applied sciences

MDPI

Article

Evaluation of Hidden Cost Risk of Prefabricated Construction Based on SEM-MEECM

Jiehui Zhang [1], Wei Wei [1], Leyan Chen [2] and Zehao Jiang [2,*]

[1] School of Management, Fujian University of Technology, Fuzhou 350117, China; zhangjiehui@fjut.edu.cn (J.Z.); 2211706013@mail.fjut.edu.cn (W.W.)
[2] School of Civil and Hydraulic Engineering, Huazhong University of Science and Technology, Wuhan 430074, China; 1904090203@hhu.edu.cn
* Correspondence: jiangzehao@hust.edu.cn

Abstract: Prefabricated construction offers numerous advantages, such as high efficiency and energy efficiency. However, its promotion is impeded by the significant associated costs. Thus, the primary objective of this study is to investigate the overall life-cycle costs of prefabricated construction, with a specific focus on hidden costs. To achieve this objective, the study establishes a comprehensive evaluation index system comprising 31 factors that facilitate the assessment of hidden cost risks at each stage of the construction's life cycle. In order to effectively evaluate these risks, the study proposes a novel evaluation method that combines the structural equation model (SEM) with the matter–element extension cloud model (MEECM). Subsequently, the proposed model is applied to an actual case of prefabricated construction projects. The findings prove valuable in managing the hidden cost risks associated with prefabricated construction and offer effective means for evaluating such risks. The stage considered in this paper is more comprehensive than that of previous studies, and a quantitative analysis of the hidden cost risk index is constructed and a SEM–MEECM evaluation model is established. Based on the model presented in this paper, future research can further enhance the hidden cost risk index and explore suitable quantitative indicators to facilitate cost risk control in prefabricated construction projects, thus promoting the widespread adoption of prefabricated construction in developing countries.

Keywords: cost management; hidden cost risk; life cycle; matter–element extension cloud model (MEECM); prefabricated construction; structural equation model (SEM)

Citation: Zhang, J.; Wei, W.; Chen, L.; Jiang, Z. Evaluation of Hidden Cost Risk of Prefabricated Construction Based on SEM-MEECM. *Appl. Sci.* **2023**, *13*, 7902. https://doi.org/10.3390/app13137902

Academic Editor: Young Hoon Kim

Received: 22 April 2023
Revised: 20 June 2023
Accepted: 2 July 2023
Published: 5 July 2023

1. Introduction

Prefabricated construction is a relatively new building mode that differs from traditional building practices. It has the potential to save materials [1], reduce energy consumption [2,3], shorten construction periods, and enhance construction environment and quality. Despite its rapid development in China, its market share remains low due to high construction costs [4]. The cost of prefabricated construction is affected by many factors, and project cost management is always a complicated process. Therefore, how to effectively control prefabricated construction costs is a prerequisite for the development of prefabricated construction.

Prefabricated construction costs are classified into explicit and hidden costs. Explicit costs, which include labor, materials, equipment, and transportation, are expenses that are monetarily recorded during construction. However, there is no accurate definition of hidden costs. Standfield et al. (2002) believes that hidden costs can be divided into internal and external hidden costs, of which internal hidden costs refer to losses caused by low production efficiency [5]. Sellés et al. (2008) contend that the hidden cost of project delays is the loss of commercial possibilities and the reputation of construction firms [6]. Shao et al. (2012) divided the hidden cost of core brain drain in construction enterprises into the low-efficiency cost prior to the resignation of talents, the vacancy cost, the learning curve cost of newly introduced talents, etc. [7]. They defined the hidden cost of construction projects as the opportunity cost of the enterprise's own resources and the current project management mode. Hidden costs, in the context of project management, encompass the opportunity costs associated with achieving optimal production capacity through effective management practices. These practices include integrating design and production, selecting appropriate suppliers, and utilizing new technologies. In the realm of construction project cost management, hidden costs are embedded within the total project cost. Previous research on hidden costs has identified two main categories: enterprise opportunity costs resulting from outstanding production capacity and scientific and rational project management. Given that each stage of the prefabricated building project's life cycle impacts the overall cost, this study takes into account the entire life cycle of prefabricated construction, considering both enterprise and project management perspectives. The uncertain nature of hidden cost risks arises from environmental and management changes during actual projects. As hidden cost risks often affect subsequent stages, managers tend to pay close attention to cost risks reflected in financial statements. Therefore, identifying and controlling hidden cost risks can optimize project costs [8].

Several studies have explored the costs associated with prefabricated construction. Arif and Egbu (2010) demonstrated that worker training can reduce direct and indirect construction costs [9]. Chang and Zhang (2016) analyzed the cost of prefabricated construction across three stages: component design, production and transportation, and installation [10]. Rafaela et al. (2019) utilized Building Information Modeling (BIM) to optimize cost control throughout the entire life cycle of prefabricated construction [11]. Khalili and Chua (2013) identified installation, production, and transportation costs of prefabricated components as key factors contributing to the high costs of prefabricated construction [12]. Peng et al. (2021) employed the fuzzy interpretive structure model (FISM) and Bayesian network (BN) to investigate hidden costs in prefabricated construction, identifying key factors leading to hidden costs [13]. However, these studies are limited to specific stages, such as the design and construction phase. Moreover, there is a scarcity of research on hidden cost risks in prefabricated construction, and practical application remains challenging. Hidden cost risks are difficult to quantify, often prompting managers to take actions only when project costs spiral out of control. Controlling hidden cost risks throughout the project's entire life cycle is crucial for cost reduction and improved efficiency.

Therefore, the primary objective of this study is to establish an evaluation index system that identifies the influencing factors contributing to hidden cost risks at each stage of the construction process. This will be achieved by employing a structural equation model (SEM) to determine the weightage of these factors. Additionally, the matter–element extension cloud model (MEECM) will be utilized to evaluate and comprehensively assess the hidden cost risks associated with prefabricated construction. Previous studies on the cost of prefabricated construction have predominantly focused on the total project cost, leading to the application of the MEECM to address issues of fuzziness, randomness, and the conversion of qualitative concepts into quantitative values when evaluating indicators. The unique contribution of this research lies in the novel combination of the SEM and the MEECM, specifically applied in the field of hidden cost risk assessment. The index system will involve a substantial number of observation variables that require direct observation to elucidate the hidden variables. The SEM effectively addresses the determination of relationships among various indicators. Moreover, the MEECM not only accounts for the susceptibility of the index to subjective preferences but also resolves the challenges related to fuzziness, randomness, and the conversion of qualitative concepts into quantitative values during cost risk evaluation. As a result, the evaluation of hidden cost risks becomes more scientifically grounded and reasonable. Additionally, the model allows for reanalysis of the evaluation results and facilitates the implementation of targeted improvement measures based on the evaluation outcomes, ultimately reducing hidden cost risks. Finally, through the utilization of an actual prefabricated construction project as an example, the rationality of the proposed model is verified and appropriate strategies for identifying and controlling hidden cost risks are presented.

2. Literature Review and Hypothesis Development

The analysis of existing literature plays a crucial role in the development of hypotheses for any study. In this study, we identified seven stages of prefabricated construction projects, namely, investment and decision-making, design, production and transportation, construction, completion acceptance, operation and maintenance, and demolition and recycling. Several studies have been conducted to understand the impact of each stage on the hidden cost risk in prefabricated construction.

