# An Analytic Model for Organization Readiness of Engineering Project Management Based on Virtual Teams

Zahra Mirzahashemi Targhi [a], Farid Khoshalhan [b*]

[a] *Faculty of Industrial Engineering, Khajeh Nasir Toosi University of Technology, Tehran, Iran*
[b] *Information Technology, Islamic Azad University, E-Campus, Tehran, Iran*

**Abstract:** The Organization Readiness of Engineering Project Management Based on Virtual Teams has been analyzed in an Iranian Engineering firm. Adapting and analyzing the latest readiness model, experts' opinions were received by questionnaires and main criteria of the readiness have been identified. The considered readiness criteria are: Infrastructure, Deliverables (Drawings, Reports, Minutes of Meetings, Letters and Invoices), Human Resources, Information Technology and Communications, Organization Chart, Financial Resources and Business Environment Factors. They have been classified by Interpretive Structural Model (ISM) and MicMac Analysis. The Priorities have been determined by Friedman Test. The sub-criteria of two main criteria with the highest priority are Human Resources and Deliverables that have been selected by experts and their priorities have been determined by calculation of the Eigenvalue in the linear system of the model. In order to enlist virtual teams in this engineering firm, it is necessary to improve human resources team knowledge, which increases the quality of the deliverables.
*key words:* Virtual Team, E-Readiness, Engineering, Analytic Model, Effective Factors

## 1. Introduction

In order to better communicate between virtual teams to performing Engineering Services in Case-Study Internal Consultant Engineers Company analyzed literature review, collecting and review existing data, selected analytical model and finally achieved results. Organization readiness and effective factors in project management should be recognized and prioritized by effective factors in order to increase the efficiency of the mentioned teams. For this purpose, the ISM model (Interpretive Structural Modeling) and the MICMAC analysis are used in this paper, and solutions will be proposed to increase effective factors.

## 2. Research Background

In some engineering companies, the executive teams at various project sites and the managers at headquarters are widely in the country. It is possible, but costly to make effective communication between the teams by personal meeting by having extensive travels and missions. A preferred way would be creation of virtual teams which is much less costly and, quicker. However, the latest needs a web-based computer facilities, webcams, relevant software and nationwide telecommunications networks. Due to lack of same location of design engineers and project sites, this effective way of creating virtual teams suggested.

The purpose of this research is to analyze the present company status, recognize its readiness and to improve the work environment and achieve positive results. A success in pilot model may cause a revolution in the engineering communities. This research is conducted in a civil engineering company as a pilot.

Priorities and trust development in project teams – A case study from the construction industry has been studied in Norway. Through a case study in the construction industry, we explore how priorities between team members influence the development of trust. We identify four important aspects; early formation of integrative work practices,

* Corresponding author, email: khoshalhan@kntu.ac.ir

development of a common philosophy, open communication, early and clear role expectations, all contributing to development of trust in an early phase. Our findings offer new, empirical insights into the complex nature of temporary project work and underscore the significance of prior ties in facilitating early trust and integration within project teams. [1]

Effective digital collaboration in the construction industry – A case study of BIM deployment in a hospital construction project has been studied in Norway. Based on diffusion of innovation theory, we identified the following set of key factors enabling digital collaboration in the project: change agents, new roles and responsibilities, a cloud computing infrastructure, BIM contracts, and a BIM learning environment. [2]

Practices and effectiveness of building information modeling in construction projects has been studied in China. This paper aims to provide an overview of current BIM practices in China, and assess how these practices differ from each other in their effectiveness. The results indicate that, through a decade of development, project BIM use in China has been clearly extended from the architectural design stage to the construction stage. Despite such a clear development, however, it is evident that in-depth BIM use is still limited principally to areas of visualization, with the aim of virtually representing complex facility shapes or conducting clash detections. In terms of participant involvement, general contractors and designers are the two types of most frequent BIM users, and overall support of BIM by clients/owners is limited, despite their increasing absorption of BIM related costs. Although there are an increasing number of disciplines involved in BIM use, the problem of insufficient inter-organizational collaboration, which is partly caused by institutional regulations on the use of traditional project delivery systems, still seems to be particularly acute in current BIM practices in China. [3]

