Multi-Criteria Decision Model for Evaluation and management of Diverting Utilities Projects in the Old Cities

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Abstract:

The construction of projects within cities with high population density is a common practice for city development, some of which can be a solution to the problem of congestion or the addition of new services to cities such as bridges, tunnels, and new service or residential buildings. To ensure the success of these projects, the existing public utilities should be studied, which in most cases require diversion or connection to link them to the newly developed projects, to avoid negative effects such as an unexpected increase in the cost of diverting them, delayed project schedule or unexpected risks. In this research paper, the previous studies and the necessary items that directly affect project management in general and the management of diverting utilities in particular were compiled and analysed to find out the main factors for different types of projects (underground, above ground and suspended) that may have an effect on utilities diversion during the construction phase. For this purpose, a multi criteria decision model has been developed to evaluate the effect of utilities diversion on projects before construction by introducing the critical parameters included under the project management triangle elements (Time - Cost - Value). A model was developed to help in evaluation of such activities and to rank the project impact on the existing infrastructure, therefore, help the decision maker to take the right/necessary action.

Keywords:
Construction, Decision Support System, Management triangle, Multi-Criteria Decision model, Utilities.

1- Introduction

During the implementation of engineering projects, the surrounding utilities that conflict with the project to be constructed should be studied, necessary data for the existing utilities are to be collected, and then a diverting schedule should be drawn up without affecting the area and assuring the comfort of the residents during the implementation period and after the completion of the project. It is also important to determine the diverting costs or the need of making new temporary or permanent replacements. The success of projects requires the study of the infrastructure and how to deal with them while planning the work of temporary traffic and facilities diversion without affecting the daily life of the population or affecting their needs for water, electricity, sanitation, or communications.

Subsurface Utility Engineering (SUE) is an engineering process that combines civil engineering, geophysics, survey, and Computer-Aided Design and Geographic Information Systems CAD/GIS. Information and coordination on the location and condition of subsurface utilities are collated and assessed to reduce interference and conflict with valuable infrastructure.

The importance of utility coordination for the project and utility owners, designers, engineers, and contractors can significantly benefit during the life cycle of a project to avoid:

1- Community dissatisfactory
2- Environmental effects and drawbacks
3- Unexpected costly solutions for utility conflicts or damage repair
4- Project delays

2- Problem Statement

Over the past few decades, project management tools and technologies have been created to improve the performance of construction projects. Despite the efforts made to enhance their performance, construction projects still suffer from low efficiency. One of the important obstacles to improving the efficiency of construction projects is the disparity between the existing theories in performance assessment and the complex and uncertain nature of modern construction projects. This knowledge gap creates the need for a paradigm shift in performance assessment approaches. In particular, better understanding and improving the ability of project systems to cope with uncertainty is an important element in enhancing performance in complex projects.

To address the limitations in the existing literature and facilitate the paradigm shift, this study investigates resilience in project systems as the ability of project systems to cope with uncertainty. In this study, complex construction projects are conceptualized as complex systems. Accordingly, theoretical underpinnings from complex system science are adopted to propose an integrated framework for performance assessment in construction project systems.

Another important aspect is project resilience. Resilience is an emergent property in a complex system which it hated to system thee the capability in coping with uncertainty. It arises from dynamic behaviors and interdependencies in complex systems. Understanding the determinants of resilience in project systems is essential in improving project performance under uncertainty. However, the current literature in project management and construction has a large gap related to characterizing and examining resilience in construction project systems. For this reason, the results of questionnaires of experts in the infrastructure engineering field and various previous research were used to determine the most important items affecting the management of diverting utilities during construction. (Alkhadrawy et al, 2021).

4- previous study

Different researchers have tried to determine the factors that leads to a successful project. Lists of variables have abounded in the literature, however, no general agreement can be made. Many researchers tried to develop a conceptual framework on critical success factors (CSFs). Seven significant journals in the construction field are chosen to review the previous works on project success. Five major groups of independent variables, namely project-related factors, project procedures, project management actions, human-related factors, and external environment are identified as crucial to project success. Further study on the key performance indicators (KPIs) is needed to determine the causal relationships between CSFs and KPIs. The causal relationships, once identified, will be a useful piece of information to implement a project successfully. (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013).

