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An ISM-Based Methodology for Interrelationships of Critical Success Factors for Construction Projects in Ecologically Fragile Regions: Take Korla, China as an Example

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Abstract: Construction activities taken place in ecologically fragile regions (EFRs) of China are facing a series of environmental obstacles. Studying critical success factors (CSFs) to arrive at the sustainable objectives for construction project in EFRs is needed. Understanding the interrelationships of these CSFs is one of the vital ways to achieve this. This paper identifies and analyzes 18 CSFs for construction projects in EFRs through a literature review from a multi-perspective and a case study of Korla City in China. The causal relationship between each CSF is obtained by pairwise comparisons and thereafter, an ISM (Interpretative Structural Modeling) method is employed to study the hierarchical structuring of the CSFs. As a result, we established a five-level ISM. Subsequently, an MICMAC (cross-impact matrix multiplication applied to classification) approach is implemented to partition and classify each CSF into four quadrants (independent, linkage, autonomous, and dependent) according to their driver and dependence powers. Through the implementation of an MICMAC approach, the degrees of relationship between each CSF is gained. The findings reveal that the studied 18 CSFs have a strong hierarchy and interrelationship. The project manager's leadership style and economic viability are the root source of project success and has the highest influence, which is supported by the result of MICMAC analysis. CSF planning and implementation of sustainable strategies are more dependent and are influenced by others. The CSFs on the top level of ISM: conflict resolution, planning and implementation of sustainable strategies and resources of water play a significant role in arriving at the project success, and has a great potential for future study. The approaches implemented in this paper can be helpful for decision-makers and managers of construction projects in comprehending the interrelationships and the degrees of CSFs for construction projects in EFRs and for efficiently achieving the project success.

Keywords: construction project; ecologically fragile regions; critical success factors; interpretative structural modeling; MICMAC analysis

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1. Introduction

At present, China's construction productivity is growing and tremendous investments are made in the construction industry. However, the development of China's infrastructure is unbalanced in different regions. Meanwhile, achieving sustainability becomes an essential objective for the construction industry. Especially, construction project practice is facing a series of challenges in such regions where the environment is degraded beyond the level that can maintain the current human use and development for a long time under the current socio-economic and technological level [1,2]. These particular regions are defined as Ecologically Fragile Regions (EFRs) [3,4] in this study. For instance, the lack of water resources and the vulnerability of the natural geographical environment are two important ecologically fragile factors in the arid regions of China [5,6]. This means that construction activities taking place in EFRs are facing a series of environmental obstacles, including saline soil [7], reduction of groundwater, drying surface water, land salinization and the sharp decline in plant and biological species [8–11]. These barriers may bring difficulties for the construction project conducted in EFRs, have negative impacts on the performance of the construction project and even result in their failure [12,13]. Hence, studying the effective ways to arrive at project success is needed and is crucial for the benefit of the project managers and participants who undertake construction projects in EFRs.

Construction activities are a result of the combination of a set of schemed projects or events and their outputs with different stakeholders and participants in the whole life cycle. Among the series of events, the particular ones which have the most critical influence on achieving a successful construction project are defined as critical success factors (CSFs) [14–18]. CSFs which have a risk management nature [19] is initially proposed by Rockart [20] as the group of special events that contribute to project success. Thereafter, a large body of studies [21–29] have investigated CSFs for construction projects. These prior studies have provided some new perspectives for the scholars in the research field of project management and participants involved in construction project practice to allocate the limited resources of a project to a certain number of factors [30,31] which promote construction project success by the process of investigation and identification of CSFs. Although the significance of studying CSFs in construction projects was gained, emphasized and strengthened, prior studies are mainly focused on the construction project conducted in non-EFRs. However, CSFs are special for various construction projects under changeable scenarios, such as the external environment, the different delivery methods of projects and project types etc. [32,33] The consensus is that there is a lack among researchers regarding the CSFs for a construction project in EFRs. Hence, exploring the CSFs for a construction project in EFRs is meaningful and necessary and there is a great potential for exploring the interrelationships between CSFs.

The present study aims to systematically identify CSFs for a construction project in EFRs, and focuses on structuring the CSFs using a hierarchal model. The objectives are: (1) identifying the CSFs through a literature review from a multi-perspective and a particular construction project; (2) investigating the interrelationships between CSFs and obtaining relevant direct factors, indirect factors, and root factors; and (3) developing a clear structure for a hierarchy model of the CSFs, and establishing a hierarchical order to prioritize them using ISM (Interpretive Structural Modeling). The findings of this paper will provide an insight into CSFs for a construction project in EFRs, and can help participants and stakeholders who are involved in construction projects to obtain more effective strategies to arrive at project success in EFRs.

2. The Methodology of ISM and MICMAC

ISM was first developed by Warfield [34] to breakdown and analyze the complex interrelationships in a network which has multiple cause events. Malone [35] introduced the initial concept, definition and methodology of ISM and illustrated the utility of ISM from the perspective of a complex system. In recent studies, ISM is used as an analysis tool which can explore the interrelationship between different objectives for decision making [36–43], break complex, unclear and fuzzy systems into a graph network. ISM has also been implemented to a number of empirical cases in various areas. For instance, Ravi and Shankar [44] explored the interacted factors among the main obstacles which influence the implementation of "reverse logistics" in the vehicle machinery field. Faisal et al. [45] built a hierarchy network model used for an assessment of the dynamics and changing status of different risk factors in the process of supply chain management. Generally, ISM is often integrated with other analysis tools of factors, such as DEMATEL (Decision Making Trial and Evaluation Laboratory), ELECTRE (Elimination and Choice Translating Reality) [46], fuzzy MICMAC [47] and SPIN (Situation, Problem, Implication, and Need) [46] etc. In this study, MICMAC analysis is selected to be integrated with ISM under the consideration of simple size and flexible implementation. MICMAC analysis is designed to classify the CSFs into different categories or clusters, such as autonomous, dependent, linkages and independent, according to their "driver and dependence powers", which indicate the degrees of interactions between CSFs [48–54].

