

## Article

# Critical Factors Influencing Cost Overrun in Construction Projects: A Fuzzy Synthetic Evaluation

Wenwen Xie <sup>1</sup>, Binchao Deng <sup>1,\*</sup> , Yilin Yin <sup>1,2</sup>, Xindong Lv <sup>1</sup> and Zhenhua Deng <sup>1</sup><sup>1</sup> School of Management, Tianjin University of Technology, Tianjin 300384, China<sup>2</sup> School of Management, Tianjin University, Tianjin 300072, China

\* Correspondence: dbchao1985@tju.edu.cn

**Abstract:** Construction industries have poor cost performance in terms of finishing projects within a budget. A fuzzy model for evaluating the critical factors of cost overrun for construction projects in China is developed by identifying, classifying and ranking cost overrun factors of the construction industries. Sixty-five cost overrun factors are identified and classified into four clusters (project macro, project management, project environment, and core stakeholders) through a detailed literature review process and a discussion with experts from the Chinese construction industry. A questionnaire survey was conducted for data collection to calculate an index of the project-influenced factors and clusters in the construction industry in China. With the help of the proposed model, it is possible to guide project managers and decision makers to make better informative decisions such as project macro, project management, project environment, and core stakeholders.

**Keywords:** cost overrun; fuzzy synthetic evaluation; project management



**Citation:** Xie, W.; Deng, B.; Yin, Y.; Lv, X.; Deng, Z. Critical Factors Influencing Cost Overrun in Construction Projects: A Fuzzy Synthetic Evaluation. *Buildings* **2022**, *12*, 2028. <https://doi.org/10.3390/buildings12112028>

Academic Editors: Yuan Chen, Hexu Liu, Xianfei Yin, Bo Xiao, Yinghua Shen and Krzysztof Zima

Received: 9 September 2022

Accepted: 17 November 2022

Published: 19 November 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

With the rapid development of the construction industry, construction projects are facing serious cost mismanagement and other problems, resulting in a large number of cost overruns in many construction projects [1]. For example, the Roads Implementation Program 2004–2005 Reports (RIP) by the Queensland Department of Main Roads, 2005 reports that 10 percent of projects costing more than \$1 million (AUD) have an overrun of over 10 percent on programmed estimates [2]; the 2008 Beijing Olympic Games Bird's Nest Stadium encountered cost overrun from the initial budget of 1.6 to 2 billion RMB to the final cost of 3.5 billion RMB [3]. Project cost is considered the most significant factors in the life cycle of construction project management and one of the most significant parameters for measuring the performance of construction projects [4]. However, many projects are not completed within approved project costs and budgets, ultimately resulting in cost overruns and causing negative impacts on clients, the relationship between contractor and consultant, mistrust, litigation, and arbitration. Therefore, it is crucial to analyze and effectively deal with cost overrun factors in construction projects, which helps firms to manage project costs and improve project performance.

In the field of cost overrun studies for engineering projects, there are many advanced experiences in other countries. Ramanathan et al. [5] conducted a questionnaire survey of relevant practitioners and ranked the factors and groups according to the overall views of the parties. The results of the study can be used as a guideline for dealing with cost overrun in construction projects in Malaysia and help improve project performance. Sohu et al. [6] selected 30 experts with more than 20 years of experience in road projects from owners, designers, and contractors to collect data related to cost overrun in Pakistani road projects and analyze them statistically. The results of the study indicate that the owner's delayed payment, the owner's intervention, and poor contract management are the main factors affecting cost overrun of a project. Memon et al. [7] list 78 relevant cost overrun influencing

factors, and involve three key construction industry players: owners, consultants and contractors. They concluded that effective financial management can significantly improve project success and help reduce cost overrun. Wang and Yuan [8] categorized the relevant cost overrun influencing factors into five subjects involving government, owner, design institute, contractor and subcontractor, and 15 cost overrun critical influencing factors are obtained. Furthermore, Car-Pušić et al. [9] selected data from 24 public and private cost overrun construction projects from 2006 to 2017 in Istria County, Republic of Croatia, to elucidate more completely the key factors of cost overrun in construction projects through literature and case studies.

In according to better study cost overrun factors, scholars have used many analytical methods in recent years. Moschouli et al. [10] analyzed project cost overrun factors using qualitative comparative analysis (QCA), in which factors of poor contract management, project completion time, and improper risk allocation are extracted. The results of the study showed that when positive conditions are combined with some negative conditions, it may still lead to cost overrun. Alhomidan [11] divided 41 cost overrun factors into six groups and mapped them into risk maps. The results of the study showed that most of the critical factors were management factors. By improving the management skills of construction teams through appropriate training and workshops, firms can reduce the negative impact of these factors. Creedy et al. [2] used multiple linear regression analysis to investigate the correlation between cost overrun risk factors and project attributes by using historical project data. They concluded that project design changes and scope changes during project development are particularly concerned. To address the problem of biased results due to subjective judgments, Dikmen et al. [12] constructed a fuzzy risk assessment method to analyze cost overrun factors and provide guidance for firms to quantify the risk of cost overrun. The concept of fuzzy sets, which can quantify the subjective opinions of many experts or respondents, led to the inspiration for using the Fuzzy Synthetic Evaluation (FSE) in this paper.

Cost overrun has become one of the most divisive issues in the construction industry; this paper will discuss the following four aspects to explore the core cost overrun factors in construction projects. Firstly, cost overrun factors of construction projects in China are summarized by combing through the relevant literature. Secondly, the required data are obtained through questionnaires. Then, the FSE model is established and the data are analyzed. Finally, the significant cost overrun factors are discussed and relevant solutions are given. The purpose of this paper is to provide insight into the existing causes of cost overrun in projects in developed and developing countries, and to outline possible recommendations for preventing cost overrun in future projects by analyzing case studies from different countries.

## 2. Literature Review

Cost overrun is one of the most impactful risks in construction projects. Being a dynamic and complex factor, it is difficult to fully mitigate [13]. The main reason is that the construction industry is resource-intensive, so many projects face resource shortages, changes in material and equipment costs, unexpected costs, and accidents during construction [14]. In addition, the main causes of cost overruns change over time (every ten years). Therefore, in order to effectively manage complexity and avoid or minimize risks, there is a need to constantly update the understanding of them [15].

Many studies have been conducted to identify the causes of cost overrun in construction projects. Enshassi et al. [16] concluded that the top affecting factors that cause cost overrun in building construction projects in the Gaza Strip are: strikes, Israeli attacks and border closures, lack of materials in markets, shortage of construction materials at the site, delay of material delivery to site, cash problem during construction, and poor site management. Koushki et al. [17] conducted a study in Kuwait. They concluded that the main affecting causes of cost overrun are: changing orders, owners' financial constraints, and owners' lack of experience. Kaming et al. [18] conducted a study to identify the main

factors affecting cost overrun in Indonesian construction projects. They concluded that inflationary increases in material cost, inaccurate material estimating, and project complexity are the main causes of cost overrun. Iyer et al. [19] concluded that the majority of factors affecting cost overrun of construction projects in India are: conflict among project participants, ignorance and lack of knowledge, presence of poor project specific attributes, and nonexistence of cooperation. To sum up, some researchers have studied the factors affecting cost overrun in construction projects. However, there are few studies concerned with cost overrun in construction projects in China. This paper aims to analyze the factors of cost overrun in construction projects in other countries, to summarize the most critical factors that may lead to cost overrun in construction projects in China.

Firstly, for project macro, factors repeatedly cited in the literature are government corruption, inefficient government approval, and market price changes. The first two factors are often complained about by owners and contractors and are prevalent in various countries or local governments. Wang and Yuan [8] argue that these are caused by the bureaucracy and overly complicated approval procedures of some Chinese government agencies, which are usually not controlled by the projects themselves. Thus, government corruption is one of the main sources of cost overrun in construction projects [20]. Market price changes are related to the external economic environment, and the price of construction materials always changes with inflation and supply and demand in the construction materials market [21]. Therefore, material price change is a global risk not directly related to each core project stakeholder, and is one of the main sources of cost overrun in construction projects.

