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DELIVERY OF MUNICIPAL INFRASTRUCTURE PROJECTS: CRITICAL PARAMETERS FOR EFFICIENT MANAGEMENT

Karim M. El-Dash[A], Mohamed Attalla[B]
A Ph.D. Assistant Professor, Civil Engineering, Zagazig University, Egypt
B Ph.D, P.Eng., The Construction Administrator, Toronto District School Board, Toronto, ON, Canada
Adjunct Professor, Civil Engineering, University of Waterloo

ABSTRACT: In the field of civil engineering, municipal infrastructure projects encounter a high level of uncertainties as compared to other types of civil engineering projects. These uncertainties impose a high-risk potential that affects investments in municipal infrastructure, especially in developing countries. These uncertainties establish the need for an efficient project management that decrease or eliminate their impact. This study focuses on the identification and analyses of the critical parameters that lead to efficient project management functions in municipal infrastructure projects in Egypt. The study was conducted through structured interviews with Fifty-one municipal infrastructure professionals who participated in this research. The study identified sixteen critical parameters, which can enhance the over all management of Municipal Infrastructure projects. Through objective statistical analysis the significance of each individual parameter was identified as well as its interdependencies with the other fifteen parameters.

1. INTRODUCTION

The Egyptian Government has invested a large amount of capital in the last two decades to improve the capacity of infrastructure in major cities as well as in other urban and rural regions. Wastewater infrastructure was one of the major areas for these expenditures. These large investments require a high level of control on the cost of projects, quality of deliverables, and the time required for completing the different programs. This high level of control may not be achieved unless the project management capabilities of all stakeholders of the infrastructure management program reach a significant level of efficiency. Investigating and analyzing the strengths and weaknesses in the current project management capabilities and the performance of staff is very crucial to identify any required improvements in the organization (Sing and Shoura, 1999).

Figure 1 shows the conventional triangle of any project management system representing cost, time, and quality. However, the majority of effort is exerted directly to the integration of different management functions such as communication, procurement, risk, and change management (Donaldson, 1999). Management of quality is a significant function since the level of quality management has an impact on the cost of construction, maintenance, and operation of the facility under contemplation (Kuprenas et al, 2000).

The nature of infrastructure projects is different from that of other construction projects in various aspects (Haigh and James, 1991). The main differentiating aspect is the higher risk potential which is associated with infrastructure projects (Songer et al, 1997). This is, even, more dramatic in developing countries where the available data for existing infrastructure facilities is not sufficient to satisfy the needs for future developments (Ezell et al, 2000). This lack of data introduces another challenge to the management of these projects and further emphasizes the need for a high level of control and an efficient project management system.

Fig. 1. Project Management Environment

This paper focuses on the assessment of the current needs in organizations in order to enhance project management functions and performance in municipal infrastructure projects in Egypt. Its purpose is to identify and analyze the critical parameters that lead to efficient project management functions. The paper presents the findings of a study, which was funded by the United States Agency for International Development. Data collection and analyses was performed in a collaborative effort with the General Organization for Sanitary Drainage.

The assessment process was divided into three phases or modules and also each module was divided into six sessions. Fifty-one municipal infrastructure professionals have participated in this research in the three modules. These professionals provided factual information related to the management of municipal infrastructure in a structured interview format.

2. PHASE ONE, DATA COLLECTION AND RESEARCH INTERVIEWS

The first phase included questions and answers related to the organizational structure as well as roles and responsibilities of each position within the structure. It also included brainstorming discussions about the special management environment of municipal infrastructure projects and their specific management needs. The focus was on this risky environment and the need for a deterministic system. The interviews were directed towards the core of project management knowledge areas and their application in the projects completed by the organization lately or being implemented at the time of the investigation. The parameters cited by the participants were grouped and categorized to represent the common difficulties in infrastructure projects. The following subsections present the major outcomes of the initial interviews with research participants, which were handled in six separate sessions.

2.1 The Environment of Infrastructure Projects

The combination of environmental, political, and commercial pressures has led the water and wastewater industry to consider alternative and faster methods of application which means that projects should start earlier and to be completed faster (Songer et al, 1997). This in turn led to consideration of the overall time to plan, design, and construct a project in order to establish where economies in the program could be made. The consequences of these considerations led to the examination of target-cost reimbursable contracts as an alternative method of procurement.