There are five steps in conducting ISM:

- Step1: investigation and identification are made to generate the list of CSFs though the combination of literature review and case studies.
- Step2: interrelationships between CSFs are explored by semi-structured interviews. In this step, a causal relationship analysis is processed through pairwise comparisons and the results are presented in the causal relationship network of CSFs.
- Step3: the causal relationship network of CSFs is converted to the adjacency matrix (A). Thereafter, a reachability matrix (R) is obtained from A and constructed to investigate the transitivity among CSFs. This process is undertaken via Boolean algebraic algorithms implemented in MATLAB software. Thereafter, a partition process is taken to break down the R into different levels. The location and distribution of CSFs in the final model are determined.
- Step4: skeleton-matrix (S) is implemented to determine the directional links between CSFs in different levels.
- Step5: the final model is generated with the obtained directional links to illustrate the causal relationship between each CSF.

After generating the ISM, the result of ISM can be integrated into a MACMIC analysis to understand the degrees of interactions between CSFs by: (1) calculating the driver and dependence powers via a summation of values in the corresponding row or column of R; (2) establishing the four-quadrant matrix with a x-y axis, where the x axis refers to the dependence powers of each CSF and the y axis refers to the driver powers of each CSF; (3) assigning each CSF into different categories. The flowchart in completing ISM and MACMIC analysis is presented in Figure 1.

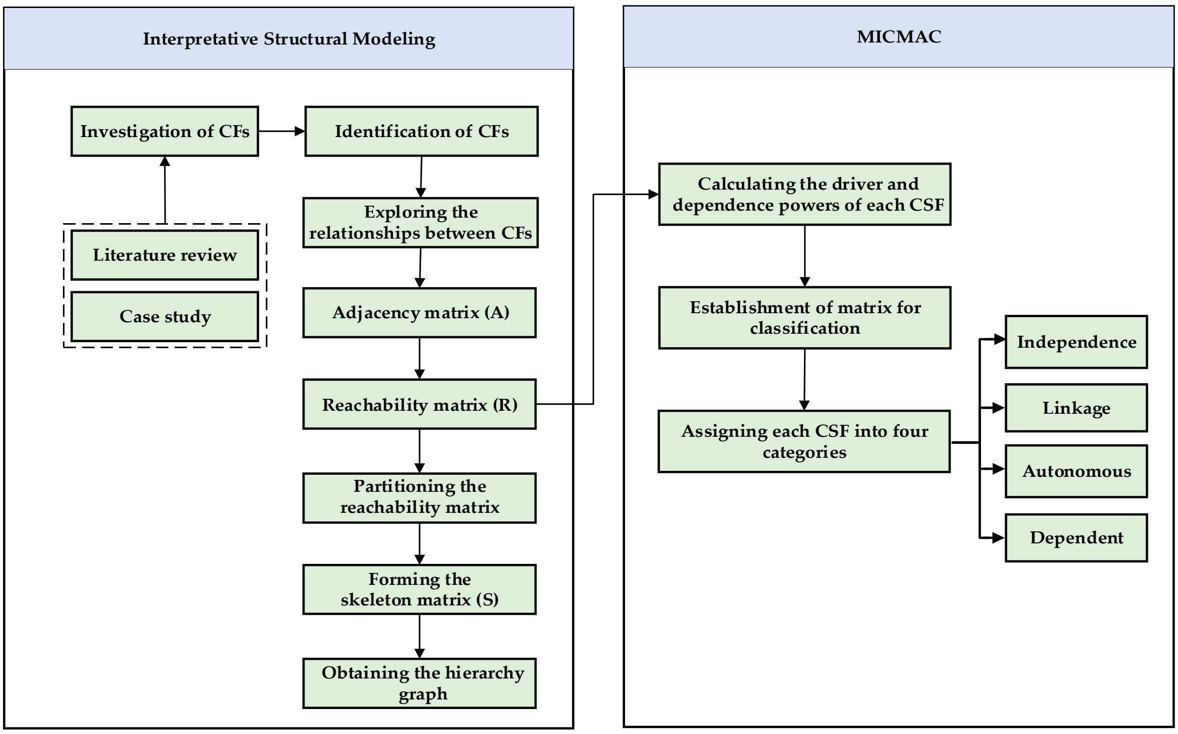

Figure 1. The flowchart in completing ISM and MACMIC analysis.

3. CSFs for Construction Projects in EFRs

3.1. Literature Review

The construction project can arrive at the point of success if schemed objectives are achieved [55]. However, each participant in a construction project has different expectations and their own viewpoint toward project success. There exists a large body of studies which have provided various definitions on project success. For instance, Albert et al. [56], Phong and Quyen [57] and Kissi et al. [58] argued that success criteria or definition always changes due to the professionalism of the project management team (PMT), practical experience of the PMT, deviation of project definition, project capital and innovative technology etc. Osei-Kyei and Chan [59], Alashwal et al. [60] and Castro et al. [61] evaluated the performance of a construction project from the aspects of project investment and cost, local financial criteria, delivery quality and workers' safety, etc. The completed project plan and adequate project resources are acknowledged as two significant criteria for the project success in previous studies [13,62,63]. In a study by De Wit [55], measurements of project success are proposed, including the leadership or leader style in a PMT and public satisfaction toward the project etc. On these bases, project success can be assessed from the perspectives of technology, PMT and organization, influence to environment and society, financial aspects etc.

Based on the understanding and clarity of the project success from prior research, a large body of studies has focused on the definition, identification and classification of CSFs for construction projects. For instance, Rockart [20] defined CSFs from the perspective of project delivery where the CSFs are acknowledged as a series of interacted events making a great contribution to the project performance and explained that the CSFs should include a key process which could achieve the project objectives. Wuni and Shen [64] put forward that CSFs are the set of internal and external events which have a serious influence on the project results. In their studies, the accurate understanding and the definition of project requirements, and a systemic perspective on project performance are regarded as essential characteristics of CSFs. Alreemy et al. [65] and Adabre and Chan [66] raised the paths to identify CSFs by considering the strategy, the environment, the resources and the operations of a construction project. CSFs were also mentioned as the systematic guide, monitoring the project schedule and process, which the special and continual attention PMT in the whole life cycle should move towards [16,67–69]. Omoush [70] provided a new paradigm for the classification of CSFs which were grouped into four dimensions (PMT and leader of construction, technology, resources and influences to the social environment). Through the new paradigm, project managers could gain a better understanding of the CSFs in different groups and adjust their leadership style accordingly [71–73].