The Use of Advanced Computer Based Management Systems by Large Saudi Companies for Managing Remote Construction Projects has been studied in Saudi Arabia. It has highlighted few unique communications and management problems such as the loose control, lack of human resources, infrastructure and experience. The present researchers recommend these actions at the following levels: 1. Strategic Planning, 2. Project Planning and Process, 3. Human Resources, and 4. Advanced Computer Based Management Systems (ACMS). [4]

Global virtual engineering teams (GVETs): A fertile ground for research in Australian construction projects context has been studied in Australia, which GVETs are receiving increasing attention within the construction context due to numerous potential benefits they can bring about for the projects and assumes the process of implementation of a GVET as an isolated project. The study then highlights the well-known main areas of necessary knowledge for managing a GVET project within the construction context based on a project lifecycle approach. [5]

In South Korea, success model of project management information system in construction has been recognized. The proposed success model consists of seven factors including system quality, information quality, and service quality, intention of PMIS use, user satisfaction, and impact of efficient construction management and impact of effective construction management. [6]

A construction entreprise readiness level in implementing e-procurement: a system engineering assessment model has been studied in china which pursed to develop a theoretical impact-role-factor assessment model to assist assessment the importance of government, organization, and technology on a construction enterprises' e-procurement implementation readiness level in developing countries. [7]

The impact of emerging information technology on project management for construction has been studied in Canada which discussed a framework for project information management in construction. This paper addresses changes to the practice of project management as a whole. [8]

Integrating information technology in the construction industry: Technology readiness assessment of Malaysian contractors has been studied in Malaysia. Technology readiness index (TRI) which measures people's propensity to embrace and use technologies for accomplishing goals in home life and at work was developed by Parasuraman [Parasuraman A. Technology readiness index (TRI): a multiple-item scale to measure readiness to embrace new technologies. The Malaysian CIDB can accelerate changes, beginning with providing IT training for managers in the construction industry. Investment in human development must be integral to changes that CIDB would like to see happen. For long-term effect, the CIDB should encourage R&D. Very often the construction industry has to wait a couple of years before technologies from other sectors trickle down to it. [9]

Evaluation of CITIS as a collaborative virtual organization for construction project management has been studied in South Korea. The construction CITIS model in Korea is a superior example of how government and industry can work together to implement IT-driven project management tools. To create the CITIS as a virtual cooperation space, it should focus more on flexibility and adaptability to take care of unofficial and informal communication as well as transmission of contractual documents rather than focusing on the contractual side. [10]

VERDICT, an e-readiness assessment application for construction companies has been done in United Kingdom. The construction industry recognizes the potential for the use of e-commerce. To address such a need, the model and e-readiness assessment prototype developed as part of this study will enable construction organizations to successfully adopt e-commerce. This adoption has to be well planned and all the key enabling factors management, process, people and technology must be geared to ensuring beneficial outcomes. The results of this work will be further used to develop appropriate strategies for achieving e-readiness in construction organizations. [11]

## 3. Methodology

According to the literature of research and specialized interviews, seven factors were identified as critical factors affecting Organization Readiness of Engineering Project Management based on Virtual Teams Infrastructure, Deliverables (Drawings, Reports, Minutes of Meetings, Letters and Invoices), Human Resources, Information Technology and Communications, Organization Chart, Financial Resources and Business Environment Factors. Then, it is time to recognize the pattern of the relations between them. Interviews were used to understand the internal relations among the main factors from the perspective of experts. In order to get feedback from the experts of this system, it is necessary to prepare a questionnaire for these criteria, in order to make a proper decision regarding the importance of organizational readiness criteria, and the relations between them is asked by the experts. To verify the validity of the questionnaire, Cronbach's alpha method was used in SPSS and based on the results, the required level was obtained.

