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Post-COVID-19 Recovery: An Integrated Framework of Construction Project Performance Evaluation in China

Han-Sen Guo [1], Ming-Xin Liu [2], Jin Xue [3,*], Izzy Yi Jian [4], Qian Xu [5] and Qian-Cheng Wang [6]

1 Department of Civil and System Engineering, Johns Hopkins University, Baltimore, MD 21218, USA
2 School of Civil Engineering, Chang'an University, Xi'an 710064, China
3 Department of Building and Real Estate, The Hong Kong Polytechnic University, Hong Kong 999997, China
4 School of Design, The Hong Kong Polytechnic University, Hong Kong 999997, China
5 Department of Management, Lincoln International Business School, University of Lincoln, Lincoln LN6 7TS, UK
6 Department of Land Economy, University of Cambridge, Cambridge CB3 9EU, UK
* Correspondence: jin.xue@connect.polyu.hk

Abstract: With the lifting of the COVID-19 lockdown, the construction industry is gradually moving towards a new normality. This study aims to evaluate the construction project performance in the post-COVID-19 pandemic context and proposes a roadmap framework to achieve project recovery in China. This paper follows a sequential mixed methodology with three core steps. First, the critical success factors (CSFs) and key performance indicators (KPIs) are derived from literature reviews and expert interviews. Second, the study conducts a questionnaire survey with 150 experts. Third, the research implements factor analysis and analytic hierarchy process (AHP) analysis for CSFs and characteristics and comparative analysis for KPIs. Based on the results, the study employs structural equational modelling (SEM) to connect the CSFs and KPIs and develop a roadmap towards the post-COVID-19 pandemic recovery of the construction projects. The study identifies 32 CSFs and 25 KPIs and categorises them into five clusters, respectively. The SEM analysis suggests that management and technological innovation significantly contribute to achieving enterprise strategic goals and advancing industrial development. The consistency of project goals and external expectations also positively affect the satisfaction level of stakeholders and social impact. In addition, the AHP clarifies that the stability of the external environment, the internal support, and the adequacy of resources are critical drivers to the post-COVID-19 recovery of construction projects. This research proffers a roadmap towards the project recovery of the construction industry in the post-COVID-19 era by connecting the performance indicators and their critical success drivers. The findings would guide comprehensive design and construction, project life cycle management, and assist in dealing with public health emergencies in construction project management to maximise the organisation's profits and positive social impact.

Keywords: COVID-19; construction project; key performance indictor; critical success factor; analytic hierarchy process; organisation management; analytic hierarchy process

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1. Introduction

The COVID-19 pandemic has resulted in dramatic global social changes and economic fluctuations. Due to the dynamic nature of the COVID-19 [1] and the compound frame of construction projects [2], the impacts of the pandemic manifested across several dimensions of the construction sector [3–6]. The growing health risk and worldwide city lockdowns swept the industry in early pandemic stages, where only approximately 35% of the construction organisations fully operated [5] and the averaged unemployment rate of construction workers increased by 95% in the US [7]. Most organisations developed and implemented pandemic response measures to mitigate the impacts on the operation of construction projects, such as remote working, social distancing, and regular health checks.

Some contractors, however, blocked labours from outside contact at construction sites to reduce the risk of exposure to the virus. Even so, a large number of construction sites still experienced supply chain crises, professional labour shortages, financial and safety issues, and reduced productivity [4,7–9]. These unforeseen risks deeply affect the performance of construction projects and have a profound influence on the entire industry.

As the pandemic is brought under control, the global economy has gradually climbed out from the depths since 2022. The urban environments began rescinding temporary policy changes resuming pre-COVID activities and contributed to the recovery process of construction project performance [8]. The term *project performance recovery* refers to the process from a project being negatively affected by an external intervention to gradually achieving the project objectives, including time, expense, safety, quality, and sustainability [10]. In the aftermath of the COVID-19, however, there remains a significant number of uncertainties in the construction project performance recovery process. For example, contractors have to recruit a sufficient professional workforce in an environment of worker shortage and rebuild the supply chains in a short period to ensure the supply of construction materials. In addition, higher sustainability requirements pose additional challenges to construction project management in the post-pandemic era [8]. Additionally, other uncertainties, such as the uptake of remote working, the risk of multi-wave infection [11], and potential structural economic and social changes [12], could prove critical challenges to construction activity recovery.

While the academia has discussed the short-term impact of COVID-19 on the development and construction industry [13], it is also important to draw a clear guideline to project performance recovery for the practitioners. However, there is limited research on comprehensive recovery strategy to address the specific challenges in the post-COVID era available to the construction organisations. To bridge this research gap, this study aims to develop an integrated roadmap to construction project performance recovery based on information from both the academia and the construction industry. The research explores important paths towards post-COVID performance recovery of construction projects through identification and analysis of the critical success factors. The study also points out the drivers to post-COVID recovery of construction projects through a sequential and mixed method analysis of key performance indicators. The outcomes of this research not only provide an action plan to manage the impacts of COVID-19 pandemic but also provide insights into project management strategies for fast project performance recovery in the post-COVID era.

The AHP is a critical component of this study as it provides a structured technique for organizing and analysing complex decisions, based on mathematics and psychology. AHP has been extensively used in complex decision-making scenarios where both qualitative and quantitative aspects need to be considered. In the context of this study, AHP helps in determining the relative importance of the CSFs in the post-COVID-19 recovery of construction projects. It allows for a comprehensive and rational analysis of the various factors that contribute to the success of construction projects in the post-COVID stage.

The remainder of this paper is organised as follows. Section 2 reviews the literature and identifies the KPIs and CSFs. Section 3 describes the sequential mixed methodology employed in this research. Section 4 introduces the survey data and analysis results. Section 5 further discusses the analysis results and proposes the roadmap based on the analysis. Section 6 concludes the paper.

2. Literature Review

This study conducts a literature review on three specific focuses: (1) the impact of COVID-19 pandemic on construction project performance, (2) critical success factors (CSFs), and (3) key performance indicators (KPIs) of construction projects. The criteria for selecting information sources included assessing the impact of the COVID epidemic on construction projects and reflecting the evaluation process of engineering projects under normal situations using CSFs and KPIs inherent to construction projects. Peer-reviewed journal articles, government guidelines, and relevant agency guidelines, published between January 2020 and March 2022, were searched and indexed for the impact of COVID on construction projects. The research only includes sources that meet all of these criteria.

A search of published information was used to identify potentially relevant literature. The same keywords were used in the same information source for each topic: (1) COVID, Coronavirus, Pandemic, Construction Project; (2) Construction Project, critical success factors, CSF; (3) Construction Project, key performance indicators, KPI. Following this strategy, relevant documents from January 2020 to March 2022 were generated for topic 1 (N1 = 74), while topics 2 and 3 were generated from the year 2000 to the present (N2 = 576, N3 = 632). The eligibility of identified documents was first assessed against the title and abstract (removing 633 documents) and was then against full text (removing 597 documents). Some documents were removed because they did not directly relate to the specific topics of interest, namely the impact of COVID-19 on construction projects, critical success factors (CSFs) in construction projects, and key performance indicators (KPIs) in construction projects. Others were excluded because they did not provide empirical data or were not peer-reviewed, which was a requirement for this study to ensure the reliability and validity of the information used. Others were based on contexts that were not relevant to this study, such as construction projects in countries with significantly different industry standards and practices than China. Some documents were also removed because they were duplicates or had overlapping data with other selected studies. After this rigorous selection process, the remaining 52 documents were deemed to meet all the criteria and were included in the review.

2.1. Impact of COVID-19 on Construction Project Performance

COVID-19 is the most impactful global infectious disease that humanity has faced in recent years, and it can be spread through direct contact with the mouth, nose, or eyes of infectious respiratory droplets, as well as direct contact with an infected person or indirect contact with an infected surface. Based on the above characteristics, most governments around the world have implemented strict lockdown measures, restricted the movement of people and gatherings, and required personal protective measures to reduce the spread of the virus, as recommended by epidemiologists [14–16]. Following the COVID-19 pandemic, these lockdowns have become stricter or more liberal depending on the country as the epidemic situation changes, but social distancing to prevent the spread of the disease will continue, which led to a significant impact on construction projects that are of a labor-intensive nature [17,18].

The pandemic has disrupted day-to-day practices in the construction industry. Construction projects are usually multiple objective process [19]. There are several reports on the impacts of COVID-19 on construction engineering, including site health and safety, economic costs, legal risks, manpower availability, supply chain instability, and uncertainty due to the unpredictable evolution of the pandemic [20–22]. The magnitude of these impacts varies based on project size, contractor characteristics, local government policies, etc. [4]. Pamidimukkala and Kermanshachi showed that the main challenges facing construction workers during the COVID-19 pandemic are organizational, economic, psychological, personal, and adjustment factors [21]. Some studies also suggest workforce protection, project performance protection, and project continuity protection as important steps to help construction workers overcome health and safety challenges modeled the spread of COVID-19 among construction workers and concluded that the workforce could be reduced by 30% to 90%, where construction managers should maximize low-risk activities related to the spread of the virus [4,23,24].

2.2. Critical Success Factors of Construction Project Performance

Critical success factor (CSF) is a widely employed management term defined as a necessary element for a construction project to achieve its mission. In the past few decades, there has been a growing emphasis to comprehensively deconstruct the complex factors contributing to the success or failure of construction projects. For example, important success factors for research and development (R&D) projects, PPP projects, and safe construction projects have been studied by previous researchers [25]. Chua et al. clearly suggested that for construction projects, the socio-political environment, the relationship between stakeholders (e.g., government, clients), and the capacity of project managers, designers, and contractors are important [26]. Chan et al. proposed that to minimize the potential costs of green building projects, creative technological approaches and the excitement of the project team are important [27]. Kog and Loh distinguished the value of influences from various stakeholder perspectives and pointed out that stakeholder capacity, project team commitment, socio-political climate, and project scale have an impact on project execution [28]. It is evident, through analyzing the literature, that the most significant CSF differs from angles. This project extracted 32 primary success factors for the construction in China based on the literature review. These are summarized in Table 1.

Table 1. Construction project critical success factors.

Item	CSFs	References
1	Organizational strategy	[5,29–34]
2	Determination of project goals and scope (to ensure that the project can continue to advance, including target identification, quantitative control index formulation, process monitoring, etc.)	[29–33,35]
3	Effective strategy and goal planning	[5,29–33]
4	Organizational design and structure of the project	[36,37]
5	Good relationship with key stakeholders	[18,29,32,38]
6	Adequate communication and coordination of the participating parties	[18,29,32,38]
7	Trust between stakeholders (for example, sticking to ethics and fulfilling promises during the project)	[29,32,39]
8	Competency and leadership level of the owner (including strategic ability, financial ability and governance ability)	[39–41]
9	The competency and leadership level of the project manager (including technical skills and communication skills)	[39,42,43]
10	The competency level of the contractor (including the construction ability and delivery ability)	[34,44,45]
11	The working ability of construction personnel	[30,34,46,47]
12	Strong support from within the organization (such as stability, unity and collaboration within the team)	[18,39–41,48]
13	Healthy organization and project culture (especially flexibility and dedication during the pandemic)	[34,49–51]
14	Adequacy of resources (including manpower, machinery, materials and construction funds)	[30,31,34,47,50,52–54]
15	Effective incentive and restraint mechanism (Positive human dynamics)	[29,32,48]
16	Project system control, coordination and integration mechanism	[29,32,38]
17	Effective risk control, reasonable risk sharing mechanism	[34,38,39,42,48]
18	Effective complexity degradation and control	[30,31,49]
19	Good scope management	[55,56]
20	Effective and detailed contract management (such as contract specification documents with equal rights and responsibilities)	[53,55–57]
21	Appropriate contracting model and project delivery system	[34,58,59]
22	Guide and focus on innovation management (including system innovation, technological innovation, construction management model innovation, investment and financing model innovation, etc.)	[49,57]
23	Preliminary scientific research and necessary personnel training (such as integrating industry-university-research innovation institutions, and organizing scientific research projects)	[47,60,61]
24	Past experience accumulation and talent reserve of similar projects (scientific research includes the accumulation of past practice of participating units, the technology developed and mastered by relevant research institutes, and the technology and experience imported from abroad)	[30,47,60]
25	Adopt or innovatively absorb advanced technologies and methods (such as BIM, modular building technology, etc.)	[61–63]
26	Application of advanced management methods (such as Dingding)	[61,64]
27	Direct or strong leadership of the country/government (so as to give full play to the advantages of the system, carry out necessary coordination, and be able to concentrate on major tasks)	[34,41,65,66]
28	Strong support from the government and related institutions (such as policies and guidelines, scientifically planned resumption plans, nucleic acid testing, etc.)	[41,65–67]
29	Public acceptance and support of construction projects	[68,69]
30	Effective external management and supervision (for example, supervision departments at all levels carry out follow-up supervision and audit of the legality and compliance of the project construction process, and relevant pandemic prevention departments supervise pandemic prevention measures, etc.)	[70–72]
31	Fully understand the restrictions on project implementation by external environmental conditions	[34,70–72]
32	Stability of the social, economic and political environment	[34,47,51,73]

2.3. Key Performance Indicator (KPI) of Construction Project Performance

Phua argued that the performance of a multi-organizational project can be specified and calculated, at least at an operational level, based on the degree to which the project meets budget, timeline, and technical requirements [74]. There are valid start and finish dates, and they will be completed in compliance with the stated requirements within the specified time span. The traditional view that it is effective to complete the construction project on time and within the budget according to requirements and stakeholder satisfaction is also supported by previous studies [75].

