Journal of Civil Engineering and Urban Planning (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jceup.2024.060310
ISSN 2616-3969 Vol. 6 Num. 3

Comprehensive evaluation of construction quality of house building projects

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Keywords: Housing construction engineering, construction quality, influencing factors, hierarchical analysis, fuzzy comprehensive evaluation

Abstract: Since China's reform and opening up, rapid economic growth has driven large-scale housing construction across the country. However, this boom has also exposed numerous quality issues, such as the Beijing West Railway Station accident and incidents like "tilted buildings" and "crumbling buildings." These problems pose significant risks to public safety and result in substantial waste of resources and economic losses. In 2014, national real estate investment reached 9.5 trillion yuan, with a year-on-year growth of 9.90%, and housing construction covered 7.265 billion square meters, growing by 9.20%. Given the scale of these projects, ensuring that new housing meets national quality standards is essential. This study examines the construction quality of housing projects, identifying key factors through extensive literature review and constructing a recursive structural model. Using real-world engineering cases, it employs a fuzzy evaluation method based on hierarchical analysis to assess and quantify project quality, determining the overall quality grade. Unlike traditional methods that evaluate quality after completion, this approach allows for ongoing assessment during construction, identifying key factors affecting quality and enabling timely control and preventive measures. This proactive approach can reduce rework and ensure that projects meet national standards and contractual requirements, offering valuable insights for industry professionals and scholars.

1. Introduction

Since the reform and opening up, China's economy has been developing continuously and rapidly. In 2014, the gross national product was 63.64 trillion yuan, an increase of 7.40% year-on-year, of which the total output value of the construction industry was 17.67 trillion yuan, an increase of 10.20% year-on-year, accounting for 27.77% of the total value of the GDP.In 2013, the national area of construction of buildings was 12.5 billion square meters, an increase of 10.40% year-on-year[1] . It can be seen that the construction industry, as an important component of China's secondary industry, has a powerful role in promoting the development of economic construction. However, at the same time of the large-scale development of the construction industry, the accompanying construction quality problems are also endless. Frequent quality problems in the construction of housing projects will not only affect the construction period, waste of funds, but also threaten the personal safety of engineering staff. After the completion of the house as residents living, working and entertainment

places, its quality will directly affect people's life comfort and safety of life and property. In recent years, the quality of China's housing construction projects have become increasingly prominent, therefore, to improve the construction quality of China's housing construction projects, to ensure that the completed housing in line with national quality standards has been imminent[1-5].

Housing and building construction quality problems have always been the oldest problem in China's construction industry, frequent construction quality problems not only affect the construction schedule, but also cause casualties and huge property losses. Every death in the construction industry, on average, directly for the loss of personnel more than 200,000 yuan, the indirect loss is 4 times to 50 times the direct loss[3] . Therefore, in the face of the tragic reality that the frequent occurrence of quality problems in China's construction projects causes a large number of innocent casualties and property losses, it is necessary to strengthen the quality management of construction projects, effectively improve the quality level of newly built houses, so that the public can live in a safe, suitable and durable house. The study takes the construction quality of housing and building projects as the core, analyzes and determines the quality influencing factors prevailing in the construction of housing and building projects on the basis of summarizing the research of domestic and foreign experts and scholars on the influencing factors of housing and building project construction and analyzes the relevant characteristics of the influencing factors as well as the influencing paths. Based on this approach, combined with actual project cases, hierarchical analysis and fuzzy comprehensive evaluation are utilized to conduct a thorough assessment of the construction quality of housing and building projects. This process quantifies the project's construction quality score, enabling project management personnel to identify the root causes of quality issues and enhance the level of quality management. Consequently, this provides a valuable reference for improving the overall quality of construction projects.

2. Background to the study

2.1 Literature review

Most of the researches of foreign experts and scholars focus on the theory of quality problem causation, and also put forward many very famous research theories, including system theory, chain reaction theory, single-factor theory, etc., and emphasize the mutual influence of quality influencing factors.

