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Empirical Assessments of the Determinants of Construction Megaprojects' Success: Evidence from China

Ting Wang [1], Emmanuel Kingsford Owusu [2], Qinghua He [3], Zidan Tian [3] and Dong Wu [4,*]

1 Shanghai Institute of Technology, College of Urban Construction and Safety Engineering, Shanghai 201418, China
2 Department of Building and Real Estate, The Hong Kong Polytechnic University, Kowloon, Hong Kong 999077, China
3 School of Economics and Management, Tongji University, Shanghai 200092, China
4 Shanghai Key Laboratory for Urban Ecological Processes and Eco-Restoration, Shanghai Engineering Research Center of Biotransformation of Organic Solid Waste, School of Ecological and Environmental Sciences, East China Normal University, Shanghai 200241, China
* Correspondence: dwu@des.ecnu.edu.cn

Abstract: This study empirically examines the success determinants that instigate or contribute to project success and empirically evaluates the levels of importance at which the ascertained determinants contribute to project success in China. Based on a literature review and interviews, a questionnaire survey used to gather a total of 129 valid responses was gathered from megaproject experts who have worked on at least a billion RMB (approximately USD 0.14 billion) worth of projects in different provinces. Moreover, factor analysis was adopted to explore and identify the underlying relationships among the identified critical success factors. The top three success factors were adequate communication and coordination among related parties, cooperation and strong support from local governments and partnering/relationships with key stakeholders. Six constructs were developed from thirty-five success variables using the Factor Analysis tool, with the topmost-ranked construct being organisational-related factors. This paper can provide valuable insights and a holistic critical success factor framework concerning construction megaproject management. Particularly, it contributes to a deepened understanding of the megaproject's success factors and helps project stakeholders to manage megaprojects more effectively. Additionally, this study could serve as the premise for further empirical research on determining factors of megaproject success in different contexts.

Keywords: megaproject management; construction infrastructure; critical success factors (CSFs); project success; factor analysis

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1. Introduction

Megaprojects have been significant drivers and boosters of economic and social development [1]. Thus, both public and private organisations and governments worldwide have resorted to the development of megaprojects as one of the most preferential routes to provide benefits to local municipalities and society [2]. However, due in part to it involving a capital of USD 1 billion or more, megaprojects are regarded as highly complex and risky endeavours that are backbreaking to manage and, as a result, often fail to realise the original stipulated goals [3]. According to Flyberg [4], megaproject expenditure across the globe spans over USD 6 to 9 trillion, or an estimated 8% of the world's total gross domestic product (GDP) annually. Given the high stake of public financial resources dedicated to the development of megaprojects, project failures can not only result in high costs to governments, but also prevent expending or committing such capital to other important purposes. Put simply, it also compromises other opportunities. Thus, it is often in the best interests of private finances and public agencies, including central governments, to realise projected and ongoing mega projects. Regardless of the best practices and frameworks implemented to drive megaproject success, several barriers, including corruption and political unrest, exist to interdict the projected success, particularly in public projects [5]. In the last decades, China has undergone massive technological advancement and high-speed urbanisation, which have fuelled enormous different mega projects developments in different cities and provinces [6]. As a result, China has been able to gather an enormous wealth of knowledge and experience in terms of managing megaprojects [7]. A typical example of the clusters of knowledge developed to date includes the determinants of megaproject success that have been diversely captured and reported in different project reports and literature surrounding megaproject management.

Given that these determinants have been identified to be scattered across different reports and literature, this study attempts not only to investigate the mentioned success determinants but also to collate such factors from leading megaproject experts across China. The study explores the various factors and clusters that contribute to project success in China. It advances the ongoing discussions on the dynamics surrounding how megaprojects can be successful or what contributes to the successes of complex projects. While most megaprojects are perceived to be enormously complex and bound to fail, particularly in most developing contexts, it is noteworthy to emphasise that several scholars and practitioners have either developed or adopted frameworks that determine or contribute to the success of such projects.

This study first reviews the mentioned success determinants that either instigate or contribute to project success and empirically evaluates the levels of importance to which the ascertained determinants contribute to project success using China's context as the geographical point of focus. This investigation contributes to the extension and deep understanding of the megaproject's success factors and the scholarship of project management in general. The study further informs project stakeholders on the leading determinants of megaproject-related success indicators. Moreover, the information provided will enable the stakeholders to make better decisions that will eventually lead to project success, and can also serve as a source of reference or a blueprint for future works in which the stakeholders may be involved. The study encapsulates six different sections. Section 1 introduces the study. Section 2 reviews relevant literature that forms the theoretical foundation of the study. Section 3 presents the research methods, including data collection and analysis approaches employed for the study. Section 4 lays out the analyses and results of the data gathered (including open-ended and close-ended questionnaires and expert interviews). Section 5 discusses the findings of the study, and lastly, Section 6 concludes the study.

2. Literature Review

2.1. The Definitions of Megaproject and Construction Megaproject

The term 'megaproject' has no standardised definition, but can be defined as 'large-scale, vast investments that typically cost one billion dollars or more, take many years to build, involve many stakeholders, and impact millions of people' [4]. While the term 'mega' means big, great, vast, large, high, mighty, tall, or important, the use of the terms 'Tera', 'Giga', and 'Peta' are used to classify projects that are larger than megaprojects [4]. Additionally, in academic publications, other words used to connote megaprojects mainly include 'major projects', 'large-scale projects', 'large projects', 'complex projects', 'public works projects', 'public construction projects', 'transportation infrastructure projects', and 'tera, giant, giga, project and program' [8–11].