To illustrate how project management contributes to the success of a construction project, there is a notional model which divides project management into two domains: process and performance [76]. The process domain designs an effective project management framework and produces goods in the stages of input, process and outcome in order to address project priorities. Conversely, the performance domain concentrates on development of performance goals, improvement measures, and performance evaluation. Researchers also argued that by developing KPIs, a more objective metric for assessing project performance assessment can be achieved [77].

The evaluation of success in construction projects has always been dominated by traditional time, cost, and quality indicators, which were collectively referred as the iron triangle [77,78]. However, in successive years, some more comprehensive measures to evaluate project efficiency have been developed and implemented. For instance, Pheung and Chuan [74] argued that conventional metrics such as time, cost, and quality are no longer confined to the measurement criteria of project performance, instead recommending applying metrics of performance to the success of project management or the success of the product or both [74].

Others have also proposed that customer contentment and stakeholder satisfaction should also be included in performance appraisal standards, apart from the iron triangle [79,80]. An early study found that the top five widely applied metrics for assessing project success include technological performance, implementation quality, management and organizational effect, personal development, manufacturing capabilities, and business performance [81]. Recent works noted the following requirements for evaluating the project performance: the facility was produced on schedule and according to budget specifications; the project provided the owner with satisfactory benefits; the project met its business objectives; the project met its predetermined goal of manufacturing facilities; the project met the needs of the project team and the successor; the project addresses the needs of stakeholders [82,83]. In addition to traditional cost, time, quality, and scope metrics, the main performance indicators are as follows: appreciation of customers; appreciation of project staff; appreciation of users; appreciation of contracting parties; appreciation of stakeholders were highlighted by [84].

Based on a detailed literature review and preliminary interviews with academic researchers and industry specialists, this project compiled a list of 25 KPIs and divided it into five categories, as shown in Table 2.

Table 2. Construction project key performance indicators.

Items	KPIs
K1	**Project implementation efficiency and effect**
KPI 1	Project management triangle (time, quality, cost) target realization
KPI 2	Occupational health, safety and environment (HSE) goals achieved
KPI 3	Meet relevant regulations and requirements of design, technology, environmental protection, etc.
KPI 4	Meet the designed function, and delivery publicly needed value/service
K2	**Satisfaction of key stakeholders**
KPI 5	Government satisfaction
KPI 6	Owner's satisfaction
KPI 7	Satisfaction of participating parties (including consulting units, design units and construction units, etc.)
KPI 8	Public satisfaction
KPI 9	Satisfaction of other key stakeholders
KPI 10	Establish good cooperation and relationship
K3	**Organizational Process Assets (OPA)**
KPI 11	New technologies
KPI 12	Profits/benefits realization

Table 2. *Cont.*

Items	KPIs
KPI 13	Opening new markets or increasing market share/competitiveness
KPI 14	New organizational capacity and competency
KPI 15	Improve brand/reputation
KPI 16	Train professionals for companies or projects
K4	**Enterprise Environmental Factors (EEF)**
KPI 17	Has industry benchmarking or demonstration effects, certain management systems or technical standards can be promoted to similar or similar projects
KPI 18	Effectively promote the innovation and coordinated development of the construction industry and related industries
KPI 19	Competitiveness of the industry in the international market
KPI 20	Contribute to theoretical and practical innovation in engineering technology and management
K5	**Comprehensive social impacts**
KPI 21	Delivery social-economic benefits to the community
KPI 22	Sustainability in environment, society and economy
KPI 23	Maintain social cohesion/society harmony
KPI 24	Enhance people's pride and self-confidence
KPI 25	Job creation

3. Methodology

The research methodology contains three key steps. First, CSFs and KPIs were derived from literature reviews and expert interviews. Second, the study conducted a questionnaire survey with 150 experts and adopted validity, reliability checks, and other checks to determine whether the questionnaire results are suitable for subsequent analysis. Third, a comprehensive framework connecting CSFs and KPIs was established. Factor Analysis and Analytic Hierarchy Process (AHP) analysis were carried out for CSFs and Characteristics and Comparative Analysis for KPIs. Structural Equational Modelling (SEM) was employed to connect the CSFs and KPIs and develop a roadmap towards the post-COVID-19 pandemic recovery of the construction projects. Figure 1 illustrates an overview of this mixed research methodology.

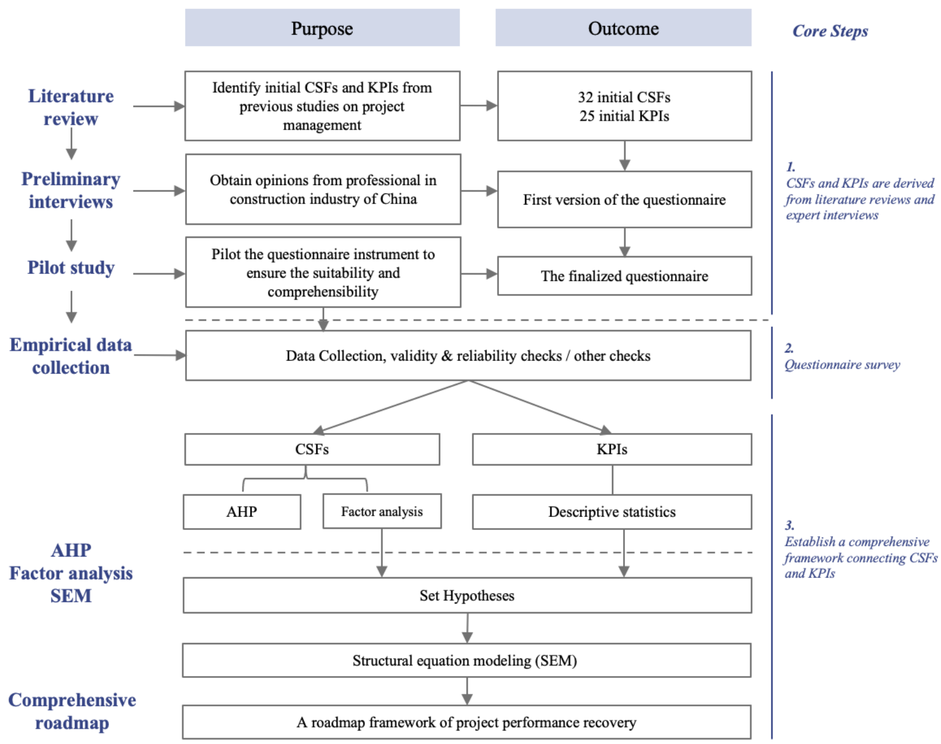


Figure 1. Research methodology.

3.1. Prospective Research and Questionnaire Survey

This research was conducted through a questionnaire. The second part of the questionnaire was designed to determine the impacts of the COVID pandemic on different KPIs of Chinese construction projects during the post-COVID pandemic period. All 25 variables included in the questionnaire were set on a five-point Likert Scale (5 for highly positive impact and 1 for very highly negative impact). The third part of the questionnaire was designed to determine the CSFs of Chinese construction projects during the post-COVID pandemic period. The 32 variables (CSFs) are from the previous literature review, which are shown in Table 1. All 32 variables included in the questionnaire are set on a five-point Likert Scale (5 for very important and 1 for very unimportant), and these scales were used to conduct the factor analysis.

3.2. Factor Analysis

The aim of evaluating a construction project's critical success factor is to avoid accidents that could go wrong and cause key factors to cause safety hazards. Risk is a factor in a project that can lead to cost overruns, time overruns, and inadequate requirements, thus jeopardizing the project's successful completion. There are risks associated with all projects, and the degree of presence of risk factors in a specific field is negatively linked to the likelihood of project success. Previous research has asserted that the use of CSF during the construction process for constructive risk management strategies and actions helps customers achieve negotiable projects on schedule and on budget [85,86].

In recent years, in different risk management areas, factor analysis techniques have been used, such as assessing the risk classification of mortgage loans and calculating the organization's downside risk. The primary objective of this analysis is to acquire coherent and reliable CSFs rankings from the crucial success factors. Factor analysis is an effective tool for the detection of a crucial success factor. Factor analysis will classify CSF into particular classes by analyzing the association between variables and CSFs will rank the weight of each factor.

3.3. Analytic Hierarchy Process (AHP)

AHP is a Multi-Attribute Decision Making (MADM) system presenting a wide range of applications in organizational decision-making and is commonly used in various fields around the world [87]. The method is composed of effective instruments to prioritize key management issues [88]. This approach focuses on prioritizing selection criteria and on separating more important criteria from less important criteria [89]. The AHP also employs actual indicators such as price, quantity, or subjective opinions as inputs to the matrix. Output includes the ratio of the ratio and the consistency index obtained by measuring the main feature vector and the value of the feature. Since human decisions frequently tend to be arbitrary, and the AHP allows for some contradictory interventions [87,90,91].