Secondly, inadequate cost management and inadequate contract management are considered to be the more significant factors causing cost overrun regarding the project management factor. Project cost management emphasizes the application of knowledge, skills, tools, and techniques to construction project activities [22]. Its role is to provide effective cost control at all levels, from the feasibility study to the completion of the project. Inadequate cost management can lead to personnel changes, waste of construction materials, and thus hinder the construction schedule [23]. As a kind of commodity with a special nature, the construction project also determines that the contract has different characteristics from general contracts, such as the large amount of money involved and the long contract time [24]. Therefore, inadequate contract management will lead to smooth and large errors in the later project settlement, directly affecting the project cost [25]; e.g., the frequent problems related to cost management and inadequate contract management in Pakistani projects have been generally taken seriously by the construction industry [1].

Thirdly, the literature involving project environmental factors is relatively sparse, so this paper refers to the literature related to road construction projects. Road construction projects are greatly influenced by project environmental factors, especially project geographical location restrictions [2]. This can lead to problems such as increased material usage and increased transport distances for the project. Pilger et al. [26] concluded that cost overrun in construction projects are mainly caused by environmental uncertainties rather than controllable risk factors. Therefore, project environmental dimension factors focus on project location and uncertain environmental elements.

Finally, core stakeholders account for the largest share of cost overrun factors, as they involve owners, contractors, subcontractors, design institutes, engineering supervisors, and consultant firms. Each stakeholder has the ability to directly influence the actual project production costs [27], such as unrealistic contract duration by the owner and unbalanced risk allocation between the owner and the contractor. Therefore, this paper will focus on cost overrun critical factors of engineering projects among core stakeholders in the subsequent analytical study.

### 3. Methodology

#### 3.1. Factors Identification

In order to comprehensively study cost overrun factors of construction projects, this paper used “construction projects”, “cost overrun factors” and “cost management” as keywords to search papers from 2000 to 2022 using the Web of Science database. By compiling the relevant literature and data, 64 papers were obtained from Web of Science and read by the researchers to ensure that there are no invalid records. Finally, 65 construction project cost overrun factors were summarized, as shown in Table 1.

**Table 1.** Summary of construction project cost overrun factor.

Factor Category	No.	Construction Project Cost Overrun Factor	Factor Category	No.	Construction Project Cost Overrun Factor
Project macro	A1	National laws and regulations [5,6,12,28]	Core stakeholders	D6	Lack of technical knowledge and experience [28,29]
	A2	Market price changes [1,7,8]		D7	Cash flow [6,28,30]
	A3	National Policy Changes [28,29]		D8	Inaccurate cost estimation [7,31,32]
	A4	Inflation [1,7]		D9	Changes in project scope [6,28,30]
	A5	Social influence and cultural influence [1,6]		D10	Inadequate supervision and control [6,30]
	A6	Inefficient government approval [7,28]		D11	Inaccurate construction period and expense prediction [8,30]
	A7	Currency exchange rate fluctuation [7,29]		D12	Risk allocation [1,7]
	A8	Local political instability [7]		D13	Fraud behavior and rebate [7]
	A9	Bank interest rate fluctuation [7]		D14	Construction staff lacks cooperation [28,29]
	A10	Government corruption [8,28]		D15	Wrong scene investigation [5,6,29]
Project management	B1	Inadequate cost management [11,31]	D16	Lack of experience with local regulations [7,32]	
	B2	Inadequate contract management [1,28]	D17	Labor shortage [6,30]	
	B3	Inadequate risk management Jackson [11,31]	D18	Financing, bonds and payment methods [7,32]	
	B4	Insufficient design Jackson [11,31]	D19	Delay in construction plan [7,11,32]	
	B5	Inadequate project schedule management [1,28]	D20	Material purchase and change [5,6,29]	
	B6	Lack of communication [5,28,30]	D21	Delay in drawing approval [5,6,11,28,31]	
	B7	Inadequate planning and scheduling [8,31]	D22	Error in construction [30,31]	
	B8	Inadequate safety management [8,28]	D23	Project rework [5,6]	
	B9	Inadequate resource management [11,29]	D24	The owner asked for additional works [6,32]	
	B10	Inadequate environmental management [8,31]	D25	Not completed design when bidding [7]	
	B11	Relationship with labor force [6]	D26	Equipment failure [5,6,30]	
Project environment	C1	Project location limitation [7]	D27	Omissions and errors occurred in quantities bill [6,32]	
	C2	Inappropriate temperature [7]	D28	Outdated construction method [11,31]	

Table 1. Cont.

Factor Category	No.	Construction Project Cost Overrun Factor	Factor Category	No.	Construction Project Cost Overrun Factor
Core stakeholders	C3	Unpredictable weather conditions [2,7]	D29		Insufficient quantity of equipment [6,28]
	C4	Unpredictable ground conditions [28]	D30		High machinery cost [7,32]
	C5	Natural disasters [7,8]	D31		Excessive overtime [7,32]
	C6	Surrounding environment [5,11,31]	D32		The strategy of bidding at the lowest price [6,28,30]
	C7	Major infectious disease [7,32]	D33		Construction site dispute [28,32]
	D1	Misestimate equipment productivity [5,28]	D34		Accidents occurred at the construction site [5,7,32]
	D2	Design changes [2,28,29,31]	D35		Too many simultaneous projects [6,32]
	D3	Owner delay payment [5,6,26,28]	D36		Lack of talents [5,28,30]
	D4	Poor drawing design [6,25,28]	D37		Construction waste [6]
	D5	Unrealistic contract terms [5,25,27]			

### 3.2. Data Analysis

#### 3.2.1. Questionnaire Design

According to the list of construction project cost overrun factors, the questionnaire includes the following two main parts:

- (1) Basic information about the respondent. This section serves as the background of the questionnaire and aims to collect relevant information about the respondents, such as the education level of the respondents, the work unit of the respondents, and familiarity with cost overrun factors in construction projects. The quality of the questionnaire is assured, and the accuracy of the study findings is improved.
- (2) Determining the importance of cost overrun factors in construction projects. In this paper, each influencing factor is evaluated using the 5-point Likert scale, and the corresponding scores are given according to the degree of importance. 1 - totally unimportant; 2 - unimportant; 3 - general; 4 - important; 5 - extremely important.
- (3) Questionnaire distribution.

Respondents work in construction units, engineering consulting agency units, government units, universities, and other construction industry related practitioners. In this paper, a total of 300 questionnaires were sent out by telephone interview and email, and 267 questionnaires were returned. The return rate of the questionnaire reached 89% [33].

#### 3.2.2. Indicator Optimization

- (1) Survey questionnaire sample reliability analysis.

Cronbach's  $\alpha$  above 0.9 indicates very high reliability of the questionnaire, and Cronbach's  $\alpha$  coefficient within 0.7 to 0.9 indicates high reliability of the questionnaire. This paper uses SPSS 26.0 to analyze the reliability of the questionnaire scale sample to determine whether the alpha coefficient reached an acceptable level. The results are shown in Table 2.

Table 2. Cronbach's  $\alpha$  coefficient from survey questionnaire.

Reliability Statistics	
Cronbach's $\alpha$ Coefficient	Item Count
0.894	65

According to Table 2, Cronbach's  $\alpha$  coefficient of the survey questionnaire is 0.894. It shows that the sample in the questionnaire has high reliability.

### (2) Questionnaire validity analysis

On the basis of the reliability analysis, the validity of the questionnaire is tested. In this paper, Kaiser-Meyer-Olkin (KMO) and Bartlett's test in SPSS 26.0 are used to test the validity of the data. If the KMO value is greater than 0.5, the structural validity of the questionnaire is favorable [34]. As shown in Table 3.

**Table 3.** KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.787
Bartlett's Test of Sphericity	Approx. Chi-Square	12,949.248
	df	2080
	Sig.	0.000

Bartlett's spherical test approximate chi-square is 12,949.248 with a significance of 0. The KMO sampling appropriateness was 0.787 and the KMO value was between 0.7 and 0.8, which indicates the good structural validity of the questionnaire.

