Hindawi
Scientific Programming
Volume 2022, Article ID 2183093, 8 pages
https://doi.org/10.1155/2022/2183093

*Research Article*

# Cost Management and Forecasting Method for the Whole Life Cycle of Water Conservancy Projects Based on Multiple Regression Analysis

**Sha Li**

*College of Hydraulic Engineering, Zhejiang Tongji Vocational College of Science and Technology, Hangzhou, Zhejiang 311231, China*

Correspondence should be addressed to Sha Li; z20220070902@zjtongji.edu.cn

Received 3 June 2022; Revised 4 July 2022; Accepted 12 July 2022; Published 23 August 2022

Academic Editor: Lianhui Li



The water conservancy project is an important livelihood engineering project, and it is also an important factor to ensure the living water supply, power supply stability, and economic development of the regional population. Therefore, the management of water conservancy projects is particularly important. The core management content is cost control, which can maximize the benefits of the project and avoid the waste of investors' funds. This study studies the whole process control of water conservancy project cost, explains the problems existing in the current domestic water conservancy project cost control, and finally expounds on the whole process control measures, in order to provide a reference for related work. In this study, SPSS software is mainly used to establish a multiple linear regression model to analyze the influencing factors of water conservancy projects. Through the method of model solving, the relationship between hydraulic engineering and various variables is analyzed, and the multi-linear verification is improved, so as to further test the model, optimize the model, and finally manage and predict it accurately.

## 1. Introduction

In recent years, with the rapid development of my country's water conservancy project construction. Due to the long construction period of water conservancy projects [1], large investment, and many cooperative departments, it is greatly affected by natural resources, topography, geology, hydrometeorological conditions, as well as local economic development level, transportation, and other resource market conditions [2, 3]. Personality is very prominent. In terms of pricing, water conservancy projects have the characteristics of a single piece, multiple times, diversity of methods, and complexity of basis [4, 5]. These characteristics determine the unique problems in the cost management of water conservancy projects that are different from other construction projects [6, 7].

At present, the cost management mode of water conservancy projects in my country is divided into stages and units, that is, the cost control in the project decision-making and design stage is completed by the cost professionals of the design unit, and the cost control in the contracting stage is carried out by the project owner who can bid by himself or can bid. The cost consulting unit with the agency qualification is completed, the cost control in the construction phase is completed by the cost professionals of the supervision unit, and the cost control in the completion and post-evaluation phases is completed by the cost consulting unit with the qualification for a price review. Project decision-making and design stage are important stages of cost management. Therefore, doing a good job in the management of water conservancy projects can ensure the daily life of the people [8], and the requirements for project cost management are the highest.

Project cost is an important part of project construction. A scientific and reasonable project cost [9, 10] plays an important role in the construction of the entire project. The construction of a project, obtaining a standard and reasonable project cost, has already made a good start and can invest in the preliminary project that has a good investment standard. The economic expenditure can be kept within a controllable range so that the construction of the project can be completed quickly and well. In the construction of water conservancy projects, the cost management of the whole process can not only measure the investment in the life cycle of the construction project but also grasp the investment as a whole [11]. In the process of project management, the influencing factors of project cost mainly include financing methods, construction plans and exploration, and other factors [12, 13]. The analysis of all quotation management in the process of water conservancy project construction can make water conservancy projects in the process of construction [14]. As a major construction project in modern society, the water conservancy project needs to pay enough attention to the cost management of the whole process, so as to ensure that the water conservancy project construction achieves the rationalization of capital utilization in the whole process of construction. It also needs to promote the completion of high-quality and high-efficiency water conservancy project construction, and improve the benefits of project construction [15, 16].

The necessity of investment control in the whole life cycle of water conservancy projects: The reason for constructing the investment control mechanism for the whole life cycle of water conservancy projects is to improve the corresponding work at each stage and link the construction system, and effectively implement the staged supervision mode because different stages have unique characteristics. Therefore, only by improving the procedural supervision and management model can the integrity of the management process and the comprehensive level of investment control be improved. The most important thing is to integrate the static control mechanism, dynamic control mechanism, deviation analysis mechanism, and remedial adjustment mechanism in the investment control structure of the whole life cycle of water conservancy projects, so as to establish a really good supervision mode and comprehensive supervision system [17]. In the whole life cycle management of water conservancy projects, to a certain extent, relies on the computer software system of integrated information [18]. The application of BIM (Building Information Modeling) technology (see Figure 1) can fully reflect the physical and geometric characteristics of water conservancy buildings, display project appearance, location, and environmental information in three-dimensional space, and integrate various engineering information of buildings, including progress, material information, and cost information. In the BIM model, all information is provided by a unified data source, and the engineering information is independent, logically related, and consistent.