In this research, interpretive structural modeling approach has been used. An interpretive structural approach analyzes the relations between factors in a multi-level analysis of the factors and examines the relations between these features.

One of the advantages of the ISM approach is its analytical approach compared with other models, and the use of the MICMAC analysis is that by giving it a comprehensive analysis it is superior to other analytical models.

As stated in the initial definition of the model, after identifying the factors, the relationship between factors was studied using the known parameters in the model. These parameters are:

O: No relation between the factors,

X: Both direction relations,

A: Relation from factor j to factor i

V: Relation from factor i to factor j

The self-interaction matrix consists of the factors and indicators studied and their comparison using the four modes of conceptual relations (O, X, A, V). This matrix was completed by a questionnaire of experts and experts in this field.

The initial reachability matrix is obtained by converting the self-interaction binary matrix of one and zeros. In the matrix, the diameter values are set to one to ensure that the secondary relations are controlled.

In fact, factor 1 leads to factor 2, then factor 2 lead to factor 3. If direct effects are taken into account on the basis of secondary relations, however, in real practice this is not happening. The table should be corrected and the secondary relationship should be shown.

With the sum of rows, the degree of drive power and sum of columns of the degree of dependency are calculated. The purpose of the MICMAC analysis is to diagnose and to analyze the power of the drive and dependency of the variables. In this analysis, variables are divided into the following four groups according to the power of drive and dependency:

Autonomous factors: These factors have weak drive power and weak dependence power. They are relatively disconnected from the system, with which they have only few links which may be very strong.

Linkage factors: These factors have strong drive power as well as strong dependence power. These factors are unstable. In fact any action on these factors will have an effect on others and also a feedback effect on themselves.

Dependent factors: These factors have weak drive power but strong dependence power.

Independent factors: These factors have strong drive power but weak dependence power. A factor with a very strong drive power, called the 'key factor' falls into the category of independent or linkage factor.

To determine the relations and factorization of the factors, the output set and input set for each factor must be extracted from the received matrix. The set of outputs includes the factor itself and the factors that affect it, and the set of inputs includes the factor itself and the factors that affect it.

If the intersection of the set equals to the input set, it will be at the highest level. After determining the level, the criterion eliminates its level in the table from the entire set, and then the input and output set are formed and the next factor level is obtained.

After identifying the first level factors, these factors are eliminated and the set of inputs and outputs are calculated regardless of the first level factors. Then, the intersection set and the factors whose inputs are equal to the input set are selected as second-order factors, thus the other levels, and finally, based on the intersection set of identifiers and the factors whose shares are equal to the input set, as the last-level variables are selected. Therefore, the higher the level of factors, are more effective and the lower level of factors, are less effective.

In the next step, the Eigen Vector to prioritize the following effective metrics will be used.

Table 1
Description Analysis – SPSS Output

| Main Criteria | N | Mean | Std. | min | Max |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Using MATLAB software, the largest value in the Eigen Vector as the most preferred subsection is considered.

## 4. Analysis

The organizational readiness level of a consultant engineer company is determined by the factors influencing the organizational readiness of engineering project management based on virtual teams. This includes Infrastructure, Deliverables (Drawings, Reports, Minutes of Meetings, Letters and Invoices), Human Resources, Information Technology and Communications, Organization Chart, Financial Resources and Business Environment Factors.

Using the Interpretive Structural Modeling (ISM), the importance of the factors and their place were measured and it was observed that human resources and IT were the most effective parameters in this regard.

The self-interaction matrix is composed of those factors and indicators were studied and a comparison was made using four modes of conceptual relations (O, X, A, V). This matrix was completed using data obtained from a questionnaire filled by relevant experts in this field.