- <u>Factors Affecting Project Success</u>

There are many variables that have been identified for their direct impact on the success of the project, and they are called critical success factors, which are also an indicator of the success of the project. The factors affecting the success of the project can be divided into five main categories (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013):

A -Project-Related Factors.

B -Procurement-Related Factors.

C -Project Management Factors.

D -Project Participants-Related Factors.

E -External Factors.

A- <u>Project-Related Factors</u>

Its measurement depends on the nature of the project, its type, number of floors, size and complexity (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013).

B- <u>Procurement-Related Factors</u>

To measure this factor, two characteristics are used, the first is the procurement method, such as choosing the entity that will design and implement the project, and the second is tendering process (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013).

C- <u>Project Management Factors</u>

Project management is the path to its success. (Hubbard 1990). Management tools must be used to plan and implement the project to increase the chances of project success. These tools include adequate communication with all parties involved in the project, access to and collection of information, control mechanisms, the ability to troubleshoot and fix errors in a timely manner, effective decision-making, continuous monitoring of the progress of work, setting and achieving time programs, and the use of expertise in Similarly related projects, attention to quality, safety and occupational health standards, business management, and subcontractors contracts, and coordinating all of the above with managerial procedures. (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013).

D- <u>Project Participants-Related Factors</u>

It is summarized in the project participants as the project manager, contractor, customer, consultants, subcontractors, supplier and manufacturers. Contractor, consultants, subcontractor, supplier, and manufacturers. Walker (1995) Construction time depends on the type of client, experience, knowledge of construction project organization, project financing and client confidence in the team. (Albert P. C. Chan; David Scott; and Ada P. L. Chan,2013).

E- External Factors

This factor includes all external influences on the construction process and includes political and social systems. This factor is measured by the economic and physical environment, the level of advanced technology, and the industrial environment. (Kaming et al. 1997 and Songer ; Chua et al. 1999; Walker and Vines 2000).

5- Critical parameters affecting utilities diversion

According to the designed questionnaire results, made for experts in the field of project management and utilities management, table (1) shows the main/critical parameters under the management triangle elements (Cost-Time-Value) that may affect the project, (Alkhadrawy et al, 2021). Noting that the questionnaire included many influential parameters, and the most influential ones were presented.

Table (1). Main critical parameters under the management triangle elements

No.	Item
1-	**Critical parameters related to Cost**
1.1.	Initial cost
1.2.	Construction cost
1.3.	Maintains cost
2-	**Critical parameters related to Time**
2.1.	Target year
2.2.	Construction time
3.	**Critical parameters related to Value (Environment,Efficiency)**
3.1.	**Environment**
3.1.1	Noise pollution
3.1.2	Air pollution
3.1.3	Soil pollution
3.1.4	Heat pollution
3.1.5	Groundwater pollution
3.2.	**Efficiency**
3.2.1.	Performance
3.2.2.	Quality

3.2.3	Durability
5.2.4	Ability of construction

It is worth mentioning that all experts assured that safety parameters in all projects should be taken into consideration as a must with a high priority/stander.

6- Methodology

There are influencing parameters that have a direct impact on project management in general and on managing the infrastructure and utilities diversion associated with the construction activities in particular. According to the management triangle (Time - Value - Cost) they are called critical parameters. There are other parameters that have an indirect impact, but they are of a great importance to the success of the project, such as attention to environmental and social factors. Experts in the field of infrastructure engineering and infrastructure project managers were questioned to determine all the influencing parameters and select the critical parameters.

The questionnaires were designed and their results were used as explained here after;

- The experts in the field completed the questionnaire which was made to determine the parameters weights according to the project type and the project location or situation.
- The parameters weight is determined according to management triangle elements analyzed using the model programmed using Java scripts.
- The weight values for main parameters (Cost, Time & Value) are fixed in all structure types in the same conditions, for comparison purpose only, and may need to differ according to the project condition (i.e., urgent project, environmentally sensitive project, …etc.). While all other sub-parameters weights were adopted as resulted from the questionnaire.
- The user such as project manager entered the weight of all critical parameters according his/her detailed study of the project and different constrains/limitation of construction process.
- The model is analyzed and evaluate the input weights with respect to the expert weights that were entered.
- The project is evaluated as percentage results. Every result is reprehensive as a percentage weight with respect to the main triangle (Cost – Time –Value).
- The previous result for project weight percentage is ranked. Rank is the standard that measure the project impact according to the total evaluation percentage according the following:

  (90-100) %.......Excellent
  (80-90) % …... Very good
  ((70-80) %.........Good
  (60-70) %...........Fair
  (<60) %..............Restudy

- The results can then be presented by chart for the percentage of every project triangle element to help in interpretation of results.
- The evaluation result can help to improve the parameters that have low weights and help the decision maker understating the effect of existing utilities and their management during construction on the cost, value or time of the project.
  Figure (1) shows the methodology process.