## 2. Existing Problems

We mainly use SPSS software to establish a multiple linear regression model to analyze the factors that affect hydraulic engineering. Through the method of model solving, the relationship between hydraulic engineering and various variables is analyzed, and the verification of multi-linearity is improved. This is to further test the model, optimize the model, and finally carry out accurate management and prediction.

### 2.1. Problems in the Decision-Making Stage

*2.1. Problems in the Decision-Making Stage.* Judging from the construction situation of water conservancy projects in recent years, some projects have not been completed in strict accordance with the construction period, which means that the investment costs that investors need to bear also need to rise, resulting in the inability to better control the cost of water conservancy projects [19]. The problem that caused this situation is that the basis for the cost estimation in the decision-making stage of the water conservancy project is not sufficient, and it is not considered according to the actual situation, and the construction plan is formulated only after the theoretical approval.

*2.2. Design Phase Issues.* Engineering design is a prerequisite for the construction of all construction projects. At present, many design institutes have fallen into a misunderstanding when designing water conservancy projects, that is, they think that as long as the quality is strictly controlled, the design scheme can be optimized, resulting in the neglect of engineering costs, to design the overall cost-effectiveness of the program is generally low. Although quality is the core criterion for determining the service life and value of a project, it does not mean that cost is unimportant. Simply considering an influencing factor will lead to deviations in the design scheme and make cost control difficult.

*2.3. Project Quotation Problem.* The project list quotation method is a cost control method after the construction of most projects in the world. At present, only a few economically developed areas in China use this method, and most areas have not yet implemented it. When using the bill of quantities for quotation, the company chooses the industry quota as the reference value, which makes the cost involved in the bill of quantities only the social average, and does not reflect the actual cost control of the construction unit, resulting in this kind of cost. The means of control cannot be implemented.

*2.4. Issues in the Implementation Phase.* The main problem affecting project cost management in the implementation stage is the modification of the construction design. At present, in many domestic water conservancy projects [20], investors and constructors randomly modify the construction design, which can directly lead to an increase in project costs. At the same time, there is no domestic law or regulation that is completely aimed at the management of construction costs, which makes the construction contract have many loopholes in the process of signing so that the construction party can make use of loopholes to modify the project quantity, which will seriously affect the water conservancy project and the cost control.