2.2 Authority and Responsibility in Public Projects

The majority of the participants in infrastructure projects whether owners, contractors, subcontractors, or suppliers are not individuals, they are corporations, partnerships, or other forms of business associations. However, decisions and approvals are required on a daily basis during the performance of a construction contract (El-Najdawi et al, 1997). It is obvious that each organization must establish lines of authority by designating individuals who are authorized to make certain decisions (Kuprenas et al, 1999). If lines of authority are established in a careful manner, the project will benefit.

Figure 2 shows the prime parameters that impact decision-making. The fish-bone diagram indicates that authorities and responsibilities are major parameters that affect any successful decision-making process along with clear target, committed management, continuous development, delegation, communication plan and skills, performance measurements, and data analysis.

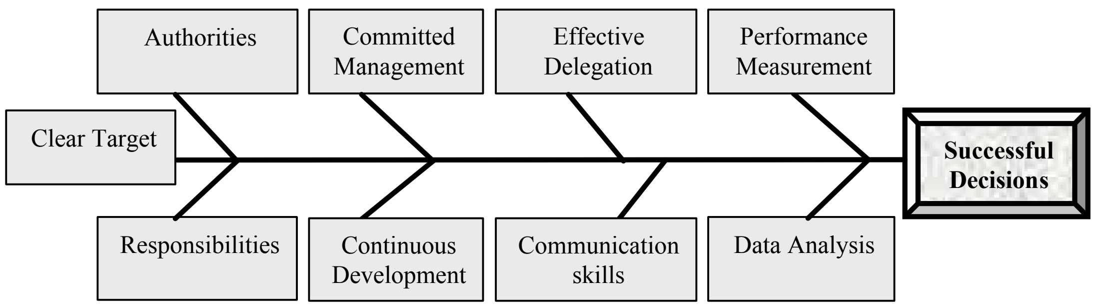

Figure 2 Prime Parameters Affecting Decision Making in Organizations

It was also proven through the interviews that the cycle of gathering, archiving, and retrieving information should be integrated within the structure of the organization as well as an authorities and responsibilities chart. This chart is claimed to be the key to all management processes, which are needed to provide highly efficient projects. The determination of authorities and responsibilities reduces the conflicts among the project's staff and motivate them to concentrate on the progress and achievements through their specific roles in the project.

2.3 Contractor

The participants have indicated that contractor's competency is one of the crucial parameters, which is affecting the overall outcome of infrastructure municipal projects. If the construction firm management system is not appropriate, it will not be able to satisfy the required management level targeted by the owner. In many cases, the contractor fails to provide a reliable project schedule. One reason for this failure may be attributed to the high-risk which is associated with infrastructure projects which also need a high level of scheduling proficiency and experience in predicting these risks and its impact. It was also concluded that the owner and the consultant have a responsibility to review schedules, which are submitted by the contractor.

One of the crucial findings is related to the contractor's Resident Representative. Occasionally, particularly in smaller size projects, the contractor's Representative is not qualified to perform the required project management functions due a variety of reasons. It was found that this parameter has a significant impact on the outcome of the project. This happens although the contract terms states that the existence of a qualified representative is a must as long as there is enduring tasks.

2.4 Communication

Public agencies experience more difficulties in developing strategic partnerships with private organizations than their counterparts in the private sector (Gransberg et al, 1999). This is because public agencies face more constraints in their internal operations and contractual relationships than private organizations. Therefore, building effective intercommunication is attractive to public agencies in improving project performance. Also (Chan et al., 2001) deduced that if interorganizational teamwork is fostered in the project, a successful project outcome would be achieved, project participants would develop a positive view for the project, and their job satisfaction would be higher.

The above concept was handled in this investigation from different perspectives. The interrelationship between the general contractor and the subcontractors depends, partially, on the efficiency of the contractor management tools and techniques. If the general contractor firm is missing the basics of communication necessity, qualified staff and technical devices, it will not be able to fulfill the needs of effective project management. Another parameter is the lack of proper communication between the contractor and the owner or the consultant. To avoid this problem, it was concluded in the investigation that a communication plan should be developed at early phases of the project.

Also, external communication with other infrastructure organizations constitutes an important parameter of project communication due to the possible overlap between the facilities of these organizations. This type of communication is crucial to the efficient management of the project due to the absence of accurate as-built drawings for the existing services, which imposes a high risk on the project. It was also reported during the study that external communication with the community is of high significance to the success of the project.