In the investment and decision-making stage, Hong and Shen (2018) analyzed the obstacles to the promotion of prefabricated construction in mainland China and concluded that the future focus is to provide policy-oriented financial support [14]. Li et al. (2020) quantitatively evaluated the investment risk factors in prefabricated construction and found that economy, technology, market, management, and policy had the highest impact on investment risk [15]. Yan et al. (2022) proposed an investment estimation model that helps with investment decision-making in prefabricated construction projects [16]. Based on these findings, the following hypothesis is proposed:

H1: *The investment and decision-making stage significantly impacts the hidden cost risk in prefabricated construction.*

In the design stage, Yan and Yong (2014) found that the reasonable splitting of prefabricated components greatly influenced the design cost [17]. Additionally, the support of relevant government departments, the perfection of design specifications and policies, and the choice of project mode by construction units directly affected the formulation of technical schemes and the determination of prefabrication rate, thus impacting the construction cost [18–20]. Based on these viewpoints, the following hypothesis is proposed:

H2: *The design stage significantly impacts the hidden cost risk in prefabricated construction.*

In the production and transportation stage, Tazikova and Strukova (2021) emphasized the impact of logistics on the cost of prefabricated construction [21]. Chang et al. (2016) discussed the cost risk factors in the transportation stage and constructed an optimization model of a transportation loading plan [22]. Demiralp et al. (2012) analyzed the cost savings brought by digital technologies to all parties [23]. Based on these findings, the following hypothesis is proposed:

H3: *The production and transportation stage significantly impacts the hidden cost risk in prefabricated construction.*

The construction stage is an important stage of the whole project in which many participants are involved and interact with each other [24]. Solving conflicts during the construction process is necessary to control the construction cost [25]. Therefore, the following hypothesis is made:

H4: *The construction stage significantly impacts the hidden cost risk in prefabricated construction.*

In the completion acceptance stage, Guo and Li (2022) used the entropy weight–TOPSIS method to construct an evaluation model for the strategic partner selection of prefabricated construction enterprises [26]. Luan et al. (2022) explored the impact of sustainable PC interface management performance from the perspective of stakeholders [27]. Quality problems during the completion acceptance stage will affect the goodwill of enterprises and further affect customer relationships. This leads to hidden costs such as the costs of customer relationship maintenance and redevelopment. Therefore, the following hypothesis is made:

H5: *The completion acceptance stage significantly impacts the hidden cost risk in prefabricated construction.*

In the operation and maintenance stage, Samani et al. (2018) pointed out that prefabricated construction has high maintenance costs [28]. Strengthening cost control during the operation and maintenance stage can benefit the overall project cost control, and it is necessary to maintain and upgrade the equipment and components of prefabricated construction. Therefore, the following hypothesis is proposed:

H6: *The operation and maintenance stage significantly impacts the hidden cost risk in prefabricated construction.*

In the demolition and recycling stage, Ruiz et al. (2020) provided the theoretical framework for a circular economy in the construction and demolition industries, thereby minimizing waste and environmental impact [29]. Vitale et al. (2017) investigated the potential impacts associated with the end-of-life stage of residential buildings [30]. Dosho (2007) suggested adopting a mature recycling system to reduce recycling costs and environmental impact [31]. Wang et al. (2020) concluded that the recovery rate of prefabricated construction was higher than that of traditional construction [32]. Purchase et al. (2022) believe that disassembly operations, hazardous material treatment, and material recovery processes are important to enhancing the ecological, economic, and social benefits of administrative facilities for the construction industry [33]. Therefore, the following hypothesis is proposed:

H7: *The demolition and recycling stage has a significant impact on the hidden cost risk in prefabricated construction.*

3. Research Methods

This study was conducted in three main phases (see Figure 1). First, relevant literature analysis and expert research was conducted to construct an evaluation index system for hidden cost risk in prefabricated construction. The index system was then fitted using SEM, and the weight of the index was determined based on the path coefficient. Finally, the evaluation model was constructed using the MEECM and applied to practical projects.

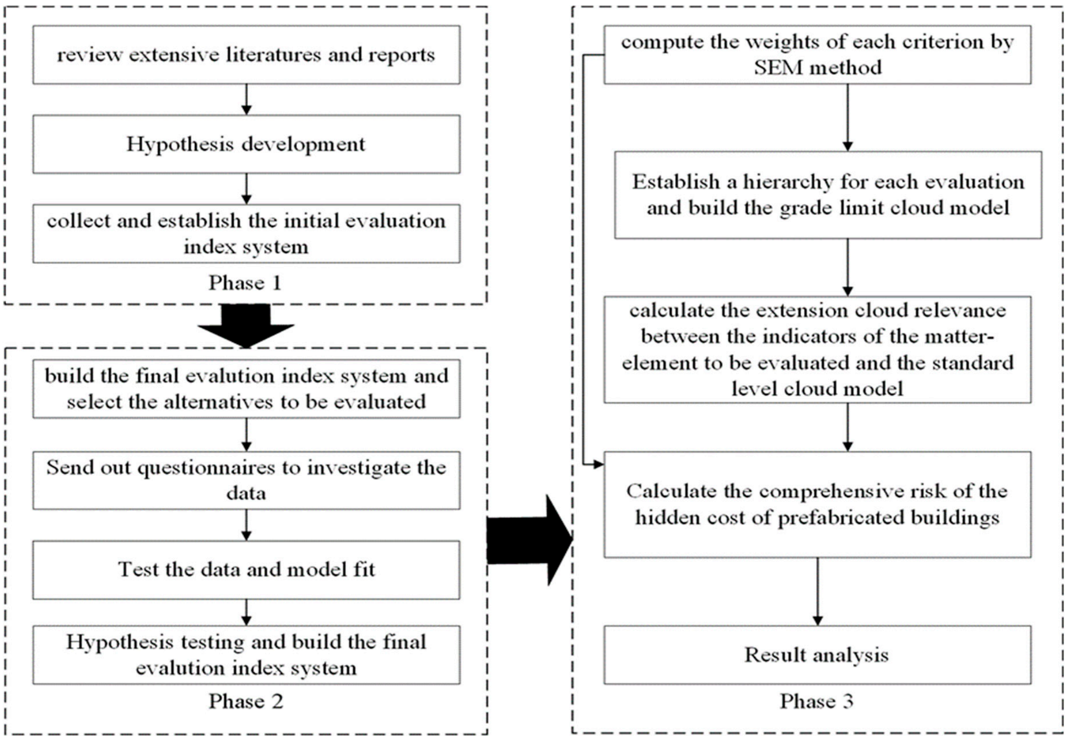

Figure 1. Overall research flow.

3.1. Development of Index System

In the development of the index system, relevant keywords such as “cost management,” “hidden cost,” and “prefabricated construction” were searched in databases such as Web of Science, Google Scholar, and CNKI. Based on the keyword search, 32 papers related to this research topic were obtained after screening, and 15 representative studies were selected, such as Standfield et al. (2002) [5], Selles et al. (2008) [6], Shao et al. (2012) [7], Hong et al. (2018) [14], Peng et al. (2021) [13], etc. Influencing factors of hidden costs at various stages of prefabricated construction were obtained. The resulting evaluation index system is presented in Table 1.

Table 1. Evaluation index system of hidden cost risk in prefabricated construction.

First-Order Index	Secondary Index	Index Interpretation
Investment decision stage ID	National construction standards and tax policies ID1	Non-compliance with national codes in a project can result in higher financial losses due to increased tax rates on prefabricated components compared to on-site construction. This shift in tax policy increases the cost risk for businesses.
	Reasonable selection of supplier ID2	The selection of suppliers without a rational and scientific examination can eventually increase the cost risk.
	Assembly project personalized and standardized decision ID3	The extent to which personalization and standardization are incorporated into prefabricated construction affects hidden cost risk.
	Degree of integration of design and production ID4	Insufficient integration between component design and production increases the cost risk.
	Project capital occupancy cost ID5	Borrowing funds incurs interest cost risk, whereas using own funds incurs opportunity cost risk.
	Project function analysis and area allocation ID6	Function analysis and area allocation facilitate scientific examination and objective demonstration of economic and technical factors.
Design phase DP	Standardization and integration of prefabricated components DP1	Modular integration of uniform components promotes universality and interchangeability, accelerates design time, enhances construction efficiency, and lowers cost risk.
	Design degree and rationality of prefabricated component splitting DP2	Unreasonable splitting of prefabricated parts can increase the difficulty of shipping and lifting, leading to potential production cost increases.
	Maturity of the design system DP3	The risk of component production cost depends on the building design and how secondary splitting of components is managed.
	Prefabrication rate and assembly rate DP4	Prefabrication rates impact cost growth in various ways. Higher prefabrication rates can speed up construction but also raise project cost risk.
	Cooperation efficiency of project participants DP5	Effective cooperation among project participants, correct information sharing, and prompt implementation can reduce cost risk.
	The degree of positive design using BIM technology DP6	BIM technology enables forward design and digital disclosure of quality and safety aspects throughout the project’s life cycle, ultimately leading to cost risk reduction.