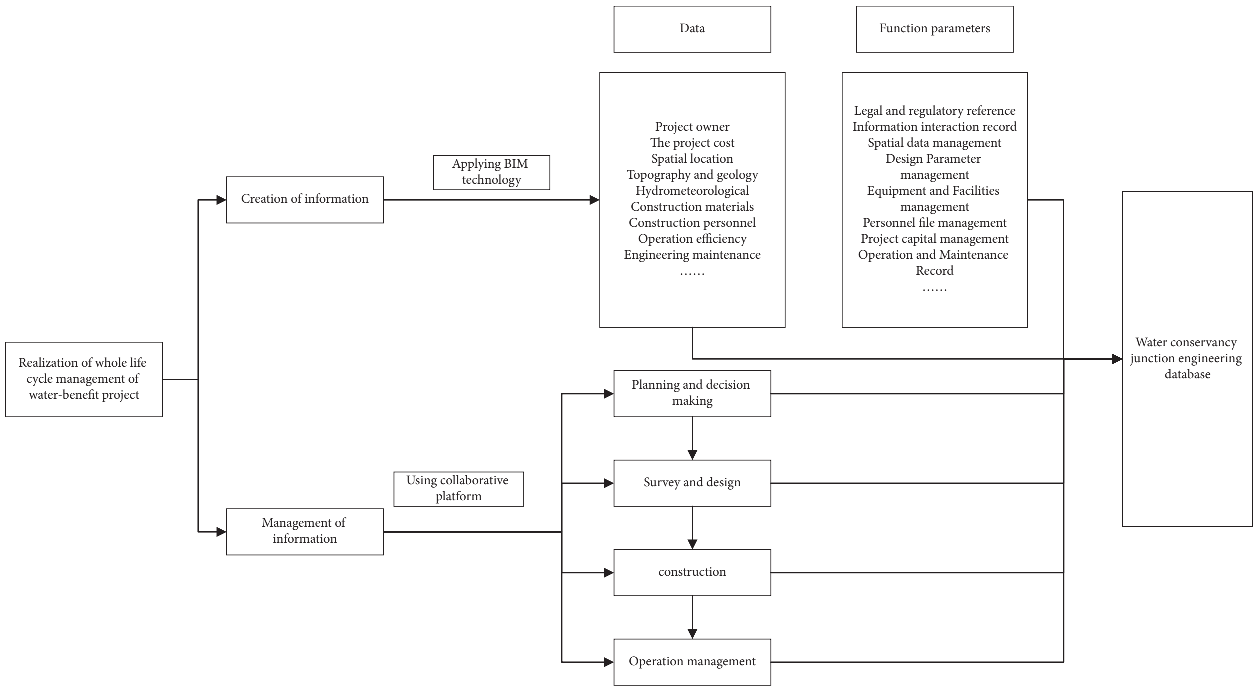


Figure 1: Full life cycle management of water conservancy projects.

*2.5. Issues in the Settlement Phase.* There may also be some loopholes in the formulation and signing of water conservancy project contracts, which leads to the situation that the investor and the construction party shirk each other when the project is settled. It is mainly manifested in the fact that the construction party increases the amount of the project cost in the settlement by falsely reporting the construction volume; while the investor bargains with the construction party under the loopholes in the contract clauses, and some construction parties try to avoid this "malicious" bargaining behavior. Therefore, there will be a situation of falsely reporting the project cost. Both parties did not strictly follow the contract settlement method, which made the cost control of the water conservancy project more difficult to carry out, and even could not be settled, so the project could not be put into use, increasing the additional cost in the later period.

## 3. Number of Control and Management Measures in the Whole Process of Water Conservancy Project Cost

*3.1. Water Conservancy Project Cost Process.* The control of water conservancy project cost is different in different stages such as project proposal, feasibility study report, initial design, bidding and construction, and complete acceptance. The construction of water conservancy projects uses a lot of manpower, material resources, and financial resources. In the process of project implementation, the implementation of good management and control of the whole process of construction cost can save a lot of cost for my country's economic construction and ensure that the project has good quality and profit. First, have a clear understanding of the concept of water conservancy project cost control and management, and then explain the management and control involved in water conservancy construction before, during, and after the event, so as to draw powerful measures for water conservancy construction project control and management, and in order to provide effective reference and basis for the management and control of engineering cost of water conservancy construction projects in my country in the future. Therefore, the corresponding preparations should be done in the early stage of the construction project, and the funds should be controlled in the reserved cost and stage coefficient in the investment decision-making stage. The following processes are usually required in the cost of water conservancy construction projects, as shown in Figure 2.

*3.2. Cost Control Measures in the Decision-Making Stage.* In the decision-making stage of a water conservancy project, the investor should communicate with the auditors in the early stage and conduct a comprehensive evaluation of the water conservancy project to be invested in. During the evaluation process, it is necessary to conduct a comprehensive survey of the market and analyze the geological exploration data of the construction site to make the construction period and early cost evaluation results more accurate.

*3.3. Cost Control Measures in the Design Stage*

(1) The design institute needs to optimize the design scheme according to the requirements of the investor. The premise of optimization includes not only the quality of the project but also the cost of the project. The design work is carried out on the