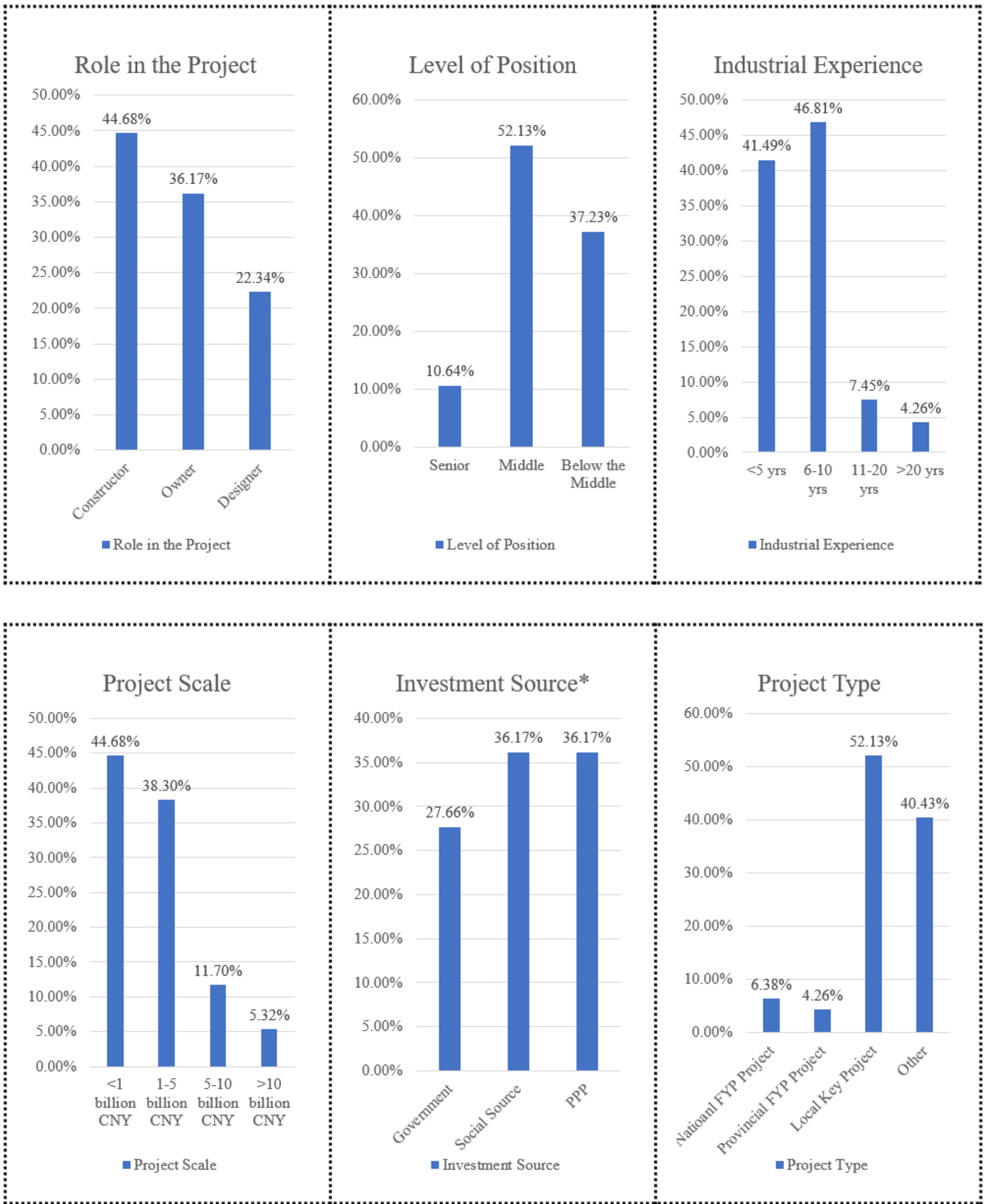
3.4. Structural Equation Modeling (SEM)

Structural equation modeling (SEM) is a statistical technique that can quantify the structural correlation between one or more continuous or discrete independent variables (IV) and one or more continuous or discrete dependent variables. This research method has been widely adopted by construction management and social science research worldwide, including risk path identification in international construction projects [92], safety behavior analysis [93], and pro-environmental behavior [1]. This article uses the SEM model to establish a CSF-KPI evaluation framework with SmartPLS 3.3.3.

4. Results

4.1. Respondent Profile

The researchers distributed the uniform questionnaire to 150 experts in the Chinese construction industry and received 135 responses, 94 of which were valid. Figure 2 illustrates the respondent profile, including their roles in the project, position levels, and experience in the industry. The figure also presents the general information of the current projects of the respondents: the project scale, source of investment, and the nature of the project. Figure 2 illustrates the respondent profile of the respondent. About 45% of the participants were contractors and over 50% of the respondents held over five years of industrial experience. The preliminary study shows that these factors have insignificant effects on the results. The questionnaire was designed to capture a broad range of perspectives within the Chinese construction industry, and as such, it is robust to variations in respondent demographics. The predominance of contractors in the sample, for instance, reflects the reality of the industry where contractors play a significant role. Their responses, therefore, provide valuable insights into the practical aspects of project recovery in the post-COVID-19 context. Furthermore, the study's methodology, which includes the use of factor analysis and the Analytic Hierarchy Process (AHP), ensures that the identified KPIs and CSFs are not unduly influenced by the characteristics of the respondents but are reflective of the broader trends and realities of the construction industry in the post-COVID-19 era.



* 1 CNY approximately equals to 0.15 USD

Figure 2. The respondent profile and project general information.

4.2. Questionnaire Result Assessment

To ensure that the result is suitable for further analysis, validity analysis was used to study the rationality of the design of quantitative data [94,95]. This project used the Kaiser–Mayer–Olkin (KMO) test and the Bartlett's test of sphericity to determine validity. Reliability analysis was used to research the quality of the test results of various items, i.e., the reliability and accuracy of the answers to quantitative data [96]. The test results are shown in the following Appendix A. The split-half reliability test was used to verify the accuracy of the reliability analysis. The split-half reliability test divided the questionnaire items into two halves, calculated the Cronbach α coefficient and the correlation coefficient of the scores of the two halves, and then estimated the reliability of the entire scale suitability of the questionnaire items [97,98].

The relevant test results are shown in Table 3, which indicates that the questionnaire survey results fit the research framework very well and can be followed up for analysis.

Table 3. Questionnaire result assessment.

Test	CSF/KPI	Appendix A	Indicator	Value	Evaluation
Validity analysis	CSF	Table A1	KMO	0,784	Good
			Bartlett's test of sphericity	1472.165 (p value = 0.000)	Very Good
	KPI	Table A2	KMO	0.932	Very Good
			Bartlett's test of sphericity	1881.479 (p value = 0.000)	Very Good
Reliability test	CSF	Table A3	Cronbach α (Standardized)	0.931	Very Good
	KPI	Table A4	Cronbach α (Standardized)	0.965	Very Good
Reliability test (split-half)	CSF	Figure A1	Spearman–Brown split-half reliability coefficient	0.877	Very Good
	KPI	Figure A2	Spearman–Brown split-half reliability coefficient	0.908	Very Good
Item analysis	CSF	Table A5	p	$p \leq 0.01$	All significant
	KPI	Table A6	p	$p = 0$	All significant

4.3. Factor Analysis of CSFs

The research conducted factor analysis of CSFs to explore that quantitative data can be condensed into several factors and the corresponding relationship between each factor and the questionnaire. The results are shown in Table A7. CSF factor analysis and Table A8. CSF factor loading is summarized in Table 4.

Table 4. CSF factor analysis and loading.

Factor 1		Factor 2		Factor 3		Factor 4		Factor 5	
CSF	**Factor Loading**	**CSF**	**Factor Loading**	**CSF**	**Factor Loading**	**CSF**	**Factor Loading**	**CSF**	**Factor Loading**
2	0.586	16	0.505	4	0.503	1	0.588	13	0.687
3	0.511	20	0.395	5	0.637	29	0.758	17	0.582
6	0.62	22	0.718	8	0.509	31	0.456	19	0.561
7	0.773	23	0.755	15	0.708	32	0.74	21	0.637
9	0.608	24	0.683	18	0.419				
10	0.532	25	0.608						
11	0.46	26	0.411						
12	0.413	30	0.437						
14	0.338								
27	0.45								
28	0.69								

For factor extraction, the principal component analysis method was used to group the listed CSFs. According to the results of the principal component analysis after the maximum variance, the 32 independent variables were divided into five meaningful groups, of which 11 variables belong to the first group, eight variables belong to the second group, five variables belong to the third group, and five variables belong to the fourth group. Four variables belong to the fifth group. Grouping extracted five potential factors with feature values greater than 1.4, which explained 52.671% of the variance. This shows that for these five components, the largest percentage (>50%) difference is explained by CSF. The eigenvalues of the remaining potential factors are less than 1.4 and the variance contribution is less than 4.35%. This shows that the model with five extracted components can fully display the characteristics of the data. To facilitate further discussion, this article renamed the five extracted groups based on the analysis results. The five potential grouping barriers can be renamed as follows.

F1. Strength of participating parties and macro support
F2. Innovation and project control
F3. Project organization management
F4. Consistency of goals and external expectations
F5. Project flexibility and risk management

4.4. CSFs Importance Index Analysis by Analytic Hierarchy Process

This questionnaire research involves importance scale questions. The characteristic of this type of question is that the higher the score, the more important or the more recognized. It can be understood that the higher the importance, the higher the weight [88]. Therefore, this information can be used to calculate weights, using the AHP hierarchy process and the optimal sequence diagram method, respectively. Both of these research methods use relative importance for weight calculation. The AHP hierarchy process itself is an expert scoring and weighting method, that is, the relative importance is described through expert scoring, and then the weight is calculated [99].

The 32-level judgment matrix (see Figure A3. AHP Judgment Matrix) was constructed for 32 items based on the AHP hierarchy process (the calculation method is the sum product method), and the eigenvector of each item was analyzed. Combining the eigenvectors can calculate the maximum eigenvalue of 32.000, using the maximum eigenvalue to calculate the CI value (0.000). The CI value was used in the following Consistency check. The CI value calculated for the 32-order judgment matrix is 0.000 (Table A9, CSF AHP analysis), and the look-up table (Table A10. RI Value) for the RI value is 1.677, so the calculated CR value is 0.000 < 0.1, which means that the judgment matrix of this study meets the consistency test, and the calculated weights are consistent. The test result was as follows: maximum eigenvalue is 32, CI is 0, RI is 1.677, CR is 0, CSF consistency test, and the weight ranking outcome is shown in Figure 3.

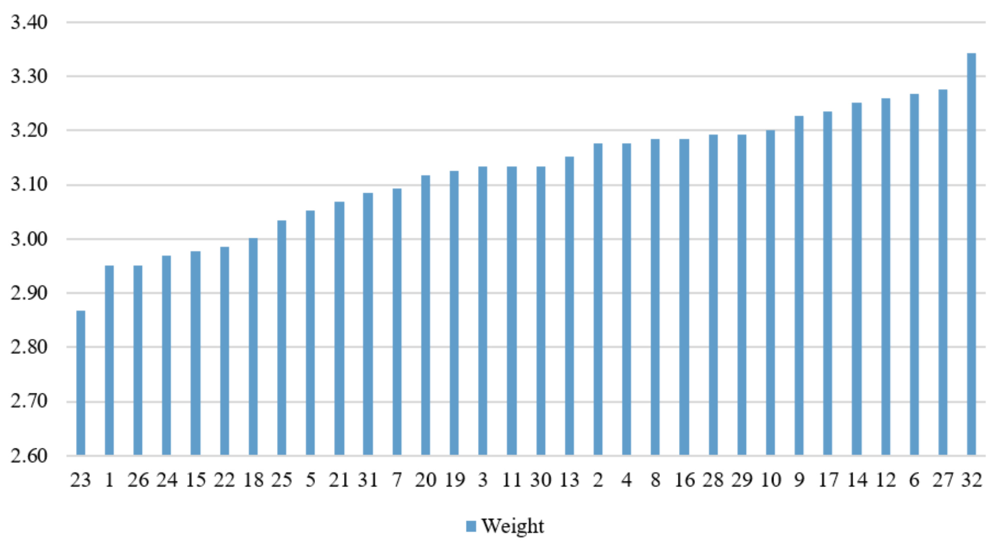


Figure 3. CSF weight ranking.

4.5. Summary of the KPI Result and Ranking Using Descriptive Statistics

Table A11, Stakeholders' perception of COVID-19 pandemic's impact on KPIs, summarizes the results and rankings using descriptive statistics. The ranking is based on the average, standard deviation (SD), and total number of respondents for a given indicator. These results are visualized in Figure 4.

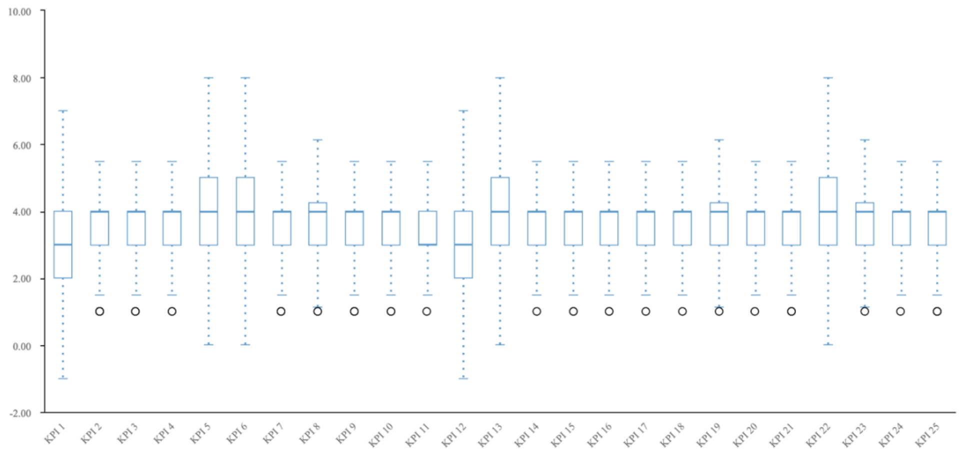


Figure 4. KPI box plot.

