

# **Modeling and Analyzing Interrelationships among Project Success Factors and Criteria**

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## **Abstract**

Previous studies have identified and modeled various factors affecting project success in the construction industry. However, in order to design and implement an effective program for achieving project success, it is necessary to integrate all the identified success factors (SFs) and their links to success criteria (SCs) into a single comprehensive model. This was accomplished in this study by using social network analysis, in which 19 SFs and 9 SCs were represented by a comprehensive graphical model. This model was complemented with a cross-impact matrix multiplication applied to classification (MICMAC) analysis in order to classify SFs and SCs in terms of their driving powers and dependence levels. Accordingly, the key factors for project success have been identified as effective project team formation, effective communication, support from top management, clearly defined goals and objectives, and the project manager's competence.

## **Keywords**

Success Factors, Success Criteria, Construction Projects, Social Network, MICMAC

## **1. Introduction**

The intense competition in today's world market forces organizations in the construction industry to examine how to ensure the success of their projects as they seek to enhance their competitiveness. However, project success is one of the most widely discussed subjects in the project management literature. Despite this, there appears to be no academic consensus on a generally acceptable definition of project success (Hughes et al. 2004, Ozorhon et al. 2007, Ozorhon et al. 2010). That said, scholars such as Ozorhon et al. (2010) and Lei et al. (2017) have construed success from the perspective of the "generic" triple constraints of time, cost, and quality. In reality, however, the notion of a triple constraint is very restricted and, in fact, represents an unrealistic approach to assessing the success of projects (see Atkinson 1999, Barclay and Osei-Bryson 2010, Bourne et al. 2002, Shenhar et al. 2001). However, despite these claims, as Barclay and Osei-Bryson (2010) point out, these criteria for project success continue to dominate project management practice.

Recognizing the unrealistic and restricted nature of the triple constraint measures, more recent research has sought to expand how project success is measured. Drawing from an acknowledgment that the success of projects is primarily multidimensional (Ojiako et al. 2008, Shenhar et al. 2001), more recent project success measures have sought to incorporate wider criteria such as stakeholder satisfaction, customer satisfaction, user satisfaction, and productivity (Bryde and Robinson 2005, Chua et al. 1999, Collins and Baccarant 2004, Gunathilaka et al. 2013, Griffith et al. 1999, Nitithamyong and Tan 2007, Shokri-Ghasabeh and Kavousi-Chabok 2009). The first step towards achieving project success is to identify success factors (SFs) and their links to selected project success criteria (SCs). A brief review of the literature that has addressed this issue is given below.

## **2. Literature Review**

SFs can be defined as variables that can be influenced to increase the likelihood of project success (Muller and Turner 2007), whereas SCs can be defined as measures used to judge the successful outcome of a project. In the literature, the reported links between SFs and SCs have been identified either conceptually or empirically. For instance, Pinto