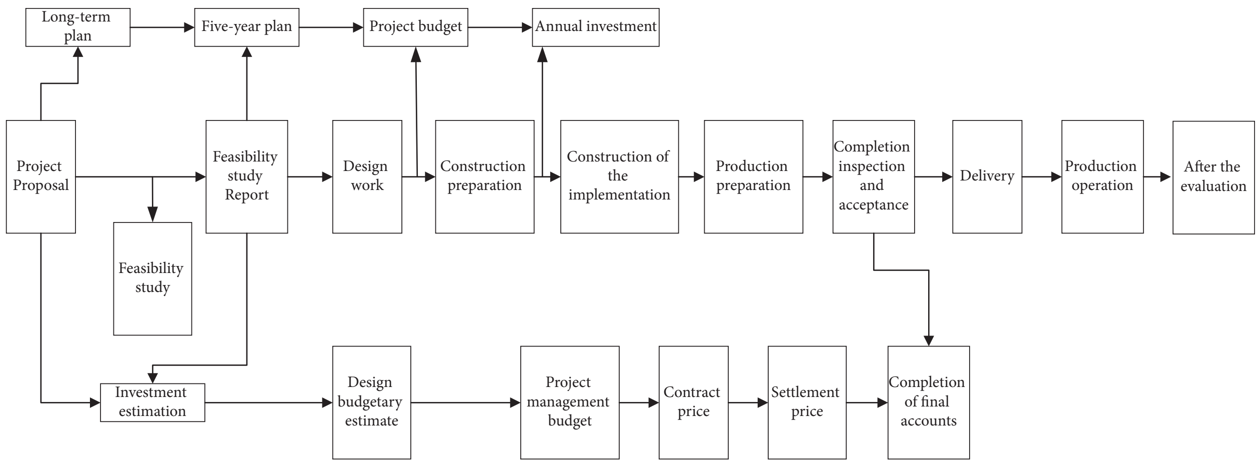


Figure 2: Construction flowchart.

premise of engineering quality, and then the economic credibility of the design scheme is evaluated, and at the same time, it is studied whether the architectural function of the design scheme meets the needs of the investor. In addition, the method of limit design can also be adopted, and the investor can directly control the estimated cost of the project within a certain range when communicating with the design institute.

(2) During the design process, it is necessary to consider the design changes in the construction stage. Designers should comprehensively consider the correlation between design changes and the impact of construction costs. Usually, the earlier design changes occur in the construction stage, the smaller the impact on the overall cost. Therefore, it is necessary to conduct a comprehensive study of the influencing factors immediately after the design is completed, so as to minimize the change in the design scheme.

*3.4. Cost Control Measures in the Construction Stage.* First of all, it is necessary to formulate a dynamic and static cost control plan in the construction stage. The static control plan is mainly to be discussed by the construction party, the investor, and the design institute before the start of construction. Modify the process links that the construction unit cannot meet in the plan. At the same time, the investor and the builder should sign a cost pre-limited contract, that is, to formulate a scope of approval for the fluctuation of the project cost, and stipulate the conditions that can affect the cost of the project, and the additional cost caused by other conditions will not be paid. Dynamic cost control refers to the review and compensation management of cost changes caused by modification of the construction design during the entire construction stage, and the reasons for changes in the construction process and the design changes are reported to the cost management department for review. The changes within the scope are approved for revision, while those beyond the contract limit need to be negotiated by the investor and the construction party for related compensation issues. It should be noted that the limited terms in the contract shall not be arbitrarily changed during the construction stage. If a party unilaterally changes the contract, it shall bear all the additional costs. In the construction stage, where investment mainly occurs, construction site management should be done well, and corresponding management and control should be done to reduce costs and eliminate waste. They should pay attention to the following aspects: 1. Do a good job in investment tracking management. Through effective tracking management, the corresponding problems can be found in a timely and effective manner, and the quality of the project can be effectively grasped in terms of quality, progress, and cost, so as to reasonably save costs and solve problems. Identify the control basis, such as project management budget and the project contract price, etc., through project measurement, control of project changes, etc., according to the actual workload completed by the contractor, and strictly determine the actual project costs incurred during the construction stage. 2. Strictly review the construction organization design. During the construction process, the construction plan that is technically feasible and economically reasonable should be selected as far as possible. According to the nature and scale of the project, the length of the construction period, the number of workers, mechanical equipment, material supply, transportation, geological, climatic conditions, and other specific technical and economic conditions, the construction organization design, construction plan, The construction schedule is optimized, and finally, the most rational use of manpower, material resources, financial resources, and resources is selected. Correctly handle the dialectical and unified relationship between project cost, construction period, and quality, and improve the comprehensive economic benefits of project construction. 3. Control engineering changes. If the corresponding project quantity is changed, it will bring a lot of unnecessary trouble to the original budget investment. In engineering contracting, many common phenomena will occur, due to factors such as construction site conditions, climate changes, changes in construction progress, and changes, differences, and delays in contract terms, specifications, standard documents, and construction drawings, which will inevitably lead to engineering contracting. Claims arise, which in turn lead to changes in the investment in the project.