2.5 Owner Organization

This research has found that existing problems within the owner organization constitute major parameters, which have a major impact on the successful outcome of any infrastructure project. One of these main parameters is the information system. The inadequacy of the information system will render it to be useless either in maintenance, operation phases or for future extensions and renovations.

Also, it was found that the compatibility and accuracy of both design and contract documents is a major source of project management inefficiency since it exposes the owner to a potential cost and time overrun. The qualification of the owner’s personnel was also reported as an important parameter, which may cause the failure of the project. These qualifications may include technical capacities, communication competence, human interrelationship manipulation, and other management skills.

3. PHASE TWO, PRIORITIZATION OF PARAMETERS

The second phase also included six sessions, which were conducted with research participants. This phase included a questionnaire survey, which contained all the findings of the previous six sessions of the first phase. The objective of this questionnaire survey was to collect quantifiable data related to the parameters, which found to impact project management efficiency in municipal infrastructure projects.

Based on the output of these interviews, the sixteen most critical parameters were selected by the discussion groups for further analyses. The research participants were then asked to rank the sixteen parameters according to their impact on the efficient management of the project. Each participant was asked to provide an individual ranking (R_{ij}) for each parameter, which was (1) for parameters that have the least impact on management efficiency, and (16) for the highest impact. A simple weighting system approach was utilized in order to identify, rank and prioritize the most critical sixteen parameters (Besterfield et al.1999). The ranks were accumulated for all of the participants and all parameter and a normalized weighted value for each parameter (w_{ni}) was calculated as per Eq. 1. Figure 3 shows the normalized weighted values (w_{ni}) for the sixteen critical parameters.

[1] $$w_{ni} = \frac{\sum_{j=1}^{m} R_{ij}}{mn} \times 100$$

Where (m) denotes the number of participants and (n) denotes the considered parameters.

The critical parameter, which has the most significant impact on management efficiency of municipal infrastructure projects as shown in Figure. 4 is the comprehensiveness of contract terms. The terms and conditions of the contract should identify and meet all the requirements of the project. The contract language must be integrated with the other project documentation such as drawings and specifications. Also, the ease of the contract language makes it possible for all stakeholders to interpret the contract in the same manner that reduces potential conflicts and changes through and after the project execution. Contractor qualification was second on the prioritized list. If contractor's selection was cost-driven only, this may expose the owner to high risk. The need for reliable schedule that meets the requirements of the owner appears in the third place. A meaningful and realistic schedule must be prepared and agreed upon at the early stages of the project. The fourth position is occupied by communication with other infrastructure organization. The significance of this parameter arises from the fact that it does not take place until a very late stage of the project which make the project suffer from cost overrun and time delay.

Organizational policies and distribution of authorities and responsibilities appeared to be one of the top critical parameters since setting authorities and responsibilities assists in enhancing the accountability of all the participants in the project.

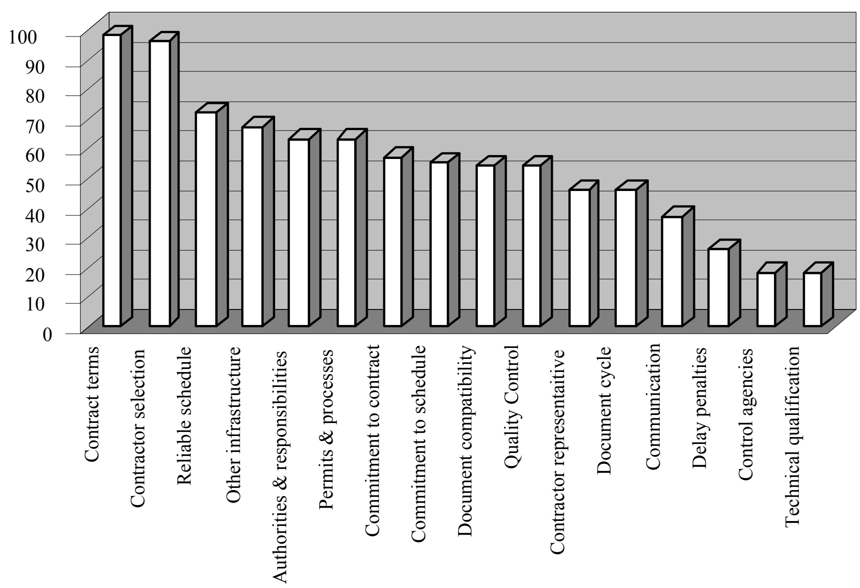

Figure 3 Normalized Weighted Values for the Critical Parameters in Infrastructure Management

4. PHASE THREE, INTERRELATIONSHIP AMONG CRITICAL PARAMETERS

In the third phase, The interdependency of the sixteen critical parameters was investigated and analyzed. Each participant was asked to assign each dual dependency relationship a Dependency Factor (D_f) on a scale from 1 to 5 where (1) is indicating the weakest dependency and (5) is indicating the strongest dependency. Table 2 presents the normalized values for the Dependency Factors of the sixteen parameters.