### (3) Data analysis of cost overrun factors in construction projects.

Construction project cost overrun factors are analyzed, and the weights of cost overrun factors are calculated and ranked. As shown in Table 4.

**Table 4.** Statistics of cost overrun factors.

Factor Category	Construction Project Cost Overrun Factor	Average	Variance	Weight	Rank
Project macro	A1: National laws and regulations	4.01	1.081	0.0992	5
	A2: Price changes	4.32	1.291	0.1069	1
	A3: National policy changes	4.30	1.182	0.1064	2
	A4: Inflation	4.10	0.960	0.1015	4
	A5: Social influence and cultural influence	3.57	1.278	0.0883	10
	A6: Inefficient government approval	3.86	1.192	0.0955	9
	A7: Currency exchange rate fluctuation	4.27	1.068	0.1057	3
	A8: Local political instability	4.01	1.202	0.0992	6
	A9: Bank interest rate fluctuation	3.98	1.070	0.0985	8
	A10: Government corruption	3.99	1.040	0.0987	7
Project management	B1: Inadequate cost management	4.28	1.012	0.0932	4
	B2: Inadequate contract management	4.34	0.994	0.1026	1
	B3: Inadequate risk management	4.31	1.125	0.0934	2
	B4: Insufficient design	4.29	0.875	0.0945	3
	B5: Inadequate project schedule management	4.25	1.098	0.0925	5
	B6: Lack of communication	4.12	1.137	0.0897	8
	B7: Inadequate planning and scheduling	4.19	0.883	0.0912	6
	B8: Inadequate safety management	4.09	1.093	0.0890	9
	B9: Inadequate resource management	4.15	1.038	0.0903	7
	B10: Inadequate environmental management	3.97	1.161	0.0864	10
	B11: Relationship with labor force	3.95	1.098	0.0860	11

Table 4. Cont.

Factor Category	Construction Project Cost Overrun Factor	Average	Variance	Weight	Rank
Project environment	C1: Project location limitation	3.91	1.052	0.1434	3
	C2: Inappropriate temperature	3.75	1.119	0.1375	7
	C3: Unpredictable weather conditions	3.87	1.023	0.1419	4
	C4: Unpredictable ground conditions	3.84	1.206	0.1408	5
	C5: Natural disasters	3.96	0.988	0.1452	2
	C6: Surrounding environment	3.81	0.984	0.1397	6
	C7: Major infectious disease	4.13	0.963	0.1514	1
Core stakeholders	D1: Misestimate equipment productivity	3.97	0.979	0.0267	28
	D2: Design changes	4.14	0.889	0.0278	1
	D3: Owner delay payment	4.08	0.963	0.0274	10
	D4: Poor drawing design	4.13	0.862	0.0278	2
	D5: Unrealistic contract terms	4.09	1.093	0.0275	7
	D6: Lack of technical knowledge and experience	4.08	0.983	0.0274	11
	D7: Cash flow	4.10	0.980	0.0276	5
	D8: Inaccurate cost estimation	4.06	1.027	0.0273	14
	D9: Changes in project scope	4.10	0.919	0.0276	6
	D10: Inadequate supervision and control	4.03	0.959	0.0271	19
	D11: Inaccurate construction period and expense prediction	4.08	0.963	0.0274	12
	D12: Risk allocation	4.03	0.979	0.0271	20
	D13: Fraud behavior and rebate	4.12	0.955	0.0277	3
	D14: Construction staff lacks cooperation	4.07	0.955	0.0274	13
	D15: Wrong scene investigation	4.06	1.047	0.0273	15
	D16: Lack of experience with local regulations	3.98	0.989	0.0268	25
	D17: Labor shortage	3.94	0.986	0.0265	32
	D18: Financing, bonds and payment methods	3.90	1.121	0.0262	34
	D19: Delay in construction plan	4.09	0.992	0.0275	8
	D20: Material purchase and change	4.03	0.918	0.0271	21
	D21: Delay in drawing approval	4.04	1.049	0.0272	18
	D22: Error in construction	4.06	1.027	0.0273	16
	D23: Project rework	4.08	0.983	0.0274	9
	D24: The owner asked for additional works	3.99	0.858	0.0268	23
	D25: Not completed design when bidding	4.06	0.804	0.0273	17
	D26: Equipment failure	3.99	0.879	0.0268	24
	D27: Omissions and errors occurred in quantities bill	4.10	1.000	0.0276	4
	D28: Outdated construction method	4.01	0.980	0.0270	22
	D29: Insufficient quantity of equipment	3.94	0.986	0.0265	33
	D30: High machinery cost	3.95	0.997	0.0266	30
	D31: Excessive overtime	3.84	1.227	0.0258	36
	D32: The strategy of bidding at the lowest price	3.98	1.091	0.0268	26

Table 4. Cont.

Factor Category	Construction Project Cost Overrun Factor	Average	Variance	Weight	Rank
	D33: Construction site dispute	3.83	1.173	0.0258	37
	D34: Accidents occurred at the construction site	3.97	1.019	0.0267	29
	D35: Too many simultaneous projects	3.88	1.097	0.0261	35
	D36: Lack of talents	3.95	1.038	0.0266	31
	D37: Construction waste	3.98	0.929	0.0268	27

According to Table 4, there are 39 construction project cost overrun factors with an average score of 4 or more, and 26 construction project cost overrun factors with an average score between 3.57 and 4. This shows that there is an inherent link between these 39 factors and whether or not cost overrun occur in construction projects. Cost overrun factors with the highest average scores in the four categories are price changes (4.32), inadequate contract management (4.34), major infectious disease (4.13), and design changes (4.14). Therefore, the core stakeholders should consider the above factors as critical factors.

### 3.3. Model Set and Analysis

Respondents are practitioners of construction units, practitioners of engineering consulting organizations, government-related personnel, professional teachers of universities, and other construction industry-related practitioners. Respondents were given sufficient time to assess the importance of each risk factor while excluding the interference of researchers. In this paper, 300 questionnaires were sent out and 267 questionnaires were returned, and the effective rate of the questionnaires reached 89%.

Fuzzy synthetic evaluation (FSE) is a fuzzy logic approach for evaluating multi-criteria decision-making in several disciplines [35], and it has been extensively used [36–38]. Because the critical factors of cost overrun evaluation are often fuzzy and shrouded in imprecision, FSE is a powerful tool for transforming such vague data. The popularity of the technique is linked to its ease of application and practicality [39]. The proposed FSE model is a multi-criteria evaluation model for critical success factors, requiring seven steps:

Step 1: Establishing the set of basic cost overrun factors as  $U$ , where  $n$  is the number of cost overrun factors.

$$U = \{f_1, f_2, \dots, f_n\} \quad (1)$$

Step 2: Setting the grade alternatives as  $L = \{L_1, L_2, L_3, L_4, L_5\}$ , with the set of grade categories being the scale measurement. The 5-point Likert scale is used as the set of grade alternatives.  $L_1$  is very unimportant.  $L_2$  is unimportant.  $L_3$  is general.  $L_4$  is important.  $L_5$  is very important.

Step 3: Establishing the set of basic cost overrun factors weigh as  $W = \{\omega_1, \omega_2, \dots, \omega_5\}$ . The  $\omega$  is determined from the survey using the following equation.

$$w_i = \frac{M_i}{\sum_{i=1}^5 M_i}, 0 \leq w_i \leq 1, 0 \leq i \leq 1 \quad (2)$$

In Formula (2),  $w_i$  is weighing and  $\sum_{i=1}^5 w_i = 1$ ,  $M_i$  means score of particular criterion or factor component. Each cost overrun factor is calculated by using Spss 26.0. An example is the impact of national laws and regulations (A1).

$$W_{A1} = \frac{4.32}{4.32 + 4.27 + 4.3 + 4.1 + 3.57 + 4.01 + 3.86 + 4.01 + 3.98 + 3.99} = 0.1069$$

Based on Step 3, the weights of cost overrun factors can be determined. As shown in Table 2.