Table 1. *Cont.*

First-Order Index	Secondary Index	Index Interpretation
Production and transportation stage PT	Turnover of production mold PT1	Low turnover of mold production increases hidden cost risk.
	Resource allocation efficiency PT2	Rational allocation of resources can improve production efficiency and reduce cost risk.
	Intelligent construction of new technology, new equipment application level PT3	Scientific and rational use of new equipment and technology improves quality and efficiency, reducing cost risk.
	Timeliness of prefabricated component supply PT4	Delayed supply of prefabricated components can paralyze the construction site, increasing the risk of hoisting equipment expenses, personnel costs, and other costs.
	Working efficiency and mechanical utilization rate of production personnel PT5	Low human and machine efficiency leads to increased cost risk.
	Location of component factory PT6	Unreasonable location of component factories increases transportation cost risk.
Construction and hoisting stage CS	Construction organization design and construction management scheme CS1	A scientific and reasonable construction group design and construction management system is crucial for successful project completion.
	Risk of fatigue and slow work CS2	Staff fatigue reduces production efficiency, resulting in less engineering being completed in the same amount of time and increasing the risk of final cost, idle labor costs, and material cost growth during idle labor.
	The technical level of the professionals CS3	The ability of professionals to optimize project construction impacts project cost risk.
	Application degree of information technology CS4	The level of application of BIM construction simulation and the perfection of a BIM collaborative management system affect cost risk.
	Mechanical efficiency of site lifting CS5	Site hoisting mechanical efficiency greatly affects the construction period, and improper operation increases hidden cost risk.
Completion acceptance phase PA	Cost of lost goodwill PA1	Goodwill loss cost includes brand image, enterprise integrity loss, social identity feeling, enterprise prospect loss, and qualification rating loss. This can increase hidden cost risk.
	Cost of damage to builder relationship PA2	The cost of damaged builder relationship includes reducing owner satisfaction, maintaining customer relationship, saving customers, and redeveloping customers. This can increase hidden cost risk.
Operation and maintenance phase OM	Application degree of intelligent operation and maintenance system OM1	The degree of application of intelligent operation and maintenance systems affects labor cost in the operation and maintenance stage, ultimately impacting overall cost.
	BIM and RFID technology application degree OM2	RFID tags and BIM databases can facilitate the timely and accurate installation of prefabricated components, analyze and detect building structure safety and durability, avoid structural damage, and remind stakeholders in a timely manner to prevent greater losses, ultimately reducing cost risk.

Table 1. *Cont.*

First-Order Index	Secondary Index	Index Interpretation
Demolition and recovery stage DR	Degree of environmental recovery difficulty DR1	Failure to address environmental problems and comply with regulations can result in penalties and increased cost risk.
	Recovery rate of prefabricated components DR2	High component recovery and regeneration rates ultimately lead to reduced cost risk.
	Site selection of recycling component factory DR4	The unreasonable location of the component recovery plant can increase cost risk.
	Remove simulation refinement and visualization degree DR3	A complete visual database improves the efficiency of the demolition recovery process. The high degree of simulation during demolition minimizes impact on the surrounding environment, reducing the risk of environmental restoration cost.

3.2. Questionnaire Design and Samples

To collect data for the study, a questionnaire was distributed both online and in the field to researchers, experts, and staff involved in various stages of prefabricated construction. The questionnaire comprised two parts, with the first part collecting basic information about the respondents and the second part using a five-level Likert scale to evaluate the hidden cost impact of each stage of prefabricated construction—for example, how important do you think national construction standards and tax policies (ID1) are to the hidden cost risk of ID in the investment decision stage of prefabricated construction? Before the questionnaire was sent out, the people to whom it was sent out were screened in advance, and those who had relevant work experience and were able to fill in the questionnaire carefully were selected, so the questionnaire data obtained were relatively complete. A total of 500 questionnaires were distributed, out of which 473 were recovered, resulting in a recovery rate of 94.6%. Of these, 432 questionnaires were deemed valid, representing an effective recovery rate of 91.33%, which met the basic requirements of further analysis. The candidates for the questionnaire were all on-the-job students with work experience, some of whom even had more than 3 years of relevant work experience, so as to ensure the validity of this research questionnaire. Figure 2 shows the years of employment, titles, and stakeholders of the respondents.

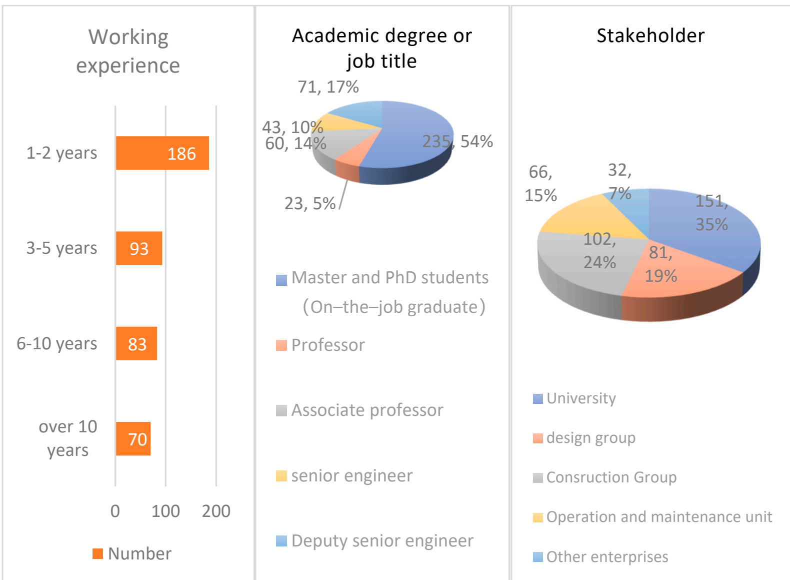

Figure 2. Basic information of respondents.

3.3. Reliability and Validity Test

Before analyzing the questionnaire data, a reliability and validity test was conducted using SPSS25.0 software (see Figure 3). Reliability was tested using the Cronbach coefficient, whereas validity was assessed using content validity and construct validity. Content validity evaluates the logical relationship between the questionnaire items and the potential variables, whereas construct validity measures the ability of each item in the questionnaire to explain the measured variables and is usually measured using KMO (Kaiser–Meyer–Olkin) and Bartlett's test of sphericity.

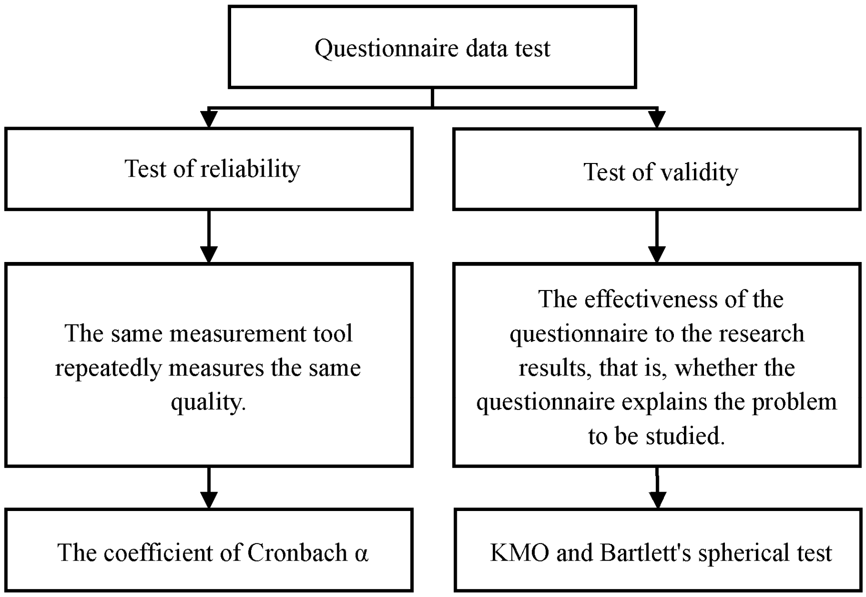

Figure 3. Flow chart of the reliability and validity tests.