Table 5, Stakeholders' perception of COVID-19 pandemic's impact on KPIs, gives different attitudes of different participants to COVID-19 pandemic's impact on KPIs of construction projects. It can be seen that, relatively speaking, the owner has a relatively conservative attitude towards the completion of the project's KPIs, and the scores of all items are lower than the average. The designer showed a relatively more optimistic attitude towards KPI 1-15, while the constructor was relatively more optimistic towards KPI 16–25.

Table 5. Ranking of stakeholders' perception of the COVID-19 pandemic's impact on KPIs.

Owner		Designer		Contractor		Overall	
KPI 15	3.824	KPI 8	4.095	KPI 25	3.952	KPI 15	3.862
KPI 18	3.735	KPI 24	3.952	KPI 15	3.952	KPI 20	3.798
KPI 17	3.735	KPI 3	3.905	KPI 20	3.905	KPI 18	3.777
KPI 20	3.676	KPI 5	3.857	KPI 23	3.881	KPI 17	3.766
KPI 14	3.647	KPI 22	3.857	KPI 3	3.833	KPI 23	3.745
KPI 5	3.618	KPI 2	3.857	KPI 22	3.833	KPI 24	3.734
KPI 24	3.618	KPI 9	3.81	KPI 5	3.81	KPI 5	3.723
KPI 4	3.559	KPI 7	3.81	KPI 18	3.81	KPI 8	3.723
KPI 23	3.559	KPI 4	3.81	KPI 17	3.81	KPI 22	3.723
KPI 22	3.559	KPI 20	3.81	KPI 13	3.81	KPI 3	3.702
KPI 6	3.529	KPI 19	3.81	KPI 8	3.786	KPI 13	3.691
KPI 19	3.529	KPI 17	3.81	KPI 19	3.762	KPI 19	3.681
KPI 8	3.5	KPI 15	3.81	KPI 16	3.762	KPI 14	3.67
KPI 13	3.5	KPI 14	3.81	KPI 24	3.738	KPI 25	3.649
KPI 10	3.471	KPI 13	3.81	KPI 9	3.69	KPI 4	3.638
KPI 3	3.441	KPI 10	3.81	KPI 2	3.667	KPI 6	3.606
KPI 16	3.412	KPI 23	3.762	KPI 6	3.643	KPI 16	3.596
KPI 9	3.353	KPI 18	3.762	KPI 4	3.643	KPI 10	3.585
KPI 25	3.324	KPI 6	3.714	KPI 21	3.643	KPI 9	3.574
KPI 21	3.324	KPI 25	3.714	KPI 14	3.643	KPI 11	3.5
KPI 11	3.324	KPI 21	3.619	KPI 11	3.595	KPI 21	3.5
KPI 7	3.265	KPI 11	3.619	KPI 10	3.571	KPI 2	3.489
KPI 2	3.118	KPI 16	3.571	KPI 7	3.548	KPI 7	3.489
KPI 1	3.029	KPI 12	3.381	KPI 12	3.357	KPI 12	3.213
KPI 12	2.941	KPI 1	3.238	KPI 1	3.238	KPI 1	3.149

In addition, the owners hold a relatively positive attitude towards the positive social impact caused by the organization or project, the growth of market share, and the promotion of innovation and development of construction industry, while they hold a relatively conservative attitude towards the completion of the project and the achievement of some objectives. The designers hold a relatively positive attitude towards the positive social impact caused by the organization or project and the achievement of some objectives (such as the satisfaction of the government), while they hold a relatively conservative attitude towards the application of innovative technologies and the achievement of some objectives (such as the achievement of the iron triangle of the project). The contractor has a relatively positive attitude towards the positive social impact and construction compliance caused by the organization or project, but a relatively conservative attitude towards the achievement of the strategic objectives of the enterprise (organization), the satisfaction of the participants, and the completion of the iron triangle of the project. In general, the completion of the inherent goals of the project may be relatively neutrally affected, while the social goals of the project and the organization social value may be relatively positively affected.

4.6. Hypothetical Explanation Linking CSF and KPI

There is evidence showing that the ability to participate parties to a large extent guarantees that the project can proceed smoothly and better adapt to the external environment, therefore continuing to promote the goal [63,100]. Therefore, Hypothesis 1 is that the strength of the participating parties and the supported macro environment have a positive effect on the project implementation efficiency and effect (F1 → K1). Ebekozien et al. pointed out the importance of digital innovative technologies (including BIM, digital platforms, etc.) in the recovery of the construction industry after the COVID-19 epidemic to achieve sustainable development and stakeholder satisfaction [8]. Hypotheses 2 and 3 are that innovation and project control have a positive correlation with the satisfaction of key stakeholders and achievement of the enterprise (organization) strategic goals. Some research pointed out that focusing on the communication and coordination between different participants and strong project organization and management can enable the opinions of stakeholders to be collected and adopted, which is essential for achieving stakeholder satisfaction [101]. Hypothesis 4 is based on this and indicates the positive correlation from F3 to K2. Another research reviewed the different expectations of external stakeholders in the development of construction projects and the actual management steps were taken by the project manager [102]. This implies that the consistency of project goals and external expectations is conducive to the progress of the project, the satisfaction of key stakeholders, and creates a positive social impact (Hypothesis 5–7: F4 → K1, F4 → K2, F4 → K5). In addition, some studies also pointed out the interaction between project flexibility and risk management and the possibility of new risk management models [103]. The updated risk management model can promote the innovative development of the industry. Better risk management can reduce the negative impact of the project on society, thereby increasing the positive impact. This provided support for Hypothesis 8–9 (F5 → K4, F5 → K5).

Based on extensive literature support, this article makes hypotheses (H1-9) about the significant positive correlation of KPI groups by CSF factors, as shown in Table 6.

Table 6. Hypotheses.

Hypothesis	Path	Literatures
1	F1 → K1 (+)	[104]
2	F2 → K3 (+)	[105,106]
3	F2 → K4 (+)	[107,108]
4	F3 → K2 (+)	[109–111]
5	F4 → K1 (+)	[70,102]
6	F4 → K2 (+)	[70,102]

Table 6. *Cont.*

Hypothesis	Path	Literatures
7	F4 → K5 (+)	[70,102]
8	F5 → K4 (+)	[103,110,112,113]
9	F5 → K5 (+)	[51,111,114]

Note: → indicates positive correlation.

4.7. Structural Equation Modeling (SEM)

SEM requires a statistically significant sample size in order to generate accurate results as it is linked to the stability of parameter estimations [115]. According to the recent literature, a sample size of 100 to 400 is appropriate and suitable for SEM analysis [116]. In this paper, SmartPLS is used for PLS-SEM method for analysis based on the above CFS factor analysis and KPI classification. This article establishes SEM based on the internal logical relationship between the KPI that has been classified in the design and the CFS that has been factored.

SEM includes a measurement model used to quantify the correlation between each exogenous variable and its respective latent variables, as well as a structural model of the correlation between structures [117]. Research cited in the literature proves that these thresholds are reasonable. Based on the above analysis and the coefficient table in the Appendix A, the value of the standard quantity exceeds the respective threshold recommended by the reference study. The results show that there is no obvious correlation between the two structures, which confirms the validity and reliability of the measurement model to further construct the SEM [117,118]. This article evaluated 5000 boot samples based on the recommendations [119]. Table 7 shows that, except for the path from F4 to K1 (p value = 0.11), the P value of all other paths was below 0.05. This means that the relevant results are within a 95% confidence interval. Therefore, this article assumes that all paths of the model are supported [119]. The visualization result of SEM is shown in Figure 5.

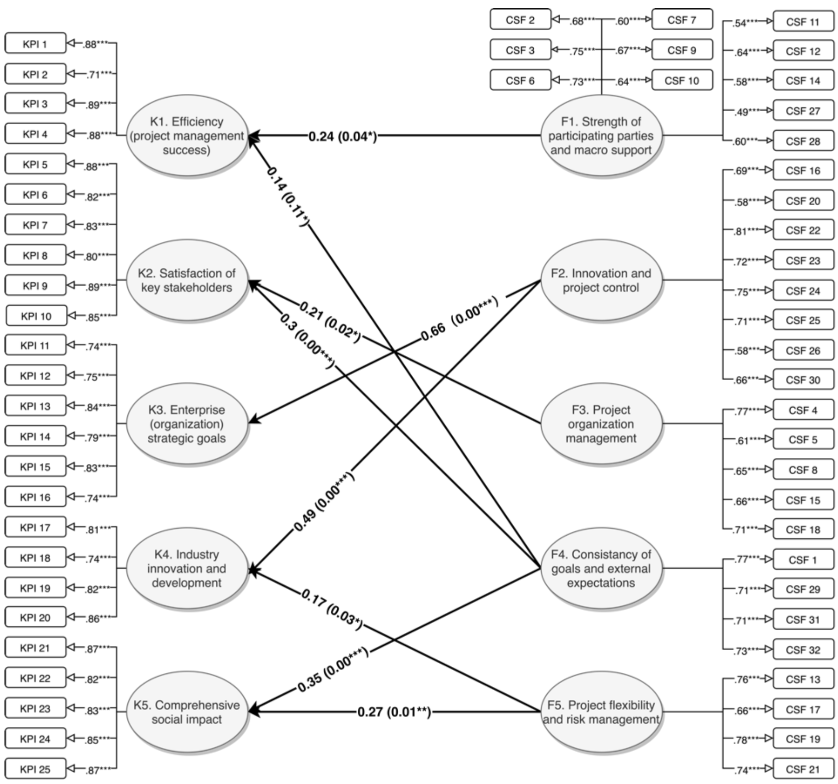


Figure 5. Structural equation modeling results. Note: * $p < 0.05$, ** $p < 0.01$; *** $p < 0.0001$.

Table 7. Structural equation modeling assessment.

Path	Coefficient	*p*-Value
F1 → K1	0.24	0.04 *
F2 → K3	0.66	0.00 **
F2 → K4	0.49	0.00 **
F3 → K2	0.21	0.02 *
F4 → K1	0.14	0.11
F4 → K2	0.30	0.00 **
F4 → K5	0.35	0.00 **
F5 → K4	0.17	0.03 *
F5 → K5	0.27	0.01 **

* $p < 0.05$ ** $p < 0.01$.

5. Interpretation and Discussion

5.1. Strength of Participating Parties and Macro Support

According to the results of the SEM, the correlation between F1 and K1 is 0.24, which indicates that the ability of the participating parties and external macro support have a significant impact on the construction project implementation efficiency and effect on the post-COVID-19 pandemic period. On the one hand, it can be seen that in the post-COVID-19 pandemic period, social and economic stability under the leadership of the government, as well as the leadership, planning, and efforts made by the government to deal with the virus, provide solid macro support in the recovery of construction projects. In the COVID-19 period, the Chinese government required personnel in outbreak areas to stop the movement, ensuring the health of relevant personnel while objectively increasing the uncertainty and cost of the project. In the post-COVID-19 pandemic period, the Chinese government actively undertook coordination and guidance for project participants to resume construction works instantly, leading to the fast project recovery in the construction industry. Therefore, solid macro support from the government is essential to lead project participants to overcome the project changes and uncertainties due to the COVID-19 outbreak.