Frank Bird's chain theory of management errors and Heinrich's chain theory of accident causation both suggest that quality problems are not caused by a single factor, but rather by a series of interconnected factors, with a causal relationship existing between them.Trokzynski, a scholar at Columbia University in Canada, put forward the concept of "quality chain" in 1996, arguing that the quality of the formation of products in the production process, the production process of many factors interact with each other and synergistically affect the quality of the project. Later experts and scholars have done some research on the quality chain, and most of the research also emphasizes the important influence of the main body of the construction on the quality of the project, especially the main body of the construction of the quality of the poorer party.Tam believes that the quality of the project affects a large number of factors, both the main factors, and also the secondary factors. The main factors should be the core of the main body to carry out quality control work. The most important factors include two aspects: the first is the quality input and management team experience; the second is the quality consciousness of workers. He also pointed out that the direct root of these two influencing factors is in fact the embodiment of culture in the process of engineering construction of various management personnel, the workforce, etc. Therefore, for construction enterprises to achieve their established quality goals, the first step is to deeply embed the quality management system into the organizational culture of the enterprise[6-10].

Some experts and scholars believe that the human factor in the quality management of housing construction projects is crucial to the impact of construction quality, and the management of people should be strengthened.RosertP.Elhott believes that, in order to ensure that the quality of the project meets the specific requirements, first of all, we should pay attention to the management of people and the whole construction process. Since then, the factors of project participants in project quality control have gradually been emphasized. HaroldKerzner emphasizes the importance of project quality management supervision, and believes that the quality management system should be continuously improved and developed, and to ensure the sustainable development of quality management, it is necessary to pay attention to the relevant personnel, and strengthen the training of personnel. Jim Emzen and Tom Feeney emphasize the critical role that construction contractors play in project quality control, suggesting that quality control should be primarily driven by the contractors[11]. At the same time, real estate companies can give contractors a certain economic incentives to improve the contractor to carry out quality control, improve the quality of the project power.

2.2 Review of domestic and international research

At present, domestic experts and scholars on the quality of housing construction project construction factors vary, some believe that the human factor, while some believe that the environmental factors, and some experts and scholars focus on the formation of engineering quality process, that the quality of the project is closely related to the design, construction, completion and acceptance of the project and other stages. Liu Yingxin and Li Qingli published in 2007 in his work on quality research proposed "4M1E" factors are recognized by more domestic experts and scholars of quality impact factors. Throughout the research on the factors affecting the quality of construction projects abroad, foreign experts and scholars generally believe that in the management of construction projects, the formation of quality is the result of the joint role of multiple participants, the influence of a variety of complex factors, in which the human factor is the decisive factor of influence, and most of the research focuses on the main body of the project to participate in the construction of engineering and construction as well as research on the cause and effect relationship between the factors affecting the study. Summarizing the views of experts and scholars at home and abroad, we find that although there are a large number of domestic and foreign studies on the factors affecting the quality of construction projects, but the research on the quality of the factors affecting the discussion of its focus, the angle perspective is not exactly the same, so the definition of the factors affecting the quality of the definition of the factors did not form a completely unified opinion. Regarding the evaluation of engineering quality, foreign research is based on the idea of continuous improvement, puts forward the concept of "benchmarking", and analyzes the implementation steps of "benchmarking" to provide a scientific and effective reference method for enterprises to implement quality management. Domestic scholars focus on quality evaluation methods, and put forward many effective quality evaluation methods, such as fuzzy evaluation method, hierarchical analysis[12]. However, the implementation of quality evaluation is more in the stage of project completion and acceptance, this post-evaluation of quality management obviously can't solve the quality problems in the construction process of building engineering from the source.

3. Housing construction engineering construction quality impact factors to determine and analyze

Housing construction project construction quality influencing factors are intricate and complex, the author based on literature research, in through a large number of related literature on the basis of research, screening, determining the housing construction project construction quality of the main influencing factors, and to determine the influence of factors related to analysis.

3.1 Principles of influencing factor screening based on literature studies

In the pursuit of excellence in housing construction quality, our goal is not only to evaluate and quantify the level of quality of the project, but also to identify and manage those critical quality influences. Through early insight and intervention, we aim to prevent quality problems from occurring and ultimately achieve continuous improvement in construction quality[13]. Given the large number of influencing factors and their different roles, the screening process needs to be guided by the following three main principles:

A. Principle of comprehensiveness

The principle of comprehensiveness emphasizes that all potential areas should be covered as far as possible when screening for influencing factors. Excellence in engineering quality cannot be achieved without careful consideration of every possible point of influence. Although the intensity of the influencing factors varies, every little oversight can be the seed of future potential problems. Therefore, we should adopt a "quality first" attitude to ensure that the screening process is flawless and that all potential impacts are fully captured.