In addition to the three main constructs used to define megaprojects, including project size, cost and duration, some researchers have explained megaprojects in terms of project complexity. For example, Caldas and Gupta [12] stated that megaprojects can be defined as projects with any of the following complexity criteria: numerous interfaces, many stakeholders, challenging project location, new technologies, inadequate resources, potential regulatory constraints, geographically and culturally dispersed teams, extensive infrastructure requirements, and significant institutional impact. In addition, the different economic, social and cultural environments could lead to different definitions of megaprojects. The

Federal Highway Administration of the United States defined megaprojects as 'major infrastructure projects costing more than one billion dollars or a costly project that attract a high level of public interests or attention because of its significant direct or indirect impacts on the community' [13]. Megaprojects can also be defined as 'initiatives that are physical, costly, and public' [14]. In China, major national projects usually involve government-funded projects approved by the National Development and Reform Commission, with a total investment of RMB 5 billion (approximately USD 0.7 billion); thus, Hu et al. [15] pointed out that 0.01% of GDP could be viewed as a reasonable criterion to define megaprojects. Sheng [7] divided megaprojects into three types, namely scientific and technological megaprojects, military and national defence megaprojects and construction megaprojects. Comparatively, construction megaprojects are more closely related to people's livelihoods. They refer to those permanent buildings, facilities, equipment, and the services they render to people's livelihoods and social production. The primary purpose of this type of megaproject is to improve people's livelihoods and facilitate social development. Although there are no standardised definitions of such projects, the following six significant characteristics of these projects can be suggested as their descriptive definition, including (1) the government or the state as the major investor and decision maker, (2) huge construction scale, (3) located in complex environmental conditions, (4) huge and far-reaching impacts on the social and economic developments in regional or national level, (5) long life cycles and (6) involving various partnerships. This study only focused on the type of construction megaproject, and eventually defined in this study as a social construct referring to a large-scale and complex construction project with a cost of more than one billion RMB (Chinese currency, approximately US$ 0.14 billion) [16].

2.2. CSFs for Construction Megaproject Success

As stated by Ika [17], CSFs refer more specifically to events, conditions, and environments that contribute to the outcome of a project. Research on CSFs is necessary to ensure success in project management [18]. However, research on construction megaproject success is still incomplete, and there is no standardized definition [19]. In analogy to the definition of megaprojects, the five dimensions investigated by He et al. can be considered as the descriptive definition of construction megaproject success. They are (1) project efficiency; (2) organizational strategic goals; (3) key stakeholders' satisfaction; (4) comprehensive impact on society; (5) innovation and development of the construction industry [19].

There have been some studies on CSFs for construction megaprojects in recent years. It is worth noting that case studies are one of the most widely used methods for identifying CSFs [20]. For example, by investigating cases in Mexico and the United States, Lopez del Puerto and Shane [21] identified four common critical factors to success, including early agency agreements and commitments, understanding of the cultural and socio-political circumstances, public outreach and recognition of events that affect the project. Shenhar and Holzmann [22] noted that factors such as clear strategic vision, comprehensive coordination and adaptation to complexity are critical to megaproject success. Hu et al. [23] used a case study of the Shanghai Expo construction, identified 12 principal factors and grouped them into three main categories (environmental capability, core capacity and motivational capability of the client's program organisation to manage its construction megaproject). Currently, instead of only investigating the CSFs, some scholars have explored the CSFs and influence mechanism of megaproject success from only one certain perspective, such as the project manager's leadership style [24], relationship quality [25], trust [26] and stakeholder support [27] However, despite the increasing interest in the CSFs of megaprojects, three problems can still be found in previous studies. First, most existing papers have concentrated mainly on qualitative analyses based on literature reviews and case studies, failing to quantitatively and comprehensively reveal the effect of CSFs that contribute to construction megaproject success. For example, He et al. [6] only identify the critical factors for construction megaproject success based on three typical case studies and fail to further explore the effect of CSFs that lead to megaproject success. Second, previous studies have seldom provided a pragmatic and holistic CSF framework that can fully address the requirements of managing construction projects. For instance, Hu. et al. [23] explored the determinants of program organization for construction megaproject success by using a case study of the Shanghai Expo. However, this research only considered determining factors from the perspective of a client to manage a megaproject. Third, the literature review noted the importance of context when exploring construction megaproject success [28]. There are similar studies, such as that of Nguyen O.D et al. [29], who conducted a study in Vietnam, which has different cultural, socio-economic contexts from China. Given that China has a unique cultural, political and economic system, further investigations of CSFs for construction megaproject success in the context of China were necessary. Therefore, to fill in current research gaps, the research objective of this study is stipulated; that is, to explore the success determinants that either instigate or contribute to construction megaproject success and empirically evaluate the levels of importance to which the ascertained determinants contribute to construction megaproject success in China.

3. Research Methods

To achieve the objectives of this study, a literature review and expert interviews are used to identify the optional list of CSFs of construction megaprojects. Then, a questionnaire survey is conducted to collect data from industry experts for analysing the significance of optional CSFs using the five-point Likert scale. Finally, CSFs are ranked based on the importance of each factor and analysed by using Statistical Product and Service Solutions (SPSS) software to explore the underlining relationships of the identified factors.

This study conducted literature searches in two databases, namely the Web of Science and Scopus. These two search engines are the largest web-based sources of peer-reviewed literature and have powerful tools to support the review work, such as the previous review publications of He et al. [30] and Hu et al. [15]. According to the definitions of construction megaprojects, the following full search codes were selected: TITLE-ABSTRACT-KEYWORD (‘success’ OR ‘successful’) AND TITLE-ABSTRACT-KEYWORD (‘megaproject’ OR ‘megaprojects’ OR ‘major projects’ OR ‘major project’ OR ‘complex project’ OR ‘complex projects’ OR ‘large projects’ OR ‘large project’ OR ‘large-scale project’ OR ‘large-scale projects’ OR ‘transportation infrastructure project’ OR ‘transportation infrastructure projects’ OR ‘public works project’ OR ‘public works projects’ OR ‘public construction project’ OR ‘public construction projects’ OR ‘Tera, Giga, giant project and program’ or ‘Tera, Giga, giant projects and programs’). Two criteria were used to filter articles: (1) peer-reviewed journal articles published from 2000 to 2022 (the search ended on 10 January 2022) and (2) papers that focused on the CSFs of megaprojects. After the literature search process, the authors identified five constructs of optional CSFs through thematic analysis, which is used to provide a rich interpretation of different aspects of a dataset [31]. In order to minimise the impact of subjective differences on the results of the thematic analysis [32], two authors independently coded and classified the literature, then aggregated the initial output and discussed it until consensus was reached [33]. The categories include project-related, project participant-related, economic and management-related, innovation-related, and external environmental factors.

3.1. Expert Interview

The interview method was used to explore the CSFs for measuring the success of construction megaprojects in this study, which aims to build and draw on the results obtained from the literature review and provide a solid basis for the questionnaire design and survey. According to the interview guide proposed by Kvale et al. [34], a two-step approach was employed to select interview experts. Official invitation letters requesting support from the members of the Research Institute of Complex Engineering Management (website: http://ricem.tongji.edu.cn/#/Home (accessed on 31 October 2022)) were sent. This institute focuses on studies of complex projects and megaproject management in China.