On the other hand, the strength of the participating construction parties has played an essential role in the project recovery of the post-COVID pandemic period. The strength of project participants enhances the project's adaptability to the changeable external environment of COVID-19. Particularly, the strength of resource resilience among participating parties can effectively deal with the negative impact of COVID-19. Resource resilience includes good financial support to deal with long-term economic risks, the reserve of talents, machines, and materials to deal with market fluctuations, etc. In addition, the previous research also suggests that the continuous support of senior management is crucial to ensure resource resilience among project participants, which is helpful to boost the performance recovery of construction projects in the post-COVID pandemic period [39].

5.2. Innovative Applications

The result of the SEM shows that the correlation between F2 and K3 is 0.66 and the correlation with K4 is 0.49. These significant correlations indicate that innovation and strict project management are essential for the construction industry to respond to the post-COVID-19 environment. The innovative applications boost the construction project performance by achieving the enterprise strategic goals for industry innovation and development.

Modular industrialization construction (MiC) technology is a strategic goal for many construction enterprises to improve construction project performance. The modularization, industrialization, automated off-site production, and on-site assembly automation brought by MiC technology will realize the product-based construction method [120]. The COVID-19 pandemic provided a unique opportunity for construction enterprises to widely use this innovative method, as MiC technology is valuable to reach efficiently controllable working conditions in building emergent healthcare facilities. In the post-COVID-19 pandemic period, MiC technology will take a leading role in project recovery, which facilitates the construction enterprises to push the construction project to the integrated automated production system with efficient off-site manufacturing.

The second innovative application is digitalization in construction, which will stimulate industry innovation and development. The COVID-19 pandemic hastened the adoption of digital tools [9]. Instead of finishing the design while construction is underway, companies can increase efficiency and integrate the design phase with the help of "digital twins" to add more levels of information such as schedule and cost by using building information modeling (BIM) to create complete 3D models at the early stage of the project [121]. This drastically altered the risk management and decision-making process in construction projects during the COVID-19 pandemic crisis. The digitalization of management and production processes will continue to help project participants to achieve efficient project recovery in the post-COVID-19 pandemic. The application of digital management methods (such as DingTalk) and digital building technology can achieve better collaboration, enabling better system control, coordination, and integration mechanisms, and shifts to more data-driven decision-making. These innovations will change construction projects' design, operation, contract, and construction management, and how these interact with project participants.

5.3. Project Organization Management

SEM pointed out that the correlation between F3 and K2 is 0.21, which implies that the project organization itself has a positive impact on the satisfaction of the project-related key stakeholders. To realize the project recovery, efficient project organization management is highlighted to strengthen stakeholder relationships dealing with challenges in the post-COVID-19 pandemic.

The COVID-19 pandemic poses many project management problems for the construction industry, such as the tight schedule, bad weather, fragile supply chain, and intensive working interfaces. Therefore, project organization management, which focuses on communication and coordination between different participants and strong organizational support, is crucial. Top management must create regulations to strengthen oversight of the strategy and minimize risks and strengthen contact with the various stakeholders. In the post-COVID-19 pandemic era, competent stakeholder management is waiting to be established based on the knowledge and lessons gained from the construction projects in the COVID-19 pandemic period.

5.4. Consistency of Goals and External Expectations

The correlations between F4 and K1, K2, and K5 are 0.14, 0.30, and 0.35, respectively. This indicates that the consistency of goals and external expectations of the project are crucial to the externally defined success of the project. However, F4 is not very relevant to the K1 project implementation efficiency and effect, as the p value of this path is above 0.1. Therefore, this hypothetical path was rejected.

The COVID-19 pandemic reinforces the importance of external expectations, which means that social operations are systematically evaluated. CSF 32 is the most important factor in this group. It also ranks first in the AHP analysis and is significantly ahead of other CSFs. The stability of the social, economic, and political environment is regarded as the most important factor in the post-COVID-19 pandemic. Correspondingly, external environmental conditions and external stakeholders also play an important role in the success of the project. According to Chan and Oppong [29] and Cleland [101], external stakeholders are divided into three main groups for discussion: government authorities, the public (consumers, environment, society, politics, and "interventionists" Groups as representatives), and affected local communities. Stakeholders use their power and intentions to influence project results according to their interests and expectations [122]. Especially in the post-COVID-19 period, stakeholders' attitudes towards construction projects and this labor-intensive work have largely affected the normal operation of the project. Therefore, project managers encourage stakeholders to participate in project delivery to ensure that the different expectations of stakeholders are systematically and formally captured and incorporated into project plans and policies [123].

At the same time, during the post-COVID-19 period, the external environment changes frequently, and the update and implementation of relevant policies may have an impact on the project itself. In the long run, the management of external environmental conditions and external stakeholders enhances the feasibility of the project and ensures the company's interests to external stakeholders. PM needs to identify and manage activities that have a significant impact on stakeholder satisfaction in the construction process [124]. Effective communication between the project manager and external stakeholders is essential to maintain a good relationship. Good communication allows the project manager to understand and understand the expectations of its stakeholders, and stakeholders can also obtain important information related to the project, which is extremely important for the advancement of the project during the post-COVID-19 period.

5.5. Project Flexibility and Risk Management

The correlation between F5 and K4, K5 is 0.17 and 0.27, respectively. This highlights that good project flexibility and risk management can positively impact industry and social post-COVID-19 project recovery.

Learning from the experience in the COVID-19 pandemic, a benign people-oriented organization and project culture construction (especially flexibility and dedication during the pandemic), can significantly reduce the social risks within the organization during the project process, including the loss of labor and the heavy working pressure. As more complex construction projects resume building in the post-COVID-19 period, flexible risk management with good scope management, effective risk control, reasonable risk-sharing mechanism, and collaborative working culture is helpful to deal with the social–technical challenges of construction projects.

5.6. Project Performance Recovery Roadmap

Based on the analysis on the identified CSFs and KPIs, this research develops a roadmap for the performance recovery of construction projects in the post-COVID pandemic era (see Figure 6). This multi-level roadmap connects four different scales: drivers, path, direction, and aim. A driver refers to a fundamental driving force to the project performance recovery and the driver level includes 32 CSFs in this research. A path refers to a common way that similar drivers work together and leads to a specific direction. A direction refers to a critical dimension of construction project performance and points to the destination. In this roadmap, there are five paths derived from the CSF grouping that contribute to five directions derived from the KPI grouping. The study employed SEM to connect the paths and directions. The destination is the final goal/perception that requires the contribution of all directions. The destination in the proposed roadmap is post-pandemic project performance recovery and advancement. With sufficient data and model support for each connection of every two levels, this process from driver to aim constitutes a comprehensive roadmap.

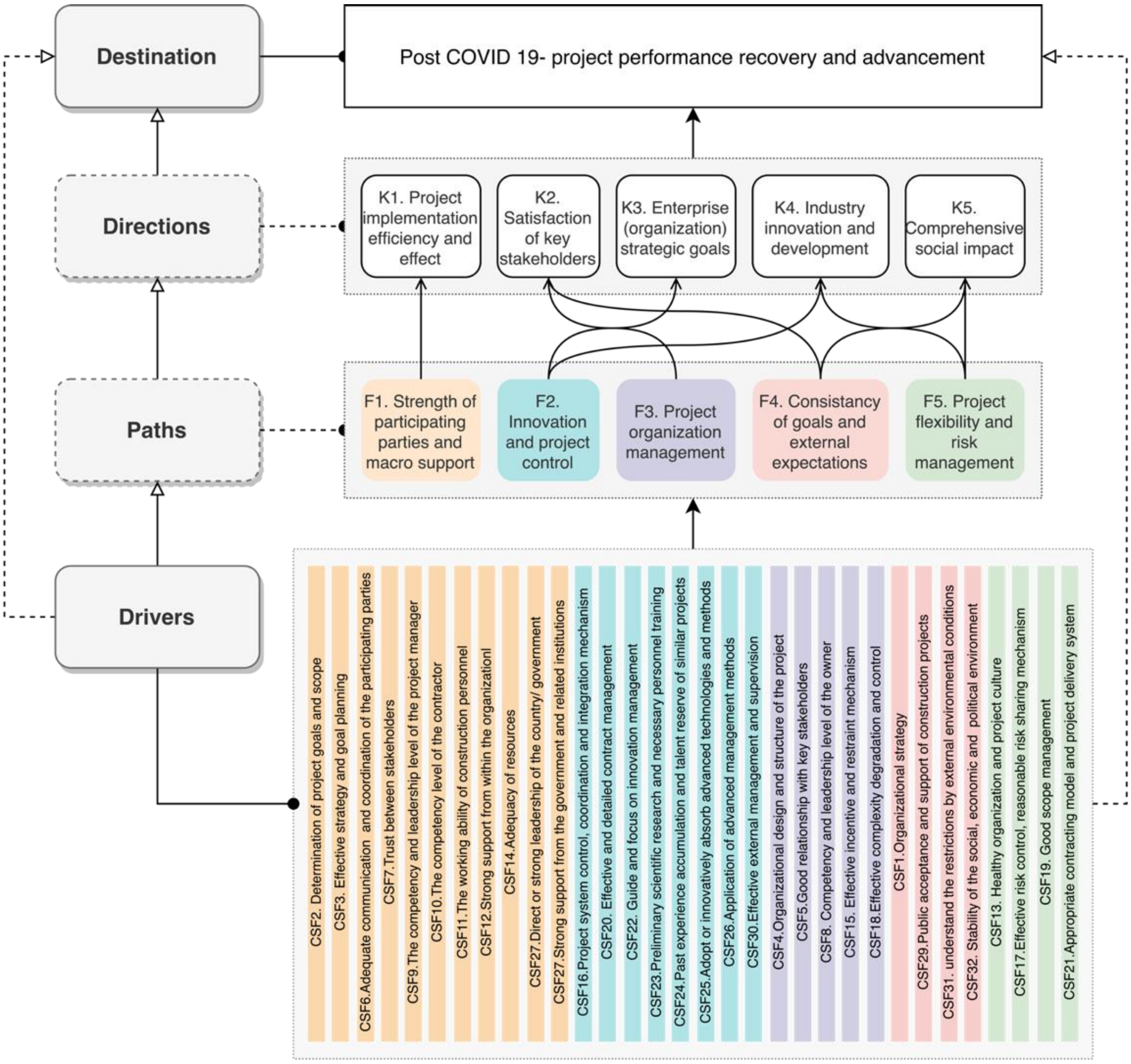


Figure 6. Project performance recovery roadmap.

6. Conclusions

This research aimed to propose an integrated framework connecting KPIs in the post-COVID-19 recovery of construction projects and the CSFs to achieve them. This study first developed a hypothetical model under the respective structures of CSFs that contribute to KPIs. Based on the professionals' views in the Chinese construction industry, the research employed AHP to classify the importance of CSFs and SEM to reveal the quantitative relationship between CSF and KPI groups. The study developed a theoretical roadmap towards the construction project performance recovery and advancement in the post-COVID-19 period based on the analysis results.

Theoretically, this study contributes to building a roadmap framework to identify the interrelationships among construction project performance promotors in four levels: driver, path, direction, and destination. Practically, the roadmap can guide comprehensive project life cycle management and deal with public health emergencies such as COVID-19 in construction and infrastructure management to maximize the organization's profits and positive social impact. There are two limitations to this study. First, the sample size used in this article is limited. Second, this research focuses on the opinions of Chinese construction professionals. Thus, the results that are applicable to other countries/regions may require further studies.

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

Appendix A

Table A1. CSF validity analysis.