B. Principle of universality

The principle of universality requires that the selected influencing factors be widely recognized both within and outside the industry. This not only means that these factors have a non-negligible impact on engineering quality in theory, but also requires that they are widely accepted and confirmed in practice. Only those time-tested factors that are generally recognized by experts and scholars can ensure the reliability and practicality of the screening results. Excluding those factors that may have an impact but have not yet gained consensus in the industry helps us to focus on the areas that are truly critical.

C. Principle of effectiveness

The principle of effectiveness, on the other hand, focuses on ensuring that the selected influencing factors have a substantial impact on the quality of the work. Neglecting any of the effective influencing factors may cause irreversible damage to the final quality of the project. For example, the importance of quality control of construction materials cannot be overstated, and any neglect of the quality of the materials could have disastrous consequences. Therefore, we need to make sure that every factor taken into account is directly related to the quality of the project and has a direct and significant impact on the final outcome of the project.

Following the above principles, we can more accurately screen out those influencing factors that play a decisive role in the quality of housing construction, provide a solid foundation for quality control, and then promote the whole industry toward higher quality standards.

3.2 Identification and analysis of influencing factors

The main purpose of this section is to determine the set of influencing factors on the quality of the construction of housing and building projects and to discuss them. Such as whether the influencing factors have certain intrinsic relationship with each other, the magnitude of their influence on the quality of the project and what is the path of the influence of each influencing factor on the quality, the following are some of the author's thoughts on these issues.

3.2.1 Statistical influences

A. Supervisory units and construction quality supervision

The role of the supervisory unit as the core supervisory force in the construction process of housing buildings should not be underestimated. The professional supervision of the supervisory personnel plays a decisive role in guaranteeing the construction quality. Through their due diligence, they

strictly monitor each construction link to ensure that the project is carried out in accordance with the design drawings and specification requirements, thus effectively enhancing the reliability and stability of construction quality.

B. Importance of construction drawings and designers

Construction drawings as the implementation of the project "blueprint", its quality is directly related to the success or failure of the project. The design level of designers directly affects the quality of drawings, which in turn determines the final quality of the project. Wrong structural design will not only lead to quality accidents, but may even jeopardize the safety of the building. Ensuring the accuracy and professionalism of drawing design is the key to guarantee the quality of housing construction.

C. Role of the constructor and the construction crew

The construction unit plays a central role in the construction of housing buildings and is responsible for the organization and arrangement of manpower, materials and machinery on site. As the direct manager on site, the construction personnel's on-site management ability directly affects the construction quality of each building. Efficient cooperation and professional management between the construction unit and the construction personnel are essential to improve the overall quality of the project.

D. The Role of Real Estate Developers and Project Managers

As the command center of project construction, real estate developers play a key role in supervising construction quality and organizing and coordinating all parties involved in the construction. They not only ensure that the quality of the project meets the standards, but also promote the optimal allocation of resources of all parties to ensure the smooth implementation of the project, which has an important impact on the control of construction quality.

E. Government Departments and Quality Regulation

As the authoritative force for project supervision, government departments assume the important responsibility of construction process supervision and final acceptance. Regular and irregular quality sampling inspections by government personnel play a crucial role in ensuring that the project complies with national laws and regulations and quality standards. Their professional supervision effectively guarantees the construction quality and safety of housing buildings.

F. Survey units and geological surveys

The geological survey work of the survey unit provides basic data for engineering design and construction. The accuracy of the geological survey report directly affects the stability of the foundation and the safety of the house building. The professional skills of the surveyor and the completeness of the report are important guarantees to ensure the quality and safety of engineering construction.

G. Duties of testing organizations and testing personnel

The inspectors strictly test the quality of construction materials and completed projects during the construction process, and the inspection reports issued by them directly reflect the objective status of project quality. The professionalism of the inspectors and the accuracy of the inspection report have an important impact on the assessment and improvement of the overall quality of the project[14-16].

In summary, the construction quality of housing buildings is affected by many factors, from supervision units, design and construction units, to government departments, survey and testing organizations, and bidding agencies, each of which plays an indispensable role. Ensuring the professionalism, sense of responsibility and cooperation spirit of all parties involved is fundamental to improving the quality of housing construction and guaranteeing the safety and success of the project.

