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Using ANP to Evaluate Factors Affecting Construction Project's Performance

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Abstract*: *The Analytic Network Process (ANP) approach was applied to evaluate the overall project performance. The interdependencies between the performance factors in sanitation infrastructure projects have been modeled, and their cumulative influences were simulated and quantified. This model focuses on the planning and construction phase of projects under unit price contracts and is intended for use by owners, supervision consulting firms (Owner's representative) and/or contractors as well. The proposed model assist both owners, consultants and contractors in controlling projects during the different phases and can also be used as a basis for simulation of various managerial scenarios/interventions to explore the best solution to correct the negative effect of poor performance. The proposed model is generic and may be applicable to almost any project in the construction industry, since all projects, regardless of size or type, follow a broadly similar pattern of development. This model focuses on the two phases; planning phase and construction phase of a project and is intended for implementation by both owners and contractors. Although the proposed evaluation model reflects to a great extent the contractors' preferences, most contractors perceive performance according to project objectives and contractual aspects. The model also reflects to some extent the owner's and/or its consultant's interventions within the different project cycle. Therefore, the objective of this research is not to standardize the priorities of performance factors, but rather to establish a systematic framework for consistent and quantitative evaluation process for performance of planning and construction of sanitation infrastructure projects in Egypt that take into consideration the interdependencies between multi-dimensional performance factors.

Keywords: Factors; Affecting; Construction Project's; Analytic Network Process

I. INTRODUCTION

Improving the performance of sanitation infrastructure projects facilitates the development of an efficient and profitable industry by continuously improving productivity and quality to deliver the best value for money outcomes taking into account the satisfaction of the related stakeholders. An effective performance model for performance monitoring and evaluation is essential to the successful delivery of construction projects. Recently, performance improvement has been the subject of many studies and initiatives in the construction industry because of complex internal and external environment (Robinson et al., 2005). The process of performance evaluation is considered a key component of business development. Therefore, many construction companies implement systems for measuring and evaluating performance. However, construction industry still lacks a practical model for performance evaluation that takes into account the natural interdependency between multi-dimensional performance indicators. This Paper introduces a new model/methodology to evaluate the performance of a construction project through the application of the Analytical Network Process (ANP) approach. The ANP-based methodology is applied to derive the priority weights for the performance factors, which are interdependent by nature. The proposed structure of the model is illustrated and finally the overall project performance is quantitatively determined.

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II. METHODOLOGY

A. Data Collection

Literature review about factors affecting the performance of the construction projects was reviewed (Eleni, et al., 2018), (Abdelnaser, 2010), (S Meeampol & S O Ogunlan, 2006), etc. to identify the factors affecting the cost of projects particularly, (Ephrem, et al., 2017) (Chen, 2007), , (Arshi & Sameh , 2007), etc. to identify another set of factors affecting the schedule of the projects only, (K. & K. N. , 2006), (Grigoroudis, et al., 2006) to identify another set of factors affecting the quality of the project and finally (Abdelnaser, 2015), (Florence & Thi, 2010), (Adnan, et al., 2009),etc. to identify a mixture of factors affecting the project management triangle. The researcher identifies the short list of the factors required to use it in preparing an/a ANP based model.

B. *Decision Support Software (ANP)*

Super Decisions software was used to implement the ANP approach, the major benefit of using the ANP approach is that complex principles can be incorporated into decision-making, using its apps for interdependence and reviews (Bobylev, 2011). This paper adopts the ANP method for deriving the priority weights / relative value of interdependent output factors; hence, to evaluate the overall project performance index.

C. *Advantages of The ANP*

All submitted The power of the ANP lies in its network structure and the use of ratio scales to capture all kinds of interactions and dependencies among the entire decision structure.

Actually, with the use of the expert knowledge, the ANP has proven a success in predicting and decision making in a variety of fields such as economic, transport, political, social, environmental, technological and telecommunications (Gasiea et al., 2010; Bobylev 2011; Topcu and Onar 2011; Saaty and Vargas, 2013a). The advantages of applying the ANP framework to handle the problem of prioritization of the indices can be summarized as follows (Saaty, 2004b; Saaty and Sodenkamp, 2010; Saaty and Vargas, 2013b):

Interdependence: the ANP model can deal with the interaction and dependency among decision levels.

