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An ISM-Based Methodology for Analyzing Interrelationships Among Influencing Factors in Reconstruction Projects

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Abstract: The frequency and scale of natural disasters are rapidly increasing due to global warming. Over time, the academic community has conducted numerous studies on post-disaster reconstruction projects. Additionally, international organizations have provided various guidelines for executing these projects efficiently. In this study, we examined and analyzed several influencing factors based on existing research to improve approaches to reconstruction projects. Although generalizing results from limited studies can be challenging, our findings suggest that "Assessing the extent of damage to facilities requiring reconstruction" should be prioritized in the implementation of reconstruction projects.

Key words: Post-Disaster Reconstruction, Reconstruction Approach, Influencing factors, Interpretive Structure Modeling (ISM), MICMAC

1. INTRODUCTION

Over the last two decades (2004-2023), a total of 8,023 natural disasters have struck globally, resulting in $3.25 trillion worth of damage[1]. In response to the physical devastation wrought by these disasters, major international organizations and non-governmental entities labor to facilitate recovery efforts. When undertaking associated projects, we meticulously research and analyze various influencing factors, mindful of local conditions, to ensure the seamless execution of the endeavor. Reconstruction projects face numerous constraints distinct from those encountered in typical construction ventures.

Undertaking construction projects in developing countries, even under ordinary circumstances, presents significant challenges. Successful implementation hinges upon careful consideration of various influencing factors, including construction methods and technologies, logistics and procurement, collaboration among stakeholders, and sufficient financial resources[2]. According to a survey of existing studies, prioritizing the selection of construction technology and methodology is imperative for the successful execution of reconstruction projects. Particularly, the scale and severity of damage to each structure or facility dictate the approach and scale of reconstruction efforts.

In this context, numerous international organizations offer guidelines for conducting operations. However, these guidelines are typically confined to outlining the impact factors that ought to be taken into account or assessing the individual significance of these factors. This study endeavors to identify the impact factors crucial for the reconstruction process following a large-scale natural disaster, and to prioritize them by employing interrelation techniques.

2. Hierarchical Structure Analysis using ISM Methodology

2.1 Identifying Influencing Factors

To identify the impact factors pertinent to reconstruction projects, we conducted a literature survey encompassing disaster-related international papers and reports published by international organizations. Subsequently, seven impact factors were selected through expert evaluation, conducted by professionals from disaster-related international organizations and non-governmental organizations, to assess the importance of each factor. The finalized impact factors and their definitions are presented in <Table 1>.

Table 1. Key Influencing Factors in the Reconstruction Approach Phases

Code.	Influencing Factors	Methodology for Factor Extraction		
		Paper	Report	Case Study
RA1	Attaining a precise comprehension of the defined goals of the reconstruction project	◎[3]	◎[4]	◎
RA2	Assessment of the extent of damage to facilities requiring reconstruction	◎[5]	◎[6]	◎
RA3	The scale and complexity of reconstruction projects		◎[7]	◎
RA4	Effective time management for the reconstruction project schedule.	◎[8]		◎
RA5	The utilization of appropriate methods and technology for reconstruction	◎[9]	◎[10]	◎
RA6	Defining adequate design standards and quality requirements for reconstruction		◎	◎
RA7	Adaptation to future environmental changes	◎	◎[11]	◎

The definitions of each influencing factor are as follows:

RA1: Attaining a precise comprehension of the defined goals of the reconstruction project

Reconstruction projects involve more than just construction; they encompass multiple objectives. In the chaotic post-disaster environment, it is imperative to establish a clear goal for the reconstruction project to ensure its success. Communicating this clear goal to all project participants is crucial, especially because reconstruction projects usually require a significant amount of time to complete.

RA2: Assessment of the extent of damage to facilities requiring reconstruction

Assessing the extent of damage to buildings and structures is crucial for planning restoration and reconstruction efforts. The type of reconstruction project—whether repair, retrofit, or rebuild—depends on the damage assessment of both residential properties and critical facilities after a disaster. Typically, the cost, construction timeline, and other criteria for a reconstruction project are determined through a multi-sectoral assessment, which includes evaluations such as damage and loss assessments.

RA3: The scale and complexity of reconstruction projects

The complexity and scale of a project determine its construction difficulty. For reconstruction projects, it is crucial to select a firm with above-average technical capabilities or relevant project experience. The scope of the project and the composition of key participants can vary depending on its scale and complexity.

RA4: Effective time management for the reconstruction project schedule.

Reconstruction projects typically operate within a limited construction period. However, aggressive and unreasonable work schedules can significantly reduce the project's quality and performance. If the project experiences delays, there is a likelihood of increased administrative tasks and unnecessary costs.