Step 4: Generating cost overrun factors evaluation matrix:  $R_i = (r_{ij})_{m \times n}$ , where  $r_{ij}$  denotes the degree to which the alternative  $L_j$  satisfies the criterion  $f_i$ .

$$R_i = \begin{pmatrix} MF_{u_{i1}} \\ MF_{u_{i2}} \\ \dots \\ MF_{u_{in}} \end{pmatrix} \tag{3}$$

$MF_{u_{i1}} = (\frac{N_{L_1}}{N}, \frac{N_{L_2}}{N}, \dots, \frac{N_{L_5}}{N})$ ,  $N = 255$ ;  $MF$  is the membership function, and  $N_{L_i}$  is the number of cost overrun factors, such as research on national legal and regulatory factors, 18 respondents selected  $L_1$  as very unimportant, no respondent selected  $L_2$  as unimportant, 28 respondents selected  $L_3$  as general, 46 respondents selected  $L_4$  as important and 163 respondents selected  $L_5$  as very important. This resulted in the following expression.

$$MF_{u_{i1}} = \left( \frac{18}{255}, \frac{0}{255}, \frac{28}{255}, \frac{46}{255}, \frac{163}{255} \right) = (0.070, 0.000, 0.110, 0.180, 0.640) \tag{4}$$

Step 5: According to Formula (4), calculate the data for the weights and evaluation results. As shown in Table 5.

**Table 5.** Fuzzy relational matrix data indicators for cost overrun factors.

Factor Category	Construction Project Cost Overrun Factor	Weight				
Project macro	A1: National laws and regulations	0.07	0	0.11	0.18	0.64
	A2: Market price changes	0.06	0	0.07	0.35	0.52
	A3: National policy changes	0.06	0	0.12	0.22	0.60
	A4: Inflation	0.05	0	0.13	0.44	0.38
	A5: Social influence and cultural influence	0.07	0.04	0.40	0.23	0.26
	A6: Inefficient government approval	0.05	0.03	0.14	0.42	0.36
	A7: Currency exchange rate fluctuation	0.06	0.03	0.22	0.37	0.32
	A8: Local political instability	0.06	0.03	0.14	0.38	0.39
	A9: Bank interest rate fluctuation	0.05	0.02	0.18	0.40	0.35
	A10: Government corruption	0.05	0	0.22	0.37	0.36
Project management	B1: Inadequate cost management	0.05	0.02	0.06	0.30	0.57
	B2: Inadequate contract management	0.05	0	0.10	0.32	0.53
	B3: Inadequate risk management	0.05	0	0.08	0.30	0.57
	B4: Insufficient design	0.04	0	0.09	0.37	0.50
	B5: Inadequate project schedule management	0.04	0.02	0.12	0.28	0.54
	B6: Lack of communication	0.05	0.02	0.15	0.32	0.46
	B7: Inadequate planning and scheduling	0.04	0	0.12	0.41	0.43
	B8: Inadequate safety management	0.04	0.02	0.17	0.34	0.43
	B9: Inadequate resource management	0.05	0	0.15	0.35	0.45
	B10: Inadequate environmental management	0.07	0	0.20	0.36	0.37
	B11: Relationship with labor force	0.05	0.03	0.18	0.40	0.34
Project environment	C1: Project location limitation	0.06	0.04	0.21	0.38	0.31
	C2: Inappropriate temperature	0.04	0.07	0.26	0.36	0.27
	C3: Unpredictable weather conditions	0.04	0.03	0.25	0.38	0.30

Table 5. Cont.

Factor Category	Construction Project Cost Overrun Factor	Weight				
	C4: Unpredictable ground conditions	0.04	0.03	0.24	0.36	0.33
	C5: Natural disasters	0.04	0.02	0.21	0.40	0.33
	C6: Surrounding environment	0.04	0.02	0.30	0.37	0.27
	C7: Major infectious disease	0.04	0.02	0.12	0.41	0.41
Core stakeholders	D1: Misestimate equipment productivity	0.05	0	0.23	0.38	0.34
	D2: Design changes	0.04	0.02	0.15	0.40	0.39
	D3: Owner delay payment	0.05	0	0.14	0.44	0.37
	D4: Poor drawing design	0.04	0.03	0.12	0.41	0.40
	D5: Unrealistic contract terms	0.06	0	0.14	0.39	0.41
	D6: Lack of technical knowledge and experience	0.05	0	0.15	0.42	0.38
	D7: Cash flow	0.06	0	0.11	0.45	0.38
	D8: Inaccurate cost estimation	0.04	0.02	0.18	0.36	0.40
	D9: Changes in project scope	0.04	0	0.17	0.40	0.39
	D10: Inadequate supervision and control	0.04	0.02	0.16	0.43	0.35
	D11: Inaccurate construction period and expense prediction	0.05	0	0.17	0.39	0.39
	D12: Risk allocation	0.05	0	0.17	0.43	0.35
	D13: Fraud behavior and rebate	0.04	0.03	0.16	0.37	0.40
	D14: Construction staff lacks cooperation	0.04	0	0.20	0.37	0.39
	D15: Wrong scene investigation	0.05	0	0.15	0.39	0.41
	D16: Lack of experience with local regulations	0.03	0.02	0.26	0.32	0.37
	D17: Labor shortage	0.05	0	0.25	0.37	0.33
	D18: Financing, bonds and payment methods	0.05	0.03	0.22	0.37	0.33
	D19: Delay in construction plan	0.05	0	0.18	0.36	0.41
	D20: Material purchase and change	0.04	0	0.20	0.41	0.35
	D21: Delay in drawing approval	0.05	0	0.20	0.36	0.39
	D22: Error in construction	0.04	0.02	0.18	0.36	0.40
	D23: Project rework	0.05	0	0.11	0.45	0.39
	D24: The owner asked for additional works	0.03	0	0.25	0.39	0.33
	D25: Not completed design when bidding	0.04	0	0.16	0.47	0.33
	D26: Equipment failure	0.04	0	0.23	0.40	0.33
	D27: Omissions and errors occurred in quantities bill	0.04	0	0.13	0.45	0.38
	D28: Outdated construction method	0.05	0	0.21	0.38	0.36
	D29: Insufficient quantity of equipment	0.04	0.02	0.22	0.40	0.32
	D30: High machinery cost	0.04	0.02	0.22	0.39	0.33
	D31: Excessive overtime	0.06	0.04	0.22	0.36	0.32
	D32: The strategy of bidding at the lowest price	0.05	0.02	0.19	0.38	0.36
	D33: Construction site dispute	0.05	0.04	0.26	0.33	0.32
	D34: Accidents occurred at the construction site	0.05	0	0.25	0.34	0.36
	D35: Too many simultaneous projects	0.05	0.03	0.22	0.39	0.31
	D36: Lack of talents	0.06	0	0.21	0.40	0.33
	D37: Construction waste	0.05	0	0.20	0.43	0.32

Step 6: By considering the weight vector and the fuzzy evaluation matrix, the final fuzzy integrated evaluation result of the assessment is generated by using the following equation.

$$T = W \times R = (w_1, w_2, \dots, w_n) \times \begin{pmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \vdots & \vdots & \vdots & \vdots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{pmatrix} = (t_1, t_2, \dots, t_n) \quad (5)$$

In this expression,  $t_i$  is the fuzzy set of the membership, and “ $\cdot$ ” is the fuzzy operator. For example, the project environment is calculated.

$$T_C = (0.141 \quad 0.138 \quad 0.142 \quad 0.143 \quad 0.145 \quad 0.140 \quad 0.151) \times \begin{pmatrix} 0.06 & 0.04 & 0.21 & 0.38 & 0.31 \\ 0.04 & 0.07 & 0.26 & 0.36 & 0.27 \\ 0.04 & 0.03 & 0.25 & 0.38 & 0.30 \\ 0.04 & 0.03 & 0.24 & 0.36 & 0.33 \\ 0.04 & 0.02 & 0.21 & 0.40 & 0.33 \\ 0.04 & 0.02 & 0.30 & 0.37 & 0.27 \\ 0.04 & 0.02 & 0.12 & 0.41 & 0.41 \end{pmatrix} \\ = (0.0428 \quad 0.0326 \quad 0.2259 \quad 0.3804 \quad 0.3183)$$

Step 7: Normalizing the final FSE matrix and calculating project influenced index for factor component by using the following equation.

$$PII = \sum_{i=1}^5 T \times L \quad (6)$$

According to (6), the project environment is calculated.

$$PII_c = (0.0428 \quad 0.0326 \quad 0.2259 \quad 0.3804 \quad 0.3183) \times \begin{pmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{pmatrix} = 3.8988$$

Based on Formula (6), the project macro, the project management and the core stakeholders are calculated. As shown in Table 6.