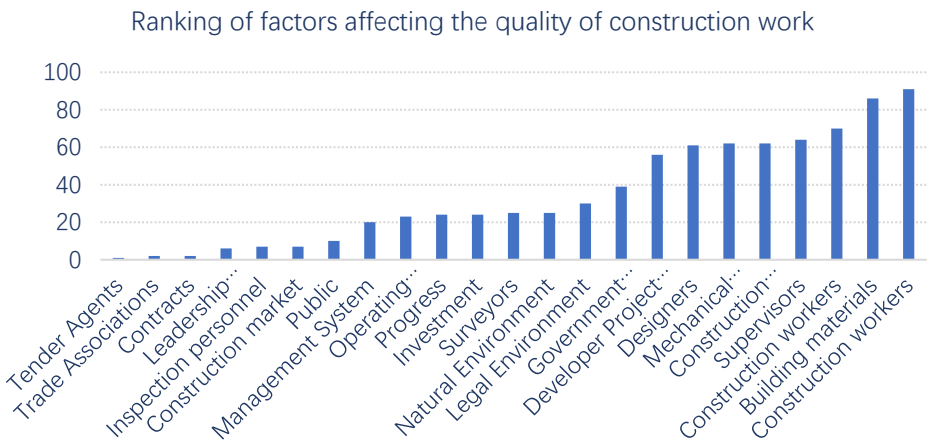

Figure 1: Ranking of factors affecting the quality of construction work

As shown in Figure 1, there is no complete consensus among experts and scholars regarding the influencing factors of construction quality in housing and building projects. To identify the main factors affecting construction quality, it is necessary to screen the 23 identified factors. Since each factor is mentioned between a maximum of M=109 times and a minimum of once, the screening process will exclude factors that have been mentioned less than 20% of the time *(M)*. The remaining influencing factors are the main influencing factors on the quality of construction of housing and building projects identified in the study and are divided according to the category of each factor and the main influencing factors are drawn as shown in Table 1.

Tables1: Influencing Factors

Factor classification	factor	Factor classification	factor
The human factor	inspector	environmental factor	operating environment
	surveyors		environment
	government employee		Legal environment
	Developer project staff	Material factors	building material
	designer		machinery and equipment
	supervisor	Other factors	investors
	construction personnel		tempo

According to the classification results, the total number of times the major categories of factors were mentioned were counted and summarized, and Figure 2 was drawn, from which it can be seen that the human factor was mentioned far more often than the other three categories of factors, accounting for 55%, which also indicates that most experts and scholars believe that the human factor has an important role in the quality of the construction of housing and building projects.

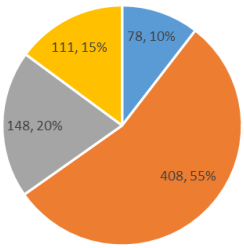

Figure 2: Percentage of each factor

4. Evaluation system construction

Focusing on the application of hierarchical analysis in the comprehensive evaluation of the construction quality of housing construction projects, firstly, we constructed a model of the construction quality influence factors of housing construction projects, based on which, we determined the judgment matrix between the factors at each level in the model, and further determined the weight values of the factors in the judgment matrix, and then verified the authenticity of the weight values by checking the consistency of the judgment matrix, so that we could draw a weight table of the factors influencing the quality of the construction projects of housing construction.

4.1 Plotting the recursive structural model

After determining the indicators of factors affecting the quality of housing construction, the prerequisite for a comprehensive evaluation of the quality of housing construction is the construction of a hierarchical structural model of the factors affecting it. The establishment of the model allows the problem to be analyzed to be decomposed into a variety of different constituent factors, which belong to different levels according to their interrelationships and their own attributes, and the factors at the next level are part of the factors at the previous level. The recursive structural model constructed by applying AHP can generally be divided into three levels. First, at the goal level, there is a single factor: the envisioned results or expected outcomes of the problem being analyzed. Second, at the guideline level, this includes the intermediate steps required to achieve the goal, which may consist of one or multiple levels. Third, at the program level, this refers to the various measures implemented to achieve the goal.Constructing a reasonable hierarchical structure is very important for problem solving. The number of levels is often unlimited, but the more levels there are, the more complicated the analysis process becomes. In order to facilitate the comparison of the interrelationships of the sub-elements under the domination of the same element, in general, the sub-elements contained in each element in each level should not exceed nine as far as possible.