Moreover, previous studies have developed and implemented different methods and tools, e.g., assessment tools [74–76], identification approaches [46,66,77–79], classification methods [80–82], etc., to investigate the CSFs of a construction project. Other studies identified the CSFs of construction projects by the certain construction project delivery methods (PDM) which determine each stage in the life cycle, including design, construction and maintenance and required a clear definition of responsibilities of each project participant [14,46]. For instance, CSFs are studied for common PDMs including designing, biding and building (DBB) [83,84], construction management under risks (CMR) [85], the PDM of designing and building (DB) [83,86,87]. In a prior study by Ling et al. [88], DBB and DB projects were investigated and 59 potential CSFs affecting construction project performance were extracted and grouped. Thereafter, they investigated the underlying relationship between CSFs through multi-data analysis and put forward that effective risk management and high credibility among partners have influence on the successful project delivery. Furthermore, external support such as policy and regulations [14,89], incentive mechanisms [46,89] and organizational project culture [90,91] were identified in other surveys. CSFs for different types of construction project (e.g., PDM of BOT and PPP) are also identified in previous studies. For instance, a comprehensive study on nine major BOT construction projects was conducted by Tiong et al. [92] and six CSFs, including the leadership style of PMT, the project feasibility assessment, the technological innovation, the financial support, the awareness of environment protection and the effective conflict resolution were identified.

Besides, the CSFs of a construction project is identified from the perspective of a partnering process (PP). The PP is a "win-win" strategy, which intends to bring a reputation to a partner, a long-term promise, mutual trust, effective communication and cooperation, a sense of belonging, a sense of participation in a team [93] and to foster a teamwork environment so that the participants involved have open interactions and performance. For instance, Black et al. [9] conducted the empirical investigation of several companies and claimed that the mutual reliance, the effective cooperation, the clear definition of a project, and the consistency and flexible principle are the CSFs toward the partnering process.

In summary, the prior literature demonstrates a lack of consensus and consistency to recognize the CSFs of a construction project. Especially, due to the diversity of the scope, types, delivery method, external and internal environment etc., CSFs vary from one project to another. Therefore, it is necessary to conduct a case study in the EFR of China. Combining the efforts of a literature review with a multi-perspective and a case study for a particular construction project, project managers and participants could draw a practical insight into how to meet the success of the construction project in EFRs.

3.2. Case Study

The study area, Korla City (KC), is the capital of Bayinguoleng Mongolian autonomous prefecture, which is the largest prefecture-level administrative region in China. KC lies in the downstream of the Tarim River, in the southern foothills of the Tianshan Mountains, on the northeastern edge of the second largest desert, the Tarim Basin Desert, in the world and the southwest of the Bosten lake. The total area of the KC is 7268 km^2. KC is the most important transportation hub and material distribution center in northern and southern Xinjiang, and the political, economic, and cultural center of the region. The geographical location of KC is presented in Figure 2.

However, due to its adjacency to the Hora Mountain in the north and the Koruk Mountain in the east, KC is invaded by the cold air in the north and the humid air in the Yanqi Basin. It has a continental arid climate in the warm and humid zone of Eurasia, and is rich in light and heat resources, with a total sunshine of 2990 h, an average frost-free period of 210 days, an annually atmospheric temperature of 52.52 °F (minimum of −18.40 °F), precipitation of 55.6 mm.

From this point of view, the ecological environment of KC is extremely fragile and faces a lot of disastrous factors, such as the freezing damage, dry and hot wind, drought, dust storm, hail, earthquake, salinity, wind and sand, crop pests and diseases etc. The scarce precipitation, large evaporation, excessive reliance on irrigation water, imperfect protection for plants, and the disturbance of the desert on the periphery makes the ecological environment of KC extremely vulnerable. The invasion of salinization, swamp and desertification makes the development of construction projects in KC more complicated and challenging.

The selected project, the Dujuan River Ecological Wetland Park (DREWP) conducted by Urban and Rural Planning Administration (URPA) of KC, is one of the winners of the national "Modern Ecological Garden" given by the Ministry of Housing and the Urban-Rural Development of China. The overall length of DREWP is approximately 8.5 miles and covers an area of 216.26 hectares.