3.4. Structural Equation Modeling

The structural equation model (SEM) is a statistical technique used to examine the relationship between latent and observed variables, which forms the basis of multivariate data analysis. SEM comprises two models: the measurement model and the structural model. The structural model is represented by Equation (1):

$$\eta = \gamma\xi + \beta\eta + \zeta, \tag{1}$$

where ξ and η are the independent and dependent latent variables, respectively; γ represents the effect of external derivative potential variables on internal derivative potential variables; β represents the relationship between internal derivative latent variables; and ζ is the error term.

The measurement model is represented by Equations (2) and (3):

$$X = \lambda_X\xi + \delta, \tag{2}$$

$$Y = \lambda_Y\eta + \varepsilon, \tag{3}$$

where X and Y are external derivative and internal derivative observation variables, respectively; δ and ε are the measurement errors of X and Y, respectively; λ_X represents the relationship between X and ξ; and λ_Y represents the relationship between Y and ε.

SEM can simultaneously analyze the relationships between multiple causes and effects while avoiding the problem of variable measurement error. In this study, we used AMOS to construct a structural equation model to investigate the relationship and weight of the influencing factors of hidden cost at different project stages of prefabricated construction.

3.5. Evaluation Based on Matter–Element Extension Cloud Model (MEECM)

In the context of the whole life cycle of prefabricated construction, there are multiple interrelated factors that influence the hidden cost risk. Such factors are not independent of each other, and the concealment, uncertainty, and continuity of hidden cost risk result in a dynamic evaluation index. The traditional matter–element model is suitable for the dynamic requirement of prefabricated building hidden cost risk assessment. However, it overlooks the randomness and discreteness of the variables, which can be remedied by the cloud model. This study introduced the MEECM to comprehensively evaluate the hidden cost risk of prefabricated construction.

3.5.1. Determination of Classical and Joint Domains

To determine the classical and joint domains of hidden cost risk assessment, a fixed range $[C_{\min}, C_{\max}]$ was considered as the boundary level. By using the $3E_n$ rule of the normal cloud, this range was transformed into cloud parameters through the conversion relationship between the interval number and the cloud model. The degree of fuzziness in the classification of hidden cost risk evaluation of prefabricated construction can be adjusted by determining the value of entropy, which increases with the fuzziness of the qualitative concept. In this study, a cloud model equal to 0.2 was selected, which provided a clear membership degree greater than 0.5 and moderate fuzziness for membership degrees less than 0.5. The positive cloud distribution of prefabricated construction hidden cost risk assessment classification is shown in Figure 4.

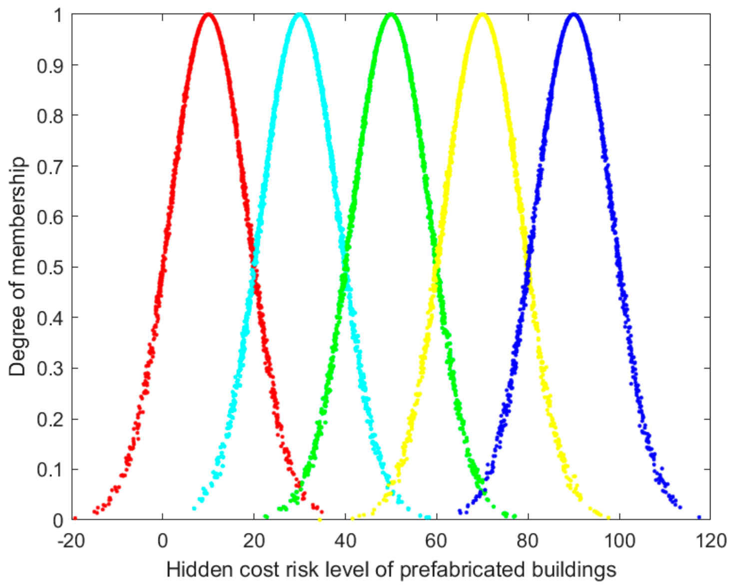

Figure 4. Graded normal cloud model map of hidden cost risk evaluation.

3.5.2. Determination of Comprehensive Evaluation Matrix

To determine the comprehensive evaluation matrix, a normal random distribution number determined by expectation E_x and standard deviation H_e was established, and the correlation between each index value x_i and the boundary cloud model $k(x_i)$ of the hidden cost risk evaluation grade of prefabricated construction was calculated:

$$k(x_i) = \exp\left[-\frac{(x_i - E_x)^2}{2{E_n}'^2}\right], \tag{4}$$

3.5.3. Correlation Degree Calculation and Level Evaluation

The correlation degree of the second-level index with respect to the risk evaluation grade of prefabricated construction hidden costs was determined, and the correlation degree between the first-level index and the hidden cost risk was calculated by Equation (4). The correlation degree of the first-level index with the hidden cost risk can be obtained by combining with the index weight W_i determined by the structural equation model.

$$Y_j(a_i) = \sum_{i=1}^{n} W_i Y_j(b_i), \quad (5)$$

where $Y_j(a_i)$ is the correlation degree between the j-th prefabricated building hidden cost risk evaluation level and the i-th first-level index. In this paper, i = 1, 2, 3, 4, 5; j = 1, 2, 3, 4, 5; and $Y_j(b_i)$ is the correlation degree of the b_i index corresponding to j hidden cost risk levels. Then, the calculated $Y_j(a_i)$ can be used to determine the correlation degree between each hidden cost risk level and the secondary index.

$$Y_j(a) = \sum_{i=1}^{n} W_i Y_j(a_i), \quad (6)$$

Finally, according to the principle of maximum correlation degree, j in the $Max\{Y_j(a)\}$ correlation degree in Equation (6) represents the risk level of the hidden cost of prefabricated construction.

4. Results

4.1. Data Reliability and Validity

The results of the validity analysis are presented in Tables 2 and 3. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was 0.917, which is above the acceptable threshold of 0.6 and close to 1, indicating that the data were suitable for factor analysis. The Bartlett sphericity test value was 0, which is less than the significance level of 0.05, indicating that the variables were significantly correlated and that factor analysis was appropriate. Furthermore, the Cronbach's alpha for the entire questionnaire was 0.929 and the Cronbach's alpha coefficients for each potential variable were above 0.7, indicating high reliability of the questionnaire.

Table 2. KMO and Bartlett test.

KMO	Bartlett Test		
	Approximate Chi-Square	Degree of Freedom	Significance
0.917	9563.932	465	0.000

Table 3. Variable reliability index value.

Latent Variable	Observed Variable Compound Values	Cronbach's α
Investment and decision stage	6	0.933
Design stage	6	0.901
Production and transportation stage	6	0.941
Construction stage	5	0.880
Completion acceptance stage	2	0.876
Operation and maintenance stage	2	0.718
Demolition and recovery stage	4	0.822
Total	31	0.922

4.2. Model Building and Fitting

The final model, consisting of seven potential variables and six, six, six, five, two, two, and four observed variables, was constructed and calculated using AMOS24.0 software, as depicted in Figure 5.