and Slevin (1987) provided methodology to determine project SFs by empirically identifying 10 factors and linked them together in an interdependent, quasisquential framework. This was done by developing a Likert scale tool consisting of 10 items for each critical SF. Chan et al. (2001) identified project SFs for design and build (D&B) projects and their importance to the project by developing a survey containing 31 SFs. Based on a survey of 53 participants in public-sector D&B projects, 6 SFs were extracted, including project team commitment, contractors' competencies, risk and liability assessment, clients' competencies, end-users' needs, and constraints imposed by end-users. The most significant factors in the success of a project were project team commitment, clients' competencies, and contractors' competencies. Chan et al. (2002) provided a framework for project success for D&B construction projects. This was done by identifying the SCs based on a comprehensive literature review of papers over 10 years and establishing an assessment framework for SFs. The literature review showed that the most significant measures include time, cost, quality, and satisfaction. Furthermore, the framework was validated by case studies of three hospital projects, which found that key performance indicators (KPIs) are good indicators of the performance of construction projects. Chan et al. (2004) developed a conceptual framework of project SFs. Based on a comprehensive literature review of seven journals related to construction, five groups of independent variables critical to the success of projects were established: project-related factors, project procedures, project management actions and human-related factors, and external environment. It was also found that a variable in one group can affect a variable in another group. Chan and Chan (2004) established a framework for the success of projects in Germany by measuring a set of KPIs, including time, cost, safety, and environmental performance, both objectively and subjectively based on a literature review. Dvir and Lechler (2004) analyzed the interactions between project success in Germany and three project planning variables (the quality of planning, goal changes, and plan changes) based on data from 448 projects by surveying the members of a German project management society. The data were analyzed using structural equation modeling, and it was found that the positive impact of the planning quality exceeded the negative impact of goal changes. In addition, project goal changes led to plan changes, which had a negative impact on the success of the project. Gunathilaka et al. (2013) identified the relationship between project success factors and project success criteria by reviewing empirical research papers in construction management journals. It was found that the relationships between many SFs and SCs is still unexplored and has been articulated only from a conceptual perspective, with little empirical evidence to support the relationships. Silva et al. (2016) provided a review for construction projects success criteria. Based on this study, they suggested developing a stronger model for relationships between success factors (SFs) and success criteria (SCs) to ensure the success of the project. They proposed a framework for construction project success based on long-term and short-term perspectives to be tested in Sri Lankan projects. Radujković and Sjekavica (2017) studied project management success factors with a focus on project management in Croatia. The factors were identified by developing project management success factors breakdown structure and then applied on 3 different EU co-financed projects. Wu et al. (2017) investigated the impacts of communication-conflict interaction on project success using data collected from 310 middle and senior managers at medium and large scale construction projects in China. The results showed that task conflict, communication willingness, and formal communication have positive impacts on project success, whereas process conflict and informal communication have negative impacts on project success. Finally, Gunduz and Yahya (2018) identified project success factors (SFs) focusing on construction projects in the Middle East. Based on a literature review, they identified 25 SFs which were assessed for their effect and contribution to the performance of the project based on 3 criteria (schedule, cost, quality) by developing a survey. A statistical analysis was performed for the 111 responses received. This study revealed that the most important factors are organization's technical capacity and scope and work definition.

### **3. Problem Statement and Research Objectives**

The above literature review reveals that several studies have identified SFs and their links to SCs. However, each study focused on linking identified SFs to a selected number of SFs. Moreover, these studies ignored the interrelationships among the SFs themselves, as well as the interrelationships among SCs. Also, these studies considered only the direct impacts of SFs on SCs, ignoring the fact that success is the result of cumulative effects. Thus, there is a need to combine the results of the various studies into one comprehensive model to give project managers a holistic view of the interactions among SFs and their influence on SCs, instead of analyzing each SF individually. In response to this need, this study proposes a novel approach that integrates social network analysis with MICMAC analysis in order to combine the SFs and SCs identified in various previous studies into one comprehensive model, and then to analyze their interrelationships to classify the modeled SFs and SCs in terms of their driving powers and dependence levels in order to identify the key factors affecting project success.

Social network analysis (SNA) originally emerged in the 1930s from movements in the field of sociology aimed at investigating social structures. SNA's applications have been extended to modeling interactions among nonhuman objects in different fields, including project management, whereas MICMAC analysis was developed by Duperrin and Godet (1973) in order to analyze relationships (both direct and indirect) among variables. Accordingly, the variables can be classified into four categories: autonomous, dependent, linkage, and independent variables. MICMAC is an abbreviation of *matrice d'impacts croisés et multiplication appliquées à un classement*, roughly translated from the French as "cross-impact matrix multiplication analysis."

## 4. The Proposed Approach

The proposed approach involves the following major steps: mapping of interrelationships among SFs and SCs, constructing the model, and performing MICMAC analysis.

### 4.1 Mapping of Interrelationships

Based on the literature review and in consultation with experts, the interrelationships among the following 28 variables (9 SCs and 19 SFs) were identified in order to prepare an adjacency matrix, an  $n \times n$  binary matrix, where  $n$  is the number of variables.

Success Criteria	Success Factors	
1. Budget/finance/cost performance	10. Effective project team formation	20. Established budget and monitoring
2. Technical performance	11. Effective communication	21. Client's consultation and involvement
3. Schedule performance	12. Support from top management	22. Clear and detailed procurement process
4. Stakeholder satisfaction	13. Allocation of sufficient resources	23. Project risk management
5. Time performance	14. Clearly defined goals and objectives	24. Project plans and schedules
6. Customer satisfaction	15. Level of technology	25. Frequent progress meetings
7. Quality performance	16. Financial stability and adequate funding	26. Commitment to the project
8. User satisfaction	17. Project manager's competence	27. Well-defined technical specifications
9. Productivity	18. Project monitoring and feedback	28. Effective quality assurance program
	19. Motivation and incentives	

In the adjacency matrix, the variables are listed along the top and along the left-hand side. If variable  $i$  influences variable  $j$ , then element  $e_{ij}$  (the element in row  $i$  and column  $j$ ) is expressed as one (1); otherwise, it takes a zero value. The developed adjacency matrix is shown in Figure 1.