Members of the Institute were asked to nominate qualified experts ((internal and external to the Institute) based on the criteria given in the letter. The criteria are (1) at least five years of working experience in construction megaprojects and good knowledge of megaproject management, (2) recent hands-on experience in at least one construction megaproject and (3) have good knowledge of project and megaproject success. The target respondents were then contacted and asked if they would like to participate in the research. Finally, ten respondents were invited, including seven industrial experts with extensive practical experience in megaproject management and three academic scholars in the research area of large-scale and complex megaprojects. The background information of the experts is shown in Table 1.

Table 1. Background information of the experts.

Interviewees	Current Positions	Years Working in the Project Management Area	Participated Megaprojects
Expert 1	Professors	36	Shanghai EXPO, Shanghai Disneyland Resort
Expert 2	Professors	27	Shanghai EXPO, Changchun West Railway Station
Expert 3	Research assistant	9	Beijing-Xinjiang Expressway
Expert 4	Project manager	20	Guangzhou Baiyun International Airport, Shanghai EXPO
Expert 5	Project manager	21	Shanghai EXPO, Shanghai West Bund Media Harbour
Expert 6	Project manager	27	Hong Kong-Zhuhai-Macau Bridge, Hangzhou Bay Bridge
Expert 7	Deputy project management	19	Shanghai Disneyland Resort, Shenzhen Qianhai New City Centre
Expert 8	Project management consultant	15	Shanghai West Bund Media Harbour, Buddhist Academy of
Expert 9	Project management consultant	16	Kunming Metro Line 2, Shanghai West Railway Station
Expert 10	Project supervisor	12	Shanghai West Bund Media Harbour, Shanghai Disneyland Resort

The interviews were split into two parts: personal information and opinions on CSFs for measuring success. The interviews were purposefully not structured, and respondents were also encouraged to express their thoughts and add any details when necessary. Each interview lasted 45 min to 1 h; the voice records were transcribed into interview reports after the interview. The accuracy of the report shall be verified by the corresponding respondents. Through the literature review and expert interviews, initial CSFs for the construction megaprojects success were identified, consisting of 35 factors grouped into five categories: project-related, project participant-related, economic and management-related, innovation-related, and external environmental factors, which are shown in Table 2.

Table 2. Option list of CSFs.

Categories	Success Factors	Source
Project-related factors	Clear strategic vision	Hu et al. [23]; Toor and Ogunlana [35]; Nguyen et al. [29]; Shenhar and Holzmann [22]
	Aligned perceptions of project goals and success	Toor and Ogunlana [35]; Caldas and Gupta [12]; Crosby [36];
	Clear goals and project definition to make sure the project goes smoothly	Hu et al. [23]; Locatelli et al. [37]; Nguyen et al. [29];
	Effective strategic planning	Hosseini et al. [38]; Al-Nahyan et al. [29]
	Good governance	Brunet and Forgues, [39]; Crosby [36]; Al-Subaie et al. [40]
	Project organization structure	Hu et al. [23]

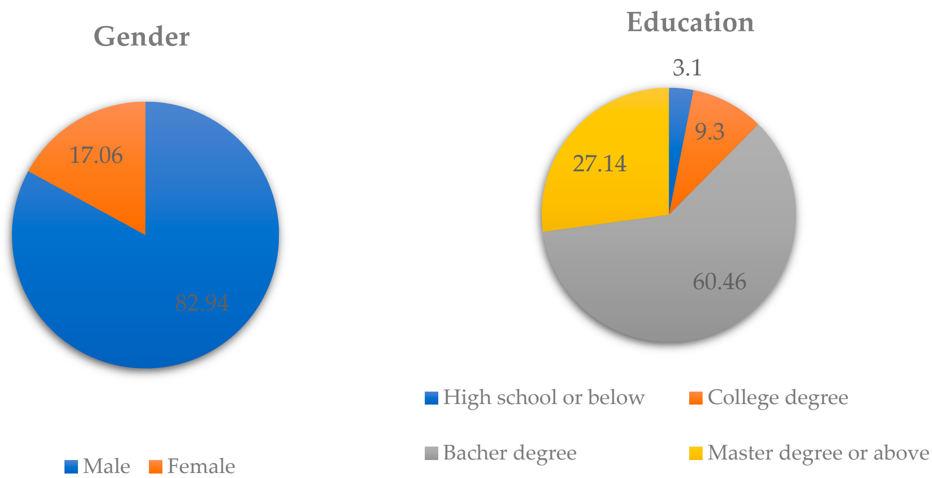
Table 2. *Cont.*

Categories	Success Factors	Source
Project participants-related factors	Partnering/relationships with key stakeholders	Hu et al. [23]; Mazur et al. [41]; Xue et al. [42]
	Adequate communication and coordination among related parties	Toor and Ogunlana [35]; Caldas and Gupta [12];
	Mutual trust among project stakeholders	Brunet and Forgues, [39]; Toor and Ogunlana [35];
	Capabilities and leadership of the owner	Winch and Leiringer [43]; Fahri et al. [44]
	Capabilities and leadership of project managers	Toor and Ogunlana [35]; Crosby [36]; Hosseini et al. [38];
	Capabilities and leadership of contractors	Mazur et al. [41]; Crosby (2017); Sturup and Low [45]; Wang et al. [3]
	Positive behaviour of project participants that could collectively facilitate the effective achievement of construction goals	Expert 1–7 and Expert 9
Economic and management-related factors	Great organizational support	Fahri et al. [44]
	Positive organizational culture for effective project management	Puerto and Shane [21]; He et al. [6]
	Adequate resource availability	Toor and Ogunlana [35]; He et al. [6]
	Establish effective incentive and punishment mechanisms	Expert 2 and Expert 5–10
	Systematic control and integration mechanisms	Crosby [36]; Nguyen et al. [29]
	Effective risk management	Kardes et al. [46]; Dimitriou et al. [47]; Crosby [36]; Sturup and Low [45]
	Effectively address complexities	Wang et al. [3]; Qiu et al. [48]
	Scope management	Hu et al. [23]
	Well-formulated and detailed contracts	Toor and Ogunlana [35]; Wang et al. [3]
	Select the appropriate contracting and delivery model	Brunet and Forgues, [39]; Locatteli et al. [37]
	Adopt a competitive and transparent procurement process to control corruption effectively	Expert 1–10
Innovation related factors	Owners need to clarify the innovation orientation and strategic choice and also need to guide the innovation management of participating enterprises	Expert 1–5 and Expert 7–10
	Owners need to provide the necessary innovation resources and an innovative environment, such as provide subsidies to promote innovative behaviour	Expert 1–10
	Focus on pre-stage research and necessary talents training	Expert 1–9
	Adopt up to date or innovatively improve technologies and methods	Crosby [36]; Hosseini et al. (2017); Nguyen et al. [29]
	Adopt up to date or innovatively improve technologies and methods	Davies et al. [49]; Kwak et al. [50]
External environment factors	Direct or strong support of the state (central government)	He et al. [6]; Locatelli et al. [37]
	Cooperation and strong support from local governments	Expert 1–10
	Public support or acceptance	Ng et al. [51]
	Adequate external supervision and audit	Expert 1–10
	Complete understanding of cultural, financial, and legislative requirements	He et al. [6]; Crosby [36]
	Economic and political stability	Hosseini et al. [38]; Wang et al. [3]

