American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-8, Issue-7, pp-77-90
www.ajer.org
Research Paper Open Access

Evaluation of Bridges' Maintenance Systems Alternatives Using Value Engineering In Developing Countries (Case Study)

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ABSTRACT: *The maintenance and strengthening of reinforced concrete bridges operations considered one of the most important factors that enlarge the whole life of the bridge, as well as reduce the risk of accidents on the bridges and roads. Thus the objective of this paper is to determine the most appropriate repair and strengthening methods, using the Value Engineering concepts, which is used for comparing the different columns, beams strengthening and slabs topping methods, for achieving the required basic function after considering the main significant factors and without affecting the desired quality. Value Engineering is an organized process that has been effectively used by a wide range of companies and establishments to achieve function improvement, time reduction, and improving performance. The potential use of the VE process can be used effectively in developing the optimum maintenance systems of bridges finding that the appropriate alternative in reinforced concrete beams strengthening method was Carbon Fiber Reinforced Polymer Jacket, and Topping with High Strength Concrete is the appropriate alternative in slabs topping system in reinforced concrete bridges.*
KEYWORDS: *repair of bridges, strengthening, value engineering, function analysis, value index, jacketing and slabs topping.*

Date of Submission: 26-06-2019 Date of acceptance: 11-07-2019

I. INTRODUCTION AND LITERATURE REVIEW

1.1. Strengthening and repair of bridges:

In the past two decades, rapid deterioration of bridge structures has become a serious technical and economic problem in many countries. The issue of maintaining the bridges has, therefore, become one of the most important challenges in the bridge industry. The term maintenance is usually defined as the systematic works performed by maintenance departments to ensure the functionality of bridges and safety of the users. It usually includes inspection, maintenance, repair and strengthening (MR&S) and replacement of the whole or a part of a bridge [16].

At the same time, (MR&S) of bridges is very expensive items that involve large investments which are not always available to the transportation agencies [6].

Most strengthening systems are composed of a composite strengthening system. The composite strengthening could be achieved by section enlargement, external post-tensioning, externally bonded steel elements, advanced fiber-reinforced polymer (FRP) composites, or a combination of these techniques. It should be tailored to serve the intended use for the designed service life of the structure without interfering with its functionality [11].

Therefore, it was necessary to study the various methods of (MR&S) until we reach the most quality and lowest prices.

Reinforced Concrete Jacket provides a better solution for avoiding buckling problems [23], the size of the jacket and the number and diameter of the steel bars used in the jacketing process depend on the structural analysis that was made to the column or beam. In some cases, before this technique is carried out, we need to

reduce or even eliminate temporarily the loads applied to the member; this is done by using mechanical jacks [15].

Steel jacket technique is chosen when increasing the cross-sectional area of the column is not permitted. Steel jacketing has been proven to be an effective technique to enhance the seismic performance of old bridge columns and beams. The steel jacket is manufactured in two shell pieces and welded in the field around the member. However, this method requires difficult welding work and, in the long term, the potential problem of corrosion remains unsolved [4].

FRP wrapping has emerged as an alternative to traditional materials for repair of concrete bridges. It can be used to rehabilitate different structural members of a bridge like columns, girders, and beams to improve the load bearing capacity. The rehabilitation is done by wrapping composite sheets around the structural members. There are many advantages to using FRP composite systems in structural applications. They are corrosion resistant, high strength, lightweight, easy to install and have a Low Impact on the existing dimensions of a structure. They provide life-cycle advantages that make these bridges financially viable even if they do sustain an initial cost premium. But when considering the entire life-cycle of the rehabilitation, the initial material cost of the FRP wrap is only a fraction of the total retrofitting cost; the rest is attributed to the application, labor and maintenance costs. Also, the overall cost of rehabilitation is reduced due to the ease of installing, storage, handling, and transportation benefits of FRP wraps [19].

External prestressing externally prestressed reinforcement technology can well meet the requirements of using load, improve the ultimate bearing capacity, improve the use performance of the old bridge, reduce the reinforcement stress amplitude and control crack, increase the lifespan and durability of the structure. The effect of this strengthening method is good and it's easy to control construction quality. It is a kind of ideal reinforcement method and it has a broad development prospect [9].

Slab topping defined as a layer of the concrete placed on an old, worn out the concrete surface to provide a dense, abrasion-resistant surface, to increase structural depth and strength of the base concrete.