**Table 6.** Construction project cost overrun factor index.

No.	Factor Category	PII	Coefficients	Rank
1	Project macro	4.0520	0.250	2
2	Project management	4.2205	0.261	1
3	Project environment	3.8988	0.241	4
4	Core stakeholders	4.0189	0.248	3

The construction project cost overrun index is therefore expressed by using the following equation.

$$PII = 0.250 \times Project\ macro + 0.261 \times Project\ management + 0.241 \times Project\ environment + 0.248 \times Core\ stakeholders \quad (7)$$

#### 4. Analysis of Results

In order to research and analyze the construction project cost overrun factors, the top three factors in the construction project cost overrun factors will be selected for discussion in

this paper, respectively. As shown in Table 2, the top three project macro factors are market price changes, national policy changes, and currency exchange rate fluctuation. In project management, the top three factors are inadequate contract management, inadequate risk management, and insufficient design. The top three factors are major infectious diseases, natural disasters, and project location limitations. The top three factors from the core stakeholders are design changes, poor drawing design, and fraud behavior and rebate.

#### 4.1. Project Macro

##### 4.1.1. Market Price Fluctuations

There are two main reasons for market price fluctuations. Firstly, the financial crisis risk is deepening in the complex and changing global environment, leading to price increases in many materials. Secondly, countries worldwide are meeting their commitments to reduce emissions. Reducing emissions means lower production, which leads to an imbalance between supply and demand, resulting in higher prices.

In response to the impact of market price fluctuations, the following four measures can be implemented to control cost: (1) specify in the contract that price adjustments can be made when affected by market price changes [40]. Specifying the range of projects and methods of price adjustment and analyzing the national policy and market orientation. For non-adjustable contracts that cannot be compromised, the impact of market price changes on the project should be fully considered. (2) Firms should pay attention to the price adjustment and compensation work, and strengthen the change claim work [41]. Managers need to establish and improve the organizational structure of change claims. In order to reasonably solve the problem of price adjustment and compensation, firms should collect and organize the basic information, and strengthen the communication with the owner and supervisor, so as to reduce the cost pressure caused by the rise of market fluctuations. (3) Firm managers need to strengthen project internal control efforts, and project performance is improved [42]. The contractor should try to sign a fixed unit price contract, and reasonably determine the unit price of subcontracting on the basis of cost measurement and bid balance to achieve risk sharing. In addition, it is necessary to regularly collect relevant price information from the market and analyze the changes in the trend of its increase during the contract execution period. (4) The firm should strengthen resource allocation management and actively prevent price risks [43]. Project managers need to adjust resource allocation in a timely manner to reduce resource waste. In accordance with the relevant provisions of the project contract guidelines, project managers forecast changes in market trends for relevant resources and carry out reasonable material procurement and inventory management.

##### 4.1.2. National Policy Changes

National policy changes mainly stem from the need for some degree of change in the legal and policy environment. Owners often invest large amounts of money derived from bank loans. Once the national fiscal policy changes, the compression of credit scale or the increase of loan interest rates will have an impact on the normal implementation of construction projects. This result increases financial costs and interest expenses, and causes higher project overhead costs.

To mitigate the impact of national policy changes, the following measures can be adopted for improvement. (1) Using policy rationally [44]. Firms need to recognize the current national policy environment correctly, and avoid conflicts between project construction priorities and current national policies. Therefore, project managers need to be integrated with the policy, such as the rational use of green construction techniques and construction materials. While meeting the requirements of the national green building policy, the firm can obtain tax benefits and support to reduce construction cost. (2) Focus on training relevant financial and legal personnel, and study the laws and regulations of the construction industry in depth [45], so that corresponding adjustments can be made as

early as possible in the construction process of subsequent projects, and prevent additional cost increases by changes in national policies.

#### 4.1.3. Currency Exchange Rate Fluctuation

During the construction of large projects, changes in material requirements due to engineering changes often occur. If procurement activities are conducted at this time, changes in the prices of raw materials, labor, and equipment will have an impact on project cost. Since international purchases are settled in foreign currencies, higher currency exchange rates cause the more local currency to be paid, which increases project costs.

In order to reduce the impact of currency exchange rate fluctuations, the firm can effectively prevent and avoid them through the following measures. (1) Reasonably estimating the exchange rate risk reserve required for the project [46], e.g., the firm should analyze the exchange rate risk that the project may suffer when preparing the tender, and then adjust the exchange rate risk reserve appropriately. (2) Preparing relevant preventive plans in advance, and taking the initiative of exchange rate risk management [47]. (3) Establishing a sharing exchange rate risks mechanism [48]; e.g., stakeholders add appropriate exchange rate risk sharing mechanism clauses to the contract, and share the losses caused by currency exchange rate changes during the contract negotiation process.

### 4.2. Project Management

#### 4.2.1. Inadequate Contract Management

There are four reasons for inadequate contract management. Firstly, the legal awareness of construction firms is low and their daily operations are not standardized. The contract of construction projects with larger value is often signed through less rigorous bidding procedures, and leaves a greater hidden danger for disputes and economic risks in later construction contracts. Furthermore, the rigorous contract management system is not established, and construction firms lack a full-time contract management department and personnel. This will lead to mistakes in contract management in the later stage. Moreover, construction firms lack effective monitoring measures and risk management measures for contract management failures. Finally, there are many defects and errors in the text of the contracts currently signed in the construction industry. When the breach of contract occurs in construction projects, the specific consequences and handling methods lack comprehensive descriptions, resulting in the inability to perform contractual duties in the later construction process.

The following measures can be taken to prevent the impact of inadequate contract management on project costs. (1) The quality of relevant contract management personnel is improved [49]; e.g., the selection of personnel through open selection and competitive recruitment, and the organization of the corresponding study for in-service contract management personnel. (2) The contract management system is established; e.g., the construction firm needs to establish perfect contract management organizations, and builds the relevant contract management system [50]. (3) Construction firms need to establish highly intelligent contract information management system to improve the efficiency of contract management in construction projects [50], so that the work on contracts can be handled more efficiently in the later phase, and avoid cost overrun due to contract losses caused by the lack of contract management.

#### 4.2.2. Inadequate Risk Management

Inadequate risk management is the result of the long-term complacency of the top management in construction projects. Therefore, managers often lack risk perception and preventive measures, such as denying risks in construction projects. This makes it difficult to carry out risk management work, and construction projects are vulnerable to receiving risks.

To avoid inadequate risk management, the following measures can be adopted for improvement. (1) Establishing a robust risk management system [51]. The risks affect-

ing the construction projects cost can be detected in time, and transferred and avoided before they have an impact. (2) Improving the risk warning awareness of staff in construction firms [52]. Continuously strengthen risk awareness education for relevant personnel in daily production management activities, so that relevant senior management can change their management style in time to make up for the weaknesses and deficiencies in risk management.

#### 4.2.3. Insufficient Design

Insufficient design is mainly caused by the following reasons: firstly, unreasonable construction schemes can lead to insufficient design. With the developments in recent years, the construction of buildings is gradually becoming more difficult, and requires more types of technology and machinery. This can lead to unreasonable construction plans, which can result in flawed project design. Secondly, the total duration of the construction project and the phase duration are unreasonable, resulting in a greater impact on the design of the construction plan and the scheduling of resources.