Table 2
Self-Interaction Matrix – ISM

| Criteria No. | Self-Interaction Matrix | Financial Resources | Organization Chart | Business Environment Factors | Information Technology and Communications | Human Resources | Deliverables | Infrastructure |
|---|---|---|---|---|---|---|---|---|
| 1 | Infrastructure | O | O | A | X | X | X | |
| 2 | Deliverables | V | X | X | A | A | | |
| 3 | Human Resources | X | X | X | X | | | |
| 4 | Information Technology and Communications | O | O | O | | | | |
| 5 | Business Environment Factors | V | O | | | | | |
| 6 | Organization Chart | X | | | | | | |
| 7 | Financial Resources | | | | | | | |

The initial reachability matrix was obtained by converting the self-interaction matrix to a binary matrix of one and zeros. In the matrix, the diameter values were set equal to one.

Table 3
Initial Reachability Matrix – ISM

| Criteria No. | Initial Reachability Matrix | Infrastructure | Deliverables | Human Resources | Information Technology and Communications | Business Environment Factors | Organization Chart | Financial Resources | The drive power of a factor |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Infrastructure | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 4 |
| 2 | Deliverables | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 5 |
| 3 | Human Resources | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 6 |
| 4 | Information Technology and Communications | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 4 |
| 5 | Business Environment Factors | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 5 |
| 6 | Organization Chart | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 4 |
| 7 | Financial Resources | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 3 |
| The Dependence Power of a factor | | 4 | 6 | 5 | 3 | 3 | 4 | 5 | |

With the sum of rows, the degree of drive power and the sum of the columns of the degree of dependency were calculated. The purpose of the MICMAC analysis was to diagnose and analyze the power of the drive and dependency of the variables.

Table 4
MICMAC Analysis – ISM

Mic Mac Analysis

| Criteria No. | X= Dependency | Y = Drive | Result |
|---|---|---|---|
| 1 | 4 | 4 | Linkage+Dependent+Independent+Autonomous |
| 2 | 6 | 5 | Linkage |
| 3 | 5 | 6 | Linkage |
| 4 | 3 | 4 | Independent+Autonomous |
| 5 | 3 | 5 | Independent |
| 6 | 4 | 4 | Linkage+Dependent+Independent+Autonomous |
| 7 | 5 | 3 | Dependent |

| Drive \ Dependency | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| 7 | | | | | | | |
| 6 | | Linkage | 3 | | | Independent | |
| 5 | | 2 | | | 5 | | |
| 4 | | | | 6 & 1 | 4 | | |
| 3 | | | 7 | | | | |
| 2 | | Dependent | | | | Autonomous | |
| 1 | | | | | | | |

After drawing the ISM model for factorization, and prior to descriptive statistics the nonparametric Friedman test was used. A nonparametric test is equivalent to analyzing variance with intra-group repeated measures for comparing the average of ratings among all group factors processed by SPSS software. Human resources were identified as one of the most important issues in the ISM model based on experts' opinions. Therefore, it was divided into a weighted sub-section and presented in the following Table.

Table 5
Human Resources Subcriteria

| Human Resources Subcriteria | Knowledge | Skills | Salary | Technical Ability |
|---|---|---|---|---|
| Knowledge | 1 | 0.7 | 1 | 0.7 |
| Skills | 1.5 | 1 | 1.5 | 1 |
| Salary | 0 | 0 | 1 | 0 |
| Technical Ability | 1.5 | 1 | 1.5 | 1 |

Using MATLAB software, the largest value in the Eigen vector was considered as the most preferred subsection.

Table 6
Human Resources Subcriteria – MATLAB Output

```
octave:1> Human_Resource=[1 0.7 1 0.7; 1.5 1 1.5 1; 0 0 1 0; 1.5 1 1.5 1]
Human_Resource =

   1.00000   0.70000   1.00000   0.70000
   1.50000   1.00000   1.50000   1.00000
   0.00000   0.00000   1.00000   0.00000
   1.50000   1.00000   1.50000   1.00000

octave:2> eig(Human_Resource)
ans =

   3.0330e+00
  -3.2971e-02
   1.9897e-31
   1.0000e+00
```

Among the subcriteria related to the human resources, priorities are: knowledge, salary, technical ability and skills which affect productivity of virtual teams. To increase productivity of the team, special attention must be paid to the knowledge of human resources. This parameter is more important than the staff salary. However, technical ability is ranked first as the most important subcriteria of human resources.
The Deliverables of this engineering company, includes drawings, reports, minutes of meetings, letters and invoices. It is highlighted that the experts' opinion in general and the way subcriteria are divided and weighted are considered and fed into the ISM model. This information is presented in the following table.