According to Table 1 draw the recursive structural model of the construction quality of housing projects, as shown in Figure 3

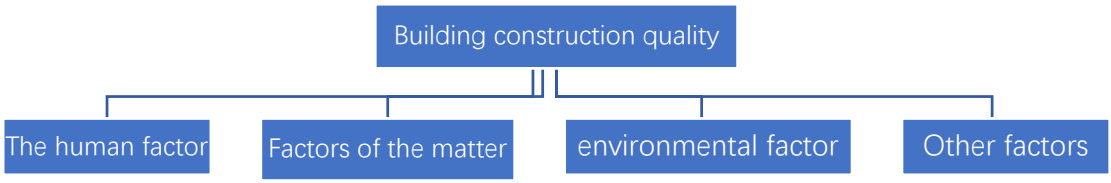

Figure 3: Factor classification

4.2 Determine the judgment matrix

The establishment of the recursive structure determines the affiliation between the factors, and the next step is to determine the impact weight of each factor at each level on the goal. The traditional methods of determining the weights are subjective judgments by the judges, and the judgment results vary from person to person and are not persuasive. AHP, on the other hand, puts forward the concept of judgment matrix, using the judgment matrix given by the judge to analyze it, so as to determine the weights, which to a certain extent improves the accuracy when determining the weights. Assuming that a certain criterion level is B, it contains the elements of the next level as$C_1, C_2, C_3, \ldots, C_n$. Then for criterion B, the judgmentalist needs to compareC_i andC_j which is more important and to what degree, and assign values to the degree of importance according to the scale defined in Table 2, thus forming a judgment matrix$A = (Aij)_{n\times n}$, also known as the positive and negative judgment matrices, wherea_{ij} are the elementsC_i andC_j scale of importance relative to criterion B[17-18].

The judgment matrix A formed has the following characteristics: i,$a_{ij} > 0$; ii,$a_{ij} = 1/a_{ji}$; iii,$a_{ii} = 1$. Based on the positive and negative characteristics of the judgment matrix, for a matrix composed of N elements, knowing either the upper or lower triangle—comprising $n(n-1)/2$ elements—is sufficient to derive the entire judgment matrix.

Tables 2: Judgment Matrix

proportionality scale	hidden meaning
1	Two elements have the same importance compared to
3	The former is slightly more important than the latter when comparing the two elements
5	When comparing the two elements, the former is significantly more important than the latter
7	The former is more strongly important than the latter when comparing the two elements
9	The former is extremely more important than the latter when comparing the two elements
2,4,6,8	denotes the intermediate value of the above neighboring judgments
1/K. K=1,..,9	If the elementX_i The relative importance ratio of the elementX_j the relative importance ratio ofa_{ij} , then the elementX_j The relative importance ratio of the element to the elementX_i The relative importance ratio of$a_{ij} = 1/a_{ji}$

As can be seen from Table 2, in order to determine the influence weights of each component factor in the progressive structure model of housing construction quality, it is necessary to construct the judgment matrices of all the factors under the model first. The author communicates with 3 project managers with rich engineering experience and 1 teacher in school, and they assign values to each judgment matrix, the assignment results are shown in Appendix E. For the same judgment matrix with the same factor of 4 assignments, remove the maximum value, minimum value, take the average of the remaining 2 values, according to the average of the difference between the corresponding proportionality scale and the principle of the smallest value of the proportionality scale, so as to determine the final judgment matrix. Thus, each judgment matrix is finally determined.

A recursive structural model of the factors influencing the quality of housing construction projects was previously constructed, and the corresponding judgment matrix was determined. Through mathematical operations on the judgment matrix, the index weights of the factors were established

and their consistency was verified. The weights of the factors influencing the quality of housing construction projects are presented in the Table 3:

Table 3: Weights of influencing factors

Level 1 indicators	weights	Secondary indicators	weights	Tertiary indicators	weights
The human factor	0.499	construction personnel	0.234	management level	0.429
				technical level	0.429
				professional ethics	0.142
		supervisor	0.049	management level	0.429
				technical level	0.429
				professional ethics	0.142
		Developer project staff	0.083	management level	0.429
				technical level	0.429
				professional ethics	0.142
		designer	0.234	technical level	0.5
				professional ethics	0.45
		surveyors	0.234	technical level	0.5
				professional ethics	0.5
		government employee	0.083	regulatory efforts	0.74
				professional ethics	0.094
				technical level	0.166
		construction worker	0.083	technical level	0.593
				professional ethics	0.277
				physical quality (in ideological education)	0.072
				educational level	0.058
Factors of the matter	0.167	building material	0.5	/	/
		machinery and equipment	0.5	/	/
environmental factor	0.167	Legal environment	0.429	/	/
		environment	0.142	/	/
		operating environment	0.429	/	/
Other factors	0.167	Construction method	0.6	/	/
		investors	0.2	/	/
		tempo	0.2	/	/