Items	Factor Loadings									Communalities
	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	
1	0.201	−0.191	0.11	0.54	0.416	0.071	0.39	0.01	0.011	0.711
2	0.206	0.284	0.354	0.16	−0.003	−0.175	0.447	0.333	0.093	0.624
3	0.111	0.16	0.079	0.404	0.244	0.191	0.59	0.005	0.106	0.662
4	0.22	−0.024	0.388	0.258	0.137	0.12	0.018	0.179	0.565	0.651
5	−0.072	−0.001	0.181	0.055	0.026	0.107	0.217	0.604	0.434	0.654
6	0.197	0.193	0.118	0.066	−0.082	0.085	0.671	0.123	0.289	0.658
7	−0.033	0.635	0.175	0.1	0.04	0.264	0.435	−0.069	−0.009	0.71
8	0.193	0.242	0.183	0.57	0.054	−0.064	0.12	0.261	0.148	0.565
9	0.077	0.178	0.554	0.136	0.029	0.3	0.502	0.031	−0.065	0.711
10	0.175	0.305	0.304	−0.097	0.164	−0.026	0.308	0.078	0.581	0.692
11	0.199	0.212	0.7	0.18	0.058	−0.005	0.161	0.167	0.093	0.673
12	0.201	0.477	−0.025	0.275	0.061	0.238	0.1	0.041	0.486	0.652
13	0.315	0.092	−0.054	−0.235	0.378	0.53	0.284	0.371	−0.033	0.81
14	−0.105	0.205	0.064	0.528	−0.023	0.282	0.245	0.135	0.19	0.529
15	0.096	0.075	0.172	0.201	0.105	0.157	−0.028	0.875	0.014	0.887
16	0.337	0.22	0.601	0.05	−0.017	0.321	0.09	0.202	0.112	0.691
17	−0.017	0.214	0.159	0.337	0.002	0.687	−0.008	0.073	0.099	0.672
18	0.265	0.103	0.19	0.728	0.152	0.117	0	0.057	−0.007	0.687
19	0.256	−0.056	0.024	0.134	0.115	0.59	0.217	−0.02	0.464	0.711
20	0.129	0.099	0.643	0.173	0.153	0.162	0.008	0.113	0.331	0.642
21	0.164	0.163	0.231	−0.032	0.221	0.593	0.163	0.143	−0.015	0.556
22	0.723	0.205	0.249	0.077	0.151	0.202	0.143	0.007	0.02	0.718
23	0.778	−0.016	0.135	0.086	0.099	−0.052	0.202	0.087	0.204	0.733
24	0.617	0.055	0.366	0.083	0.31	0.125	0.088	−0.08	0.03	0.652
25	0.651	0.248	−0.038	0.327	−0.148	0.223	−0.049	0.158	0.154	0.716
26	0.366	−0.011	0.134	0.145	0.363	0.418	−0.302	0.002	0.076	0.577
27	0.167	0.521	0.17	0.212	0.359	−0.001	0.124	0.41	−0.073	0.691
28	0.114	0.798	0.191	0.068	0.17	0.063	0.129	0.034	0.146	0.763
29	0.057	0.089	0.136	0.031	0.857	0.124	0.03	0.031	−0.026	0.783
30	0.383	0.527	0.268	0.199	−0.007	0.239	−0.026	0.191	0.051	0.633
31	0.333	0.302	0.14	0.284	0.361	0.007	0.086	0.036	0.265	0.512
32	0.099	0.17	−0.058	0.179	0.734	0.115	−0.006	0.138	0.299	0.735
Eigenvalues (Initial)	10.276	2.076	1.624	1.471	1.407	1.381	1.296	1.123	1.004	-
% of Variance (Initial)	32.114%	6.488%	5.073%	4.598%	4.398%	4.315%	4.051%	3.509%	3.137%	-
% of Cum. Variance (Initial)	32.114%	38.602%	43.675%	48.274%	52.671%	56.986%	61.037%	64.546%	67.684%	-
Eigenvalues (Rotated)	3.132	2.66	2.634	2.445	2.406	2.399	2.211	1.904	1.868	-
% of Variance (Rotated)	9.788%	8.311%	8.231%	7.641%	7.519%	7.496%	6.909%	5.951%	5.838%	-
% of Cum. Variance (Rotated)	9.788%	18.099%	26.330%	33.970%	41.489%	48.986%	55.895%	61.845%	67.684%	-
KMO					0.784					-
Bartlett's Test of Sphericity (Chi-Square)					1472.165					-
df					496					-
p value					0					-

Table A2. KPI validity analysis.

Items	Factor Loadings			Communalities
	Factor 1	Factor 2	Factor 3	
KPI 1	0.44	0.26	0.743	0.813
KPI 2	0.178	0.173	0.705	0.559
KPI 3	0.259	0.094	0.847	0.794
KPI 4	0.168	0.298	0.768	0.707
KPI 5	0.65	0.44	0.338	0.73
KPI 6	0.69	0.203	0.363	0.65
KPI 7	0.664	0.326	0.435	0.736
KPI 8	0.508	0.424	0.389	0.588
KPI 9	0.807	0.3	0.246	0.801
KPI 10	0.782	0.288	0.229	0.746
KPI 11	0.332	0.513	0.297	0.462
KPI 12	0.727	0.244	0.329	0.696
KPI 13	0.608	0.531	0.161	0.677
KPI 14	0.353	0.632	0.157	0.549
KPI 15	0.348	0.727	0.226	0.7
KPI 16	0.401	0.583	0.144	0.521
KPI 17	0.291	0.67	0.243	0.592
KPI 18	0.102	0.782	0.127	0.638
KPI 19	0.585	0.49	0.21	0.627
KPI 20	0.225	0.728	0.236	0.636
KPI 21	0.582	0.514	0.245	0.663
KPI 22	0.502	0.523	0.359	0.653
KPI 23	0.516	0.598	0.241	0.682
KPI 24	0.538	0.626	0.105	0.693
KPI 25	0.644	0.494	0.1	0.669
Eigenvalues (Initial)	13.794	1.693	1.097	-
% of Variance (Initial)	55.174%	6.772%	4.386%	-
% of Cum. Variance (Initial)	55.174%	61.946%	66.333%	-
Eigenvalues (Rotated)	6.645	6.121	3.817	-
% of Variance (Rotated)	26.578%	24.486%	15.268%	-
% of Cum. Variance (Rotated)	26.578%	51.064%	66.333%	-
KMO		0.932		-
Bartlett's Test of Sphericity (Chi-Square)		1881.479		-
df		300		-
p value		0		-

Table A3. CSF reliability test.

Reliability Statistics (Cronbach Alpha)			
Items	Corrected Item—Total Correlation (CITC)	Cronbach Alpha if Item Deleted	Cronbach α
1	0.468	0.928	0.93
2	0.526	0.928	
3	0.573	0.927	
4	0.569	0.927	
5	0.402	0.929	
6	0.495	0.928	
7	0.487	0.928	
8	0.531	0.928	
9	0.561	0.927	
10	0.547	0.928	
11	0.586	0.927	
12	0.574	0.927	
13	0.481	0.928	
14	0.435	0.929	

Table A3. *Cont.*

Reliability Statistics (Cronbach Alpha)			
Items	**Corrected Item—Total Correlation (CITC)**	**Cronbach Alpha if Item Deleted**	**Cronbach α**
15	0.466	0.929	
16	0.646	0.926	
17	0.473	0.928	
18	0.527	0.928	
19	0.514	0.928	
20	0.583	0.927	
21	0.503	0.928	
22	0.631	0.926	
23	0.515	0.928	
24	0.557	0.927	
25	0.52	0.928	
26	0.394	0.929	
27	0.589	0.927	
28	0.552	0.928	
29	0.382	0.93	
30	0.616	0.927	
31	0.578	0.927	
32	0.475	0.928	
Cronbach α (Standardized): 0.931			

Table A4. KPI reliability test.

Reliability Statistics (Cronbach Alpha)			
Items	**Corrected Item—Total Correlation (CITC)**	**Cronbach Alpha if Item Deleted**	**Cronbach α**
KPI1	0.756	0.963	
KPI2	0.502	0.966	
KPI3	0.576	0.965	
KPI4	0.604	0.964	
KPI5	0.829	0.962	
KPI6	0.712	0.963	
KPI7	0.808	0.962	
KPI8	0.74	0.963	
KPI 9	0.803	0.963	
KPI 10	0.769	0.963	
KPI 11	0.63	0.964	
KPI 12	0.75	0.963	
KPI 13	0.768	0.963	0.965
KPI 14	0.656	0.964	
KPI 15	0.743	0.963	
KPI 16	0.653	0.964	
KPI 17	0.679	0.964	
KPI 18	0.567	0.965	
KPI 19	0.753	0.963	
KPI 20	0.667	0.964	
KPI 21	0.781	0.963	
KPI 22	0.782	0.963	
KPI 23	0.79	0.963	
KPI 24	0.759	0.963	
KPI 25	0.742	0.963	
Cronbach α (Standardized): 0.965			

Reliability Statistics (Split-half)			
Cronbach's Alpha	Part 1	Value	0.878
		N of Items	16
	Part 2	Value	0.879
		N of Items	16
	Total N of Items		32
Correlation Between Forms			0.78
Spearman-Brown Coefficient	Equal Length		0.877
	Unequal Length		0.877
Guttman Split-Half Coefficient			0.876

Figure A1. CSF reliability test (split-half).

Reliability Statistics (Split-half)			
Cronbach's Alpha	Part 1	Value	0.94
		N of Items	13
	Part 2	Value	0.94
		N of Items	12
	Total N of Items		25
Correlation Between Forms			0.845
Spearman-Brown Coefficient	Equal Length		0.916
	Unequal Length		0.916
Guttman Split-Half Coefficient			0.908

Figure A2. KPI reliability test (split-half).

Table A5. CSF item—analysis.

	Group (M ± SD)		t(CR)	p
	Low Grouping (n = 25)	High Grouping (n = 25)		
1	3.36 ± 0.64	4.12 ± 0.53	−4.597	0.000 **
2	3.44 ± 0.96	4.60 ± 0.50	−5.354	0.000 **
3	3.44 ± 0.65	4.56 ± 0.58	−6.41	0.000 **
4	3.56 ± 0.87	4.56 ± 0.51	−4.967	0.000 **
5	3.44 ± 0.82	4.20 ± 0.65	−3.64	0.001 **
6	3.48 ± 0.82	4.48 ± 0.65	−4.76	0.000 **
7	3.40 ± 0.71	4.40 ± 0.58	−5.477	0.000 **
8	3.52 ± 0.87	4.60 ± 0.50	−5.373	0.000 **
9	3.44 ± 0.77	4.60 ± 0.50	−6.328	0.000 **
10	3.60 ± 0.82	4.48 ± 0.59	−4.378	0.000 **
11	3.16 ± 0.75	4.36 ± 0.49	−6.722	0.000 **
12	3.56 ± 0.77	4.68 ± 0.56	−5.903	0.000 **
13	3.52 ± 0.77	4.52 ± 0.51	−5.413	0.000 **
14	3.84 ± 0.80	4.68 ± 0.56	−4.309	0.000 **
15	3.28 ± 0.68	4.40 ± 0.71	−5.715	0.000 **
16	3.24 ± 0.72	4.56 ± 0.51	−7.473	0.000 **
17	3.72 ± 0.61	4.56 ± 0.51	−5.278	0.000 **
18	3.28 ± 0.46	4.28 ± 0.61	−6.528	0.000 **
19	3.44 ± 0.82	4.60 ± 0.58	−5.781	0.000 **
20	3.44 ± 0.82	4.56 ± 0.51	−5.807	0.000 **
21	3.48 ± 0.71	4.48 ± 0.51	−5.698	0.000 **
22	2.96 ± 0.68	4.48 ± 0.59	−8.497	0.000 **
23	2.80 ± 1.00	4.24 ± 0.72	−5.834	0.000 **
24	2.84 ± 0.90	4.48 ± 0.65	−7.384	0.000 **
25	3.20 ± 0.76	4.52 ± 0.59	−6.856	0.000 **
26	3.40 ± 0.82	4.24 ± 0.60	−4.152	0.000 **
27	3.52 ± 0.82	4.68 ± 0.48	−6.102	0.000 **
28	3.32 ± 1.07	4.68 ± 0.56	−5.641	0.000 **
29	3.64 ± 0.91	4.44 ± 0.65	−3.582	0.001 **
30	3.28 ± 0.68	4.64 ± 0.49	−8.128	0.000 **
31	3.36 ± 0.86	4.48 ± 0.59	−5.38	0.000 **
32	3.96 ± 0.79	4.68 ± 0.48	−3.905	0.000 **

** $p < 0.01$.

Table A6. KPI item—analysis.