The traditional techniques for strengthening reinforcing concrete slab using section enlargement removing the concrete cover and applying new bottom steel rods to flexural zones of the slab to enhance its positive flexural capacity [11]. There are a lot of concrete mixes used in the topping system. Such as topping with ferrocement, topping with fiber concrete, topping with High Strength Concrete and topping with self-compacted Concrete.

The main objective of this research is to evaluate the techniques of the strengthening methods of bridges and chooses the best alternative techniques by using "the value engineering technique VE".

Where; Value = Quality/Cost [7]. the term quality or performance expresses about the value of the project, product, service, or the system. The results obtained from the study improve the efficiency of the VE as a powerful tool to enhance the quality or the performance of the project, product, service, or system with optimizing the cost.

1.2. Strengthening and repair of bridges:

Value engineering (VE) was introduced into the construction industry in the early 1960s by Dell'Isola and became a trend thereafter. It is a systematic and organized process that maximizes the different values of multi-disciplinary stakeholders in a construction project. Traditionally, VE is a value-enhancing tool rather than just a method of cost-cutting [25].

[10] Assess the value engineering, value analysis and value management of vertical Slip Forming (SF) technology by investigating its performance, cost, constructability, and productivity in construction projects that are matching modern construction technology, VE is a methodology used to analyze the function of the goods and services to obtain the required functions of the user at the lowest total cost without reducing the necessary quality or performance. The approach of VE implemented is concerned with function improvement, time reduction, and improving performance through lesser consumption of energy, as well as, cost reduction.

[2] Described that Value Engineering is not just "good engineering." It is not a suggestion program and it is not a routine project or plan review. It is not a typical cost reduction in that it doesn't "cheapen" the product or service, nor does it "cut corners." Value Engineering simply answers the question "what else will accomplish the purpose of the product, service, or process we are studying?" It stands to reason that any technique so users should be applied to every product, and at each stage of the normal day-to-day development of a highway product. This is not the case. The practice of VE entails a certain amount of expense, that must be justified by potential cost savings. Accordingly, there must be a recognized need for change and a distinct opportunity for financial benefit to warrant the added cost of a VE effort as illustrated in

[3] applied the principles of VE (value engineering) in construction projects, and by covering Bregana-Zagreb-Dubrovnik Motorway construction in Croatia by BECHTEL – ENKA joint venture as the sample project, practices of VE in this project are described. The satisfactory results of time and cost saving are achieved by applying value engineering principles through the VE team during the project preparation phase and

project revision phase. Approximately 43,000,000$ and 12 months of the time were saved in total thanks to all these VE works. This saving provided the builder company with 6% financial saving and 17% work time reduction.

[18] applied the VE principle for different components of the structures relating its quality and quantity to achieve A cost-effective solution. This study mainly focuses on new techniques, methods, and materials that can be adopted in the construction industry, in which, its cost, quality, process time and feasibility are considered. Value Engineering focuses on accomplishing the required functions at the lowest overall cost. It helps in eliminating or minimizing wastage of material, time, and unnecessary cost, which improves value to the customer. And the case study indicates that the proposed value engineering technique can be successfully applied to a real construction project. The proposed technique greatly assists the decision making process to the owner, designer, and the contractors. In addition, this method can be used for the evaluation and selection of any construction system by following the procedure presented in this research.

[13] States that VE is applied in an organized process known as a VE job plan. The purpose of the job plan is to assist a study team to identify and focus on key project functions in a systematic manner, in order to create new ideas that will result in value enhancements. The VE job plan consists of five phases: Information Phase, Creative Phase, Evaluation Phase, Development Phase, and Presentation Phase. She also concluded that using value engineering by a multidisciplinary team, value and economy are improved through the study of alternative design concepts, material and construction methods without compromising functional requirement and quality.

[1] Illustrated that VE can be used in many fields such as construction phase, government, and privet sector construction. Also the VE studies in transportation and bridges.

[14] Applied the value engineering technique on box-girder bridges which consider as one of the most common systems of Nile bridges constructed in Egypt. By using the machine learning model that developed to determine the most appropriate box-girder bridge construction method, using the Value Engineering concepts, the results improve the importance of applying the VE technique and recommended to use this technique for other materials like steel bridges, and other different bridge cross sections.

[28] Mention that all VE methodology should contain the following minimal essential features: i. Description of the objectives and scope of the project in enough detail to assure the direction of the study. ii. Goals for the study. iii. Schedule for completion of each phase of VE including the anticipated VE study timing. iv. Establishment of a target data for the formal presentation of project results.