### 4.2 Constructing the Model

The adjacency matrix shown in Figure 1 was used as an input for the Social Network Visualizer (SocNetV) software package to construct the graphical model shown in Figure 2. In Figure 2, each SF or SC is represented by a node. A direct link from a node  $i$  to a node  $j$  means that the SF or SC represented by node  $i$  has an influence on the SF or SC represented by node  $j$ .

### 4.3 Performing MICMAC Analysis

To identify the key SFs, a MICMAC analysis was conducted, which involves obtaining a stabilized adjacency matrix and classifying SFs and SCs based on their driving powers and dependence levels. The idea behind obtaining a stabilized adjacency matrix is to identify all interrelationships, both direct and indirect. To do so, the diagonal entries of the adjacency matrix are replaced with 1s, and then the matrix is multiplied by itself by performing Boolean matrix multiplication repeatedly until a stabilized matrix is obtained. The obtained stabilized matrix for SFs and SCs is shown in Figure 3.

The classification of SFs and SCs was accomplished by computing the driving power and dependence level of each variable, and the computed values were then plotted in a two-dimensional diagram called a driving power and dependence level diagram consisting of four quadrants. The first quadrant comprises autonomous variables, which

have a weak driving power (ability to influence other variables) and a weak dependence level (slight influence by other variables). The second quadrant comprises dependent variables, which have a weak driving power but a strong dependence level. The third quadrant features linkage factors, which have a strong driving power and a strong dependence level. Any change in these variables will impact both the linkage variables and the other variables. The fourth quadrant includes independent variables with a strong driving power but a weak dependence level. The dependence level of variable  $j$  can be computed by summing all the values of column  $j$  of the stabilized matrix, whereas the driving power of variable  $i$  can be computed by adding all the values of row  $i$ .

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	0	1	0	1	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	0	0	1	0	0	0	1	0	0
13	1	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0
15	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	0	0	1	0	1	0	0	1	1	1	0	0	1
18	1	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
20	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
22	1	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
24	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
26	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
27	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 1. Adjacency matrix

## 5.0 Results

The network shown in Figure 2 provides evidence that project success is not a result of isolated factors; rather, it is the net result of many factors occurring in sequence or parallel. Figure 4 shows that effective project team formation (Variable 10), effective communication (Variable 11), support from top management (Variable 12), clearly defined goals and objectives (Variable 14), and the project manager's competence (Variable 17) can be classified as independent SFs and can also be called driver or determinant SFs; they are very influential and have low levels of dependence. They are located in the northwest corner of the aforementioned diagram. If the network shown in Figure 2 were converted to a hierarchical graph, then these SFs would be placed in the bottom level of that graph. Thus, they can be considered to be the root causes for success. Any effort to achieve project success that does not consider these SFs would be futile. Figure 4 also shows that all the SCs except for SC 3 and the rest of the SFs can be classified as autonomous, as they are weak drivers and also have weak dependence; hence, they have less influence on project success than the independent SFs.