Measurement: the ANP model can handle both quantitative and qualitative data under multiple criteria based on individual or collective judgment of the situation. Network structure: the ANP uses network to model problems instead of a hierarchy, which allows feedback with components having inner and outer dependence among their elements.

Systematic: the ANP is a mathematical theory that makes it possible to deal systematically with all kinds of dependence and feedback.

Consistency: the ANP assesses the logical consistency of judgments by means of a consistency ratio.

Judgments: the ANP ability to incorporate the experience and knowledge of experts to define priorities and weights.
Data Limitations: the ANP model can handle data limitations based on individual or collective judgment of the situation.

D. *Interdependence between the performance factors*

- Generally, many decision makers evaluate performance indicators without considering the interdependency among the indicators or, at most, consider those dependencies in an implicit way, without the possibility of addressing it through a rigorous approach. This could compromise the quality of the results of the evaluation process. The proposed decision model provides a more accurate approach to deal with the evaluation of performance factors.
- The ANP approach is applied to capture the flow of influences among the proposed indices. The decision is decomposed into a rational system, like a network. For the purpose of deriving priority weights /relative importance among the interdependent performance factors of a sanitation infrastructure project, the proposed ANP network consists of two clusters, named: (1) Performance and (2) factors.

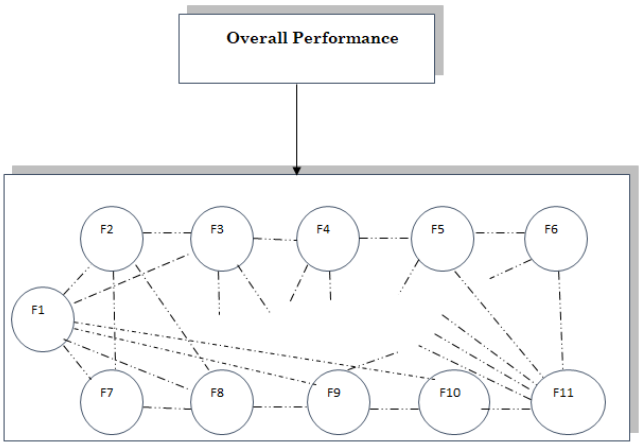


Figure 1 the Proposed ANP-Based Decision Model

E. *Pairwise Comparisons*

It is possible to compare the relative value of clusters.. Saaty (1999a) proposed a scale of 1–9 for relative importance in pairwise comparisons as shown in Table 1

.

Table 1 Fundamental Scale of Absolute Numbers for Pairwise Comparisons (Source: Saaty, 2008b)

Intensity of Importance	Definition	Explanation
1	Equal Importance.	Two indices contribute equally to the project performance.
3	Moderate importance.	Experience and judgment slightly favor one index over another.
5	Strong importance.	Experience and judgment strongly favor one index over another.
7	Very strong or Demonstrated importance.	An index is very strongly favored and its dominance demonstrated in practice.
9	Extreme Importance	The evidence favoring one index over another is of the highest possible order of affirmation.
2,4,6,8	Intermediate values.	When compromise is needed.
Reciprocals of above	If activity has one of the above nonzero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with.	A comparison mandated by choosing the smaller element as the unit to estimate the larger one as a multiple of that unit.

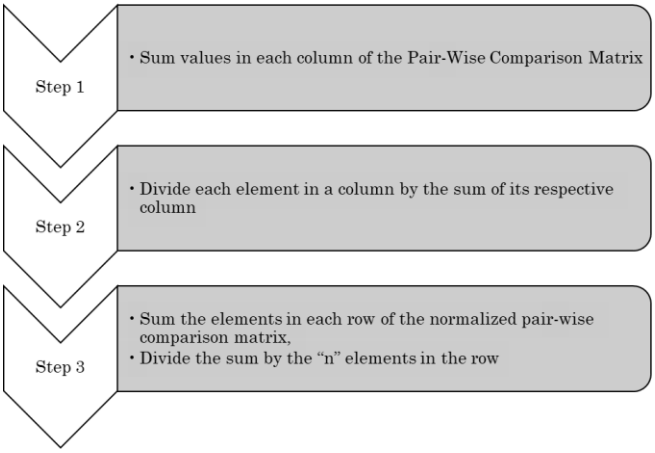
An effective way to concentrate judgment is by comparing a pair of elements on a single property without concern for other properties or other elements.