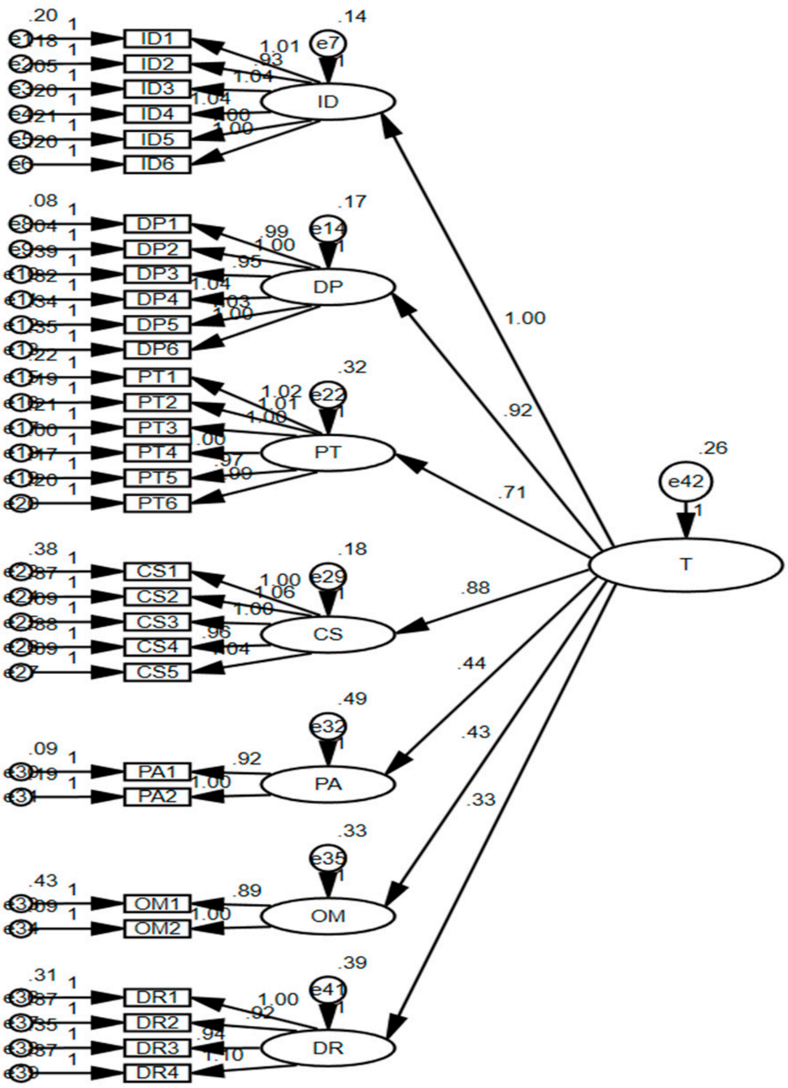

Figure 5. Results of SEM.

The collected sample data were used to fit the measurement model, and various indicators of confirmatory factor analysis were obtained. The Bartlett sphericity test value was less than 0.05, indicating that the intrinsic quality of the model met the expected requirements. Standardized factor loads of each measurement index met the requirements and were significant at the 0.001 level, indicating the good quality of the measurement model, as shown in Table 4, where S.E. is the standard errors used to evaluate the reliability and stability of the SEM model, C.R. is the critical ratio, and P is the significance value.

The model-fitting index is a crucial criterion for evaluating the model quality. The higher the fitting degree, the more usable the model and the more meaningful the parameter estimation will be. Table 5 shows the main fitting index of the model, which met the requirements of the structural equation model, as determined by comparing the judgment criteria and index values.

The hypotheses proposed in this study were analyzed through structural equation model analysis and model calculation results, which showed that the significance p was less than 0.001, indicating that the seven first-level indicators significantly impact the hidden cost risk of prefabricated construction. Through the established SEM model, the reliability and validity of the evaluation index system were tested, and it was concluded that the final prefabricated building hidden cost risk evaluation index system is reasonable.

Table 4. Regression coefficient of each path.

Measured Variable	Correlation	Latent Variable	Estimate	S.E.	C.R.	*p*	Label	Estimate (Standardization)
ID	<---	T	1					0.806
DP	<---	T	0.915	0.087	10.483	***	par_25	0.75
PT	<---	T	0.706	0.077	9.16	***	par_26	0.538
CS	<---	T	0.876	0.075	11.616	***	par_27	0.726
PA	<---	T	0.444	0.091	4.879	***	par_28	0.307
OM	<---	T	0.433	0.073	5.903	***	par_29	0.358
DR	<---	T	0.332	0.077	4.338	***	par_30	0.262
ID6	<---	ID	1					0.817
ID5	<---	ID	1.003	0.051	19.832	***	par_1	0.808
ID4	<---	ID	1.043	0.051	20.511	***	par_2	0.829
ID3	<---	ID	1.045	0.041	25.227	***	par_3	0.946
ID2	<---	ID	0.932	0.046	20.123	***	par_4	0.814
ID1	<---	ID	1.01	0.05	20.349	***	par_5	0.821
DP6	<---	DP	1					0.724
DP5	<---	DP	1.028	0.067	15.312	***	par_6	0.74
DP4	<---	DP	1.036	0.067	15.524	***	par_7	0.75
DP3	<---	DP	0.955	0.067	14.195	***	par_8	0.69
DP2	<---	DP	1.001	0.051	19.73	***	par_9	0.947
DP1	<---	DP	0.985	0.052	19.03	***	par_10	0.912
PT6	<---	PT	0.988	0.046	21.49	***	par_11	0.829
PT5	<---	PT	0.974	0.044	22.214	***	par_12	0.846
PT4	<---	PT	0.997	0.034	29.572	***	par_13	1
PT3	<---	PT	1					0.823
PT2	<---	PT	1.014	0.046	21.946	***	par_14	0.84
PT1	<---	PT	1.015	0.048	21.205	***	par_15	0.821
CS5	<---	CS	1.038	0.038	26.979	***	par_16	0.901
CS4	<---	CS	0.96	0.056	17.032	***	par_17	0.692
CS3	<---	CS	1					0.899
CS2	<---	CS	1.056	0.057	18.527	***	par_18	0.731
CS1	<---	CS	0.999	0.057	17.626	***	par_19	0.706
PA2	<---	PA	1					0.862
PA1	<---	PA	0.916	0.118	7.759	***	par_20	0.914
OM2	<---	OM	1					0.898
OM1	<---	OM	0.887	0.173	5.118	***	par_21	0.639
DR4	<---	DR	1.097	0.08	13.77	***	par_22	0.76
DR3	<---	DR	0.937	0.07	13.465	***	par_23	0.715
DR2	<---	DR	0.924	0.07	13.276	***	par_24	0.699
DR1	<---	DR	1					0.76

Note: *** means $p < 0.001$, which is significant.

Table 5. Index of structural equation.

Parameter	Value	Standard	Parameter	Value	Standard
χ^2/df	1.063	<5	RMSEA	0.012	<0.05
GFI	0.938	>0.9	TLI	0.997	>0.9
IFI	0.997	>0.9	CFI	0.997	>0.9
PGFI	0.808	>0.5	PNFI	0.876	>0.5

4.3. Indicator Weight Calculation

The weight of each index was determined using the standardized factor load, the ratio of the system weight reuse of each latent variable to the sum of the diameter coefficients of each latent variable, and the ratio of the corresponding diameter coefficient of the index weight reuse to the sum of the diameter coefficients of other observed variables. Table 6 shows the specific weight of each index.

Table 6. Weight of each evaluation index.