Insufficient design can be addressed by the following measures: (1) raising awareness of design among construction project managers [53]. Construction firms need to regularly train relevant project organization and design personnel in the context of the project. The process of construction project organization design is adjusted to refine the concept of organization design. (2) Optimizing the project construction scheme [31]. The construction firm can coordinate the rational deployment of all resources in tandem with the actual construction period to achieve cost-optimization.

### 4.3. Project Environment

#### 4.3.1. Major Infectious Disease

Major infectious disease causes cost overrun for two main reasons. Firstly, in order to prevent the wide spread of the epidemic, firms had to purchase and stockpile large quantities of epidemic prevention and control materials. This results in higher epidemic protection costs for construction firms, and makes projects prone to cost overrun. Secondly, delays due to the epidemic, idling of machinery, idleness of workers, additional overhead costs, and reduced returns to the owner from project delays can all add to project costs.

For major infectious disease, the following measures can be countermeasures to prevent. (1) Strengthening management efforts to promote the degree of epidemic prevention of construction site personnel [6]. Firms need to prevent imported and aggregated infections to ensure the safe operation of construction sites under epidemic situations. (2) Improving the degree of intelligent and informative applications, and promoting flexible office mechanisms such as online approval for various procedures [54]. The efficiency of office operations of firms in the high-pressure state of epidemic prevention and control is improved, and the emergency response capability of construction firms in epidemic conditions is strengthened. This ensures that construction projects do not cause delays caused by reduced construction efficiency.

#### 4.3.2. Natural Disasters

The surrounding environment of the construction project is complex, and there may be natural disasters such as floods and earthquakes affecting the normal construction of the project. In addition, natural disasters can lead to damage to machinery and the idleness of workers, and add significant additional costs. The following measures can be used to reduce the impact of natural disasters: (1) monitoring the geographical environment in which the construction project is located [55]. Construction firms should research the number of natural disasters that have occurred in the area, and locate the project in a relatively safe location. (2) Establishing monitoring feedback avoidance mechanisms for natural disasters [56].

#### 4.3.3. Project Location Limitation

Project location limitation is mainly due to the geographical location of the construction project itself, and this objective condition cannot be adjusted. In order to reduce the impact of project location limitations on cost overrun, construction firms can collect detailed information on the environmental conditions of the site in advance of the project [55], such as resources, transportation, and power supply. Construction firms can analyze this information to ensure that the project is in the best geographic location for construction.

#### 4.4. Core Stakeholders

##### 4.4.1. Design Changes

Design changes are mainly due to the following reasons. Firstly, the owner's needs are not realized in the design process of the construction drawings. This can lead to frequent requests from the owner to revise the construction drawings, significantly increasing construction costs. Furthermore, the design engineer failed to maintain good communication, which in turn prevented the owner's needs from being met. Finally, the design engineers were not able to understand the market changes in construction materials well. The materials used in the drawings cannot be used in the actual construction, which also causes frequent design requirement changes in the later drawings.

For design changes, the following measures can be countermeasures to prevent these issues: (1) optimizing the drawings during the design phase of construction projects. Designers need to analyze the construction drawings to avoid rework in the field construction phase and reduce the waste of construction costs [57]. (2) Establishing a review mechanism for construction drawings [58]. Strengthening the review mechanism of construction drawings is the key to reducing design changes; e.g., entrusting relevant qualified units to conduct secondary audits of construction drawings to avoid cost increases due to design changes in the construction site.

##### 4.4.2. Poor Drawing Design

The following reasons mainly cause poor drawing design. Firstly, the designers of construction drawings are not familiar with the construction technology of some special items in the construction projects, so they cannot ensure that the drawings can be carried out normally in the construction stage. Secondly, some construction projects need a short time to produce drawings. The construction design firms may not be able to mobilize enough personnel to deepen the design of the project in time, resulting in the designed construction drawings being prone to mistakes.

To ensure the normal operation of construction projects, the firms can effectively prevent and avoid poor drawing designs through the following measures: (1) priority is given to design units with higher qualification degrees and experience [59]. High-level design units can reduce the errors in the design drawings to a certain extent, and can have relevant experienced designers to assist in adjusting the construction drawings. (2) Improving the design degree and economic consciousness of architectural design firm practitioners [59]. Some construction firms only pursue the ideal construction situation, and the resulting design is out of touch with reality. Therefore, firms need to regularly carry out design practitioner learning to improve their professional knowledge.

##### 4.4.3. Fraud Behavior and Rebate

There are four reasons for fraud behavior and rebate. Firstly, the owner wants to reduce the project cost and improve the project's economic benefits. Thus, the design drawings and quantity list in the bidding stage are deducted, which will lead to the construction of the firm resulting in the actual project quantity does not match with the bidding. Secondly, in order to get the corresponding rebate, the supervisory unit does not inspect the construction project to a high standard as required by the contract text. This result causes the project site construction to not be carried out properly, and the construction firm must bear the additional cost required by the supervisory unit and the owner's unit.

To avoid fraud behavior and rebate, the following measures can be adopted for improvement: (1) proper handling of the relationship among the core stakeholders in construction projects [60]; (2) investigating the qualifications and background of each core stakeholder [61]. Firms should abandon or replace stakeholders with poor creditworthiness to avoid possible fraud behavior and rebate risk; (3) strengthening the internal management of construction projects and improving the overall quality of management personnel [62].

## 5. Conclusions

Achieving project completion within the budgeted cost is the fundamental and essential criterion of any successful project [63]. To guarantee this, various procurement systems and methodologies are being practiced [7]. However, the construction industry is still facing many issues, including project delay and cost overrun worldwide [64]. Fuzzy sets were proposed by Zadeh [65] to deal with significant problems that cannot be quantified in a general mathematical sense. A major contribution of fuzzy set theory is its capability of representing vague data [66–68]. Based on the FSE, this paper discusses the mitigation measures for cost overrun in construction projects from the supplier and the owner. Through structured questionnaires and interviews with expert respondents, 65 common and significant factors were identified. The results showed that market price changes, national policy changes, currency exchange rate fluctuation, inadequate contract management, inadequate risk management, insufficient design, major infectious disease, natural disasters, project location limitation, design changes, poor drawing design and fraud behavior, and rebate are most significant and common factors affecting construction costs.

Moreover, cost overrun is still happening and will continue to happen during the construction process for various known and unknown reasons [69], such as market price changes, social influence and cultural influence, inadequate risk management, inadequate resource management, adverse weather conditions, design changes and changes in project scope. However, cost overrun may not be prevented entirely, but the evolving new technology like BIM, experience, and new methods could be used to reduce the impact of recognized cost overrun factors. Finally, this paper concludes that it is significant to evaluate the critical cost overrun factors and take necessary proactive actions at the early stage of a project and before preparing the execution plan so that cost overrun could be minimized in future construction projects.

The results of this study provide theoretical support to supplement the cost overrun factors in the construction supply chain and offer some insights into the practice of cost overrun management in the construction supply chain. The model in this paper can be used in the future to assess the cost overrun factors in each construction project. However, the findings presented here are unlikely to be applicable to all industries. Therefore, the results and conclusions of this study should be viewed and interpreted in this context.

**Author Contributions:** Conceptualization, B.D.; Methodology, X.L.; Investigation, Y.Y.; Data curation, Z.D.; Writing—original draft preparation, W.X.; Writing—review and editing, W.X. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was funded by the National Natural Science Foundation of China, grant number. 71602144, the Tianjin education commission Project of Key Research Institute of Humanities and Social Sciences at Universities, grant number 2017JWZD15, and the Program for Innovation Research Team In Universities of Tianjin, grant number TD13-5019.