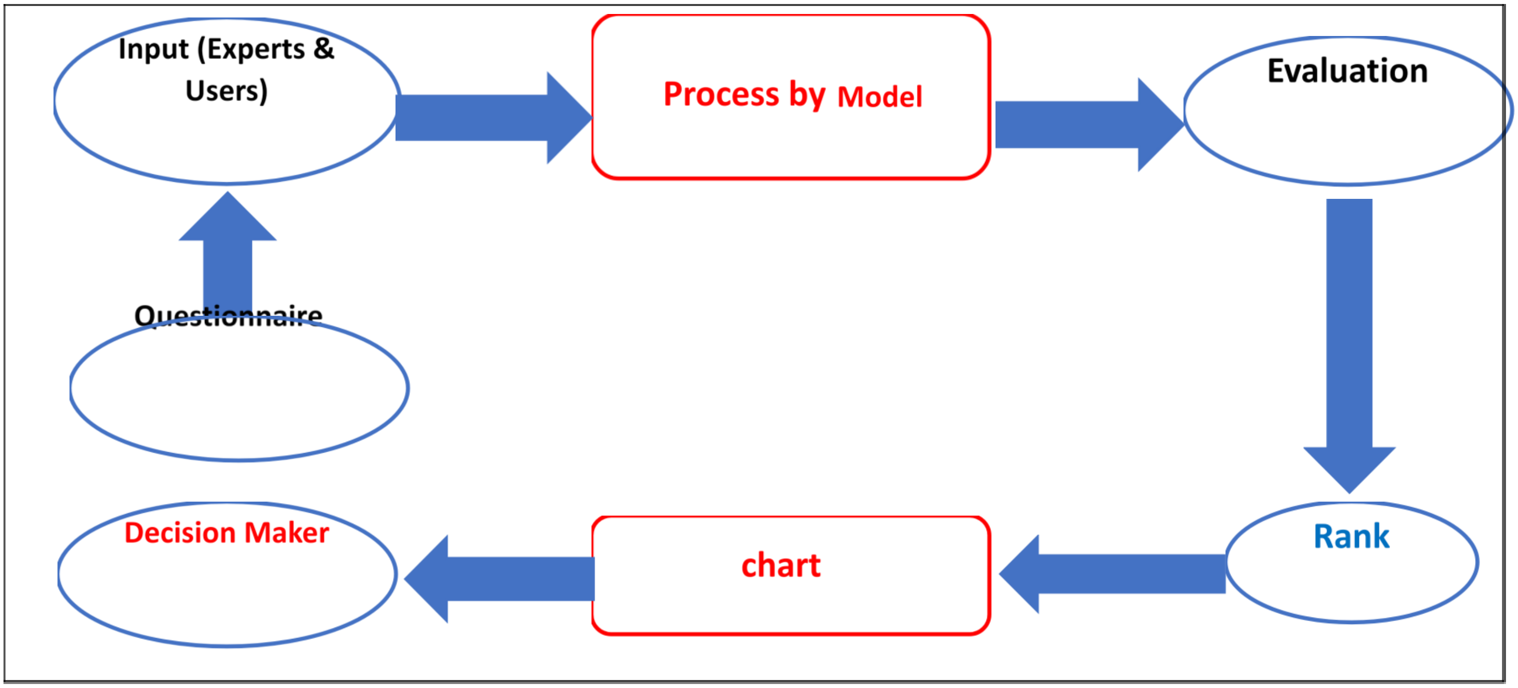

Fig. (1) The methodology of projects evaluation process

7- Multi criteria decision making (MCDM)