Latent Variable	System Weight	Measurement Variable	Indicator Weight	Indicator Total Weight
ID	0.2151	ID1	0.1623	0.0349
		ID2	0.1605	0.0345
		ID3	0.1646	0.0354
		ID4	0.1879	0.0404
		ID5	0.1617	0.0348
		ID6	0.1631	0.0351
DP	0.2002	DP1	0.1520	0.0304
		DP2	0.1554	0.0311
		DP3	0.1575	0.0315
		DP4	0.1449	0.0290
		DP5	0.1988	0.0398
		DP6	0.1915	0.0383
PT	0.1436	PT1	0.1607	0.0231
		PT2	0.1640	0.0235
		PT3	0.1938	0.0278
		PT4	0.1595	0.0229
		PT5	0.1628	0.0234
		PT6	0.1591	0.0228
CS	0.1938	CS1	0.2293	0.0444
		CS2	0.1761	0.0341
		CS3	0.2288	0.0443
		CS4	0.1861	0.0360
		CS5	0.1797	0.0348
PA	0.0819	PA1	0.4854	0.0398
		PA2	0.5146	0.0422
OM	0.0955	OM1	0.5843	0.0558
		OM2	0.4157	0.0397
DR	0.0699	DR1	0.2590	0.0181

Table 6. *Cont.*

Latent Variable	System Weight	Measurement Variable	Indicator Weight	Indicator Total Weight
		DR2	0.2437	0.0170
		DR3	0.2382	0.0167
		DR4	0.2590	0.0181

4.4. Evaluation of a Case Project

Based on the weight of each index, an evaluation model based on the MEECM was established to evaluate the hidden cost risk of specific prefabricated construction projects. For instance, Table 7 illustrates a residential building project with a total construction area of 125,903.1 m^2, above-ground construction area of 90,121.37 m^2, and underground building area for a floor of approximately 35,732.34 m^2.

Table 7. Project overview.

Project Overview	Building No. 10	Building No. 15
Area of structure (m^2)	17,715.53	23,766.73
Building height (m)	79.51	89.98
Number of floors	21	25
Story height (m)	3.5	3.5
Prefabricated floor	2~21F	2~25F
Structural system	Assemble the monolithic shear wall structure	Assemble the monolithic shear wall structure
Assembly rate	61.35%	60.5%
Type of prefabricated component	Prefabricated truss reinforced composite plate (including balcony), prefabricated staircase segment, prefabricated beam, prefabricated air conditioning board	Prefabricated truss reinforced composite plate (including balcony), prefabricated staircase segment, prefabricated beam, prefabricated air conditioning board

The hidden cost risk evaluation was categorized into five levels in this study: I = highest risk, II = higher risk, III = general risk, IV = tolerable risk, V = lower risk. The data range of each grade standard was summarized, and the evaluation grade limit and standard cloud model of the hidden cost risk of prefabricated construction were obtained, as shown in Tables 8 and 9. Table 8 shows the grade limit of each risk evaluation index, and Table 9 shows the grade limit of each evaluation index of the hidden cost risk level of prefabricated construction standard cloud model (Ex, En, He).

Table 8. Grade limit of hidden cost risk evaluation.

Index	I	II	III	IV	V
ID1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
ID2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
ID3	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
ID4	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
ID5	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
ID6	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DP1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DP2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]

Table 8. *Cont.*

Index	I	II	III	IV	V
DP3	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DP4	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DP5	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DP6	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT3	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT4	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT5	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PT6	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
CS1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
CS2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
CS3	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
CS4	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
CS5	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PA1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
PA2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
OM1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
OM2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DR1	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DR2	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DR3	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]
DR4	(0, 20]	(20, 40]	(40, 60]	(60, 80]	(80, 100]

Table 9. Standard cloud model of hidden cost risk evaluation grade.

	I	II	III	IV	V
ID1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
ID2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
ID3	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
ID4	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
ID5	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
ID6	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP3	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP4	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP5	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DP6	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PT1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PT2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)

Table 9. *Cont.*

	I	II	III	IV	V
PT3	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PT4	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PT5	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PT6	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
CS1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
CS2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
CS3	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
CS4	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
CS5	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PA1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
PA2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
OM1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
OM2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DR1	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DR2	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DR3	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)
DR4	(10, 8.4933, 0.04)	(30, 8.4933, 0.04)	(50, 8.4933, 0.04)	(70, 8.4933, 0.04)	(90, 8.4933, 0.04)

A 12-member evaluation team consisting of experts in the prefabricated construction sector, owners, and builders was formed. The scoring value was between the five risk grade values, and the average value of the index was calculated after removing the highest and lowest scores from the original data of the scoring value. Tables 10 and 11 show the results of the index calculation. The evaluation team included three researchers and nine experts from government departments and design, construction, and operation sectors. Experts scored each indicator according to the current documentation standards and on-site observation of the project. Compared with the explicit cost, the implicit cost is more difficult to measure separately, but it has a more significant impact on the total cost. Therefore, this study used subjective data to analyze the influencing factors of hidden costs. The details are shown in Table 10, and Table 11 shows the specific scores of the 12 experts.

Table 10. Experts of the evaluation team.

Classification	Researcher	Government Sector	Design Sector	Construction Sector	Operation Sector
Number	3	3	2	2	2

Table 11. Initial score of hidden cost risk index.

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	Final Score
ID1	80	94	85	91	93	82	86	84	76	77	70	73	82.7
ID2	45	57	64	55	53	61	62	47	48	50	44	50	52.8
ID3	56	69	54	62	66	63	68	49	48	60	47	61	58.7
ID4	81	83	79	73	82	80	79	78	71	76	72	77	77.7
ID5	50	50	53	52	47	44	48	55	56	51	53	53	51.2
ID6	61	64	67	63	65	66	59	70	71	61	64	61	64.2

Table 11. *Cont.*

	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	E11	E12	Final Score
DP1	71	73	65	74	78	80	64	72	71	73	72	68	71.7
DP2	87	87	90	85	93	91	80	82	86	87	86	85	86.6
DP3	56	54	51	61	54	53	57	62	66	58	62	60	57.7
DP4	75	77	69	72	80	78	81	74	72	72	76	77	75.3
DP5	69	72	68	72	70	75	74	78	73	74	69	73	72.1
DP6	51	51	53	52	56	49	57	51	48	47	49	53	51.3
PT1	51	57	60	54	49	57	62	52	53	55	51	53	54.3
PT2	53	56	62	54	54	51	60	52	58	57	53	54	55.1
PT3	70	70	71	68	68	73	72	77	69	65	70	72	70.3
PT4	62	64	64	67	68	59	67	70	72	68	66	67	66.3
PT5	57	52	61	54	60	53	55	62	65	57	63	65	58.7
PT6	54	54	59	56	61	57	58	60	57	62	64	62	58.6
CS1	50	55	53	60	56	54	57	63	60	59	58	60	57.2
CS2	49	51	52	63	56	55	61	62	48	51	60	56	55.3
CS3	67	65	68	74	76	74	74	75	69	70	71	76	71.8
CS4	45	47	46	47	48	47	46	45	44	45	45	45	45.8
CS5	51	55	51	56	53	55	57	53	52	56	53	49	53.5
PA1	73	68	71	72	68	75	72	73	69	73	75	70	71.6
PA2	64	63	65	67	68	70	73	69	69	71	71	73	68.7
OM1	50	55	51	52	49	47	61	63	48	57	56	54	53.3
OM2	51	52	61	46	47	48	59	58	55	51	55	52	52.8
DR1	60	59	61	63	57	56	54	55	54	51	55	58	56.9
DR2	58	60	57	51	53	62	67	55	59	61	59	58	58.2
DR3	54	54	49	60	56	58	48	62	55	55	56	58	55.5
DR4	33	34	31	34	36	34	41	35	35	35	33	32	34.1

Using Equation (4), the exp function in MATLAB was employed to determine the correlation degrees of the prefabricated building hidden cost risk evaluation index belonging to different risk levels. The weight and value of the index were considered while calculating the correlation degrees. The results are presented in Table 12 and Figure 6.