	Group (M ± SD)		t(CR)	*p*
	Low Grouping (*n* = 25)	High Grouping (*n* = 25)		
KPI 1	2.00 ± 0.58	4.12 ± 0.65	−12.24	0.000 **
KPI 2	2.44 ± 0.96	4.35 ± 0.94	−7.178	0.000 **
KPI 3	3.04 ± 0.54	4.50 ± 0.86	−7.294	0.000 **
KPI 4	2.96 ± 0.68	4.23 ± 0.91	−5.651	0.000 **
KPI 5	2.48 ± 0.65	4.69 ± 0.47	−13.83	0.000 **
KPI 6	2.40 ± 0.82	4.46 ± 0.58	−10.416	0.000 **
KPI 7	2.20 ± 0.76	4.46 ± 0.58	−11.925	0.000 **
KPI 8	2.64 ± 0.70	4.62 ± 0.57	−11.062	0.000 **
KPI 9	2.24 ± 0.72	4.42 ± 0.64	−11.399	0.000 **
KPI 10	2.48 ± 0.77	4.42 ± 0.58	−10.217	0.000 **
KPI 11	2.80 ± 0.65	4.15 ± 0.73	−6.996	0.000 **
KPI 12	1.96 ± 0.61	4.23 ± 0.71	−12.217	0.000 **
KPI 13	2.40 ± 0.96	4.73 ± 0.53	−10.682	0.000 **
KPI 14	2.96 ± 0.79	4.27 ± 0.67	−6.407	0.000 **
KPI 15	3.00 ± 0.82	4.58 ± 0.50	−8.336	0.000 **
KPI 16	2.80 ± 0.82	4.31 ± 0.68	−7.18	0.000 **
KPI 17	2.96 ± 0.73	4.38 ± 0.64	−7.405	0.000 **
KPI 18	3.08 ± 0.76	4.42 ± 0.76	−6.322	0.000 **
KPI 19	2.52 ± 0.65	4.54 ± 0.58	−11.664	0.000 **
KPI 20	2.88 ± 0.78	4.54 ± 0.51	−9.022	0.000 **
KPI 21	2.28 ± 0.84	4.35 ± 0.56	−10.342	0.000 **
KPI 22	2.60 ± 0.65	4.65 ± 0.49	−12.878	0.000 **
KPI 23	2.72 ± 0.74	4.54 ± 0.71	−8.999	0.000 **
KPI 24	2.64 ± 0.86	4.35 ± 0.63	−8.109	0.000 **
KPI 25	2.36 ± 0.91	4.42 ± 0.58	−9.643	0.000 **

** $p < 0.01$.

Table A7. CSF factor analysis.

Total Variance Explained									
Factor	Eigen Values			% of Variance (Initial)			% of Variance (Rotated)		
	Eigen	% of Variance	Cum. % of Variance	Eigen	% of Variance	Cum. % of Variance	Eigen	% of Variance	Cum. % of Variance
1	10.276	32.114	32.114	10.276	32.114	32.114	3.132	9.788	9.788
2	2.076	6.488	38.602	2.076	6.488	38.602	2.66	8.311	18.099
3	1.624	5.073	43.675	1.624	5.073	43.675	2.634	8.231	26.33
4	1.471	4.598	48.274	1.471	4.598	48.274	2.445	7.641	33.97
5	1.407	4.398	52.671	1.407	4.398	52.671	2.406	7.519	41.489
6	1.381	4.315	56.986	-	-	-	-	-	-
7	1.296	4.051	61.037	-	-	-	-	-	-
8	1.123	3.509	64.546	-	-	-	-	-	-
9	1.004	3.137	67.684	-	-	-	-	-	-
10	0.964	3.012	70.696	-	-	-	-	-	-
11	0.907	2.835	73.53	-	-	-	-	-	-
12	0.87	2.72	76.25	-	-	-	-	-	-
13	0.791	2.47	78.72	-	-	-	-	-	-
14	0.687	2.148	80.869	-	-	-	-	-	-
15	0.657	2.052	82.92	-	-	-	-	-	-
16	0.649	2.028	84.948	-	-	-	-	-	-
17	0.591	1.847	86.795	-	-	-	-	-	-
18	0.501	1.567	88.362	-	-	-	-	-	-
19	0.452	1.412	89.775	-	-	-	-	-	-
20	0.433	1.352	91.127	-	-	-	-	-	-
21	0.4	1.25	92.377	-	-	-	-	-	-
22	0.37	1.156	93.533	-	-	-	-	-	-
23	0.351	1.097	94.63	-	-	-	-	-	-
24	0.287	0.896	95.526	-	-	-	-	-	-
25	0.268	0.836	96.362	-	-	-	-	-	-
26	0.242	0.756	97.118	-	-	-	-	-	-
27	0.222	0.694	97.812	-	-	-	-	-	-
28	0.195	0.61	98.422	-	-	-	-	-	-
29	0.156	0.486	98.909	-	-	-	-	-	-
30	0.146	0.457	99.366	-	-	-	-	-	-
31	0.113	0.354	99.719	-	-	-	-	-	-
32	0.09	0.281	100	-	-	-	-	-	-

Table A8. CSF factor loading.

Factor Loading (Rotated)						
Items	**Factor Loading**					**Communalities**
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**	**Factor 5**	
1	0.133	0.223	0.258	0.588	−0.006	0.479
2	0.586	0.271	0.325	0.069	−0.144	0.547
3	0.511	0.094	0.218	0.406	0.118	0.497
4	0.141	0.42	0.503	0.164	0.138	0.495
5	0.212	−0.007	0.637	0.001	0.169	0.479
6	0.62	0.171	0.202	−0.006	0.071	0.459
7	0.773	−0.033	−0.006	0.096	0.242	0.667
8	0.299	0.283	0.509	0.276	−0.129	0.522
9	0.608	0.202	0.171	0.017	0.247	0.501
10	0.532	0.281	0.171	0.115	0.093	0.413
11	0.46	0.434	0.32	0.045	0.011	0.505
12	0.413	0.221	0.281	0.196	0.237	0.393
13	0.181	0.139	0.018	0.24	0.687	0.582
14	0.338	−0.047	0.491	0.174	0.142	0.408
15	0.051	0.106	0.708	0.112	0.236	0.584
16	0.385	0.505	0.282	−0.083	0.352	0.613
17	0.196	0.053	0.359	0.063	0.582	0.512
18	0.115	0.369	0.419	0.402	−0.013	0.487
19	0.13	0.261	0.237	0.132	0.561	0.474
20	0.283	0.395	0.383	0.104	0.187	0.429
21	0.263	0.163	0.098	0.126	0.637	0.527
22	0.278	0.718	−0.038	0.172	0.264	0.693
23	0.143	0.755	0.058	0.159	0.019	0.62
24	0.176	0.683	−0.064	0.289	0.196	0.624
25	0.119	0.608	0.254	0.026	0.191	0.486
26	−0.188	0.411	0.072	0.325	0.471	0.537
27	0.45	0.158	0.256	0.415	0.107	0.476
28	0.69	0.15	0.025	0.209	0.148	0.565
29	0.075	0.062	−0.088	0.758	0.289	0.675
30	0.413	0.437	0.221	0.057	0.265	0.484
31	0.299	0.383	0.163	0.456	0.067	0.474
32	0.076	0.083	0.147	0.74	0.258	0.648

Mean	*Items*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
3.777	*1*	1	0.929	0.942	0.929	0.967	0.903	0.954	0.927	0.915	0.922	0.942	0.906	0.937	0.908	0.992	0.927
4.064	*2*	1.076	1	1.013	1	1.041	0.972	1.027	0.997	0.985	0.992	1.013	0.974	1.008	0.977	1.067	0.997
4.011	*3*	1.062	0.987	1	0.987	1.027	0.959	1.013	0.984	0.972	0.979	1	0.962	0.995	0.964	1.053	0.984
4.064	*4*	1.076	1	1.013	1	1.041	0.972	1.027	0.997	0.985	0.992	1.013	0.974	1.008	0.977	1.067	0.997
3.904	*5*	1.034	0.961	0.973	0.961	1	0.934	0.987	0.958	0.946	0.953	0.973	0.936	0.968	0.939	1.025	0.958
4.181	*6*	1.107	1.029	1.042	1.029	1.071	1	1.056	1.026	1.013	1.021	1.042	1.003	1.037	1.005	1.098	1.026
3.957	*7*	1.048	0.974	0.987	0.974	1.014	0.947	1	0.971	0.959	0.966	0.987	0.949	0.982	0.951	1.039	0.971
4.074	*8*	1.079	1.003	1.016	1.003	1.044	0.975	1.03	1	0.987	0.995	1.016	0.977	1.011	0.98	1.07	1
4.128	*9*	1.093	1.016	1.029	1.016	1.057	0.987	1.043	1.013	1	1.008	1.029	0.99	1.024	0.992	1.084	1.013
4.096	*10*	1.085	1.008	1.021	1.008	1.049	0.98	1.035	1.005	0.992	1	1.021	0.982	1.016	0.985	1.075	1.005
4.011	*11*	1.062	0.987	1	0.987	1.027	0.959	1.013	0.984	0.972	0.979	1	0.962	0.995	0.964	1.053	0.984
4.17	*12*	1.104	1.026	1.04	1.026	1.068	0.997	1.054	1.023	1.01	1.018	1.04	1	1.034	1.003	1.095	1.023
4.032	*13*	1.068	0.992	1.005	0.992	1.033	0.964	1.019	0.99	0.977	0.984	1.005	0.967	1	0.969	1.059	0.99
4.16	*14*	1.101	1.024	1.037	1.024	1.065	0.995	1.051	1.021	1.008	1.016	1.037	0.997	1.032	1	1.092	1.021
3.809	*15*	1.008	0.937	0.95	0.937	0.975	0.911	0.962	0.935	0.923	0.93	0.95	0.913	0.945	0.916	1	0.935
4.074	*16*	1.079	1.003	1.016	1.003	1.044	0.975	1.03	1	0.987	0.995	1.016	0.977	1.011	0.98	1.07	1
4.138	*17*	1.096	1.018	1.032	1.018	1.06	0.99	1.046	1.016	1.003	1.01	1.032	0.992	1.026	0.995	1.087	1.016
3.84	*18*	1.017	0.945	0.958	0.945	0.984	0.919	0.97	0.943	0.93	0.938	0.958	0.921	0.953	0.923	1.008	0.943
4	*19*	1.059	0.984	0.997	0.984	1.025	0.957	1.011	0.982	0.969	0.977	0.997	0.959	0.992	0.962	1.05	0.982
3.989	*20*	1.056	0.982	0.995	0.982	1.022	0.954	1.008	0.979	0.966	0.974	0.995	0.957	0.989	0.959	1.047	0.979
3.926	*21*	1.039	0.966	0.979	0.966	1.005	0.939	0.992	0.963	0.951	0.958	0.979	0.941	0.974	0.944	1.031	0.963
3.819	*22*	1.011	0.94	0.952	0.94	0.978	0.913	0.965	0.937	0.925	0.932	0.952	0.916	0.947	0.918	1.003	0.937
3.67	*23*	0.972	0.903	0.915	0.903	0.94	0.878	0.927	0.901	0.889	0.896	0.915	0.88	0.91	0.882	0.964	0.901
3.798	*24*	1.006	0.935	0.947	0.935	0.973	0.908	0.96	0.932	0.92	0.927	0.947	0.911	0.942	0.913	0.997	0.932
3.883	*25*	1.028	0.955	0.968	0.955	0.995	0.929	0.981	0.953	0.941	0.948	0.968	0.931	0.963	0.934	1.02	0.953
3.777	*26*	1	0.929	0.942	0.929	0.967	0.903	0.954	0.927	0.915	0.922	0.942	0.906	0.937	0.908	0.992	0.927
4.191	*27*	1.11	1.031	1.045	1.031	1.074	1.003	1.059	1.029	1.015	1.023	1.045	1.005	1.04	1.008	1.101	1.029
4.085	*28*	1.082	1.005	1.019	1.005	1.046	0.977	1.032	1.003	0.99	0.997	1.019	0.98	1.013	0.982	1.073	1.003
4.085	*29*	1.082	1.005	1.019	1.005	1.046	0.977	1.032	1.003	0.99	0.997	1.019	0.98	1.013	0.982	1.073	1.003
4.011	*30*	1.062	0.987	1	0.987	1.027	0.959	1.013	0.984	0.972	0.979	1	0.962	0.995	0.964	1.053	0.984
3.947	*31*	1.045	0.971	0.984	0.971	1.011	0.944	0.997	0.969	0.956	0.964	0.984	0.946	0.979	0.949	1.036	0.969
4.277	*32*	1.132	1.052	1.066	1.052	1.095	1.023	1.081	1.05	1.036	1.044	1.066	1.026	1.061	1.028	1.123	1.05