Multi-criteria decision making (MCDM) is a process of integrated assessment of projects, alternatives or options for ranking or selecting, priority setting among the finite set of projects, alternatives or options. It is a structured approach to determine overall preference among alternatives, where the alternatives accomplish several objectives.
MCDM methods have been widely used in the area of environmental resources planning and management. (Alkhadrawy et al ,2021), (Riad,2018), and (Recio et al,1999). The following equation was implemented in the developed model to determine the final weight of each criterion:

$$criteriaweight = \frac{X_u}{(X_{Max})} * X_e \ldots\ldots\ldots\ldots..(1)$$

That:

$$X_u = Weightvalue(userinput)$$

$$X_e = Weightvalue(expertinput)$$

$$X_{Max} = MaximumWeight$$

8- Model Development and Implementation:

The Model was designed to be applied for utilities evaluation during the construction of any type of building in general. Figure 2 shows the flow chart of the designed model as will be explained in this section.

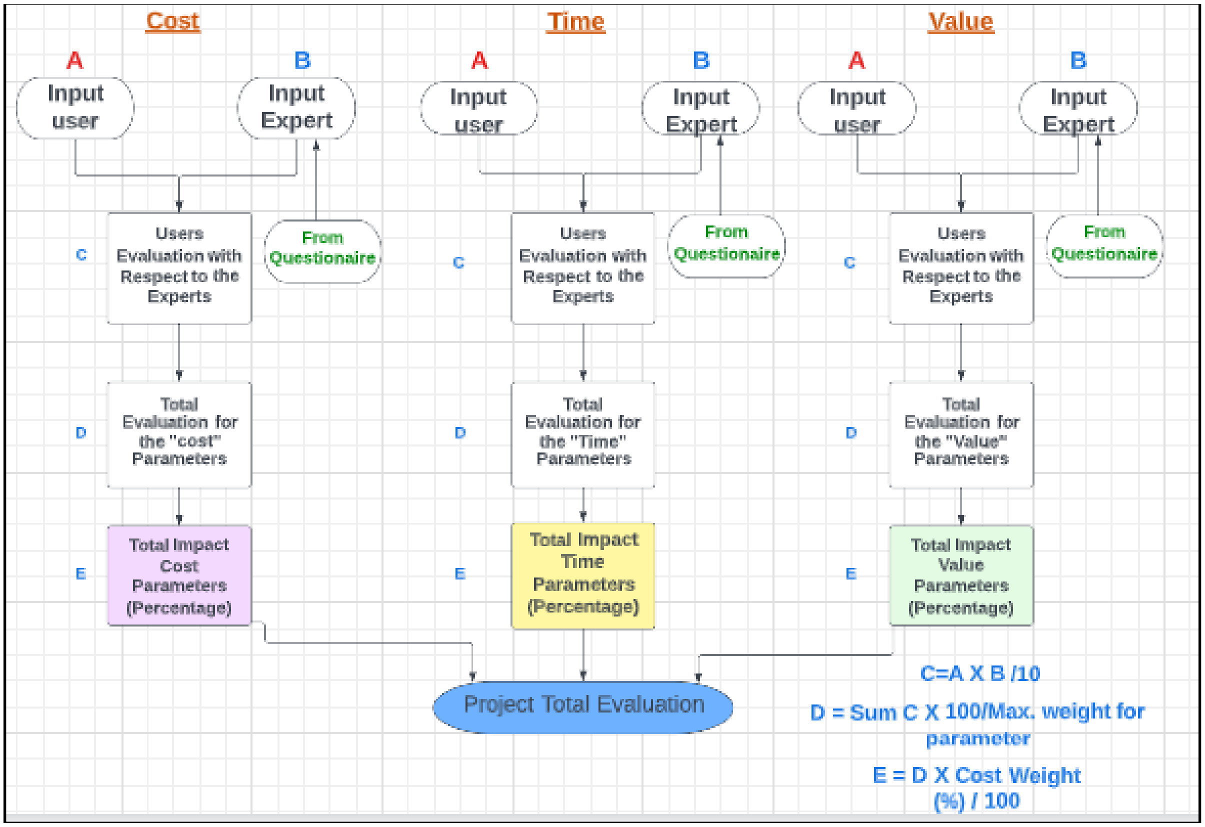

Fig. (2) The model flow chart

The flow chart, is divided into levels (rows) and tracks (column) Under the main element of the management triangle (Cost, Time & Value). Levels (A) and (B) indicates two types of inputs, the first one (A) is from direct user such as project manager and the second input (B) is related to the weights of parameters as defined from questionnaire of expert in similar projects type.