3.2. Questionnaire Survey

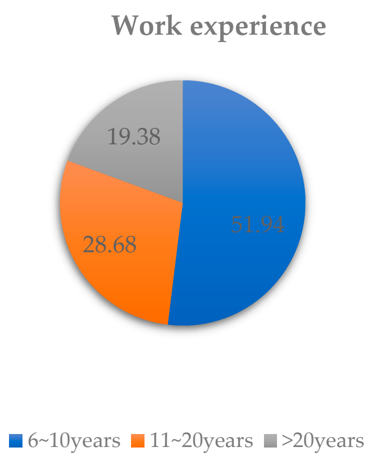
The questionnaire survey was employed to collect data for analysing the significance of selected factors in Table 2. The adequacy and readability of the designed questionnaire were tested through a pilot study. Five experts who were not invited in the section of the expert interview were involved in this stage. They have abundant practical experience in megaproject management. The questionnaire was administered to the five experts in the same way as it will be administered in the main study. The feedback of these experts was helpful to promote the questionnaire design. The designed questionnaire included three sections. At the beginning of the questionnaire, project information was collected, such as the name of the megaproject. The respondents were asked to select a construction megaproject t they are recently involved in as a reference for answering the questionnaire. The second section was developed based on the initially identified 35 CSFs in Table 2. For example, the questions designed for project-related factors are 'The project has a clear strategic vision; alignment between project objectives and success; clear project objectives and project definition to ensure that the project is sustainable, including objective identification, quantitative control indicator development and process monitoring; effective project strategy and objective planning; good project governance, e.g., top-level system design for project governance; and organisational design and structure of the project.' In this questionnaire, a five-point Likert scale was adopted to measure the level of importance, where 5 represents 'strongly agree', 4 = 'agree', 3 = 'neutral', 2 = 'disagree', and 1 = 'strongly disagree'. The final section of the questionnaire included the background information of the respondents. A total of 300 questionnaires were delivered to respondents, and 129 valid ones were retrieved (43% return rate). Of the respondents, 47 were owners (e.g., government officials related directly to the project, or a member of the owner's project team and consultants commissioned by the owner), 69 were contractors and 13 were designers (i.e., commissioned by the owner and design consultants).

Figure 1 shows the backgrounds of the respondents. The table shows that 51.94% of the respondents had 6 to 10 years of work experience in construction project management, 28.68% had 11 to 20 years of experience and 19.38% had more than 20 years of experience. The results could indicate that the respondents in this questionnaire survey had good experiences and the required knowledge to provide sensible answers. In terms of project size, 36.43% of construction megaprojects had a total investment between 1 billion (US$ 0.14 billion) to 3 billion RMB (US$ 0.42 billion), 32.56% of projects had a total investment between 3 billion (exclusive) to 5 billion RMB (US$ 0.7 billion), 13.18% cost between 5 billion (exclusive) to 10 billion RMB (US$ 1.4 billion), and 17.83% cost more than 10 billion RMB. The results indicated that projects involved in the questionnaire survey meet the criteria of construction megaprojects. In terms of location, approximately 31% of the construction megaprojects were in Eastern China (Jiangsu, Shanghai, and Zhejiang provinces), 21.71% of the construction megaprojects were in central China (Henan and Hubei provinces), 17.05% of the projects were in southwest China (Guangxi and Sichuan provinces), 17.05% were in southeast China (Guangdong and Hainan provinces), and 3.1% were in northern China ('Others' are not counted) [52]. This distribution of samples ensures that the findings derived from the survey cover all variations across the country.

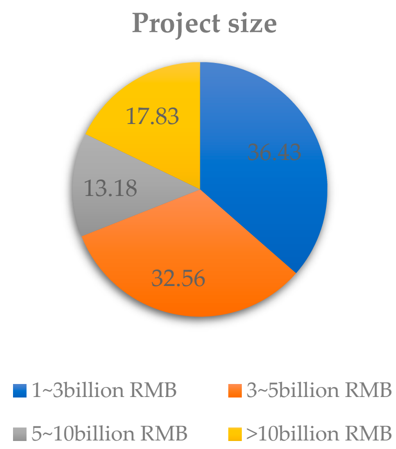


(**a**) Respondents' gender (**b**) Respondents' education background

Figure 1. *Cont.*



(**c**) Respondents' work experience



(**d**) Project size

Figure 1. Backgrounds of the respondents.

SPSS V 25.0 was used to analyse the data collected for the CSFs. As the basis for data analysis, we examined the reliability and validity of the survey with the Cronbach's alpha coefficient method. Afterward, based on reliable and valid data, scale ranking and factor analysis were conducted to cluster the final CSFs. The detailed calculations and procedures will be discussed in the Section 'Data Analysis and Findings'.

4. Data Analysis and Findings

Research data were collected through a questionnaire survey to analyse the significance of the list in Table 3. SPSS V 25.0 was used to analyse the data collected for the CSFs. The overall Cronbach's coefficient alpha value was 0.955, and the Cronbach's coefficients of the five categories were 0.861, 0.870, 0.881, 0.728, and 0.751, respectively. All Cronbach's coefficients were more than 0.7, indicating that the five-point scale measurement was reliable. Table 3 lists the results of Cronbach's alpha data. Scale ranking and factor analysis were applied to analyse the data. The procedure, findings, and relevant discussion will be provided in the following sections.