Table 7
Human Resources Subcriteria

| Deliverables Subcriteria | Quality | Time | Cost |
|---|---|---|---|
| Quality | 1 | 2.5 | 1.7 |
| Time | 0.4 | 1 | 0.7 |
| Cost | 0.6 | 1.5 | 1 |

Using MATLAB software, the largest value in the Eigen vector was considered as the most preferred subcriteria.

Table 8
Deliverables Subcriteria – MATLAB Output

```
octave:3> Deliverables=[1 2.5 1.7; 0.4 1 0.7; 0.6 1.5 1]
Deliverables =

   1.00000   2.50000   1.70000
   0.40000   1.00000   0.70000
   0.60000   1.50000   1.00000

octave:4> eig (Deliverables)
ans =

   3.0232e+00
   1.3205e-16
  -2.3155e-02
```

Therefore, among the subsections of the deliverables, priorities are: quality, time, and cost. Virtual teams attempt to increase productivity. One of the most important parameters of productivity is quality, which in this section is considered prior than time and cost and it is used as the most important subcriteria of the deliverables.
The main criteria of the readiness have been identified as the following criteria: Infrastructure, Deliverables (Drawings, Reports, Minutes of Meetings, Letters and Invoices), Human Resources, Information Technology and Communications, Organization Chart, Financial Resources and Business Environment Factors. Effective factors in human resources were: knowledge, skills, salary and technical ability, and factors affecting deliverables were quality, cost and time.
In order to increase productivity, knowledge in human resources has to be increased, leading to improved deliverables quality.

## 5. Results

According to the experts, this field of activity is the factor 1 (infrastructure), which is a combination of interconnected and dependent factors. With moderate dependency, the change in this factor causes a moderate change in the system.

Factors 2 and 3 (deliverables and human resources) are linkage variables. That is why they have a strong leadership and dependency. If a change occurs in the system, it will affect these variables, and vice versa, by changing these variables, strong changes will occur in the whole system.

Factor 4 (ICT) is a combination of autonomous and independent variables. They have a moderate driving power and a weak attachment, therefore, a little connection with the stimulus in the system. Factor 5 (business environment) is an independent variable. That means it has a strong guidance power and the dependence of the entity, thus it plays as a driving force in the system.

Factor 6 (infrastructure and organizational chart) is a combination of all four variables (linkage, independent, Autonomous and dependent). This means that they have a moderate leadership and interdependence, as well as moderate communication and influence.

Finally, factor 7 (financial resources) is a variable dependent. This means that it has a low conductivity and high dependence, and as a result it is a target variable.

## 6. Conclusion

In this pilot study, the company carries out the engineering design at headquarter in the capital city of Iran while site supervision and execution of the projects conducted in different cities of the country. The need for a better integrity between the designers and contractors requires creation of virtual teams in a new way.

Based on the present research, the human resources of the studied company consisting of management, engineers and countenance team, was highly dependent on the use of IT-based facilities. These facilities were: web-based software, internet, LAN, emails, web security systems, online video conferencing. These facilities facilitate information exchange, accurate and up-to-date file updates and rapid decision making without a need for team members to be gathered in a single location.

In order to maximize the productivity of virtual teams using the above-mentioned elements, the company must constantly strive to update the knowledge of its virtual teams in sync with information technology and also to increase the network security and upgrade its IT tools.

The present study was conducted at zero level. It is suggested that future studies cover higher levels. It is also recommended that the sub-criteria of these levels are identified and prioritized. Company financial parameters may be considered in a more complex model. The ISM model might be combined with multi-criteria decision-making models.

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