(SAVE International) Confirmed that Function Analysis (FA) is the foundation of a value methodology and is the key activity that differentiates this body of knowledge from other problem-solving or improvement practices. During the FA phase of the job Plan (JP), functions are identified that describe the work being performed within the scope of the project under study. These functions are described using two words, active verb, and measurable noun pairings".

1.3. Research Objectives:

The objective of this research is to identify the optimum bridges' maintenance systems by using the VE Methodology.

II. THE VALUE METHODOLOGY JOB PLAN

Value Methodology is a systematic process that follows the Job Plan (JP). A value methodology is applied by a multidisciplinary team to improve the value of a project through the analysis of functions. The JP consists of the following sequential phases, as shown in Fig. 1. [10].

- Information phase: In this phase, the project current conditions and identifies the study goals are defined and reviewed.
- Function analysis phase: The functions are defined using two words, active verb/measurable or noun. These functions are reviewed and analyzed to determine which need to meet the project's goals.
- Creative phase: Create techniques are employed to perform the function of the project by identifying other ways.
- Evaluation phase: A structured evaluation process is followed to select those ideas that offer the value improvement potential while delivering the functions of the project and considering requirements of performance and resource limits.
- Development phase: Development of the selected ideas with a sufficient level of documentation to allow decision makers to determine if the alternative should be implemented.
- Presentation phase: Development of a report that documents and coveys the adequacy of the alternatives.

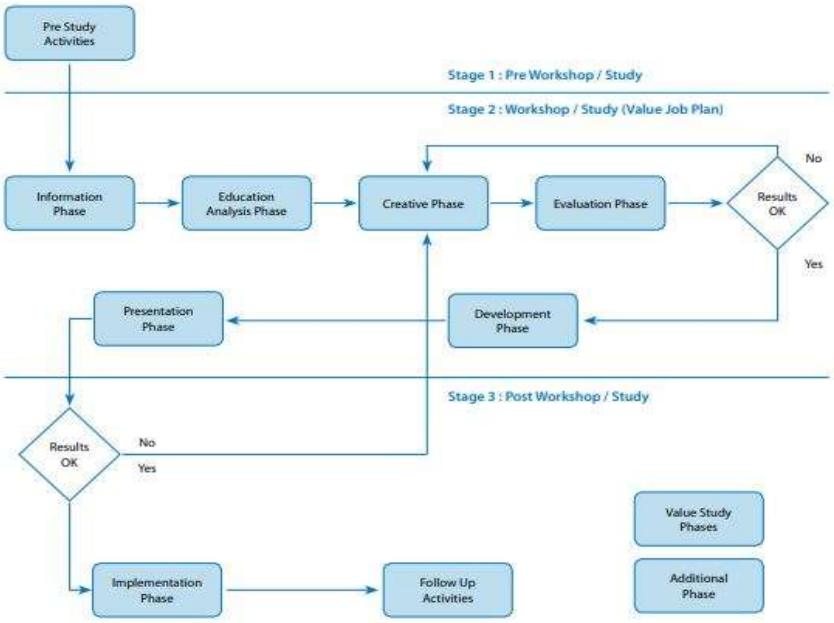

Fig. 1. VE Process flow diagram

Value engineering methodology has been defined as a systematic approach of recognized techniques by a multidisciplinary team(s) that identifies the function of a product or service, establishes a worth for that function, generates alternatives through the use of team creative thinking and provides needed functions, reliably at the lowest overall cost [20].

From this definition, it is clear that effective value engineering process needs to combine an effective team. The team members will be involved in the creative development of systems' alternatives in which they subsequently select the best alternatives that benefit the project at the lowest overall cost and at the greatest level of performance and quality. Overall, the value engineering process needs effective human factor ingrained so as to actively reach decisions that meet clients'/owners' requirements [27].

And then a questionnaire designed instead of the value study team to become this research mainly based on experts' opinions, knowledge and expertise.

III. DATA COLLECTION

Initial interviews conducted with the experts include professionals who are knowledgeable in management, cost, procurement, financing, construction, and operation of similar projects in the repair of the reinforced concrete bridges field, the interviewees mentioned the major and frequent issues in R.C. bridges are in the slabs, the columns and the beams of bridges and they treat these problems by:

i) Columns and beams strengthening methods,
ii) Slabs topping.