4.1. Ranking of CSFs

Table 4 lists the ranking or CSFs for the success of construction megaprojects. If two or more factors have the same mean value, then the one with the lowest standard deviation will be ranked as the factor with the highest importance. Xu et al. [53] suggested that in the five-point questionnaire, factors with means greater than or equal to 4 can be viewed as CSFs. This criterion is adopted in this study. A total of 32 factors were identified as CSFs that significantly influence the success of construction megaprojects. The factors 'effective external supervision and audit', 'establish effective incentive and punishment mechanisms' and 'owners need to clarify the innovation orientation and strategic choice and guide the innovation management of participating enterprises' were excluded from the CSFs list. Table 5 summarises the ranking of the factors according to the mean values.

4.2. Factor Analysis

Thirty-two CSFs are not sufficient to explain the success of a project; a more refined and insightful CSF structure needs to be proposed. Thus, factor analysis was adopted to explore and identify the underlying relationships among the identified CSFs. This statistical technique can analyse the structure of interrelationships of a considerable number of variables by defining a set of common underlying factors [54]. The factor analysis was conducted through a two-step process: factor extraction and rotation, with the former aiming to determine the factors through principal component analysis (PCA). PCA is a common factor analysis method that can mathematically represent the derived linear combinations to avoid the need for questionable causal models [55]. In contrast, factor rotation was conducted to enhance the interpretability of the factors. The Varimax rotation technique was used in this step because this technique can produce rotated component matrices that are easy to interpret [56]. This approach is widely used in construction management research [57]. Table 5 shows the results of the factor analysis of the 32 CSFs.

The eigenvalue represents the total variance explained by each factor. For example, the linear combination formed by the combination of component 1 has a variance of 14.335, which accounts for 44.797% of the total variance of the 32-factor variables (Table 5). As stated in a previous section, the Kaiser–Meyer–Olkin (KMO) test is a measure of sampling adequacy that compares the magnitudes of the partial correlation coefficients [58]. The value of KMO in this study is 0.910, which is greater than 0.5. In addition, the result for the Bartlett test of sphericity is 3188.353, and the associated significance level is 0.000. These results indicate that the sample data are acceptable and appropriate for factor analysis.

After factor extraction and rotation, the extracted factors should be renamed as a cluster in the interpretation of the results of the analysis. Six clusters with eigenvalues of more than one are extracted. Table 6 shows the cluster matrix after the Varimax rotation, and Table 7 presents the final statistics of the PCA. The extracted clusters account for 70.489 of the variances.

Table 3. Cronbach's alpha of data.

Categories	Cronbach Alpha	Mean if Deleted	Standard Deviation if Deleted	Alpha if Deleted
Project-related factors	0.861	21.21	10.198	0.858
		21.32	9.281	0.832
		21.22	9.999	0.846
		21.29	9.381	0.828
		21.32	9.140	0.834
		21.36	9.341	0.828
Project participants-related factors	0.870	34.24	19.325	0.848
		34.22	19.113	0.847
		34.36	19.827	0.857
		34.35	18.713	0.849
		34.32	18.219	0.842
		34.36	18.497	0.845
		34.29	22.769	0.891
		34.30	19.838	0.858
		34.40	19.335	0.858
Economic and management-related factors	0.881	33.37	23.595	0.871
		33.73	27.137	0.907
		33.53	21.829	0.847
		33.47	22.157	0.851
		33.52	22.548	0.857
		33.53	22.173	0.850
		33.45	22.359	0.852
		33.47	23.485	0.868
		33.59	25.400	0.898
Innovation-related factors	0.728	16.38	5.394	0.622
		16.34	5.695	0.629
		16.22	5.874	0.633
		16.20	6.834	0.767
		16.19	6.657	0.731
External environment factors	0.751	21.12	6.328	0.693
		21.09	7.360	0.736
		21.22	6.531	0.696
		21.47	7.204	0.772
		21.19	6.043	0.667
		21.16	6.715	0.719

Table 4. Ranking of CSFs.

	Success Factors	Mean	Standard Deviation
CSF1	Adequate communication and coordination among related parties	4.38	0.752
CSF2	Cooperation and strong support from local governments	4.36	0.637
CSF3	Partnering/relationships with key stakeholders	4.36	0.728
CSF4	Clear goals and project definition to make sure the project goes smoothly	4.33	0.741
CSF5	Clear strategic vision	4.33	0.764
CSF6	Direct or strong support of the state (central government)	4.33	0.782
CSF7	Adequate resource availability	4.33	0.842
CSF8	Positive behaviour of project participants that could collectively facilitate the effective achievement of construction goals	4.32	0.696
CSF9	Great organizational support	4.3	0.756
CSF10	Economic and political stability	4.29	0.762
CSF11	Capabilities and leadership of project managers	4.29	0.85
CSF12	Complete understanding of cultural, financial, and legislative requirements	4.26	0.786
CSF13	Well-formulated and detailed contracts	4.26	0.803
CSF14	Capabilities and leadership of the owner	4.26	0.832
CSF15	Effective strategic planning	4.25	0.781
CSF16	Capabilities and leadership of contractors	4.25	0.829
CSF17	Mutual trust among project stakeholders	4.24	0.748
CSF18	Effective risk management	4.24	0.818
CSF19	Select the appropriate contracting and delivery model	4.24	0.827
CSF20	Public support or acceptance	4.23	0.734
CSF21	Aligned perceptions of project goals and success	4.22	0.822
CSF22	Good governance	4.22	0.859
CSF23	Positive organizational culture for effective project management	4.21	0.835
CSF24	Project organization structure	4.19	0.788
CSF25	Effectively address complexities	4.19	0.827
CSF26	Scope management	4.18	0.805
CSF27	Systematic control and integration mechanisms	4.18	0.824
CSF28	Adopt up to date or innovatively improve technologies and methods	4.14	0.845
CSF29	Experience and talents accumulated from previous similar projects	4.13	0.905
CSF30	Focus on pre-stage research and necessary talents training	4.12	0.797
CSF31	Adopt a competitive and transparent procurement process to control corruption effectively	4.12	0.941
CSF32	Owners need to provide the necessary innovation resources and innovative environment, such as provide subsidies to promote innovative behaviour	4.00	0.843
CSF33	Adequate external supervision and audit	3.98	0.824
CSF34	Establish effective incentive and punishment mechanisms	3.98	0.852
CSF35	Owners need to clarify the innovation orientation and strategic choice and also need to guide the innovation management of participating enterprises	3.95	0.917

Table 5. Variance explained by the success factor variables.