Items	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*
1	0.913	0.983	0.944	0.947	0.962	0.989	1.029	0.994	0.973	1	0.901	0.924	0.924	0.942	0.957	0.883
2	0.982	1.058	1.016	1.019	1.035	1.064	1.107	1.07	1.047	1.076	0.97	0.995	0.995	1.013	1.03	0.95
3	0.969	1.044	1.003	1.005	1.022	1.05	1.093	1.056	1.033	1.062	0.957	0.982	0.982	1	1.016	0.938
4	0.982	1.058	1.016	1.019	1.035	1.064	1.107	1.07	1.047	1.076	0.97	0.995	0.995	1.013	1.03	0.95
5	0.943	1.017	0.976	0.979	0.995	1.022	1.064	1.028	1.005	1.034	0.931	0.956	0.956	0.973	0.989	0.913
6	1.01	1.089	1.045	1.048	1.065	1.095	1.139	1.101	1.077	1.107	0.997	1.023	1.023	1.042	1.059	0.978
7	0.956	1.03	0.989	0.992	1.008	1.036	1.078	1.042	1.019	1.048	0.944	0.969	0.969	0.987	1.003	0.925
8	0.985	1.061	1.019	1.021	1.038	1.067	1.11	1.073	1.049	1.079	0.972	0.997	0.997	1.016	1.032	0.953
9	0.997	1.075	1.032	1.035	1.051	1.081	1.125	1.087	1.063	1.093	0.985	1.01	1.01	1.029	1.046	0.965
10	0.99	1.066	1.024	1.027	1.043	1.072	1.116	1.078	1.055	1.085	0.977	1.003	1.003	1.021	1.038	0.958
11	0.969	1.044	1.003	1.005	1.022	1.05	1.093	1.056	1.033	1.062	0.957	0.982	0.982	1	1.016	0.938
12	1.008	1.086	1.043	1.045	1.062	1.092	1.136	1.098	1.074	1.104	0.995	1.021	1.021	1.04	1.057	0.975
13	0.974	1.05	1.008	1.011	1.027	1.056	1.099	1.062	1.038	1.068	0.962	0.987	0.987	1.005	1.022	0.943
14	1.005	1.083	1.04	1.043	1.06	1.089	1.133	1.095	1.071	1.101	0.992	1.018	1.018	1.037	1.054	0.973
15	0.92	0.992	0.952	0.955	0.97	0.997	1.038	1.003	0.981	1.008	0.909	0.932	0.932	0.95	0.965	0.891
16	0.985	1.061	1.019	1.021	1.038	1.067	1.11	1.073	1.049	1.079	0.972	0.997	0.997	1.016	1.032	0.953
17	1	1.078	1.035	1.037	1.054	1.084	1.128	1.09	1.066	1.096	0.987	1.013	1.013	1.032	1.049	0.968
18	0.928	1	0.96	0.963	0.978	1.006	1.046	1.011	0.989	1.017	0.916	0.94	0.94	0.958	0.973	0.898
19	0.967	1.042	1	1.003	1.019	1.047	1.09	1.053	1.03	1.059	0.954	0.979	0.979	0.997	1.013	0.935
20	0.964	1.039	0.997	1	1.016	1.045	1.087	1.05	1.027	1.056	0.952	0.977	0.977	0.995	1.011	0.933
21	0.949	1.022	0.981	0.984	1	1.028	1.07	1.034	1.011	1.039	0.937	0.961	0.961	0.979	0.995	0.918
22	0.923	0.994	0.955	0.957	0.973	1	1.041	1.006	0.984	1.011	0.911	0.935	0.935	0.952	0.968	0.893
23	0.887	0.956	0.918	0.92	0.935	0.961	1	0.966	0.945	0.972	0.876	0.898	0.898	0.915	0.93	0.858
24	0.918	0.989	0.949	0.952	0.967	0.994	1.035	1	0.978	1.006	0.906	0.93	0.93	0.947	0.962	0.888
25	0.938	1.011	0.971	0.973	0.989	1.017	1.058	1.022	1	1.028	0.926	0.951	0.951	0.968	0.984	0.908
26	0.913	0.983	0.944	0.947	0.962	0.989	1.029	0.994	0.973	1	0.901	0.924	0.924	0.942	0.957	0.883
27	1.013	1.091	1.048	1.051	1.068	1.097	1.142	1.104	1.079	1.11	1	1.026	1.026	1.045	1.062	0.98
28	0.987	1.064	1.021	1.024	1.041	1.07	1.113	1.076	1.052	1.082	0.975	1	1	1.019	1.035	0.955
29	0.987	1.064	1.021	1.024	1.041	1.07	1.113	1.076	1.052	1.082	0.975	1	1	1.019	1.035	0.955
30	0.969	1.044	1.003	1.005	1.022	1.05	1.093	1.056	1.033	1.062	0.957	0.982	0.982	1	1.016	0.938
31	0.954	1.028	0.987	0.989	1.005	1.033	1.075	1.039	1.016	1.045	0.942	0.966	0.966	0.984	1	0.923
32	1.033	1.114	1.069	1.072	1.089	1.12	1.165	1.126	1.101	1.132	1.02	1.047	1.047	1.066	1.084	1

Figure A3. AHP judgment matrix.

Table A9. CSF AHP analysis.

Items	Eigenvectors	Weight	Maximum Eigenvalue	CI
1	0.945	2.952%	32	0
2	1.016	3.176%		
3	1.003	3.135%		
4	1.016	3.176%		
5	0.976	3.051%		
6	1.046	3.268%		
7	0.99	3.093%		
8	1.019	3.185%		
9	1.032	3.226%		
10	1.024	3.201%		
11	1.003	3.135%		
12	1.043	3.259%		
13	1.008	3.151%		
14	1.04	3.251%		
15	0.953	2.977%		
16	1.019	3.185%		
17	1.035	3.234%		
18	0.961	3.002%		
19	1	3.126%		
20	0.998	3.118%		
21	0.982	3.068%		
22	0.955	2.985%		
23	0.918	2.869%		
24	0.95	2.968%		
25	0.971	3.035%		
26	0.945	2.952%		
27	1.048	3.276%		
28	1.022	3.193%		
29	1.022	3.193%		
30	1.003	3.135%		
31	0.987	3.085%		
32	1.07	3.342%		

Table A10. RI value.

RI Table														
Order	3	4	5	6	7	8	9	10	11	12	13	14	15	16
RI	0.52	0.89	1.12	1.26	1.36	1.41	1.46	1.49	1.52	1.54	1.56	1.58	1.59	1.5943
Order	17	18	19	20	21	22	23	24	25	26	27	28	29	30
RI	1.6064	1.6133	1.6207	1.6292	1.6358	1.6403	1.6462	1.6497	1.6556	1.6587	1.6631	1.667	1.6693	1.6724
Order	31	32	33	34	35	36	37	38	39	40	41	42	43	44
RI	1.6755	1.6773	1.68	1.6828	1.6837	1.6864	1.6883	1.6903	1.6921	1.6929	1.6947	1.6958	1.6985	1.6991
Order	45	46	47	48	49	50	51	52	53	54	55	56	57	58
RI	1.7006	1.7015	1.7023	1.7045	1.7056	1.7065	1.7066	1.7071	1.709	1.71	1.7109	1.7113	1.7123	1.7127

Table A11. Stakeholders' perception of the COVID-19 pandemic's impact on KPIs.

Dimensions	Indicators	Assessment Outcome															
		A. Owner (N = 34)				B. Designer N = 21)				C. Constructor (N = 39)				Overall			
		Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation
Efficiency (Project management success)	KPI 1	1	5	3.029	1.193	1	4	3.238	0.995	1	5	3.238	1.185	1	5	3.149	1.136
	KPI 2	1	5	3.118	1.365	2	5	3.857	0.964	1	5	3.667	1.162	1	5	3.489	1.233
	KPI 3	1	5	3.441	1.078	1	5	3.905	0.995	2	5	3.833	0.824	1	5	3.702	0.971

Table A11. *Cont.*

Dimensions	Indicators	Assessment Outcome															
		A. Owner (N = 34)				B. Designer N = 21)				C. Constructor (N = 39)				Overall			
		Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation	Min	Max	Mean	Std. Deviation
Satisfaction of key stakeholders	KPI 4	1	5	3.559	1.021	2	5	3.81	0.75	1	5	3.643	0.932	1	5	3.638	0.926
	KPI 5	1	5	3.618	1.28	2	5	3.857	0.91	1	5	3.81	0.943	1	5	3.723	1.062
	KPI 6	1	5	3.529	1.212	2	5	3.714	0.956	1	5	3.643	1.186	1	5	3.606	1.147
	KPI 7	1	5	3.265	1.163	2	5	3.81	0.873	1	5	3.548	1.173	1	5	3.489	1.124
	KPI 8	2	5	3.5	1.052	2	5	4.095	0.831	1	5	3.786	1.025	1	5	3.723	1.01
	KPI 9	1	5	3.353	1.228	2	5	3.81	0.981	1	5	3.69	1.07	1	5	3.574	1.122
	KPI 10	2	5	3.471	0.896	1	5	3.81	0.928	1	5	3.571	1.107	1	5	3.585	0.999
Enterprise (organization) strategic goals	KPI 11	2	5	3.324	0.912	2	5	3.619	0.74	1	5	3.595	0.885	1	5	3.5	0.877
	KPI 12	1	5	2.941	1.324	2	5	3.381	1.117	1	5	3.357	1.265	1	5	3.213	1.26
	KPI 13	1	5	3.5	1.261	2	5	3.81	0.928	1	5	3.81	1.174	1	5	3.691	1.173
	KPI 14	2	5	3.647	0.812	2	5	3.81	0.75	1	5	3.643	0.932	1	5	3.67	0.847
	KPI 15	2	5	3.824	0.834	1	5	3.81	1.03	1	5	3.952	0.854	1	5	3.862	0.875
	KPI 16	2	5	3.412	0.821	1	5	3.571	0.978	1	5	3.762	0.958	1	5	3.596	0.931
Industry innovation and development	KPI 17	2	5	3.735	0.828	2	5	3.81	1.03	1	5	3.81	0.833	1	5	3.766	0.873
	KPI 18	2	5	3.735	0.963	2	5	3.762	0.889	1	5	3.81	0.862	1	5	3.777	0.894
	KPI 19	2	5	3.529	1.022	2	5	3.81	0.873	1	5	3.762	1.078	1	5	3.681	1.018
	KPI 20	2	5	3.676	0.976	3	5	3.81	0.68	1	5	3.905	0.932	1	5	3.798	0.899
Comprehensive social impact	KPI 21	1	5	3.324	1.199	1	5	3.619	1.117	1	5	3.643	0.932	1	5	3.5	1.075
	KPI 22	2	5	3.559	1.133	2	5	3.857	1.014	1	5	3.833	1.08	1	5	3.723	1.092
	KPI 23	2	5	3.559	0.894	2	5	3.762	0.889	1	5	3.881	1.041	1	5	3.745	0.961
	KPI 24	2	5	3.618	1.045	2	5	3.952	0.921	1	5	3.738	0.885	1	5	3.734	0.952
	KPI 25	1	5	3.324	1.093	1	5	3.714	1.056	1	5	3.952	1.058	1	5	3.649	1.095

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