The hidden cost risk of the prefabricated building project was evaluated using the cloud matter–element evaluation model. The comprehensive evaluation results placed the project at level III, indicating a general risk level with a trend towards level IV. This result suggests that the overall hidden cost risk of the project is good but that there are still management deficiencies that need to be addressed. To reduce the hidden cost risk of the project, there is ample room for improvement in risk control at every stage of the project's life cycle, including investment decision-making, design, production, transportation, construction, operation, and maintenance. In particular, factors with high weight ratios should be analyzed to improve the management of hidden cost risk and remove obstacles to the development of prefabricated construction. Furthermore, the factors affecting the hidden cost risk of prefabricated construction can be identified from the secondary index, and targeted measures can be proposed to control the hidden cost risk of prefabricated construction more effectively.

Table 12. The correlation degree of each index with respect to each level.

	Highest Risk	Higher Risk	General Risk	Tolerable Risk	Lower Risk	Max	Subordination Level
ID	0.000000	0.002666	0.097040	0.088257	0.038493	0.097040	III
DP	0.000000	0.001848	0.061843	0.111256	0.042632	0.111256	IV
PT	0.000000	0.000837	0.072518	0.076819	0.002440	0.076819	IV
CS	0.000006	0.007711	0.124568	0.071508	0.004595	0.124568	III
PA	0.000000	0.000001	0.005357	0.080743	0.005542	0.080743	IV
OM	0.000000	0.002357	0.089309	0.013061	0.000007	0.089309	III
DR	0.000343	0.016481	0.040363	0.015740	0.000029	0.040363	III
Comprehensive correlation degree	0.000025	0.003935	0.079598	0.075108	0.018512	0.079598	III

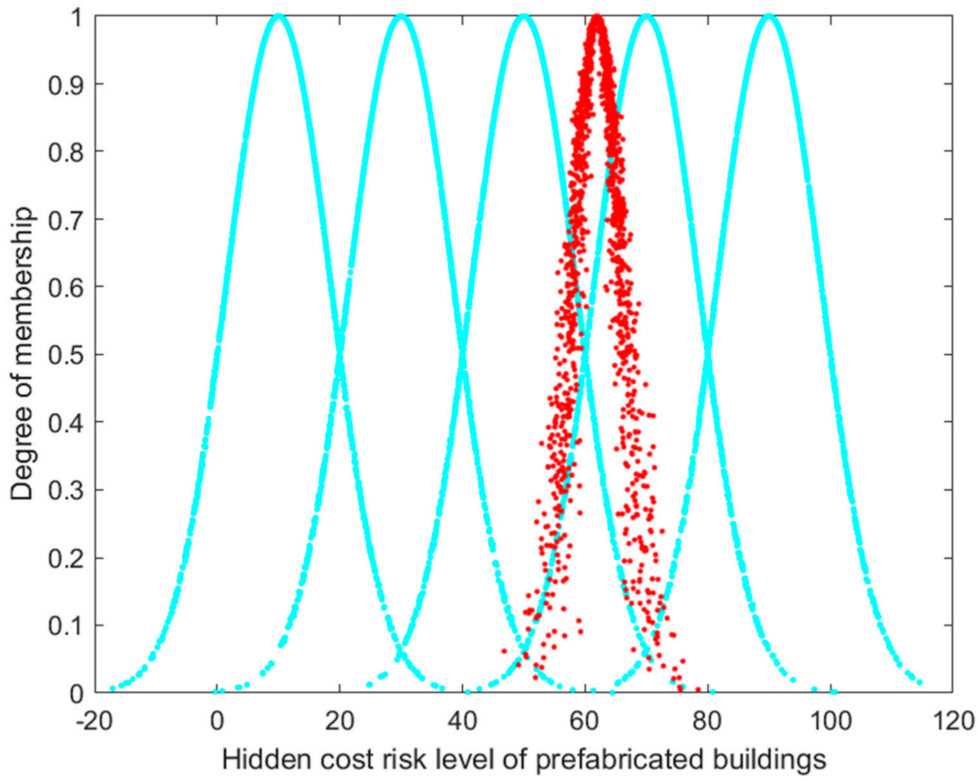

Figure 6. Hidden cost risk evaluation results.

The current study established an evaluation index system for the hidden cost risk of prefabricated construction, providing significant advantages over other approaches in cost risk assessment. The study used the SEM to calculate the weights of assessment indicators at each level and used the MEECM to develop a standard cloud model of grade boundary and hidden cost risk of prefabricated construction. This practical and straightforward approach accurately depicted the hidden cost risk at each phase of the prefabricated construction project, and the evaluation's findings were quantitatively displayed to study the development trend and reflect the hidden cost risk objectively. Corresponding actions were performed in accordance with the evaluation's findings.

The investment and decision-making stage is given the most weight, followed by the design stage. The collaboration with component production units, construction units, parts production units, and other collaborative design during the design phase is essential to reducing project hidden costs. The degree and logic of prefabricated component separation, component standardization, and component integration stand out in the design stage.

The timely delivery of prefabricated components, the production team's productivity, and the mechanical utilization rate are secondary indices that carry more weight during the production and transportation phases. The construction stage uses a construction management system with higher technical standards for expert staff. The acceptance stage of completion considers the influence of business goodwill, an intangible asset of an enterprise. The operation and maintenance phase prioritizes the application of innovative information technology. The demolition and recovery stage considers the difficulty of environmental restoration and the component recycling rate to ensure the project meets pertinent national standards.

Compared to alternative evaluation techniques, the proposed evaluation index system significantly enhances the scientific rigor of assessment outcomes by ensuring the suitability and adjustment of the evaluation model. Given that previous studies on prefabricated construction cost have primarily focused on the total project cost, and considering the strong randomness and fuzziness associated with hidden cost risks, the MEECM was primarily applied to address the challenges related to the fuzziness and randomness of evaluation indicators, as well as the difficulty of converting qualitative concepts into quantitative values. Therefore, this paper pioneers the combination of SEM and the MEECM in the field of hidden cost risk assessment. The findings of this study provide practical guidance for implementing cost risk management in prefabricated construction and offer a novel perspective on the theoretical foundations of hidden construction costs.

5. Conclusions

Prefabricated construction offers several advantages over traditional structures, such as improved quality, reduced labor requirements, and lower carbon emissions. However, the hidden cost risk of prefabricated construction poses a significant challenge, as it is concealed and persists throughout the project life cycle. In this regard, the matter–element extension cloud model and structural equation model are employed to investigate the variables that affect the hidden cost risk of prefabricated construction.

This study focused on the factors that influence the risk of declining costs in prefabricated construction. The data were collected through a questionnaire survey, and after reliability and validity testing, 7 primary and 31 secondary indicators were chosen for the preliminary evaluation. These indicators cover the seven stages of the project life cycle. Using the developed evaluation model in a real-world case project, this study identified the primary causes of the hidden cost risk of prefabricated construction, which can guide decision-makers in developing appropriate measures to control this risk.

This study makes a significant contribution to the assessment of hidden cost risks in prefabricated construction projects by effectively integrating the SEM and the MEECM. The theoretical implications of this study are noteworthy, particularly in the context of cost risk management, whereas the practical implications are relevant to policies aimed at mitigating hidden costs. However, it is important to acknowledge a limitation of this study, namely, the insufficient attention given to the interaction between indicators and the inherent unpredictability of the relationships between hidden costs at each level. Therefore, future research endeavors should delve into the specific impact of each hidden cost on different stages of prefabricated construction and develop relevant models to determine the extent to which each index influences each stage. Building upon the proposed model, future studies can further refine the hidden cost risk index and explore suitable quantitative methods for indexing. These efforts will be instrumental in effectively identifying and controlling cost risks in prefabricated construction, reducing the overall project costs, and facilitating the widespread adoption of prefabricated construction in developing countries.