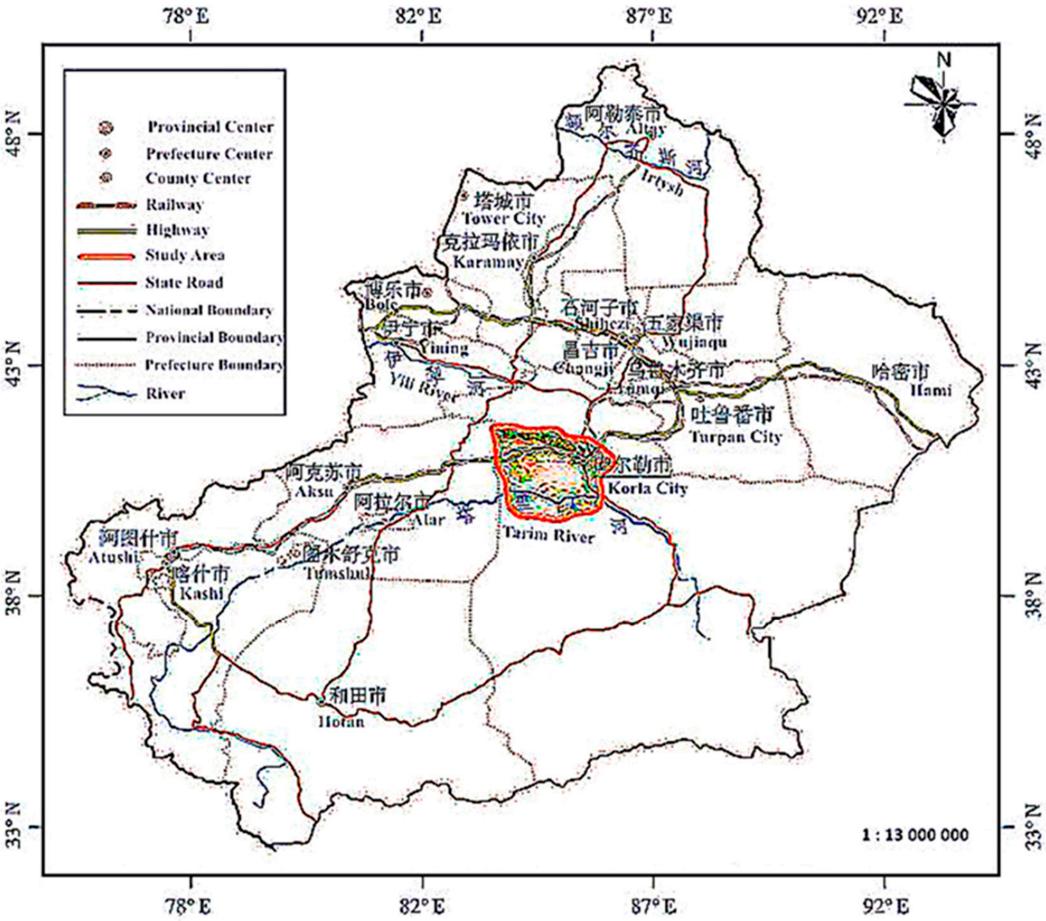

Figure 2. Geographical location of Korla City.

At the stage of planning and designing, the PMT of DREWP faced a series of obstacles. Due to the lack of water resources, the condition of soil in KC is special, which requires it to be particularly designed for the building subgrade. To solve this problem, URPA designed and constructed a complete artificial river (Dujuan River) in advance, introduced the irrigation technology and established an effective water circulation system in buildings, which provided the essential construction conditions for DREWP. During this process, the creativity and the professionalism of partners play an important role to arrive at the project success.

Toward the partners, the URPA applied a series of measurements to select project participants where the professionalism, high credibility and partnering experience are required. For instance, all of the participants are required to be aware of their roles and to reach detailed and formal written agreements, so that all of the participants have a clear cognition of their responsibilities, as well as the interests or benefits which they can obtain from the construction project. Moreover, having a clear understanding of roles is critical in order to build harmonious partnerships between partners. The URPA of KC, which is the conductor of the DREWP, establishes a harmonious partnership with the stakeholder, such as design institute, academic institution and consultation team, and constructed and implemented a consistent information communication system for all of the partners. All of the partners have good evaluation and credibility, as well as mature experience in project management, which is necessary to arrive at sound cooperation and innovation. High credibility can also generate mutual trust, which is essential and helpful in solving conflicts, especially in a complex organization which includes plenty of complicated interfaces due to the activities of different stakeholders. Besides, the URPA has taken a series of measures to solve conflicts, such as the establishment and communication of conflict-resolving strategies, effective coordination, joint problem solving etc.

The URPA of Korla City applied a lot of complete governance measurements to build the partnerships and reduce the risks of the project. For instance, the URPA of Korla City systematically set a number of documents, including the contracts about the partnering agreement and the partnering goals' achievement, etc. The URPA of Korla City conducted a professional risk and reliability assessment before the project and also has appropriate contractual arrangements which can be promoted to make an appropriate allocation of risks and interests.

Along with the effective risk management, responsiveness to external environmental changes is another advantage the URPA has to conduct in the DREWP of Korla City. It is necessary to carefully take the special building materials, the construction techniques and the building facilities into careful consideration, due to the changing conditions of vegetation, soil and climate.

Moreover, the URPA has another advantage in the systematic monitoring of the project process. For instance, different to other construction projects, due to the excessive reliance on irrigation water, the imperfect protection of plants, and the disturbance of the desert, the DREWP project requires innovative water supply systems (such as dropper and sprinkler irrigation technology), artificial rivers and cultivation of desert plants. The local government needs to provide policy support for the protection of the local ecological environment and make sustainable strategies, which could be planned and implemented in the long-term. Furthermore, adequate resources, especially water resources, and financial support, a sound financial package and a favorable investment environment, are the advantages of DREWP.

3.3. Identification of CSFs

There are two steps to identify and extract CSFs: (1) identifying CSFs through a literature review; (2) extracting CSFs by semi-structured interviews on a practical construction project (i.e., DREWP in KC of China). First, we conducted a process of literature collection based on two types of database: Scopus and Web of Science. Two types of key words such as "construction project" and "environmentally fragile regions" are settled for the search strategies including title, abstract and keywords. The time span is settled to "2000 to 2021". As a result, 246 articles are collected and prepared for the next screening process. After the screening process, including: (1) removal of the duplicate articles; (2) filtering of the articles according to the correlation toward the title, abstract and full-text etc.; (3) replenishment of the omission articles from the references cited in the remaining ones. Finally, 30 articles related to the CSFs for a construction project in EFRs are identified. The CSFs in these 30 articles are dispersed and have various descriptions, which may not specifically be related to the construction project conducted in EFRs. For instance, "resources of water" may not be critical in non-EFRs. "Sustainable strategies" were differently prioritized between EFRs and non-EFRs. The solutions to reducing the impact on the local ecological environment from construction activities and to adapting to the fragile environment are described as a strategy for practicing sustainable construction projects, etc. Hence, it is necessary to consider the extracted CSFs into a specific scenario, the construction project conducted in EFRs.

We designed and carried out semi-structured interviews with 20 experts and key project participants (KPPs) to obtain a detailed and consistent description for each CSF for construction project in EFRs. These KPPs play different roles and have essential positions in the DREWP, e.g., the chief engineer, project contractor, site personnel, safety and quality supervision, business manager, designer and supervisors from URPA etc. They are asked to accomplish two crucial tasks: (1) finalizing the CSFs with the consistent description by a careful review of the whole process and the main work to which they contributed in the DREWP project, and (2) determining the causal relationship between any two CSFs through pairwise comparisons with the experience and knowledge of these KPPs. Some similar descriptions of CSFs from the literature are categorized. For instance, "the clear definition of responsibilities" [94] and "a clear understanding of roles" [22] are both identified as a description of the CSF in the collected 30 articles. Therefore, a combination could be made correspondingly. The finalized CSFs for a construction project in EFRs and their source of data are presented in Table 1. Three rounds of discussion were made to arrive at the conclusion by each KPP and their determinations are recorded to form a causal relationship network (presented in Figure 3), which will be used in the next steps for the ISM.