*3.5. Cost Control Measures at the Completion Stage.* The completion settlement report is the most direct data reflecting the actual cost of the water conservancy project, and it is also the core reference data for investors to consider the projected income. In order to control the project cost at the time of completion and settlement, it is necessary to conduct a comprehensive review of the actual construction volume of the water conservancy project, compare the early design drawings, revised drawings, and as-built drawings, and cooperate with auditors to inspect all construction links. Carefully check whether there is any false report of construction volume. At the same time, it is also necessary to refer to the limited terms in the contract when completing the settlement to avoid the problem of "malicious" price reduction by the investor and ensure the economic benefits of the construction party, so as to avoid their fraudulent behavior and make the whole process of cost work more complete and accurate.

## 4. Multiple Regression Analysis Models

*4.1. Introduction to Multiple Regression Models.* Multiple regression analysis [21, 22] refers to the establishment of a linear or nonlinear mathematical model between multiple variables by considering one variable as a dependent variable and one or more other variables as independent variables. Statistical analysis methods use quantitative relationships and use sample data for analysis. In addition, there is also a multiple regression analysis that discusses the linear dependence of multiple independent variables and multiple dependent variables, which is called the multiple multiple regression analysis models (or simply many-to-many regression) [23]. Usually, multiple factors affect the dependent variable, and the problem that multiple independent variables affect one dependent variable can be solved by multiple regression analysis [24]. For example, economic knowledge tells us that in addition to commodity price P, commodity demand $Q$ is also affected by factors such as the price of substitutes, the price of complementary products, and consumer income, and even includes the quality variable of commodity brand (Brand Quality variables cannot be measured numerically, and dummy variables need to be introduced into the model). Multiple regression analysis has a wider range of applications. Since linear regression analysis is relatively simple and common, the following first introduces multiple linear regression [25, 26]. On the basis of linear analysis, dummy variable regression and a class of curve regression models that can be transformed into linear regression are gradually introduced.

One of the more famous multiple regression models is principal component analysis, which we use in this article. When using statistical analysis methods to study multivariate subjects, too many variables will increase the complexity of the subject. People naturally want to get more information with fewer variables. In many cases, there is a certain correlation between variables. When there is a certain correlation between two variables, it can be interpreted that the information of the two variables reflecting the subject overlaps to a certain extent. Principal component analysis is to delete the redundant variables (closely related variables) for all the variables originally proposed, and establish as few new variables as possible so that these new variables are uncorrelated, and these new variables reflect. The information on the subject should be kept as original as possible. The principal component analysis is the basic mathematical analysis method, and its practical application is very wide, such in demographics, quantitative geography, molecular dynamics simulation, mathematical modeling, mathematical analysis, and other disciplines. Analytical method is that the component analysis is a multivariate statistical method that examines the correlation between multiple variables. It studies how to reveal the internal structure of multiple variables through a few principal components, that is, derive a few principal components from the original variables so that they can be as fully as possible. It is possible to retain a lot of information about the original variables, and they are not related to each other. Usually, the mathematical processing is to linearly combine the original P indicators as a new comprehensive indicator.

The most classic way is to use the variance of F1 (the first linear combination selected, that is, the first comprehensive indicator) to express, that is, the larger the Var(F1), the more information F1 contains. Therefore, F1 selected in all linear combinations should have the largest variance, so F1 is called the first principal component. If the first principal component is not enough to represent the information of the original P indicators, then consider selecting F2 to select the second linear combination. In order to effectively reflect the original information, the existing information of F1 does not need to appear in F2 again, which is called F2, is the second principal component, and so on, and this way the third, fourth, . . ., $P$-th principal components can be constructed.

*4.2. Statistics of Data.* Due to its public welfare nature, the construction funds of water conservancy projects are mostly invested by the government. The policies and financial levels of different provinces affect the decision-making of water conservancy project construction. In addition, engineering projects of different times and scales also have a greater impact on decision-making. The author counted a total of 20 initial approvals as samples, from which 17 samples were selected to estimate the regression model, and the remaining 3 samples were used for model testing.

*4.3. Data Analysis.* The multiple regression function is

$$E(y) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_k x_k. \quad (1)$$

It can be seen from formula (1) that the value of the dependent variable in the model is composed of the linear function of the independent variable and the random variable of the error term, and the model parameters determine the specific form of the linear relationship between the dependent variable and the independent variable. The key point of using multiple regression analysis is to determine the specific values of the model parameters, then determine the specific form of the multiple linear regression model, and analyze the results according to the results. It is the mean or expected value and zero, and obeys the normal distribution, and it is independent.