The Dependency Factors of each parameter were then accumulated generating the Interdependency Factor which resembles the over all interrelationship of each parameter with the other sixteen parameters. This Interdependency Factor (D_{if}) is represented mathematically in the following form:

[2] $$D_{if} = \sum_{i}^{n} D_f$$ where n is the total number of the considered parameters.

The normalized weighted value (w_{ni}) is introduced to calculate the Weight of each parameter (w_i) by the form of:

[3] $$w_i = \frac{w_{ni}}{\sum_{i=1}^{n} w_{ni}}$$

The multiplication product of each parameter's Interdependency Factor and its Weight is called the Interdependency Weight (I_{wi}) and calculated as shown in equation 4.

[4] $$I_{wi} = D_{if} \times w_i$$

The Interdependency Weight is necessary to evaluate the significance of each parameter with respect to its incorporation with other the other parameters in unified management system. The values of the Weights (w_i) and Interdependency Weights (I_{wi}) are given in Table 2. The results show that commitment to contract and communications are the most interactive categories that affect and being affected by other categories in the infrastructure project management process. On the other hand, the weights of the parameters play the dominant role in controlling the value of the Interdependency Weights. Hence, the highest Interdependency Weights were obtained for the requirement of a reliable and controllable schedule and for the comprehensiveness of the contract terms. Note that the late categories had the highest weight values.

The parameters were, then, divided into three management levels, which are Micro, Organization and Macro levels (Han, 2001). The Micro level includes the parameters that contribute directly to the project and controlled by the stakeholders of the project; the Organization level includes the parameters that influence that project as well as other projects within the organization; and the Macro level accounts for the parameters that are associated with the policy and economy of the country. The distribution of the considered parameters among the three management levels is shown in Table 3. The objective of this distribution is to study and analyze the impact of the efficiency or inefficiency of each level of management on the other levels. In order to achieve this objective, the Coefficient of Correlation for each of the sixteen critical parameters is calculated as shown in Table 3. Then an Interdependency Correlation between each level is calculated as shown in Table 4.

Table 2: Dependency Factors and the Interdependency Weights

	Contract terms	Reliable schedule	Commitment to contract	Commitment to schedule	Document compatibility	Quality Control	Contractor representative	Delay penalties	Contractor selection	Authorities & responsibilities	Document cycle	Communication	Control agencies	Technical qualification	Other infrastructure organization	Permits & processes
Contract terms		2	5	4	4	3	1	5	1	2	2	2	2	2	1	1
Reliable schedule	2		5	5	3	1	1	1	1	2	2	3	3	3	3	3
Commitment to contract	5	5		5	4	3	3	5	1	2	3	3	3	3	1	3
Commitment to schedule	4	5	5		2	1	1	1	1	2	2	3	3	3	3	3
Document compatibility	4	3	4	2		2	2	3	1	2	4	4	3	2	1	1
Quality Control	3	1	3	1	2		3	1	1	3	3	3	3	4	1	1
Contractor representative	1	1	2	1	2	3		1	1	2	1	3	3	3	1	1
Delay penalties	5	1	5	1	3	1	1		2	3	2	3	3	3	2	2
Contractor selection	1	1	1	1	1	1	1	2		3	1	1	3	1	1	1
Authorities & responsibilities	2	2	2	2	2	3	2	3	3		3	3	3	3	1	1
Document cycle	2	2	3	2	4	3	1	2	1	3		5	4	3	1	3
Communication	2	3	3	3	4	3	3	3	1	3	5		3	4	3	3
Control agencies	2	3	3	3	3	3	3	3	3	3	4	3		4	1	1
Technical qualification	2	3	3	3	2	4	3	3	1	3	3	4	4		1	1
Other infrastructure organization	1	3	1	3	1	1	1	2	1	1	1	3	1	1		4
Permits & processes	1	3	3	3	1	1	1	2	1	1	3	3	1	1	4	
Interdependency Factor (D_{if})	37	38	48	39	38	33	27	37	20	35	39	46	42	40	25	29
Weight (w_i)	0.113	0.110	0.083	0.077	0.072	0.072	0.066	0.063	0.062	0.062	0.053	0.053	0.043	0.030	0.021	0.021
Interdependency Weight (I_{wi})	4.17	4.19	3.97	3.00	2.75	2.39	1.77	2.34	1.24	2.17	2.06	2.43	1.79	1.20	0.52	0.60