**Data Availability Statement:** All data have been provided in the corresponding chapters of the paper.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Aziz, A.A.A.; Memon, A.H.; Rahman, I.A.; Karim, A.T.A. Controlling cost overrun factors in construction projects in Malaysia. *Res. J. Appl. Sci. Eng. Technol.* **2013**, *5*, 2621–2629.
2. Creedy, G.D.; Skitmore, M.; Wong, J.K. Evaluation of risk factors leading to cost overrun in delivery of highway construction projects. *J. Constr. Eng. Manag.* **2010**, *136*, 528–537. [[CrossRef](#)]
3. Yuan, J.; Skibniewski, M.J.; Li, Q.; Zheng, L. Performance objectives selection model in public-private partnership projects based on the perspective of stakeholders. *J. Manag. Eng.* **2010**, *26*, 89–104. [[CrossRef](#)]
4. Tejale, D.S.; Khandekar, S.D.; Patil, J.R. Analysis of construction project cost overrun by statistical method. *Int. J.* **2015**, *3*, 349–355.
5. Ramanathan, C.; Potty, N.S.; Idrus, A.B. Analysis of time and cost overrun in Malaysian construction. *Adv. Mater. Res.* **2012**, *452*, 1002–1008. [[CrossRef](#)]
6. Sohu, S.; Halid, A.; Nagapan, S.; Fattah, A.; Latif, I.; Ullah, K. Causative factors of cost overrun in highway projects of Sindh province of Pakistan. *IOP Conf. Ser. Mater. Sci. Eng.* **2017**, *271*, 012036. [[CrossRef](#)]
7. Memon, A.H.; Rahman, I.A.; Azis, A.A.A. Preliminary study on causative factors leading to construction cost overrun. *Int. J. Sustain. Constr. Eng. Technol.* **2011**, *2*, 1.
8. Wang, J.Y.; Yuan, H.P. Major cost-overrun risks in construction projects in China. *Int. J. Proj. Organ. Manag.* **2011**, *3*, 227–242. [[CrossRef](#)]
9. Car-Pušić, D.; Tijić, K.; Marović, I.; Mlađen, M. Predicting buildings construction cost overruns on the basis of cost overruns structure. *Przegląd Nauk. Inżynieria I Kształtowanie Sr.* **2020**, *29*, 366–376.
10. Moschouli, E.; Soeipto, R.M.; Vanelslander, T. Cost performance of transport infrastructure projects before and after the global financial crisis (GFC): Are differences observed in the conditions of project performance? *Res. Transp. Econ.* **2019**, *75*, 21–35. [[CrossRef](#)]
11. Alhomidan, A. Factors affecting cost overrun in road construction projects in Saudi Arabia. *Int. J. Civ. Environ. Eng.* **2013**, *13*, 1–4.
12. Dikmen, I.; Birgonul, M.T.; Han, S. Using fuzzy risk assessment to rate cost overrun risk in international construction projects. *Int. J. Proj. Manag.* **2007**, *25*, 494–505. [[CrossRef](#)]
13. Sepasgozar, S.M.; Costin, A.M.; Karimi, R.; Shirowzhan, S.; Abbasian, E.; Li, J. BIM and Digital Tools for State-of-the-Art Construction Cost Management. *Buildings* **2022**, *12*, 396. [[CrossRef](#)]
14. Ashtari, M.A.; Ansari, R.; Hassannayebi, E.; Jeong, J. Cost Overrun Risk Assessment and Prediction in Construction Projects: A Bayesian Network Classifier Approach. *Buildings* **2022**, *12*, 1660. [[CrossRef](#)]
15. Chadee, A.A.; Chadee, X.T.; Ray, I.; Mwashu, A.; Martin, H.H. When parallel schools of thought fail to converge: The case of cost overruns in project management. *Buildings* **2021**, *11*, 321.
16. Enshassi, A.; Al-Najjar, J.; Kumaraswamy, M. Delays and cost overruns in the construction projects in the Gaza Strip. *J. Financ. Manag. Prop. Constr.* **2009**, *14*, 126–151. [[CrossRef](#)]
17. Koushki, P.A.; Al-Rashid, K.; Kartam, N. Delays and cost increases in the construction of private residential projects in Kuwait. *Constr. Manag. Econ.* **2005**, *23*, 285–294. [[CrossRef](#)]
18. Kaming, P.F.; Olomolaiye, P.O.; Holt, G.D.; Harris, F.C. What motivates construction craftsmen in developing countries? A case study of Indonesia. *Buuld. Environ.* **1998**, *33*, 131–141. [[CrossRef](#)]
19. Iyer, K.C.; Jha, K.N. Factors affecting cost performance: Evidence from Indian construction projects. *Int. J. Proj. Manag.* **2005**, *23*, 283–295. [[CrossRef](#)]
20. Niazi, G.A.; Painting, N. Significant factors causing cost overruns in the construction industry in Afghanistan. *Procedia Eng.* **2017**, *182*, 510–517. [[CrossRef](#)]
21. Zou, P.X.; Zhang, G.; Wang, J. Understanding the key risks in construction projects in China. *Int. J. Proj. Manag.* **2007**, *25*, 601–614. [[CrossRef](#)]
22. Schaufelberger, J.E.; Holm, L. *Management of Construction Projects: A Constructor's Perspective*; Routledge: London, UK, 2017.
23. Derakhshanlavijeh, R.; Teixeira, J.M.C. Cost overrun in construction projects in developing countries, Gas-Oil industry of Iran as a case study. *J. Civ. Eng. Manag.* **2017**, *23*, 125–136. [[CrossRef](#)]
24. Ke, H.; Cui, Z.; Govindan, K.; Zavadskas, E.K. The impact of contractual governance and trust on EPC projects in construction supply chain performance. *Eng. Econ.* **2015**, *26*, 349–363. [[CrossRef](#)]
25. Foroutan Mirhosseini, A.; Pitera, K.; Odeck, J.; Welde, M. Sustainable Project Management: Reducing the Risk of Cost Inaccuracy Using a PLS-SEM Approach. *Sustainability* **2022**, *14*, 960. [[CrossRef](#)]
26. Pilger, J.D.; Machado, E.L.; de Assis Lawisch-Rodriguez, A.; Zappe, A.L.; Rodriguez-Lopez, D.A. Environmental impacts and cost overrun derived from adjustments of a road construction project setting. *J. Clean. Prod.* **2020**, *256*, 120731. [[CrossRef](#)]
27. Olander, S.; Landin, A. Evaluation of stakeholder influence in the implementation of construction projects. *Int. J. Proj. Manag.* **2005**, *23*, 321–328. [[CrossRef](#)]
28. Shehu, Z.; Endut, I.R.; Akintoye, A. Factors contributing to project time and hence cost overrun in the Malaysian construction industry. *J. Financ. Manag. Prop. Constr.* **2014**, *19*, 55–75. [[CrossRef](#)]
29. Vu, H.A.; Wang, J.; Min, L.; Mai, S.H.; Nguyen, H.P. Research on cost overrun risk of construction phase of Vietnam highway international contracting project. *Engineering* **2016**, *8*, 86–98. [[CrossRef](#)]
30. Ismail, I.; Memon, A.H.; Rahman, I.A. Expert opinion on risk level for factors affecting time and cost overrun along the project lifecycle in Malaysian construction projects. *Int. J. Constr. Technol. Manag.* **2013**, *1*, 2289.