The least-squares method is used to obtain the estimator of the regression coefficient, and the normal equation is as follows:

$$\begin{aligned}
&\widehat{\beta}_0 n + \widehat{\beta}_1 \sum_{i=1}^{n} x_{i1} + \cdots + \widehat{\beta}_k \sum_{i=1}^{n} x_{ik} = \sum_{i=1}^{n} y_i,\\
&\widehat{\beta}_0 \sum_{i=1}^{n} x_{i1} + \widehat{\beta}_1 \sum_{i=1}^{n} x_{i1}^2 + \cdots + \widehat{\beta}_k \sum_{i=1}^{n} x_{i1}x_{ik} = \sum_{i=1}^{n} x_{i1} y_i,\\
&\widehat{\beta}_0 \sum_{i=1}^{n} x_{ik} + \widehat{\beta}_1 \sum_{i=1}^{n} x_{ik}x_{i1} + \cdots + \widehat{\beta}_k \sum_{i=1}^{n} x_{ik}^2 = \sum_{i=1}^{n} x_{ik} y_i,
\end{aligned} \tag{2}$$

The dependent variable is the total static investment of the project, and the independent variables are the storage capacity, the irrigation surface, and the dam height. With the help of SPSS software, the estimated quantities of the regression coefficients are: $\widehat{\beta}_0 = 51281.672$, $\widehat{\beta}_1 = 10.797$, $\widehat{\beta}_3 = 1420.701$, $\widehat{\beta}_4 = -315.564$.

So the empirical regression equation between static total investment and storage capacity, irrigation surface, and dam height is: $y' = 51281.672 + 10.797x_1 + 1420.701x_1 - 315.564x_3$.

Where $y'$ means Static total investment (ten thousand yuan), $x_1$ means Reservoir storage capacity (ten thousand $m^3$), $x_2$ *means* Irrigated area (ten thousand mu), and $x_3$ means reservoir dam height ($m$).

The accuracy of the estimation depends on how well the regression equation fits the sample data. Usually, the multiple determination coefficient $R^2$ is used to evaluate the goodness of fit of the empirical equation of the multiple regression model. In order to avoid increasing the independent variable and overestimating $R^2$, this study adopts the modified multiple determination coefficient, and its calculation formula is

$$\left(R^2 = 1 - \frac{n-1}{n-k-1}\right)\left(1 - R^2\right), \tag{3}$$

where $R^2$ means modified multiple determination coefficient, $n$ means sample size, and $k$ means the number of parameters in the model.

The regression coefficient of determination is $R^2 = 0.948$ and modified multiple determination coefficient is $R^2 = 0.936$, which show that the goodness of fit of the empirical equation of the multiple linear regression model is good. The histograms and standard P-P plots of regression standardized residuals are shown in Figures 3 and 4, respectively.

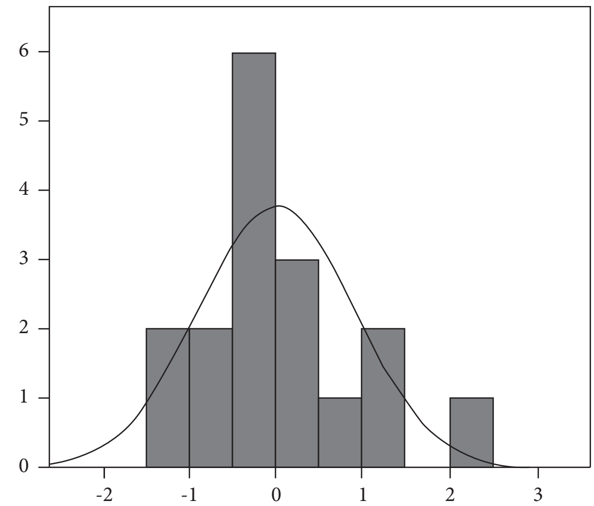


Figure 3: Histogram of regression standardized residuals.