RA5: The utilization of appropriate methods and technology for reconstruction

When implementing a reconstruction project, it is essential to consider the characteristics of the local construction market, including technical capability and the post-disaster environment. These factors should inform the selection of appropriate reconstruction methods and technologies, such as deciding whether to maintain or upgrade existing construction methods. Project failure can occur if project participants lack understanding and experience with the new construction techniques implemented in the reconstruction project.

RA6: Defining adequate design standards and quality requirements for reconstruction

Considering the region's construction capabilities and the availability of materials, it is necessary to evaluate whether to maintain or upgrade the design and quality of the reconstruction facilities. During the design phase, it is imperative to adhere to local laws and regulations. In cases where local laws are absent or standards fall significantly below international norms, upgrading to meet international standards and incorporating universal design principles becomes essential. To ensure consistent quality across all facilities involved in the reconstruction project and to align the expectations of various stakeholders, clear construction quality standards and definitions need to be established.

RA7: Adaptation to future environmental changes

Building resilience to minimize physical damage from disasters and preparing for future events is essential. Additionally, incorporating sustainable reconstruction practices can enhance ongoing efforts. Long-term planning for the supply of public services by critical infrastructure facilities should also consider the potential for population growth, urbanization, and other social changes.

2.2 Development of Structural Self-Interaction Matrix

To evaluate the influence between the factors, a self-interaction matrix (SSIM) was created by analyzing literature on disaster recovery published by international organizations such as the International Recovery Platform (IRP) and the International Federation of Red Cross and Red Crescent Societies (IFRC). An online assessment with international experts was also conducted. The results are presented in <Table 2>. The contextual relationships between the factors were developed using the four symbols mentioned below. The relationship between two influencing factors (i and j) is defined by both the direction and the nature of their influence.

- V: When Influencing Factor i impacts or affects Influencing Factor j
- A: When Influencing Factor j impacts or affects Influencing Factor i
- X: When Influencing Factors i and j impact or affect each other
- O: When neither Influencing Factor impacts the other (unrelated Influencing Factors)

Table 2. Structural Self-Interaction Matrix

Code.	RA7	RA6	RA5	RA4	RA3	RA2
RA1	A	A	A	A	A	A
RA2	O	V	V	O	V	
RA3	O	V	V	V		
RA4	V	V	V			
RA5	X	V				
RA6	X					
RA7						

2.3 Development of Reachability Matrix

Based on the evaluation results of the Self-Interaction Matrix (SSIM) using the four symbols, the influence relationships between each factor are assessed. The Initial Reachability Matrix derived from this evaluation is shown in <Table 3>.

Table 3. Initial Rechability Matrix

Code.	RA1	RA2	RA3	RA4	RA5	RA6	RA7
RA1	1	0	0	0	0	0	0
RA2	1	1	1	0	1	1	0
RA3	1	0	1	1	1	1	0
RA4	1	0	0	1	1	1	1
RA5	1	0	0	0	1	1	1
RA6	1	0	0	0	0	1	1
RA7	1	0	0	0	1	1	1

The Final Reachability Matrix is derived from the Initial Reachability Matrix, incorporating transitivity. The results are presented in <Table 4>.

Table 4. Final Rechability Matrix

Code.	RA1	RA2	RA3	RA4	RA5	RA6	RA7
RA1	1	0	0	0	0	0	0
RA2	1	1	1	1*	1	1	1*
RA3	1	0	1	1	1	1	1*
RA4	1	0	0	1	1	1	1
RA5	1	0	0	0	1	1	1
RA6	1	0	0	0	1*	1	1
RA7	1	0	0	0	1	1	1

Notes) 1* is included to consolidate fulfillment.

2.4 Level Partitions

The Reachability Set and Antecedent Set are derived from the Final Reachability Matrix. The Intersection Set is composed of the common elements between the Reachability Set and the Antecedent Set. The results are shown in <Table 5>.

Table 5. Level Partitions

Code.	Rechability Set	Antecedent Set	Intersection Set	Level
RA1	1	1,2,3,4,5,6,7	1	Ⅰ
RA5	5,6,7	2,3,4,5,6,7	5,6,7	Ⅱ
RA6	5,6,7	2,3,4,5,6,7	5,6,7	Ⅱ
RA7	5,6,7	2,3,4,5,6,7	5,6,7	Ⅱ
RA4	4	2,3,4,	4	Ⅲ
RA3	3	2,3,	3	Ⅳ
RA2	2	2	2	Ⅴ

The ISM hierarchy model of the seven impact factors related to the reconstruction approach was divided into five hierarchical levels. The levels and correlations of each impact factor are illustrated in <Figure 1> below.