Every parameter weight from (1-10), (1) means that the parameter has a week influence on the project and (10) has a strong influence (Alkhadrawy et al ,2021).

For Example in the (Cost) track, Level C is where the total evaluation with respect to expert is calculated by the percentage of the user input with expert input divided by the maximum weight. Level D is the total evaluation for the cost parameter calculated by the percentage of the total evaluation for the Cost parameter from level C divided by the maximum total weight.

$$Total evaluation for cost = \frac{user input weight}{(maximum weight)} * Input Expert weigh$$

The same is applied for all management triangle elements is the project total evaluation.

Every type of structures can be evaluated by input every item weight according to the impact of/on utilities affected by the expected construction activities and depending on structure type (underground, above ground and suspended).

8.1. Input data:

The input data is the first step in the model that depends on the questionnaire and users as mentioned before and should be entered carefully. The data entered are weights of critical parameters with values ranges between (1-10). 1 means that the parameter has a week influence on the project and (10) means a strong influence. The same type of building in different condition will be given different weights An example for two buildings in same type and different places (i.e. different construction conditions) will be applied in section (9) in order to make a comparison for the critical impact factors on the different buildings types. Yet, the same percentages for management triangle elements [Cost, Time& Value] (Tracks) will be given for simplicity.

8.2. Model data analysis:

The input data are analyzed through the model processes by using multi criteria decision making (MCDM) to calculate the users' evaluation of each criterion with respect to those of the experts in the project as following:

$$usersevaluationw.r.texperts = \frac{usersinput}{(X_{Max})} * expertsquestionnaireoutput$$

That:

$$X_{Max} = Maximumweight\,..(1-10)$$

$$Thetotalevaluationpercentageforcostparameter = \frac{Totalevaluationforcost * 100}{Max.totalweight} \dots\dots\dots.(1)$$

$$Thetotalevaluationpercentagefortimeparameter = \frac{Totalevaluationfortime * 100}{Max.totalweight} \dots\dots\dots.(2)$$

$$Thetotalevaluationpercentagefortimeparameter = \frac{Totalevaluationforvalue * 100}{Max.totalweight} \ldots\ldots\ldots (3)$$

The max. total parameter weight according to the sum of items in every parameter are 30, 20, and 90 for cost, time, and value parameters respectively. Those values depend on the total number of parameters related to the triangle management element

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8.3. Model output:

According to the previous input and model calculations, the project evaluation grade will depend on the percentage of the project total evaluation.

$$Thetotalprojectevaluation = (1) + (2) + (3)$$

The total evaluation score of the project is then used to rank the project as per the below ranking score;

(90-100) %.......Excellent
(80-90) % …... Very good
(70-80) %.........Good
(60-70) %...........Fair
(<60) %..............Restudy

9. The Model Application:

The model can be applied on any type of structure. Yet, in the current work it will be applied to the more critical structures types, to study their influences on the existing infrastructure. These structures are the rested with foundation depths less than 10m, where most of the utilities are located in this range and may need to be diverted before construction.