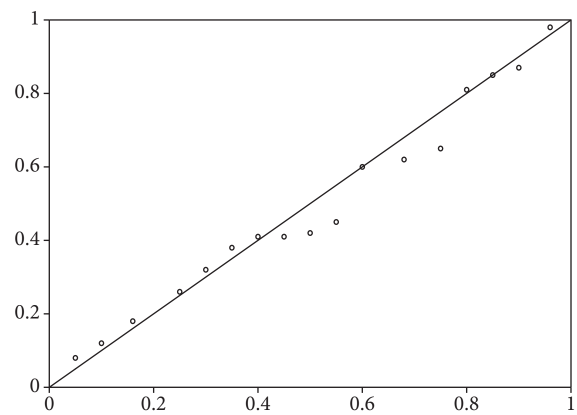


Figure 4: Standard P-P plot of regression standardized residuals.

Figure 5: Logo of SPSS.

*4.4. SPSS Software Application Analysis.* Using SPSS software (Figure 5) analysis, the following can be obtained (Tables 1, 2, 3).

The data used in this study is tested by multiple regression estimation models, and through the multiple regression analyses of SPSS software, the regression equation is summarized as $Y = -587.209 + 0.115 + 103.464$.

Table 1: Table data obtained after multiple regression analysis.

| Model | R | R Part | Adjusted $R$ squared | Errors in standard estimates |
|---|---|---|---|---|
| 1 | 0.976[a] | 0.953 | 0.947 | 388.04391 |
| 2 | 0.987[b] | 0.975 | 0.967 | 304.74013 |

Note: a. Predictor variables: (constant), total floor area; b. Predictor variables: (constant), total floor area, number of floors; c. Dependent variable: total project cost. At this time, the = 0.967 obtained by the regression analysis is relatively close to 1, so the reliability of this regression model is considered acceptable.

Table 2: Excluded variables.

| | Model | Enter beta | $t$ | Significant | Partial correlation | Collinear statistical tolerance |
|---|---|---|---|---|---|---|
| 1 | Construction layer | 0.472b | 2.444 | 0.045 | 0.678 | 0.097 |
| | Building height | 0.298b | 1.849 | 0.107 | 0.573 | 0.174 |
| | Time limit for a project | −0.478b | −0.879 | 0.408 | −0.315 | 0.020 |
| 2 | Building height | −0.592c | −1.113 | 0.308 | −0.414 | 0.012 |
| | Time limit for a project | −0.217c | −0.467 | 0.657 | −0.187 | 0.019 |

Note: a. Dependent variable: total project cost; b. Predictors in the model: (constant), gross floor area; c. Predictors in the model: (constant), gross floor area, The number of building floors thus obtain a regression equation: $Y = -587.209 + 0.115 + 103.464$.

Table 3: Coefficients.

| | Model | Unnormalized coefficient | | Normalization coefficient | $t$ | Significant |
|---|---|---|---|---|---|---|
| | | B | Standard error | Beta | | |
| 1 | (Constant) | 96.677 | 300.262 | | 0.322 | 0.756 |
| | Gross floor area | 0.213 | 0.017 | 0.976 | 12.730 | 0.000 |
| 2 | (Constant) | −587.209 | 365.957 | | −1.605 | 0.153 |
| | Gross floor area | 0.115 | 0.042 | 0.528 | 2.732 | 0.029 |
| | Construction layer | 103.464 | 42.339 | 0.472 | 2.444 | 0.045 |

The meaning of this equation is that the total cost of recent engineering projects is greatly affected by the total construction area of the project and the number of building layers.

## 5. Conclusion

The cost control and management of water conservancy projects should run through the whole process, including engineering decision-making, design, construction, completion settlement, and other stages. Among them, cost control in the engineering design and construction stages is particularly important. In the design stage, the project quality and cost should be used as reference standards to design the optimal water conservancy project plan. The technical and economic demonstration and comparison are an important part of the project evaluation and selection in the feasibility study stage. In this study, the key contents considered in the design of the slope reinforcement scheme are analyzed in detail, and the multiple linear regression is carried out on the important parameter samples that affect the cost. After comparing with the real cost, the model accuracy meets the estimation requirements, and each parameter is easy to obtain in the feasibility study stage, and the model is easy to use. Therefore, this model has strong applicability to the economic comparison and selection of slope reinforcement schemes in the feasibility study stage.

## Data Availability

The dataset can be accessed upon request.

## Conflicts of Interest

The author declares that there are no conflicts of interest.

## Acknowledgments

The authors thank Basic Scientific Research Funds Provincial and Ministerial Level Cultivation Projects; Research on water conservancy Project cost Management Technology System based on the view of the whole life cycle (No. FRF22PY001).

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