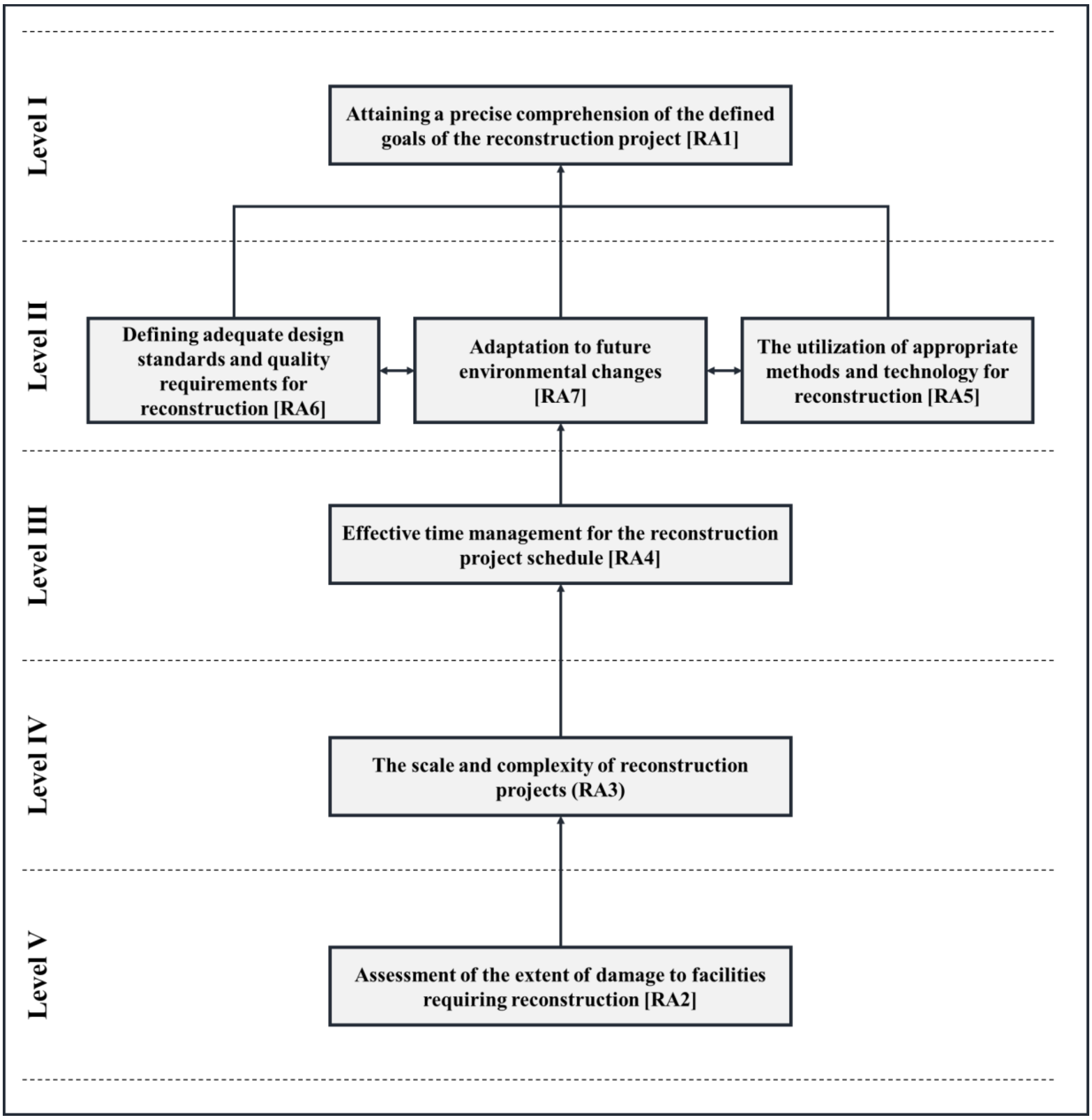

Figure 1. ISM-based Structural Model of Reconstrcution Approach

From the hierarchy analysis of the impact factors, ' Assessment of the extent of damage to facilities requiring reconstruction (RA2)' emerged as the top priority impact factor, while ' Attaining a precise comprehension of the defined goals of the reconstruction project (RA1)' was identified as the least influential factor.

3. MICMAC Analysis

MICMAC analysis was conducted to examine the correlations between the influencing factors. The results are presented in <Table 6>.

OPTION 1

Table 6. Dependence Power and Driving Power

Code.	RA1	RA2	RA3	RA4	RA5	RA6	RA7	Driving Power
RA1	1	0	0	0	0	0	0	1
RA2	1	1	1	1	1	1	1	7
RA3	1	0	1	1	1	1	1	6
RA4	1	0	0	1	1	1	1	5
RA5	1	0	0	0	1	1	1	4
RA6	1	0	0	0	1	1	1	4
RA7	1	0	0	0	1	1	1	4
Dependence	7	1	2	3	6	6	6	-

The distribution of quadrants based on influence factors, determined by their dependence power and driving power, is illustrated in Figure 2.