A list of 18 CSFs for construction projects in EFRs was collected based on the combination of a literature review of collected references and a case study on the DREWP project, followed by additional screening and a combination of relevant information. Table 1 provides the list of 18 collected CSFs.

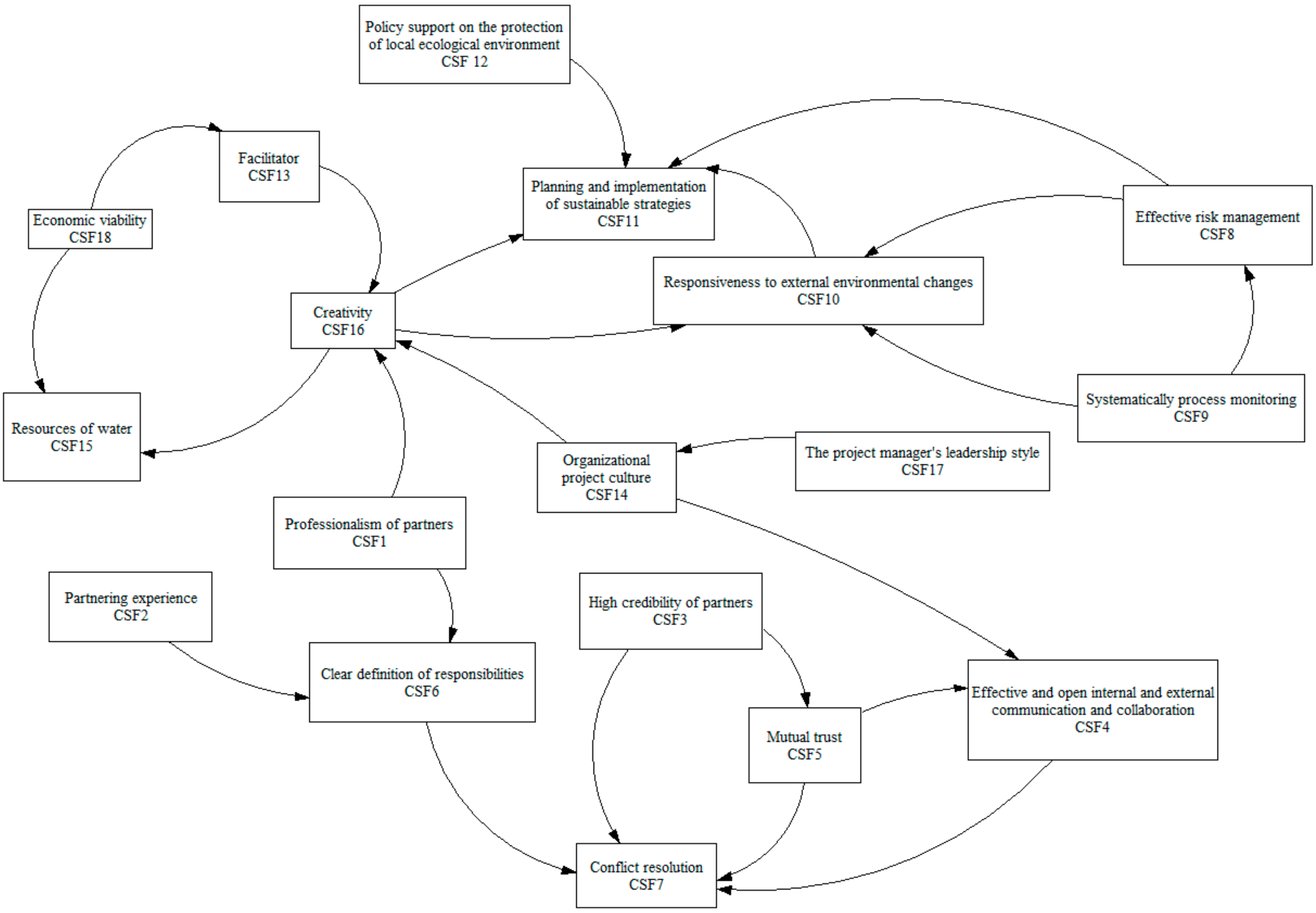

Figure 3. The causal relationship network of CSFs.

Table 1. CSFs for construction projects in ecologically fragile regions.

Code (*i*)	Critical Success Factor	Source of Data
1	Professionalism of partners	[46,93,95]
2	Partnering experience	[22,24,94]
3	High credibility of partners	[94,96]
4	Effective and open internal and external communication and collaboration	[22,24,97]
5	Mutual trust	[22–24,61,97,98]
6	Clear definition of responsibilities	[22,99,100]
7	Conflict resolution	[24,70,97]

Table 1. *Cont.*

Code (*i*)	Critical Success Factor	Source of Data
8	Effective risk management	[13,23,24,101,102]
9	Systematically process monitoring	[94,103]
10	Responsiveness to external environmental changes	[14,98]
11	Planning and implementation of sustainable strategies	[14,32,66]
12	Policy support on the protection of local ecological environment	[14,24,89]
13	Facilitator	[24,46,67]
14	Organizational project culture	[24,60,90,98]
15	Resources of water	[97]
16	Creativity	[97,98,100]
17	The project manager's leadership style	[67,71–73,98]
18	Economic viability	[101,102]

4. Hierarchical Structuring of CSFs

4.1. Causal Interrelationships between CSFs

The causal relationship network of CSFs is converted to a binary matrix so that the interrelationship between any two CSFs can be analyzed by a unified data structure. The contextual interrelation of "lead to" is used to make a judgement on the logical relationship between any two CSFs and the associated direction of the interrelations (CSF "*i*" influence CSF "*j*"). For instance, if CSF "*i*" impacts CSF "*j*", the adjacency matrix (A) is generated by $A = [a_{ij}]_{n \times n}$ as $a_{ij} = 1$. The adjacency matrix (A) is presented in Table 2.