SMEs are asked to respond to a series of pairwise comparisons of two elements to be evaluated with respect to which element has greater influence on the parent element. The architecture of the proposed ANP model enables the eleven (11) performance factors to be compared with respect to the overall project performance to evaluate their relative importance.

III. RESULTS

As a result, a list of 11 factors was identified that covers various aspects of performance of sanitation infrastructure projects in Egypt.

A. Building the Model



B. Formulations of the Super-matrix

The "Performance" cluster represents the overall performance of the project, while the eleven (11) performance factors are grouped into the cluster named "Indices". In this model, the overall performance is influenced by the proposed factors, which represented by an arrow between the two clusters to indicate the outer dependency. On the other hand, there are various degrees of interdependence between the multi-dimensional performance factors. The looped arc represents the inner dependency among the indices in the same cluster. The proposed model adopts ANP approach as a more general formulation of the AHP, which extends it to cases of dependencies (Saaty, 2008b).

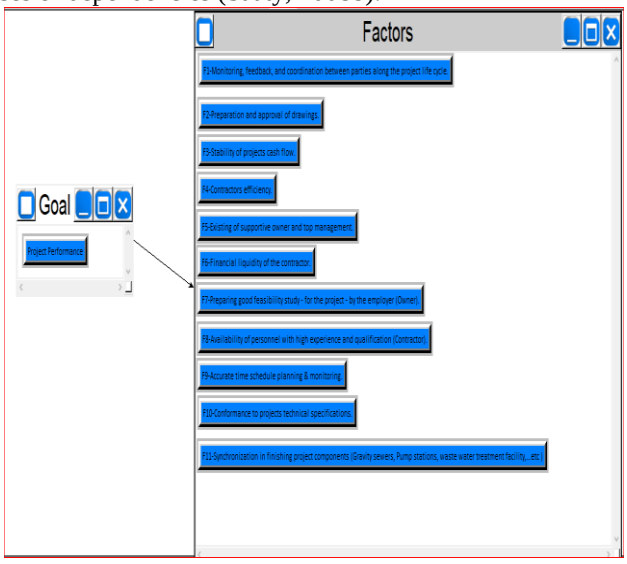


Figure 2 Factors ANP-Based Decision Model

The relative weight of these factors was identified with 15 participants who responded to our questionnaire. An example of a survey question is as follows: "How much more important is Contractor's efficiency than Good feasibility studies? "As shown in figure 3

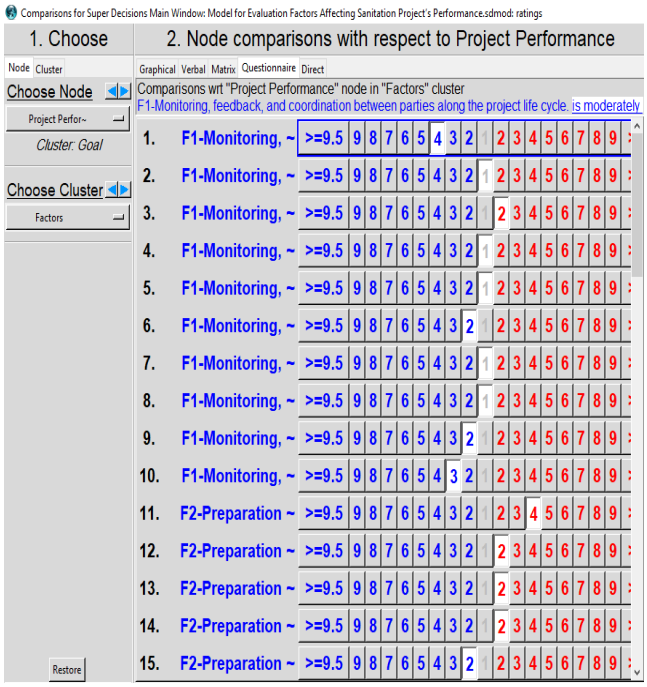


Figure 3 Comparisons Factors ANP-Based Decision Model

The local priority vectors are placed in columns of a super matrix according to the flow of influence from one factor to another, or from a factor to itself. In this model, the priorities of the factors with respect to the overall performance are clearly discernible in the super matrix.