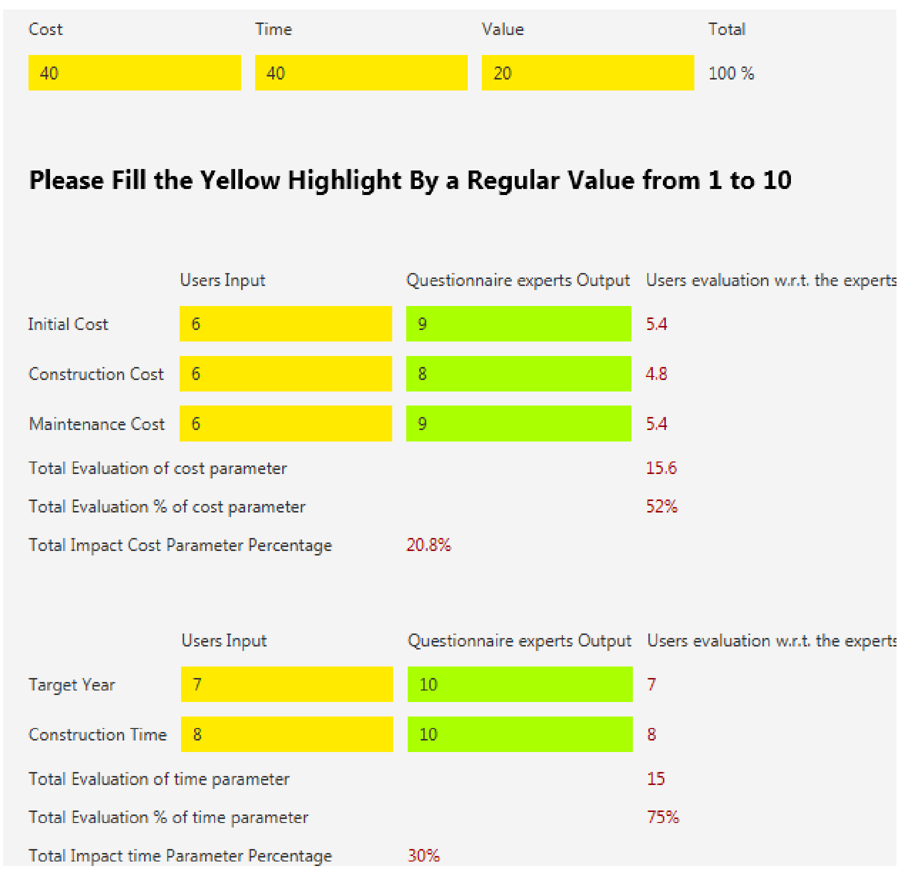
In this practical example a comparison between two projects in different conditions will be carried out. Building (A) is an administrative building in a new urban community and the other one Building (B) is planned to be constructed in a natural protected area.

<u>9.1. Building (A): administrative building in a new urban community</u>

This building will be constructed in the down town of Cairo, Egypt which is very crowded area and needs a lot of diverting utilities taking into account the effect of the daily uses of theses utilities during construction for residents in the area. So, the weight of critical parameters for input data will have high weights for both parameters related to cost and time.

<u>9.1.1. Building (A) Output data:</u>

The output data from the input weights from experts and users as mentioned is evaluated as a percentage that the time has the highest evaluation percentage according to fig. (3) because that the time is very critical parameter for this project according to building crowded location that will be presented with the other parameters in a column chart in fig. (5) that can help the decision makers to make the appropriate decision. The total evaluation rank for the project is fair. This rank is classified as mentioned in section (8.4) that this project has high impact on diverting utilities during construction.



Cost	Time	Value	Total
40	40	20	100 %

Please Fill the Yellow Highlight By a Regular Value from 1 to 10

	Users Input	Questionnaire experts Output	Users evaluation w.r.t. the experts
Initial Cost	6	9	5.4
Construction Cost	6	8	4.8
Maintenance Cost	6	9	5.4
Total Evaluation of cost parameter			15.6
Total Evaluation % of cost parameter			52%
Total Impact Cost Parameter Percentage		20.8%	

	Users Input	Questionnaire experts Output	Users evaluation w.r.t. the experts
Target Year	7	10	7
Construction Time	8	10	8
Total Evaluation of time parameter			15
Total Evaluation % of time parameter			75%
Total Impact time Parameter Percentage		30%	

	Users Input	Questionnaire experts Output	Users evaluation w.r.t. the experts
Noise Pollution	5	5	2.5
Air Pollution	5	8	4
Soil Pollution	10	10	10
Heat Pollution	1	5	0.5
Ground Water Pollution	8	10	8
Performance	10	10	10
Quality	10	10	10
Durability	10	10	10
Ability To Construction	10	10	10
Total Evaluation of value parameter			65
Total Evaluation % of value parameter			72.22%
Total Impact value Parameter Percentage			14.44%
Project Total Evaluation			65.24%
			Fair

Fig. (3) The output data for building (A)