Author Contributions: Methodology, J.Z.; Software, W.W.; Validation, L.C.; Investigation, W.W. and L.C.; Writing—original draft, J.Z.; Supervision, Z.J.; Project administration, Z.J.; Funding acquisition, Z.J. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the China Postdoctoral Science Foundation (No. 2021M701312), Key Laboratory of Road and Traffic Engineering of the Ministry of Education, Tongji University (No. K202201), and the Open Project of Key Laboratory of Ministry of Public Security for Road Traffic Safety (No. 2023ZDSYSKFKT09).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

References

1. Li, X.J.; Chen, W.; Ali, A.; Shilpi, B. Game analysis on prefabricated building evolution based on dynamic revenue risks in China. *J. Clean. Prod.* **2020**, *267*, 121730. [CrossRef]
2. Hong, J.; Shen, G.Q.; Mao, C.; Li, Z.; Li, K. Life-cycle energy analysis of prefabricated building components: An input–output-based hybrid model. *J. Cleaner. Prod.* **2016**, *112*, 2198–2207. [CrossRef]
3. Zhu, H.; Hong, J.; Geoffrey, S. The exploration of the life-cycle energy saving potential for using prefabrication in residential buildings in China. *Energy Build.* **2018**, *166*, 561–570. [CrossRef]
4. Xue, H.; Zhang, S.; Su, Y.; Wu, Z. Factors Affecting the Capital Cost of Prefabrication—A Case Study of China. *Sustainability* **2017**, *9*, 1512. [CrossRef]
5. Standfield, K. *Intangible Management: Tools for Solving the Accounting and Management Crisis*; Academic Press: San Diego, CA, USA, 2002.
6. Sellés, M.E.S.; Rubio, J.A.C.; Mullor, J.R. Development of a Quantification Proposal for Hidden Quality Costs: Applied to the Construction Sector. *J. Constr. Eng. Manag.* **2008**, *134*, 749–757. [CrossRef]
7. Shao, W. Research on Estimation Mode of Construction Project Implicit Cost Based on Activity-Based Costing. *Constr. Econ.* **2012**, *10*, 38–42.
8. Lu, W.; Zhang, L.; Pan, J. Identification and analyses of hidden transaction costs in project dispute resolutions. *Int. J. Proj. Manag.* **2015**, *33*, 711–718. [CrossRef]
9. Arif, M.; Egbu, C. Making a case for offsite construction in China. *Eng. Constr. Archit. Manag.* **2010**, *17*, 536–548. [CrossRef]
10. Chang, C.G.; Zhang, Y. Study on the production cost control of assembly building components. *J. Shenyang Univ. Archit. Soc. Sci. Ed.* **2016**, *5*, 470–475.
11. Rafaela, B.; Carlos, T.F.; Daniela, D.V. Site logistics planning and control for engineer-to-order prefabricated building systems using BIM 4D modeling. *Automat. Constr.* **2019**, *98*, 248–264.
12. Khalili, A.; Chua, D. IFC-Based Framework to Move beyond Individual Building Elements toward Configuring a Higher Level of Prefabrication. *J. Comput. Civ. Eng.* **2013**, *27*, 243–253. [CrossRef]
13. Peng, J.; Zhou, J.; Meng, F.; Yu, Y. Analysis on the hidden cost of prefabricated buildings based on FISM-BN. *PLoS ONE* **2021**, *16*, e0252138. [CrossRef] [PubMed]
14. Hong, J.; Shen, G.; Li, Z.; Zhang, W. Barriers to promoting prefabricated construction in China: A cost benefit analysis. *J. Cleaner Prod.* **2018**, *172*, 649–660. [CrossRef]
15. Li, X.J. Research on Investment Risk Influence Factors of Prefabricated Building Projects. *J. Civ. Eng. Manag.* **2020**, *26*, 599–613. [CrossRef]
16. Yan, H.Y.; He, Z.; Gao, C.; Xie, M.J.; Sheng, H.Y.; Chen, H.H. Investment estimation of prefabricated concrete buildings based on XGBoost machine learning algorithm. *Adv. Eng. Inform.* **2022**, *54*, 101789. [CrossRef]
17. Yan, E.H.; Yong, Q.L. Technical Analysis of Optimal Design for Building Structure Considering Cost Constraint of Project. *Appl. Mech. Mater.* **2014**, *496*, 2563–2568.
18. Fiorentino, A. Cost drivers-based method for machining and assembly cost estimations in mould manufacturing. *Int. J. Adv. Manuf. Technol.* **2014**, *70*, 1437–1444. [CrossRef]
19. Shakantu, W.; Tookey, J.E.; Bowen, P.A. The Hidden Cost of Transportation of Construction Materials: An Overview. *J. Eng. Des. Technol.* **2003**, *1*, 103–118. [CrossRef]
20. Hwang, B.G.; Shan, M.; Looi, K.Y. Key Constraints and mitigation strategies for prefabricated prefinished volumetric construction. *J. Clean. Prod.* **2018**, *183*, 183–193. [CrossRef]
21. Tazikova, A.; Strukova, Z. The impact of logistics on the cost of prefabricated construction. *Acta Logist.* **2021**, *8*, 65–71. [CrossRef]
22. Chang, C.G.; Wu, F.F.; Dan, L. Optimization Model of Load and Transportation for Prefabricated Construction Components. In Proceedings of the 2016 International Forum on Energy, Environment and Sustainable Development, Shenzhen, China, 16–17 April 2016.
23. Demiralp, G.; Guven, G.; Ergen, E. Analyzing the benefits of RFID technology for cost sharing in construction supply chains: A case study on prefabricated precast components. *Autom. Constr.* **2012**, *24*, 120–129. [CrossRef]

24. Yang, Y.H.; Liu, P. Benefits and Development of Adoption Building Information Models for Construction Management. In Proceedings of the International Conference on Electromechanical Control Technology and Transportation (ICECTT), Zhuhai, China, 31 October–1 November 2015.
25. Ye, M.W.; Wang, J.W.; Si, X.; Zhao, S.M.; Huang, Q.Y. Analysis on Dynamic Evolution of the Cost Risk of Prefabricated Building Based on DBN. *Sustainability* **2022**, *14*, 1864. [CrossRef]
26. Guo, Z.X.; Li, L.H. A Study of Collaborative Innovation Mechanism of Prefabricated Construction Enterprises Using Order Parameter. *Front. Built Environ.* **2022**, *8*, 858650. [CrossRef]
27. Luan, H.Y.; Li, L.; Zhang, S.X. Exploring the Impact Mechanism of Interface Management Performance of Sustainable Prefabricated Construction: The Perspective of Stakeholder Engagement. *Sustainability* **2022**, *14*, 10704. [CrossRef]
28. Samani, P.; Gregory, J.; Leal, V.; Mendes, A.; Correia, N. Lifecycle Cost Analysis of Prefabricated Composite and Masonry Buildings: Comparative Study. *J. Archit. Eng.* **2018**, *24*, 05017012. [CrossRef]
29. Ruiz, L.A.L.; Ramon, X.R.; Domingo, S.G. The circular economy in the construction and demolition waste sector—A review and an integrative model approach. *J. Clean. Prod.* **2020**, *248I*, 119238. [CrossRef]
30. Vitale, P.; Arena, N.; Di Gregorio, F.; Arena, U. Life cycle assessment of the end-of-life phase of a residential building. *Waste Manag.* **2017**, *60*, 311–321. [CrossRef]
31. Dosho, Y. Development of a Sustainable Concrete Waste Recycling System. *J. Adv. Concr. Technol.* **2007**, *5*, 27–42. [CrossRef]
32. Wang, H.; Zhang, Y.Q.; Gao, W.J.; Kuroki, S. Life Cycle Environmental and Cost Performance of Prefabricated Buildings. *Sustainability* **2020**, *12*, 2609. [CrossRef]
33. Purchase, C.K.; Al Zulayq, D.M.; O'Brien, B.T.; Kowalewski, M.J.; Berenjian, A.; Tarighaleslami, A.H.; Seifan, M. Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits. *Materials* **2022**, *15*, 76. [CrossRef]