Table 2. Adjacency matrix of CSFs.

CSFs (*i*/*j*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1					1										1		
2		1				1												
3			1		1		1											
4				1			1											
5				1	1		1											
6						1	1											
7							1											
8								1		1	1							
9								1	1	1								
10										1	1							
11											1							
12											1	1						
13													1			1		
14				1										1		1		
15															1			
16										1	1				1	1		
17														1			1	
18													1		1			1

A reachability matrix (R) describes the transitivity between two CSFs. For instance, if CSF1 can reach CSF2 by the path length of one-unit, while CSF2 can arrive at CSF3 by a path length of one-unit, then CSF1 has a transitivity to CSF3. The driver and dependence powers were calculated by a summation of values in the corresponding row and column. The results are shown in Table 3.

Table 3. Reachability matrix of CSFs.

CSFs (*i*/*j*)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Driver Power
1	1					1	1			1	1				1	1			7
2		1				1	1												3
3			1	1	1		1												4
4				1			1												2
5				1	1		1												3
6						1	1												2
7							1												1
8								1		1	1								3
9								1	1	1	1								4
10										1	1								2
11											1								1
12											1	1							2
13										1	1		1		1	1			5
14				1			1			1	1			1	1	1			7
15															1				1
16										1	1				1	1			4
17				1			1			1	1			1	1	1	1		8
18										1	1		1		1	1		1	6
Dependence power	1	1	1	5	2	3	9	2	1	9	11	1	2	2	7	6	1	1	

4.2. Partitioning the Reachability Matrix (R) of CSFs

Factors set $R(S_i)$ and $A(S_i)$ are calculated to partition the reachability matrix. $R(S_i)$ refers to a set of CSFs on which the CSF i has an impact. $A(S_i)$ refers a set of CSFs, which impact CSF i. The Common Set $C(S_i)$ is obtained by Equation (1).

$$C(S_i) = R(S_i) \cap A(S_i) \tag{1}$$

If $C(S_i) = R(S_i)$, then the CSFs that are in a common L_i, will be located on the same level of the ISM (Equation (2)), and will be taken out from the set before the next partition.

$$L_i = \{S_i \,|C(S_i) = R\,(S_i)\} \tag{2}$$

The process is repeatedly completed to order the CSFs at different levels. The detailed calculating process is presented in Table 4.

Table 4. Decomposition of reachability matrix (*R*).

CSF (*i*)	$R(S_i)$	$A(S_i)$	$C(S_i)$	L_i
		$L1 = \{7, 11, 15\}$		
1	1,6,7,10,11,15,16,	1	1	
2	2,6,7	2	2	
3	3,4,5,7	3	3	
4	4,7	3,4,5,14,17	4	
5	4,5,7	3,5	5	
6	6,7	1,2,6	6	
7	7	1~7,14,17	7	7
8	8,10,11	8,9	8	
9	8,9,10,11	9	9	
10	10,11	1,8,9,10,13,14,16,17,18	10	
11	11	1,8~14,16,17,18	11	11
12	11,12	12	12	
13	10,11,13,15,16	13,18	13	

Table 4. *Cont.*

CSF (i)	$R(S_i)$	$A(S_i)$	$C(S_i)$	L_i
14	4,7,10,11,14,15,16	14,17	14	
15	15	1,13~18	15	15
16	10,11,15,16	1,13,14,16,17,18	16	
17	4,7,10,11,14,15,16,17	17	17	
18	10,11,13,15,16,18	18	18	
		$L2 = \{4, 6, 10, 12\}$		
1	1,6,10,16,	1	1	
2	2,6	2	2	
3	3,4,5	3	3	
4	4	3,4,5,14,17	4	4
5	4,5	3,5	5	
6	6	1,2,6	6	6
8	8,10	8,9	8	
9	8,9,10	9	9	
10	10	1,8,9,10,13,14,16,17,18	10	10
12	12	12	12	12
13	10,13,16	13,18	13	
14	4,10,14,16	14,17	14	
16	10,16	1,13,14,16,17,18	16	
17	4,10,14,16,17	17	17	
18	10,13,16,18	18	18	
		$L3 = \{2, 5, 8, 16\}$		
1	1,16,	1	1	
2	2	2	2	2
3	3,5	3	3	
5	5	3,5	5	5
8	8	8,9	8	8
9	8,9	9	9	
13	13,16	13,18	13	
14	4,14,16	14,17	14	
16	16	1,13,14,16,17,18	16	16
17	14,16,17	17	17	
18	13,16,18	18	18	
		$L4 = \{1, 3, 9, 13, 14\}$		
1	1	1	1	1
3	3	3	3	3
9	9	9	9	9
13	13	13,18	13	13
14	14	14,17	14	14
17	14,17	17	17	
18	13,18	18	18	
		$L5 = \{17, 18\}$		
17	17	17	17	17
18	18	18	18	18

4.3. Forming the Skeleton Matrix (S) of CSFs

A skeleton matrix (S) is a simplified matrix of the reachability matrix (R) and provides the key and readable information on both the directional links and the levels for CSFs. A skeleton matrix (S) can be formed by (1) rewriting the R as K with the rows and columns with the order of CSFs in Table 4, (2) forming a skeleton matrix (S) by the equation of $S = K - I - (K - I)^2$. The final result of the skeleton matrix (S) is displayed in Table 5.

Table 5. Skeleton matrix (*S*) of CSFs.

