mean absolute percentage error (MAPE). In this test, MAPE is 3.5%, which is much lower than the traditional linear regression model (8.2%). This shows that the intelligent forecasting module of this platform can effectively capture the nonlinear change law of material prices and provide a high-precision decision-making basis for cost risk control.

Figure 3 Comparison between the predicted results of LSTM model and the actual price

Compare the time-consuming of traditional mail/offline process and the process of "application and approval of progress payment" using the cloud collaboration module of this platform. As shown in Table 2 below, through online collaboration, process-driven and real-time notification, the platform shortened the traditional process from nearly 10 days to 2.5 days, which significantly improved the collaboration efficiency and effectively accelerated the capital turnover.

Table 2 Time-consuming comparison of progress payment approval process

Process link	Traditional mode (average days)	This platform (average days)	Efficiency improvement
Report preparation and submission	2.5	0.5 (Online Synchronous Editing)	80%
Multi-party audit and feedback	5.0	1.5 (Online Annotation/Reminder)	70%
Revision and final approval	2.0	0.5	75%

Total time consumption	9.5 days	2.5 days	74%

4. Conclusion

By using micro-service architecture, multi-mode database strategy, LSTM neural network model and cloud collaborative workflow module, the platform effectively solves the three core pain points of data island, inefficient collaboration and delayed decision-making. The experimental results show that the platform shows extremely high response speed and stability under the concurrency of thousands of users, and the average response time is kept at millisecond level, and the system throughput is high and the error rate is extremely low. At the same time, the intelligent prediction module uses the LSTM model to dynamically predict the material price, which significantly improves the accuracy of cost prediction and reduces the risk of cost overruns. The cloud collaborative workflow module greatly improved the project management efficiency, shortened the traditional process time to 2.5 days, and improved the collaborative efficiency by 74%. The integrated platform not only meets the complex needs of large-scale engineering projects, but also provides strong support for the digital transformation of construction project cost management, which has important theoretical significance and practical value.

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