31. Aljohani, A.; Ahiaga-Dagbui, D.; Moore, D. Construction projects cost overrun: What does the literature tell us? *Int. J. Innov. Manag. Technol.* **2017**, *8*, 137. [[CrossRef](#)]
32. Abusafiya, H.A.; Suliman, S.M. Causes and effects of cost overrun on construction project in Bahrain: Part I (ranking of cost overrun factors and risk mapping). *Mod. Appl. Sci.* **2017**, *11*, 20. [[CrossRef](#)]
33. Othman, I.; Kineber, A.F.; Oke, A.E.; Zayed, T.; Buniya, M.K. "Barriers of value management implementation for building projects in Egyptian construction industry". *Ain Shams Eng. J.* **2021**, *12*, 21–30. [[CrossRef](#)]
34. Napitupulu, D.; Kadar, J.A.; Jati, R.K. Validity testing of technology acceptance model based on factor analysis approach. *Indones. J. Electr. Eng. Comput. Sci.* **2017**, *5*, 697–704. [[CrossRef](#)]
35. Xu, Y.; Yeung, J.F.; Chan, A.P.; Chan, D.W.; Wang, S.Q.; Ke, Y. Developing a risk assessment model for PPP projects in China—A fuzzy synthetic evaluation approach. *Autom. Constr.* **2010**, *19*, 929–943. [[CrossRef](#)]
36. Ameyaw, E.E.; Chan, A.P. Evaluation and ranking of risk factors in public–private partnership water supply projects in developing countries using fuzzy synthetic evaluation approach. *Expert Syst. Appl.* **2015**, *42*, 5102–5116. [[CrossRef](#)]
37. Zhao, X.; Hwang, B.G.; Gao, Y. A fuzzy synthetic evaluation approach for risk assessment: A case of Singapore's green projects. *J. Clean. Prod.* **2016**, *115*, 203–213. [[CrossRef](#)]
38. Zafar, I.; Wuni, I.Y.; Shen, G.Q.; Ahmed, S.; Yousaf, T. A fuzzy synthetic evaluation analysis of time overrun risk factors in highway projects of terrorism-affected countries: The case of Pakistan. *Int. J. Constr. Manag.* **2022**, *22*, 732–750. [[CrossRef](#)]
39. Lo, S.M. A fire safety assessment system for existing buildings. *Fire Technol.* **1999**, *35*, 131–152. [[CrossRef](#)]
40. Dore, R. Goodwill and the spirit of market capitalism. In *The Sociology of Economic Life*; Routledge: London, UK, 2018; pp. 456–473.
41. Walker, J.P.; Van Duzor, A.G.; Lower, M.A. Facilitating argumentation in the laboratory: The challenges of claim change and justification by theory. *J. Chem. Educ.* **2019**, *96*, 435–444. [[CrossRef](#)]
42. Ika, L.A.; Diallo, A.; Thuillier, D. Critical success factors for World Bank projects: An empirical investigation. *Int. J. Proj. Manag.* **2012**, *30*, 105–116. [[CrossRef](#)]
43. Yang, T.T.; Li, C.R. Competence exploration and exploitation in new product development: The moderating effects of environmental dynamism and competitiveness. *Manag. Decis.* **2011**, *49*, 1444–1470. [[CrossRef](#)]
44. Pu, L.; Wang, X.; Tan, Z.; Wang, H.; Yang, J.; Wu, J. Is China's electricity price cross-subsidy policy reasonable? Comparative analysis of eastern, central, and western regions. *Energy Policy* **2020**, *138*, 111250. [[CrossRef](#)]
45. Chien, K.F.; Wu, Z.H.; Huang, S.C. Identifying and assessing critical risk factors for BIM projects: Empirical study. *Autom. Constr.* **2014**, *45*, 1–15. [[CrossRef](#)]
46. Combes, J.L.; Kinda, T.; Plane, P. Capital flows, exchange rate flexibility, and the real exchange rate. *J. Macroecon.* **2012**, *34*, 1034–1043. [[CrossRef](#)]
47. Sun, R.; Park, C. Interactions between the exchange rate of RMB/USD in the onshore and offshore markets: Evidence from the comparative analysis on '8.11' exchange rate reform in China. *Int. J. Econ. Financ. Stud.* **2021**, *13*, 318–339.
48. Feng, Q.; Sun, X.; Liu, C.; Li, J. Spillovers between sovereign CDS and exchange rate markets: The role of market fear. *North Am. J. Econ. Financ.* **2021**, *55*, 101308. [[CrossRef](#)]
49. Wei, F. Research on the Professionalization of Administrative Personnel in Colleges and Universities. In Proceedings of the 2017 4th International Conference on Education, Management and Computing Technology (ICEMCT 2017), Hangzhou, China, 15–16 April 2017; pp. 970–973.
50. Wang, J.; Wu, P.; Wang, X.; Shou, W. The outlook of blockchain technology for construction engineering management. *Front. Eng. Manag.* **2017**, *4*, 67–75. [[CrossRef](#)]
51. Chang, S.I.; Huang, S.M.; Roan, J.; Chang, I.; Liu, P.J. Developing a risk management assessment framework for public administration in Taiwan. *Risk Manag.* **2014**, *16*, 164–194. [[CrossRef](#)]
52. Gao, S.S.; Sung, M.C.; Zhang, J. Risk management capability building in SMEs: A social capital perspective. *Int. Small Bus. J.* **2013**, *31*, 677–700. [[CrossRef](#)]
53. Doloi, H.; Sawhney, A.; Iyer, K.C.; Rentala, S. Analysing factors affecting delays in Indian construction projects. *Int. J. Proj. Manag.* **2012**, *30*, 479–489. [[CrossRef](#)]
54. Ogunnusi, M.; Hamma-Adama, M.; Salman, H.; Kouider, T. COVID-19 pandemic: The effects and prospects in the construction industry. *Int. J. Real Estate Stud.* **2020**, *14*, 120–128.
55. Connors, J.P.; Lei, S.; Kelly, M. Citizen science in the age of neogeography: Utilizing volunteered geographic information for environmental monitoring. *Ann. Assoc. Am. Geogr.* **2012**, *102*, 1267–1289. [[CrossRef](#)]
56. Zhang, X.; Yi, L.; Zhao, D. Community-based disaster management: A review of progress in China. *Nat. Hazards* **2013**, *65*, 2215–2239. [[CrossRef](#)]
57. Dehghan, R.; Hazini, K.; Ruwanpura, J. Optimization of overlapping activities in the design phase of construction projects. *Autom. Constr.* **2015**, *59*, 81–95. [[CrossRef](#)]
58. Dang, W. Research on examination of construction drawings of university construction projects. *Archit. Eng. Sci.* **2021**, *2*, 4325–4345. [[CrossRef](#)]
59. Hadi, Z.; Samikon, S.A.; Rahim, F.N.A. Enhancement of The Current Iraqi Construction Industry Performance (Time and Cost) By Building Information Modeling (BIM) Utilization. *Des. Eng.* **2021**, *4*, 1330–1358.
60. Alhiddi, A.; Osborne, A.N.; Anyigor, K.T. Organizational culture and stakeholder success criteria in construction projects. *Period. Polytech. Archit.* **2019**, *50*, 148–154. [[CrossRef](#)]

61. Hujainah, F.; Bakar, R.B.A.; Al-Haimi, B.; Abdulgaber, M.A. Stakeholder quantification and prioritisation research: A systematic literature review. *Inf. Softw. Technol.* **2018**, *102*, 85–99. [[CrossRef](#)]
62. Li, X. The effectiveness of internal control and innovation performance: An intermediary effect based on corporate social responsibility. *PLoS ONE* **2020**, *15*, e0234506. [[CrossRef](#)]
63. Chan, A.P.; Chan, A.P. Key performance indicators for measuring construction success. *Benchmarking Int. J.* **2004**, *11*, 203–221. [[CrossRef](#)]
64. Ahady, S.; Gupta, S.; Malik, R.K. A critical review of the causes of cost overrun in construction industries in developing countries. *Int. Res. J. Eng. Technol.* **2017**, *4*, 2550–2558.
65. Zadeh, L.A. Fuzzy sets. *Inf. Control* **1965**, *8*, 338–353. [[CrossRef](#)]
66. Mokhtari, K.; Ren, J.; Roberts, C.; Wang, J. Decision support framework for risk management on sea ports and terminals using fuzzy set theory and evidential reasoning approach. *Expert Syst. Appl.* **2012**, *39*, 5087–5103. [[CrossRef](#)]
67. Zhou, H.; Zhao, Y.; Shen, Q.; Yang, L.; Cai, H. Risk assessment and management via multi-source information fusion for undersea tunnel construction. *Autom. Constr.* **2020**, *111*, 103050. [[CrossRef](#)]
68. Pang, B.; Bai, S. An integrated fuzzy synthetic evaluation approach for supplier selection based on analytic network process. *J. Intell. Manuf.* **2013**, *24*, 163–174. [[CrossRef](#)]
69. Shah, R.K. An exploration of causes for delay and cost overrun in construction projects: A case study of Australia, Malaysia & Ghana. *J. Adv. Coll. Eng. Manag.* **2016**, *2*, 41–55.