CSF (*i*/*j*)		**7**	**11**	**15**	**4**	**6**	**10**	**12**	**2**	**5**	**8**	**16**	**1**	**3**	**9**	**13**	**14**	**17**	**18**
L_1	7																		
	11																		
	15																		
L_2	4	1																	
	6	1																	
	10		1																
	12		1																
L_3	2					1													
	5				1														
	8						1												
	16			1			1												
L_4	1					1						1							
	3									1									
	9										1								
	13											1							
	14				1							1							
L_5	17																1		
	18															1			

4.4. Obtaining the Hierarchy Graph

The hierarchy graph is generated by identifying the interrelationships between each pair of CSFs according to *S*. The element in row 1 of the skeleton matrix (*S*) appears at the first level of ISM. Hence, CSFs (7, 11 and 15) appear at the top of the ISM. Thereafter, CSFs (4, 6, 10 and 12) located in the 4th to the 7th row of the skeleton matrix (*S*) appear at the second level of ISM. The process continues in a similar form. The interrelationship between CSFs can be drawn from a skeleton matrix (*S*) (Table 5). For instance, for CSF12 (policy support on the protection of local ecological environment), the entry corresponding to CSF11 (planning and implementation of sustainable strategies) is 1 and entries for all other CSFs are 0. Therefore, CSF12 influences CSF11, whereas there is no relationship between CSF12 and the other remaining CSFs. In a similar way, the interrelationships between different CSFs are identified and denoted as directional links in the ISM (Figure 4).

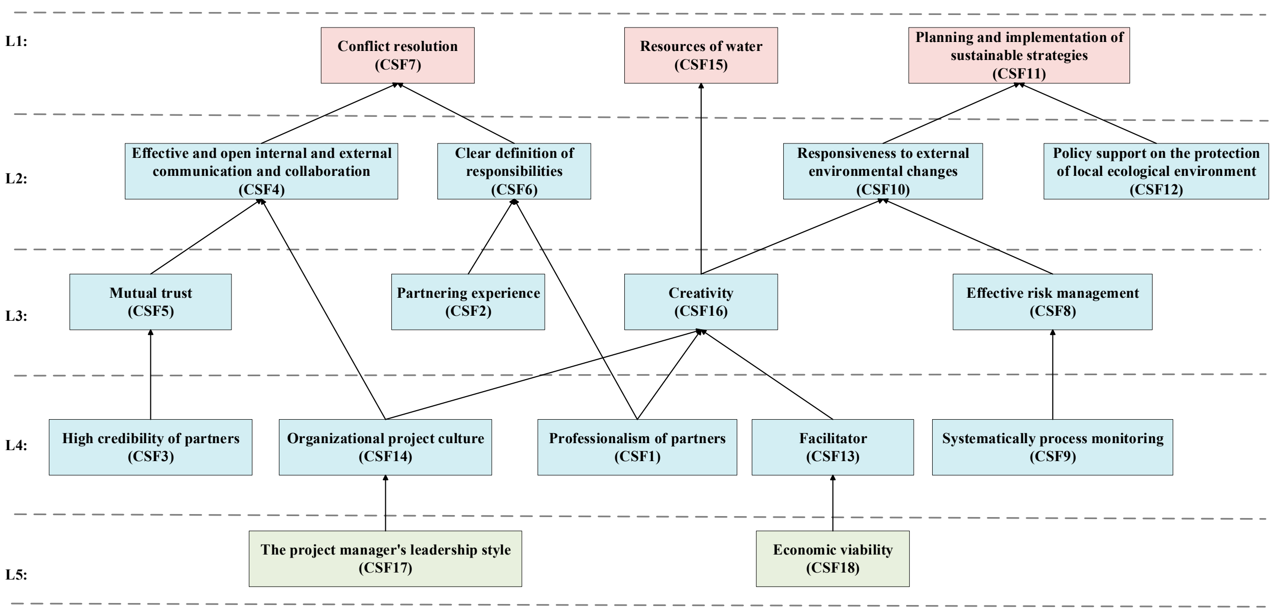

Figure 4. Interpretative structural model.

5. Classification of the CSFs Based on MIMAC Analysis

MICMAC analysis is implemented to classify CSFs and to ascertain their relationship according to their driver and dependence powers. The CSFs with more driver power can strongly influence the others and the CSFs with more dependence power are greatly influenced by others. All of the 18 CSFs are partitioned into four different quadrants (independent, linkage, autonomous and dependent) [46,104], as shown in Figure 5. The independent quadrant consists of CSFs with strong driver powers and weak dependence powers. The linkage quadrant consists of CSFs with both strong driver and dependence powers. The autonomous quadrant consists of CSFs with both weak driver and dependence powers. The dependent quadrant consists of CSFs with weak driver powers and strong dependence powers.

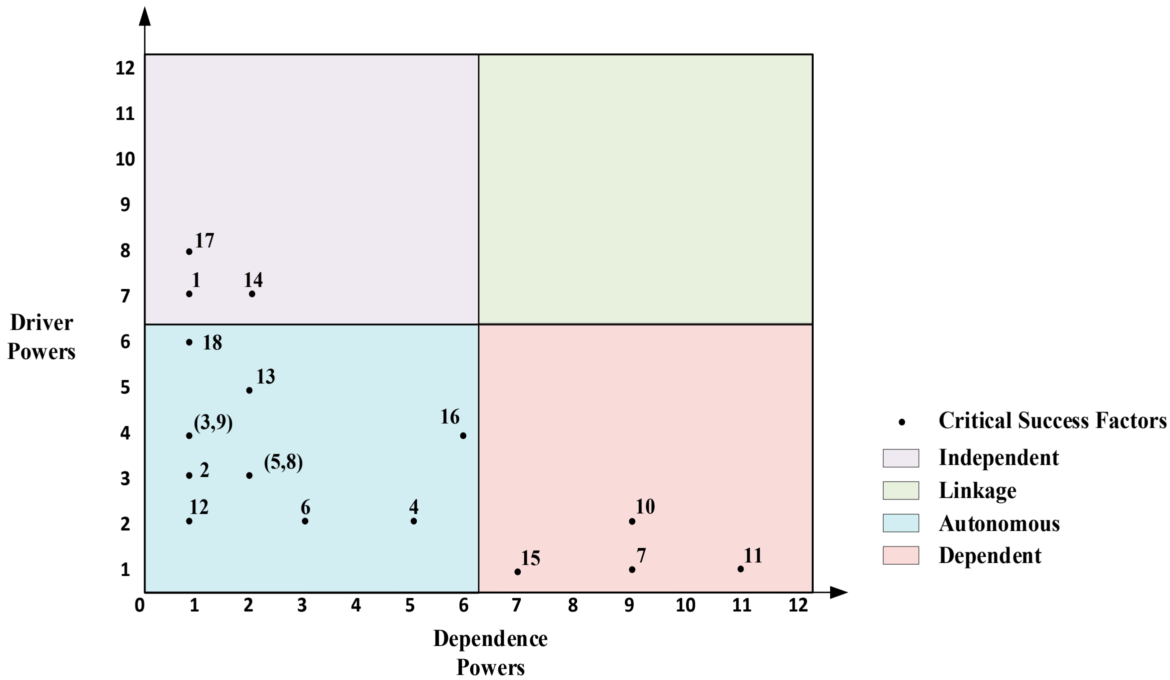

Figure 5. The MICMAC analysis for classification of CSFs.