Component	Eigenvalue	Percent of Variance Explained	Cumulative Percent of Variance Explained
CSF1	14.335	44.797	44.797
CSF2	2.986	9.331	54.128
CSF3	1.507	4.709	58.837
CSF4	1.308	4.087	62.924
CSF5	1.252	3.914	66.838
CSF6	1.168	3.651	70.489
CSF7	0.916	2.861	73.350
CSF8	0.784	2.449	75.799
CSF9	0.763	2.385	78.183
CSF10	0.710	2.218	80.401
CSF11	0.657	2.053	82.454
CSF12	0.531	1.659	84.113

Table 5. *Cont.*

Component	Eigenvalue	Percent of Variance Explained	Cumulative Percent of Variance Explained
CSF13	0.494	1.543	85.655
CSF14	0.453	1.417	87.072
CSF15	0.440	1.376	88.448
CSF16	0.403	1.260	89.708
CSF17	0.364	1.137	90.844
CSF18	0.359	1.121	91.966
CSF19	0.330	1.031	92.996
CSF20	0.294	0.918	93.915
CSF21	0.244	0.764	94.678
CSF22	0.241	0.753	95.432
CSF23	0.217	0.678	96.110
CSF24	0.210	0.656	96.766
CSF25	0.191	0.598	97.363
CSF26	0.160	0.500	97.863
CSF27	0.152	0.474	98.338
CSF28	0.136	0.425	98.763
CSF29	0.116	0.362	99.125
CSF30	0.110	0.345	99.470
CSF31	0.092	0.288	99.758
CSF32	0.077	0.242	100.000

Table 6. Cluster matrix after varimax rotation.

	Components					
	1	2	3	4	5	6
CSF25	0.823					
CSF26	0.735					
CSF13	0.693					
CSF4	0.693					
CSF27	0.691					
CSF18	0.688					
CSF17	0.589					
CSF21	0.587					
CSF7	0.572					
CSF15	0.491					
CSF11		0.791				
CSF14		0.764				
CSF22		0.740				
CSF16		0.629				
CSF24		0.560				
CSF3		0.539				
CSF1		0.524				
CSF5		0.500				
CSF29		0.471				
CSF30			0.870			
CSF2			0.823			
CSF32			0.812			
CSF31			0.628			
CSF20				0.794		
CSF12				0.693		
CSF6				0.571		
CSF19					0.792	
CSF10					0.724	
CSF28					0.523	
CSF8						0.829
CSF9						0.728

Table 7. Final statistic of PCA.

Clusters	Eigenvalues	Percentage of Variance	Cumulative Percentage of Variance
1	5.629	17.592	17.592
2	5.138	16.057	33.649
3	3.118	9.744	43.393
4	3.034	9.480	52.873
5	2.853	8.917	61.790
6	2.784	8.699	70.489

5. Discussion of Findings

Six clusters were extracted using factor analysis (Table 8) based on the examination of the inherent relationships among the 32 CSFs under each of the clusters. The clusters include project management action, project participant-related factors, application of innovation management approaches, external factors, economic factors and organisational factors. The success index, which refers to the constructs that contribute more towards the success of megaprojects, is presented in Figure 2.

Table 8. Six clusters extracted by factor analysis.

Clusters		CSFs
Cluster 1	Effectiveness of project management action	CSF25 Effectively address complexities CSF26 Scope management CSF13 Well-formulated and detailed contracts CSF4 Clear goals and project definition to make sure the project goes smoothly CSF27 Systematic control and integration mechanisms CSF18 Effective risk management CSF17 Mutual trust among project stakeholders CSF21 Aligned perceptions of project goals and success CSF7 Adequate resource availability
Cluster 2	Project participants-related factors	CSF15 Effective strategic planning CSF11 Capabilities and leadership of project managers CSF14 Capabilities and leadership of the owner CSF22 Good governance CSF16 Capabilities and leadership of contractors CSF24 Project organization structure CSF3 Partnering/relationships with key stakeholders CSF1 Adequate communication and coordination among related parties CSF5 Clear strategic vision
Cluster 3	Application of innovation management	CSF29 Experience and talents accumulated from previous similar projects CSF30 Focus on pre-stage research and necessary talents training CSF2 Cooperation and strong support from local governments CSF32 Owners need to provide the necessary innovation resources and innovative environment, such as provide subsidies to promote innovative behaviour CSF31 Adopt up to date or innovatively improve technologies and methods
Cluster 4	External factors	CSF20 Public support or acceptance CSF12 Complete understanding of cultural, financial and legislative requirements CSF6 Direct or strong support of the state (central government)
Cluster 5	Economic factors	CSF19 Select the appropriate contracting and delivery model CSF10 Economic and political stability CSF28 Adopt competitive and transparent procurement process to control corruption effectively
Cluster 6	Organizational factors	CSF8 Positive behaviour of project participants that could collectively facilitate the effective achievement of construction goals CSF9 Great organizational support CSF23 Positive organizational culture for effective project management

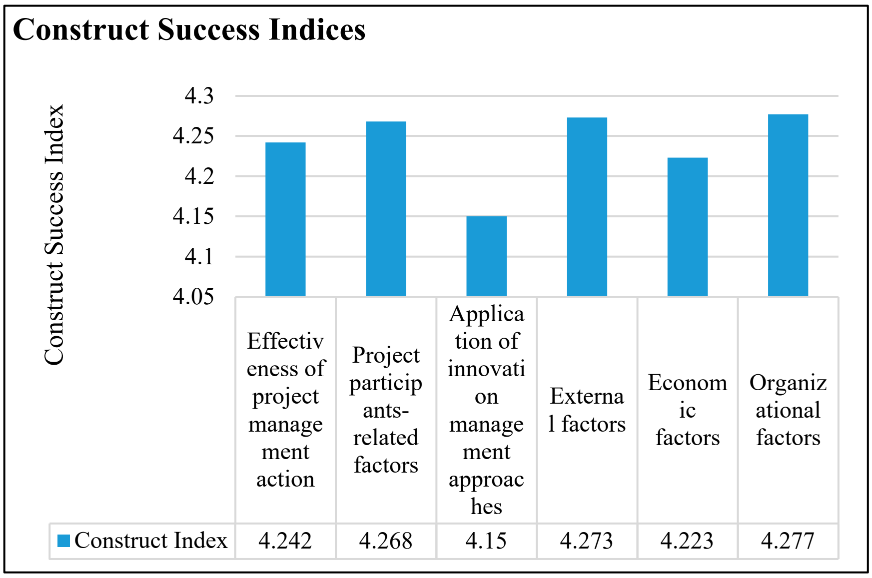


Figure 2. Construct Success Indices.