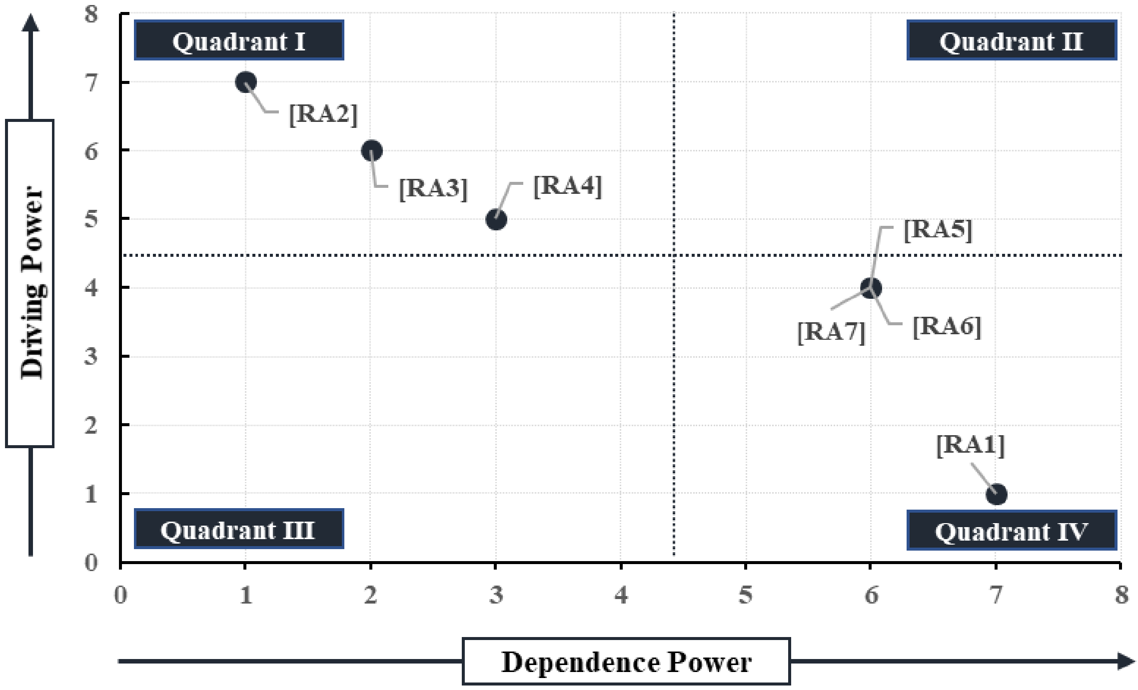

Figure 2. Driving and Dependence Power for Reconstruction Approach

Quadrant I (Independent): The impact factors in this quadrant exhibit significant influence at lower levels (Level III ~ V) of the ISM hierarchy model, encompassing three key factors: Assessment of the extent of damage to facilities requiring reconstruction (RA2), The scale and complexity of reconstruction projects (RA3), and Effective time management for the reconstruction project schedule (RA4).

Quadrant IV (Dependent): The impact factors in this quadrant heavily rely on the higher levels (Levels I to II) of the ISM hierarchy model. They comprise four influential factors: 'Attaining a precise comprehension of the defined goals of the reconstruction project (RA1), The utilization of appropriate methods and technology for reconstruction (RA5), Defining adequate design standards and quality requirements for reconstruction (RA6), and Adaptation to future environmental changes (RA7)'

4. Conclusion

This study identified crucial factors for the "Reconstruction approach" in post-disaster reconstruction projects and employed the ISM technique to delineate their hierarchy. Through MICMAC analysis, the interconnections among these factors were examined. The primary consideration essential for successful reconstruction projects was identified as the "Assessment of the extent of damage to facilities requiring reconstruction." Specifically, priority investigation and analysis of the extent of damage to main walls and buildings, major infrastructure, and utility facilities (such as water, sewerage, roads, bridges, electricity, telecommunications, etc.) are necessary to establish an appropriate reconstruction plan [12].

Reconstruction projects should aim not only to restore target facilities (housing, infrastructure, etc.) to pre-disaster levels but also to enhance resilience and prepare for future disasters. They should be approached from a performance improvement perspective [13], reflecting the concept of Build-Back Better (BBB). Future research must consider the characteristics of the facility type to be rebuilt and the region where the project is undertaken. Efficient approaches and management plans should be proposed through expert verification of the analysis results.

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