6. Discussions

Figure 4 illustrates a clear hierarchy of CSFs and shows that the 18 CSFs have strong interrelationships. For instance, it is demonstrated that CSF17 (the project manager's leadership style) and CSF18 (economic viability) are the root factors, as expected, and have a profound influence on other CSFs. CSF17 promotes the CSF14 (organizational project culture) and CSF18 contributes to CSF13 (facilitator). There is some evidence in prior stuides on the relationship between the project manager's leadership style and the organizational project culture [105–108]. Fiol [109] proposed that the organizational project culture is the bridge between different elements of project organization and enhances their cohesion. This is supported by the findings that an appropriate leadership style can lead to better project performance and increases in levels of leadership may enhance relationships among team members [71]. CSF18 (economic viability) is another CSF which has a direct influence on the CSF13 (facilitator). Economic viability can provide necessary resources and stimulations to build a strict incentive system, such as funds or rewards for participants [110–112]. Furthermore, this strict incentive system plays an important role in organizing a construction crew to work in an extremely poor ecological environment. Meanwhile, Bower et al. [113] argued that the establishment of an incentive mechanism must meet the needs of the stakeholder, legitimately allocate resources, and reduce the cost risk. Once the economic conditions meet the requirements, sufficient resources are then applied to establish an incentive mechanism by PMT [24,46].

CSF7 (conflict resolution), CSF11 (planning and implementation of sustainable strategies) and CSF15 (resources of water) are the direct factors appearing at the top level of ISM. Establishment and communication of a conflict resolution strategy, such as joint problem solving [94,98], can benefit the project manager to establish a sound harmonious teamwork. As is presented in ISM, CSF7 (conflict resolution) is influenced by two CSFs which are the CSF4 (effective and open internal and external communication and collaboration) and the CSF6 (a clear definition of responsibilities). This means that we could make the conflict resolution by carrying out effective communication and collaboration and have a clear understanding of the roles for each of the project's participants. For instance, Jari and Bhangale [114] raised the suggestion that the project manager should undertake the responsibility of organizing, selecting and defining the responsibilities of the PMT. The most significant point is that the project manager should clearly have a knowledge of their responsibilities as the leader of a PMT and have proficient management skills and authority in the control of personnel [115–117].

CSF11 (planning and implementation of sustainable strategies), appearing at the top level of ISM, is influenced by CSF10 (responsiveness to external environmental changes) and CSF12 (policy support on the protection of the local ecological environment). The adaptation and sustainability of buildings to the natural ecological environment should be important research issues in the future. According to the different types of external ecological environment, it is noticed that in the adjustments and changes in construction methods, the implementation of environmentally friendly and sustainable building materials [118–120], and the reduction in environmental pollution [121] and damage by limited building emissions [122–124], are critical success factors for the construction projects in EFRs.

Finally, through the MICMAC analysis, the CSFs for construction projects in EFRs were classified. It is presented that there are no CSFs located at the linkage quadrant. The autonomous quadrant consists of the majority of CSFs (11 out of 18) with both weak driver and dependence powers. Three CSFs (1, 14 and 17) with strong driver powers but weak dependence powers were in the independent quadrant. They are located at the lower levels (the 4th and 5th levels) of the ISM, serving as the root CSFs. Therefore, as the most influential CSFs, extensive efforts should be exerted to enhance leadership abilities and management knowledge to form the appropriate leadership style of project managers, to cultivate an organizational project culture and to increase the sense of cognition and belonging and improve the professionalism of project partners. The dependent quadrant included four CSFs (7, 10, 11 and 15), which have more dependence powers but fewer driver powers. These factors are more likely to be influenced by others. Specifically, CSF7 (conflict resolution) and CSF10 (responsiveness to external environmental changes) has a high dependence power of 9, and CSF11 (planning and implementation of sustainable strategies) has the highest degree of dependence power of 11. Therefore, it can be deduced that a high priority should be placed on the planning and implementation of sustainable strategies such as the use of sustainable construction materials (which have an optimal consumption of resource, have the least environmentally ecological influences, and exert minimal health risks to users), developing green buildings, taking advantage of water and sewage management, etc., in the whole life cycle.

7. Conclusions

This paper has identified 18 CSFs for construction projects in EFRs through a systematic literature review and a case study in China. ISM was applied to hierarchically structure the CSFs according to the causality relationships between the CSFs through pairwise comparisons with rigorous logical judgement. Thereafter, MICMAC analysis was completed to analyze the degree of interrelationship between CSFs and to provide a distribution of CSFs based on the value of driver power and dependence power. The findings show that the 18 CSFs had a strong hierarchy and are divided into five levels. Furthermore, it can be deduced from the MICMAC analysis that CSF17 (the project manager's leadership style) owns the highest driver power of 8 and has a direct influence on the organizational project culture (CSF14), which can generate creativity (CSF16) and promote the effective and open internal and external communication and collaboration (CSF4). Therefore, the competence and leadership style of a project leader will have a profound and important impact on the harmonious partnership with fewer conflicts in a construction project. Moreover, it can be noted that both of the two CSFs (17: the project manager's leadership style and 18: economic viability) located at the bottom of ISM can propagate to CSF16 (creativity), which has an influence on CSF10 (responsiveness to external environmental changes) and thereafter arrive at the direct CSF11 (planning and implementation of sustainable strategies). Sustainable strategies are essential for a construction project in EFRs. Construction activities should be to promote and form a more resilient and sustainable local ecological environment instead of for obtaining short-term economic efficiency economy profits.

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