5. Conclusion

5.1 Summary

The subject of the research is the comprehensive evaluation of the construction quality of housing construction projects, although there have been a large number of studies on the quality of housing construction projects at home and abroad, and some experts and scholars have analyzed the factors affecting the quality of the project and its evaluation. However, regarding the quality influencing factors, the experts and scholars in the industry have their own opinions and have not formed a completely unified opinion so far. This study is based on literature research, based on statistics, summarization and analysis of a large number of experts and scholars in the field of related research, screening and determining the main factors affecting the construction quality of housing and building projects, so that the quality of the main factors identified by the study has a certain degree of universality. With regard to the evaluation of the quality of housing construction projects, most of the current research is focused on the quality evaluation of the housing completion and acceptance process, and the evaluation results are only used to determine whether the new housing meets the acceptance conditions, which is an ex post facto control method in quality management. This study is based on the quality control in the construction process of housing construction projects, through the comprehensive evaluation of the quality of the project under construction, to determine the quality status of the project, so as to find out the direct and fundamental factors affecting the quality of the project, and then formulate corresponding quality improvement measures to improve the quality of the project, to ensure that the project quality objectives are successfully achieved to provide a certain basis. Finally, the feasibility, rationality and effectiveness of the selected indexes and evaluation methods are verified by combining with actual cases.

The main findings of this paper are obtained as follows:

A. There are numerous factors influencing the construction quality of housing construction projects, some of which are major influencing factors and some of which are minor factors. The screening of influencing factors and the finalization of major factors in the study are based on a large amount of relevant literature, which to a certain extent ensures the comprehensiveness of the selected major influencing factors, and the selected factors can provide certain references for people in the industry.

B. The ultimate goal of engineering quality evaluation should be to serve the quality management, the research proposed comprehensive evaluation of the construction quality of housing construction projects is a pre-quality control methods, before the construction of a sub-part of the project, through a comprehensive evaluation of its construction quality, quantitative quality score, so as to determine its quality level, and to find out the impact of the quality of the construction of a certain stage of the direct and fundamental factors, and then in a certain procedure to carry out the construction quality of the construction quality of the project. Before implementing measures to control the direct factors, it is essential to ensure that the quality of subsequent construction meets the expected standards. Additionally, summarizing the lessons learned will provide valuable insights for the long-term development of the enterprise and serve as a reference for future projects.

C. The quality influencing factors at each stage of the construction process are not fixed, and the degree of their influence on quality is constantly evolving and changing with the passage of time, so the comprehensive evaluation of the quality of the construction of housing and building projects proposed by the study should also be carried out throughout the entire process of construction, combined with the need for the project to carry out multiple evaluations and make continuous improvements

5.2 Shortcomings and prospects

The study utilizes the hierarchical analysis method and fuzzy evaluation method in the comprehensive evaluation of the quality of housing construction projects, and this combination method can play an important role in the comprehensive judgment of the quality grade of housing construction projects through the combination of qualitative analysis and quantitative analysis, but there are also shortcomings. Although the judgment matrix between the influencing factors is successfully constructed through the hierarchical analysis method, it is still based on the expert's empirical judgment when determining the mutual importance of the quality influencing factors, and the determination of the final quality grade is also based on the weight value of the influencing factors in the previous period, and the different weight value of the influencing factors will directly affect the assessment of the engineering quality grade. Therefore, this leads to the human subjective experience will indirectly affect the results of quality evaluation. However, since there is a test link for the interrelationships determined by the experts when applying the hierarchical analysis method, and when the consistency test does not meet the requirements, the weight values are to be re-determined, therefore, this also reduces the degree of human influence. In order to minimize the influence of human subjective judgment on the results of quality evaluation, the study selects the questionnaire respondents as much as possible when choosing the relevant personnel with strong professionalism, and then carries out in-depth communication and exchange.

The study is mainly centered on the quality of housing construction project construction, and as we all know, standing in the real estate development enterprise's point of view, the goal of engineering project management is not only the quality goal, but also includes the progress goal, the investment goal, the safety goal, etc., of which the quality, the progress and the investment are the three major eternal goals of the engineering project management, so in the follow-up study, the author hopes to be able to use this as a starting point to Explore the housing construction project construction progress and investment, find a suitable method of housing construction project construction progress, construction cost impact factors for comprehensive evaluation. This will provide valuable reference information for industry professionals involved in the project management of housing construction projects.

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