Table 3: Coefficients of Correlation among Different Parameters

	Level	Contract terms	Reliable schedule	Commitment to contract	Commitment to schedule	Document compatibility	Quality Control	Contractor representative	Delay penalties	Contractor selection	Authorities & responsibilities	Document cycle	Communication	Control agencies	Technical qualification	Other infrastructure organization	Permits & processes
Contract terms	Micro		0.36	0.80	0.26	0.42	(0.25)	(0.14)	(0.13)	(0.23)	(0.16)	(0.18)	0.03	0.32	0.21	0.06	0.16
Reliable schedule		0.36		0.42	0.90	0.28	0.02	0.15	0.22	(0.13)	(0.28)	0.10	0.09	(0.03)	0.03	0.35	0.63
Commitment to contract		0.80	0.42		0.51	0.67	0.02	(0.08)	0.22	(0.36)	(0.22)	0.01	(0.01)	0.16	0.20	0.10	0.25
Commitment to schedule		0.26	0.90	0.51		0.43	0.16	0.10	0.48	(0.15)	(0.29)	0.07	(0.04)	(0.13)	(0.05)	0.20	0.46
Document compatibility		0.42	0.28	0.67	0.43		0.49	0.24	0.45	(0.15)	0.29	0.33	0.11	0.41	0.34	(0.32)	0.03
Quality Control		(0.25)	0.02	0.02	0.16	0.49		0.74	0.59	0.18	0.64	0.46	0.06	0.51	0.38	(0.50)	(0.29)
Contractor representative		(0.14)	0.15	(0.08)	0.10	0.24	0.74		0.37	0.21	0.52	0.63	0.36	0.56	0.51	(0.29)	0.06
Delay penalties		(0.13)	0.22	0.22	0.48	0.45	0.59	0.37		0.13	0.05	0.27	(0.09)	0.03	(0.14)	(0.35)	(0.03)
Contractor selection		(0.23)	(0.13)	(0.36)	(0.15)	(0.15)	0.18	0.21	0.13		0.45	(0.08)	(0.48)	0.11	(0.03)	0.16	0.03
Authorities & responsibilities	Organization	(0.16)	(0.28)	(0.22)	(0.29)	0.29	0.64	0.52	0.05	0.45		0.33	0.07	0.80	0.63	(0.31)	(0.24)
Document cycle		(0.18)	0.10	0.01	0.07	0.33	0.46	0.63	0.27	(0.08)	0.33		0.71	0.41	0.40	0.06	0.36
Communication		0.03	0.09	(0.01)	(0.04)	0.11	0.06	0.36	(0.09)	(0.48)	0.07	0.71		0.39	0.41	(0.05)	0.23
Control agencies		0.32	(0.03)	0.16	(0.13)	0.41	0.51	0.56	0.03	0.11	0.80	0.41	0.39		0.71	(0.32)	(0.09)
Technical qualification		0.21	0.03	0.20	(0.05)	0.34	0.38	0.51	(0.14)	(0.03)	0.63	0.40	0.41	0.71		(0.04)	0.04
Other infrastructure organization	Macro	0.06	0.35	0.10	0.20	(0.32)	(0.50)	(0.29)	(0.35)	0.16	(0.31)	0.06	(0.05)	(0.32)	(0.04)		0.79
Permits & processes		0.16	0.63	0.25	0.46	0.03	(0.29)	0.06	(0.03)	0.03	(0.24)	0.36	0.23	(0.09)	0.04	0.79	

Table 4. Interdependency Correlation among Different Management Levels

Management Level	Micro	Organization	Macro
Micro	0.55	0.48	0.35
Organization	0.48	0.59	0.30
Macro	0.35	0.30	0.80

5. CONCLUSION

This study identified the drawbacks and problems that are associated with the management processes in Municipal Infrastructure Projects. Through a structured interview format most critical sixteen parameters were identified. Utilizing mathematical analyses the sixteen parameters were prioritized and their interrelationship was analyzed.

6. ACKNOWLEDGEMENT

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