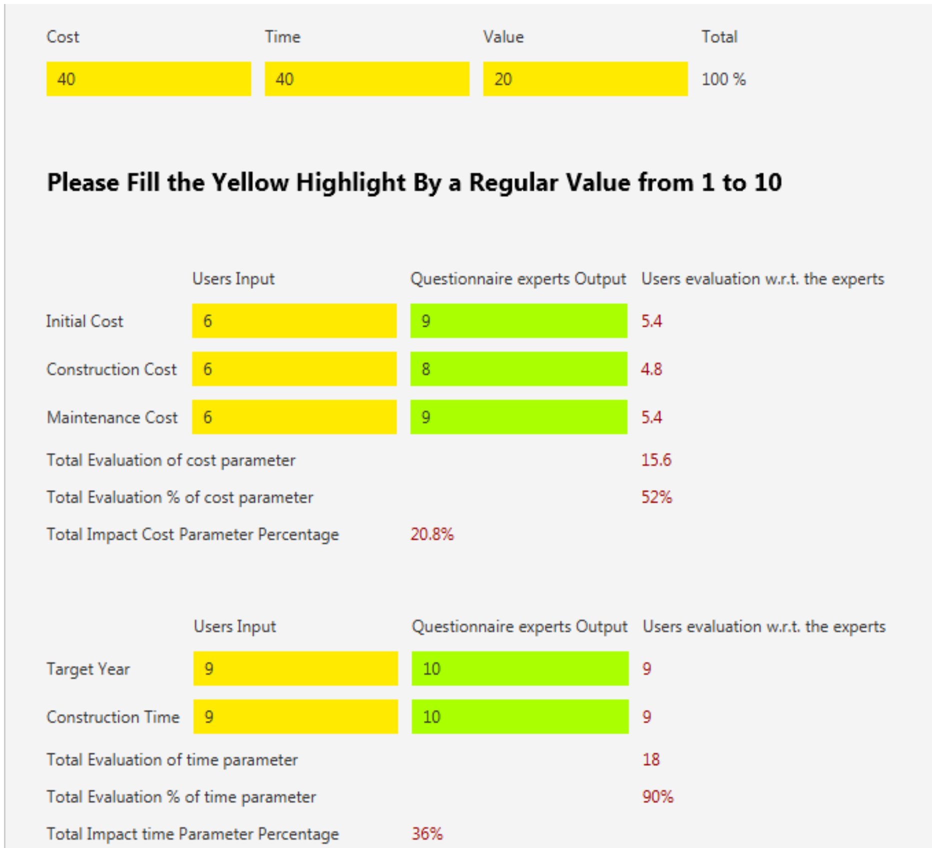
9. 2. Building (B): administrative building in a natural protected area

This building will be constructed in Nabq natural protected area in Sharm El Sheikh city, Egypt. The building is located in an area with low density of population, so the diverting utilities during construction may have low impacts on the residents. So, the weight of critical parameters for the input data will be higher in the "value" parameter, as the environmental impact has very high weight.

Both buildings (A & B) will be applied in the model according to the questionnaire results as follows:

9.2.1. Building (B) Output data:

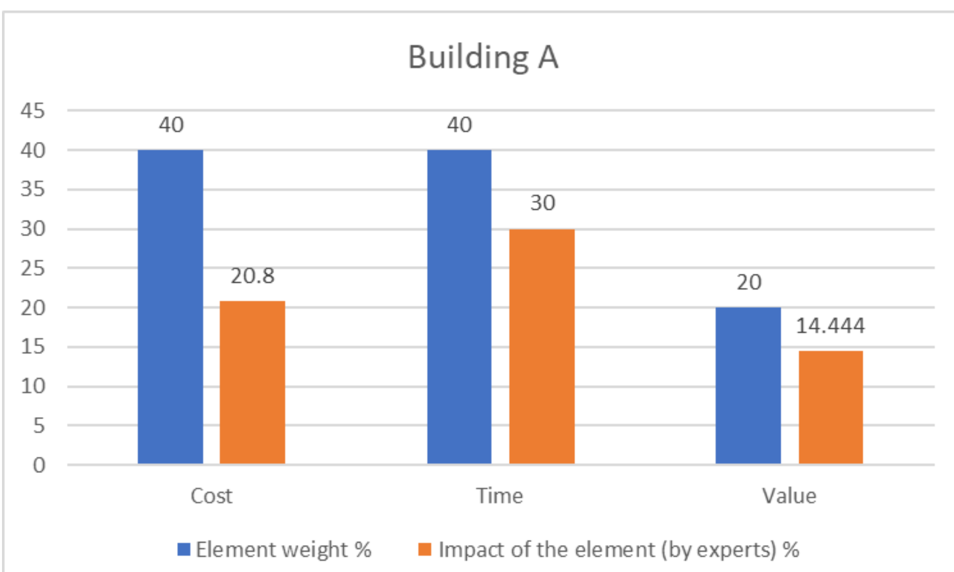
The output data from the input weights from experts and users as mentioned is evaluated as a percentage that the value has the highest evaluation percentage according to fig. (4) because that the environment (soil pollution, air pollution , heat pollution and groundwater pollution) is very critical parameter for this project according to building located in natural protected area .It will be presented with the other parameters in a column chart in fig. (5) that can help the decision makers to make the appropriate decision. The total evaluation rank for the project is good. This rank is classified as mentioned in section (8.4) that this project has high impact on diverting utilities during construction.