5.1. Cluster 1: Effectiveness of Project Management Action

This cluster comprises ten CSFs, including 'scope management', 'effectively addressing complexities', 'well-formulated and detailed contracts', 'clear goals and project definition to ensure the smooth delivery of the project', 'systematic control and integration mechanisms', 'effective risk management, 'mutual trust amongst project stakeholders', 'adequate resource availability' 'aligned perceptions of project goals and success', and 'effective strategic planning.'

Project management is critical for the success of a project. Some factors, such as scope management and well-formulated and detailed contracts, are identified as CSFs regardless of whether the project involves normal construction or is a large-scale project [57]. However, some CSFs are highly crucial to the success of construction megaprojects. For example, complex megaprojects can be exposed to unexpected risks not typically found in traditional construction projects, including catastrophic loss, political risks, sophisticated engineering, design risk and substantial unknowns, that can affect budgets and schedules [13]. Therefore, effective risk management is vital to achieving project goals and success. In addition, effectively addressing complexities and systematic control and integration mechanisms should be emphasised in megaproject management to ensure project success [59]. The complexity of a system depends on the number and variety of components, including its interdependencies [60]. Components produced by different organisations must be integrated into a functioning system. Previous studies have revealed that system integration as the core organisational capability refers to dealing with the interdependency, uncertainty and change inherent in complex projects [61]. Megaprojects must devote considerable resources to systems integration to address the highly distinct cross-functional structures [62].

5.2. Cluster 2: Project Participant-Related Factors

This cluster includes nine CSFs, including 'capabilities and leadership of project managers', 'capabilities and leadership of the owner', 'good governance', 'capabilities and leadership of contractors', 'project organisation structure', 'partnering/relationships with key stakeholders', 'adequate communication and coordination among related parties', 'clear strategic vision' and 'experience and talents accumulated from previous similar projects'.

Capabilities and leadership have been mentioned as essential success factors in several previous studies [29]. The capabilities and leadership of project managers refer to technical, communication and coordination skills. The capabilities and leadership of the owners involve strategic, financial and governance aspects. The capabilities and leadership of contractors refer to robust construction and delivery capabilities. The governance of megaprojects has become an emerging issue in the expansion of globalisation and plays an essential role in project success. Nowadays, it is common for multiple governance structures to coexist within an organisation in large projects [13].

The importance of organisational mode and structure in megaproject performance has been emphasised in many previous studies [23]. In China, the mode and structure of organisations in megaprojects are closely related to the administration, which refers to the following: (1) top management groups and construction committees usually organised by the central or local governments and (2) top project leaders often play dual roles in governmental departments and project management systems [23]. This kind of organisation mode has been proved to contribute to achieving the project goals [63].

Current research shows that good partnering and relationships, which may extend beyond contracts, play important roles in helping to improve project governance and efficiency and contribute to project success [64]. The lack of cross-functional communication is one of the main obstacles to maintaining the organization's effectiveness [65]. Considering the construction of megaprojects, which involves numerous participants, communication and coordination are significant factors in achieving successful outcomes during the project's execution.

A clear strategic vision is another crucial factor of megaprojects. The strategic vision of the construction megaprojects is invariably presented visually and effectively and can act as a powerful link to provide leadership excellence [22]. Good leaders are adept at using the strategic vision to effectively motivate employees, including aligning the vision with the right strategy [66]. In addition, the accumulated and cultivated technical and managerial experience from previous project practices or relevant academic programs can provide valuable contributions to the success of similar megaprojects [6].

5.3. Cluster 3: Application of Innovation Management Approaches

The third cluster comprises four CSFs, namely 'focus on pre-stage research and necessary talents training', 'cooperation and strong support from local governments', 'provision of the necessary innovation resources and innovative environment, such as subsidies, from the owners to promote innovative behaviour' and 'adoption of up-to-date or innovative technologies and methods.'

For mega-sized projects, mature technologies and professionals are not always available. Therefore, relevant academic research and talent training is necessary for the pre-project stage. The adoption of up-to-date or innovative technologies and methods is essential. Technological challenges have been recognised as a crucial issue in megaprojects [67]. The project organisation explored, identified, adopted, and experimented with new technologies and operating procedures to enhance the processes of the megaproject [68]. In addition, innovations in management systems in megaprojects are an important aspect. The innovation and application of management systems can be interpreted as the creation or promotion of management systems, based on project characteristics, to guide, standardise and control the work to ensure the successful delivery of megaprojects [6]. Traditional management systems are not enough to meet the requirements of megaprojects, such as cost, schedule, quality, and safety goals. At the same time, these systems cannot effectively handle megaproject emergencies or incidents because they are high in complexity, risks, and stakeholders. In the Hong Kong–Zhuhai–Macao Bridge, a three-level organisational structure was innovatively established to ensure the shared construction and management of decision-making mechanisms [48]. Such innovative project construction systems ensure the effective execution of the project objectives and project success.

Megaprojects are engines for technological innovation. Important technological innovations can exceed the needs of the project itself and further expand to improve the competitiveness of the industry and even the country. Owners often represent the country or the government to organise and arrange related technological innovation activities on a strategic level [69]. For example, owners need to provide the necessary resources and environment for innovation, such as subsidies, to promote innovative behaviours amongst participants. Lastly, the cooperation and strong support from local governments belong to this cluster. Local governments usually coordinate on major construction issues to facilitate the work of project teams and help solve problems.

5.4. Cluster 4: External Factors

The cluster of external factors includes 'public support or acceptance', 'complete understanding of cultural, financial, and legislative requirements, and 'direct or strong support of the state (central government).' Belassi and Tukel [70] stated that some external organisational factors still exert influence on project success or failure.