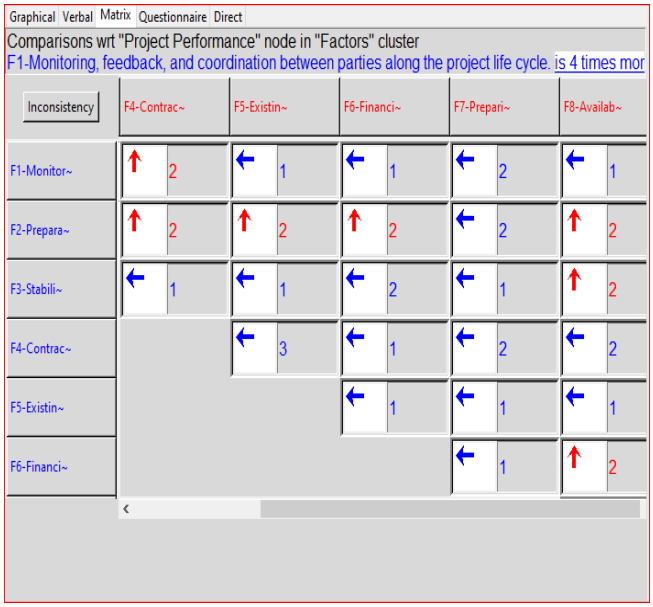


Figure 4 Comparisons Matrix ANP-Based Decision Model

In general, CR value less than 0.1 indicates satisfaction of judgments. Actually, perfect consistency is hard to maintain.

A certain degree of consistency is required in judgments to get valid results for the decision-making process. In case of CR≤ 0.1, the pairwise comparison matrix is considered consistent enough and therefore acceptable (Saaty and Vargas, 2013a). Otherwise, the comparison matrix should be improved, and experts have to reevaluate their judgments.

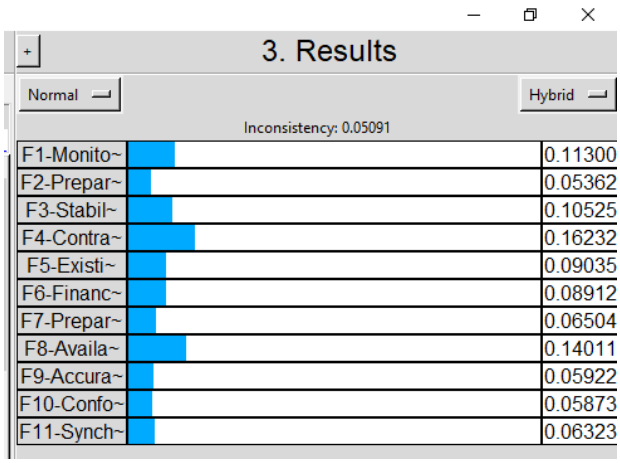


Figure 5 Priority Results ANP-Based Decision Model

IV. SUMMARY AND CONCLUSIONS

This Paper addresses a crucial aspect in the construction project management, which is the proper monitoring and evaluation for the project performance from perspectives of project's owner and contractor. Based on the documented literature review in this thesis, it has been shown that the existing models are usually focused on traditional project performance indices or limited to one or few performance aspects from the contractor perspective only. In addition, this research captured the interactions amongst the different performance factors considered in one inclusive model.

As such, the core contribution of this work is the development of a system to model such interactions. The major research contributions are summarized as follows:

- Identification of the critical factors affecting the sanitation infrastructure projects in Egypt.

- Development of a performance measurement model that applies a systematic method to measure project performance.

- Identification and subsequently modeling the complex interactions and dependencies that occur amongst project performance factors and related variables.

- Development of a tolerated performance-evaluation model based on the ANP approach to be used by the owner and contractor staff.

The developed model is an original work that contributes to the body of knowledge on Egyptian sanitation infrastructure project performance evaluating. This model supports the decision making process by allowing better visibility of the impact of the managerial intervention actions on multiple project objectives over time.

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