	Users Input	Questionnaire experts Output	Users evaluation w.r.t. the experts
Noise Pollution	5	5	2.5
Air Pollution	10	10	10
Soil Pollution	10	10	10
Heat Pollution	1	5	0.5
Ground Water Pollution	10	10	10
Performance	10	10	10
Quality	10	10	10
Durability	10	10	10
Ability To Construction	10	10	10
Total Evaluation of value parameter			73
Total Evaluation % of value parameter			81.11%
Total Impact value Parameter Percentage			16.22%
Project Total Evaluation			73.02%
			Good

Fig. (4) The output data for building (B)

From above results between building (A & B) the building (B) has higher evaluation which means that it has less impacts on diverting utilities compared with building (A).



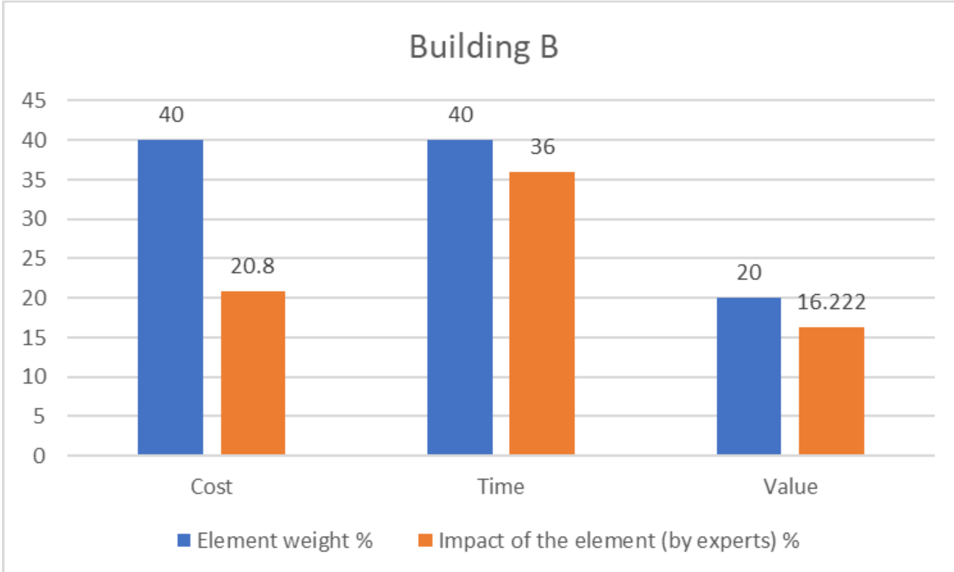


Fig. (5) Column charts for impacts of management elements on diverting utilities in buildings (A) and (B)

The charts results shown in fig. (5) explain the percentage of every impact value management element (Cost, Time & Value) with respect to the percentage that achieved. These charts can help in identifying the weakness parameters to restudy and improve them for decision support system (DSS). The percentage of the "value" element is lowest for building (A) than building (B), which is existing in protected natural area. It can be improving the "cost" element for building (A) to increase the total rank.

10. conclusions:

According to the results of the model for evaluating the effects of constructing different types of structures on utilities diversion, conclusions can be summarized in the following points:

- A new model programmed to evaluate the impacts of the projects on diverting utilities before construction was built and tested.
- The expert's questionnaire is basic factor for input data that differs from a project to another according to its type or conditions as mentioned.
- The critical parameters factors are changed according to the structure type (suspended, Overground structures rested, Underground structures).

- The final evaluation is according to the sum of total weights and the grade of the project impact on the diverting utilities and rank the project before construction that can help to improve the element weight by restudy the project again.
- The results of the model represent a guide for the way forward for restudying or improving the shortage in any evaluation percentage for the parameters impacts.
- The model can help for decision support system (DSS) that some projects, which have ranks less than 60% to be restudied.

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