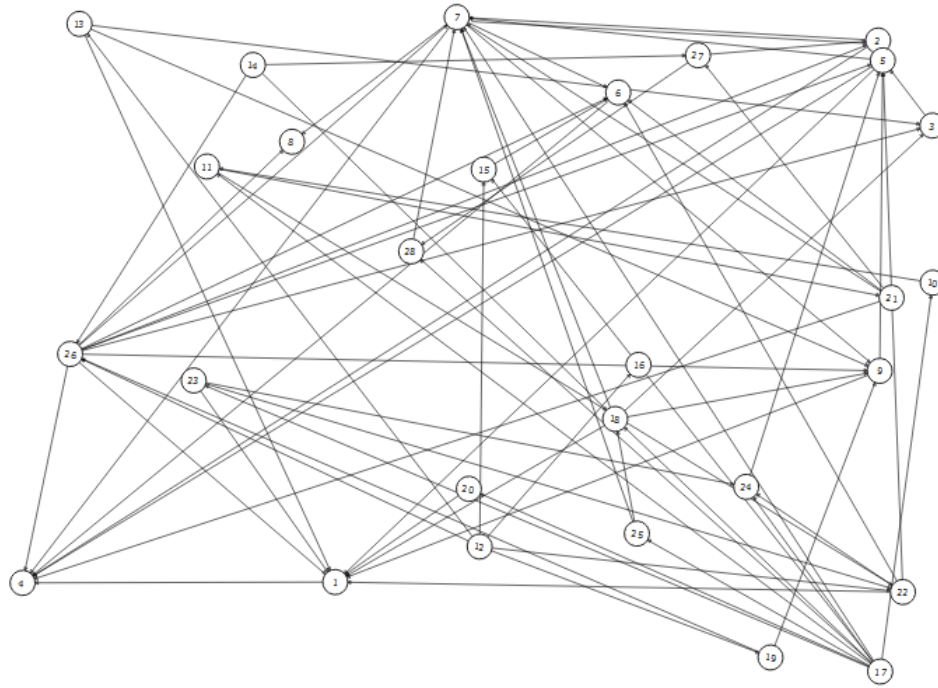


Figure 2. Interactions among SFs and SCs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1
11	1	1	0	1	1	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	1	1
12	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	0	0	1	0	0	1	0	1	0	1	0	0
13	1	1	1	1	1	1	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	1	1	1
15	0	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
17	1	1	1	1	1	1	1	1	1	1	0	0	0	0	1	0	1	1	0	1	1	1	1	1	1	0	1	1
18	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
19	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
20	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
21	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0
22	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0
23	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0
24	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
25	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
26	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
27	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
28	1	1	0	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3. Stabilized matrix

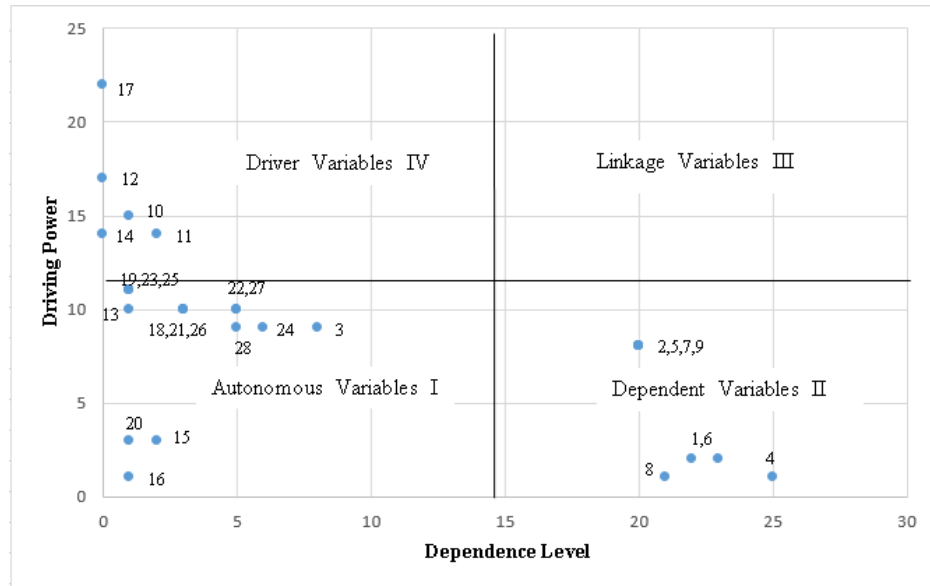


Figure 4. Driving power and dependence level diagram

## 6. Conclusions

Decision makers should be aware of not only the relative importance of the various SFs and their direct impact on SCs, but also the relationships among them. Based on the results reported previously in the literature and on expert opinions, 19 SFs and their interrelationships with 9 SCs were identified and used to build a comprehensive graphical model using social network analysis. As a complement to this model, a MICMAC analysis was performed to classify the modeled variables based on their driving powers and dependence levels. Three clusters of SFs and SCs were identified: a cluster of autonomous variables, a cluster of dependent variables, and a cluster of independent variables. Accordingly, effective project team formation, effective communication, support from top management, clearly defined goals and objectives, and the project manager's competence are the keys to project success. Therefore, project managers should pay special attention to these SFs, since otherwise, any efforts towards achieving success would be futile. The present study can be extended in several ways. In particular, future research may consider modeling and analyzing the interrelationships among SFs and SCs in projects in other industries. Using fuzzy interrelationships instead of binary interrelationships may also be considered in future studies.

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