Megaprojects usually attract great public attention because of the involvement of public entities and public expenditure in the construction process [71]. Therefore, public support plays a critical role in establishing a harmonious and steady social environment for the smooth implementation of megaproject construction, specifically when some works may negatively affect people's living surroundings (e.g., demolition works) [28]. Support from the public on such occasions, such as active cooperation and support in the area of migration, can reduce conflict and contribute to the project team achieving the project objectives and ensuring project success. Comprehensive knowledge of financial, cultural and legislative requirements ensures that the megaproject construction is legal. If the project is stopped due to non-compliance with the cultural, financial, and legislative requirements, then substantial cost and schedule losses will be incurred.

These projects are always built with great importance by the central and local authorities, as they are often symbolic in nature. There is no substitute for the role of government, especially the central government, in the decision making and construction of megaprojects [72]. Although some scholars have argued that 'projects and politics do not mix', these two are combined in China [64]. The setting where participants are either state-owned companies or are closely connected with the government contributes to successful project outcomes in China [73].

5.5. Cluster 5: Economic Factors

This cluster includes 'selecting the appropriate contracting and delivery model', 'economic and political stability' and 'adopting a competitive and transparent procurement process to effectively control corruption control corruption effectively'. Many previous studies have reported that economic factors can affect project success [70]. Economic and environmental factors can influence the function and decisions of businesses in terms of inflation, economic policy, interest rates and unemployment rates.

Appropriate contracting and delivery model selection is a critical factor in project success. An appropriate contracting and delivery mode can reduce risks, complexities and costs. Taking the Hong Kong–Zhuhai–Macao Bridge as an example, the project has high-complexity elements, such as a deep and complex seabed, high technical standards and high risk in marine construction. Consequently, the Island Tunnel project has adopted a modified pre-requisite EPC model—design/build. Under this model, the owner provides the preliminary design and has the authority to manage the construction consortium. This mode helps to creatively and effectively degrade the unique complexities that arise from the multiple dimensions of the project [59]. Economic and political stability, which is a critical issue in projects, is also one of the CSFs in this cluster. This factor is highly crucial to the success of megaproject construction because of the considerable investment and political importance involved. Moreover, voluntary procurement procedures that are competitive and transparent can be effective in reducing corruption in large projects and also play an important role in ensuring project success [74].

5.6. Cluster 6: Organisational Factors

The last cluster is the organisational factor, which comprises 'positive behaviour of project participants that can collectively facilitate the effective achievement of construction goals', 'great organisational support' and 'positive organisational culture for effective project management.

In academia, project participants' positive behaviour, which can collectively contribute to the effective achievement of construction goals, is referred to as organizational citizenship behaviour. In megaprojects, megaproject citizenship behaviour involves positive discretionary behaviours of project participants that are not formally required by contracts or legislation, but contribute to the achievement of project objectives [75]. This kind of behaviour can be beneficial to the improvement of labour productivity and organisational efficiency and further benefit the megaproject as a whole [6]. In China's megaproject practice, labour contests launched by the public sectors are common methods to motivate megaproject citizenship behaviour [75]. The winners will not garner economic awards, but they will receive medals and praise from the media and the government [76].

Great support from organisations is also a contributor to megaprojects' success. Megaprojects are commonly managed by the top management team, which plays a vital role in monitoring and managing the projects [77]. Crosby [78] highlighted that senior support is essential to project success. This kind of team plays a vital role in helping the organisation to tackle complex environments and systems that will ensure the implementation and successful delivery of construction projects [25].

Culture can also affect the participating entities' and employees' behaviour, which in turn promotes project performance [79]. Research outcomes have demonstrated that positive culture in organisations can effectively enhance employees' work enthusiasm, reduce conflicts and even maintain a harmonious atmosphere within or among organisations in megaprojects [75].

6. Conclusions

While it has been recurrently pointed out in the literature that most megaprojects fail to realise their projected goals, the cases have been the opposite in China, such as the Hong Kong–Zhuhai–Macao Bridge and the Three Gorges Dam. Therefore, this study empirically evaluated the determinants that contribute to megaproject success in China. With the significant robust developments and success in megaprojects, China has not only become one of the fastest developing countries in terms of megaproject construction but also a successful model to emulate.

Following an extensive literature review and interviews to ascertain over thirty-five success-determining factors, a host of megaproject-related experts were invited to participate in a survey to evaluate the significance or the contributory index for the recorded factors. At the end of the survey, a total of 129 valid responses were gathered from these experts who have had tremendous experience in megaproject construction and delivery. Even though none of the variables was evaluated to be insignificant, the experts revealed that some factors were more critical and often carried the highest contributory significance to the success of a project.

From the experts, the top five factors determining megaproject success were as follows: establishing adequate communication and coordination among related parties, building sturdy cooperation and strong support from local governments, partnering/relationships with key stakeholders, developing clear goals and project definitions to ensure that the project goes smoothly and the establishment of clear strategic vision for forecasted projects. These variables had a mean index score within the range of 4.28 to 4.33. Moving further, the factor analysis technique was employed to develop six new constructs from the thirty-five examined variables.

Given the constructs' significance indices from the highest of 4.277 to the least of 4.15, the developed constructs were organisational factors, external factors, project participant-related factors, effectiveness of project management actions, economic factors and the application of innovation management approaches. The leading determinants of megaproject success are conceptualised by encapsulating these CSFs in a conceptual model and fulfil an evaluated need to explore the levels of importance of CSFs. The contributions of this study mainly lie in two aspects. First, this study not only extends the knowledge domain of construction project management but also demonstrates that achieving megaproject success can be emulated following some of the leading variables ascertained in this study, which can be adapted in different contexts. Second, this study can deepen the participants' understanding of megaproject success and provide references for effectively improving the possibility of project success. For instance, decision makers and managers of megaprojects can develop tailored measures based on a defined list of CSFs before the megaproject begins. As a result, the likelihood of project success can be increased. A deep understanding of CSFs may also encourage the government to contribute to megaproject success in terms of policy formulation and innovation strategy orientation. However, the limitations of this study in data collection cannot be ignored. The regional characteristics of China's system and culture have led to regionality in the results. However, China plays a rapidly growing and important role in the construction of megaprojects in the world. It is undeniable that the factors determining megaproject success revealed in this study are represented by the international scope and have certain reference value for future research in other regions. For example, scholars from other regions can use the CSFs list identified in this study as the foundation of interview outline or questionnaire design to conduct further investigations in their countries. Therefore, this study serves as the premise for further empirical assessments of factors determining megaproject success in different contexts.

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