There were four main objectives of the questionnaire survey:

1. To identify the (MR&S) methods used for reinforced concrete bridges.
2. To ranking the criteria affecting the choice of (MR&S) methods for concrete bridges in order to its importance to consider each factor weight in the evaluated matrix.
3. To familiarize participants with the research, explore their views of resource materials and their willingness to participate in future stages.

The questionnaire was divided into three parts: The first part works as an introduction where the research background was explained and some basic information was required from respondents (e.g., name, organization, etc.). The second part enquired about the most common deteriorated parts in the bridges and its repair methods as shown in fig. 2. The third and the main part require respondents to rank each criterion which affected in the choosing of the repair method according to its importance and evaluate each repair method alternative according to these criteria.

Survey Questionnaire For Msc. Thesis In Structural Engineering (Value Engineering) 2018

6. What is the most common deteriorated part which you repair in the bridges you work?
ما هو الجزء الأكثر تدهوراً في الجزء العلوي للكوبري والذي قمت بصيانته في الكباري التي عملت بها ؟

Bridge Superstructure الجزء العلوي للكوبري	Always دائما	Often أحيانا	Rarely نادرا	Never أبدا
Bridge slabs بلاطة الكوبري				
Girders الكمرات				
Expansion Joints فواصل التمدد				
Bridge Substructure الجزء السفلي للكوبري	**Always دائما**	**Often أحيانا**	**Rarely نادرا**	**Never أبدا**
Bridge Columns أعمدة الكوبري				
Bridge Bearings كراسي الارتكاز				
Bridge Abutments أكتاف الكوبري				
Bridge Foundations أساسات الكوبري	**Always دائما**	**Often أحيانا**	**Rarely نادرا**	**Never أبدا**
Piles الخوازيق				
Pile caps هامات الخوازيق				

Fig. 2. A sample of the questions contained in the questionnaire

IV. SURVEY RESULTS AND ANALYSIS

Seventy-five questionnaires were returned, out of the 105 questionnaires sent. Seventy-four questionnaires were usable, which represents a response rate of 70 % as shown in table 1, and is relatively high when compared to what [8]. conceive in this type of survey: 25-35% response rate. This high response rate may be attributed to the fact that most respondents have been contacted by phone and were handed the questionnaires by the researcher himself or by a special messenger.

Table 1. Questionnaire survey responses

Number of questionnaires sent	**105**
Number of replies received	**75**
Number of usable replies	**74**
Percentage of usable replies	**70 %**

20% percent of the responses received were from consultants, 57% from contractors, 17% from owners and 6% not mentioned. As shown in Fig. 3.

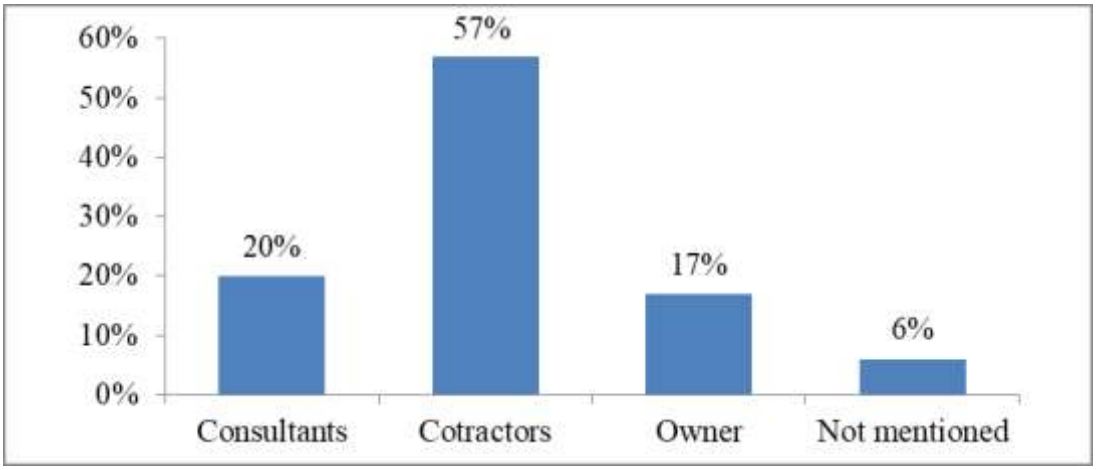

Fig. 3. The decision makers of the repair methods

The respondents who had 20 years or over of experience were 20% of the total responses, 27% of the respondents had between 10 to less than 20 years of experience, while 53 % had between 1 to less than 10 years of experience. As shown in Fig. 4.

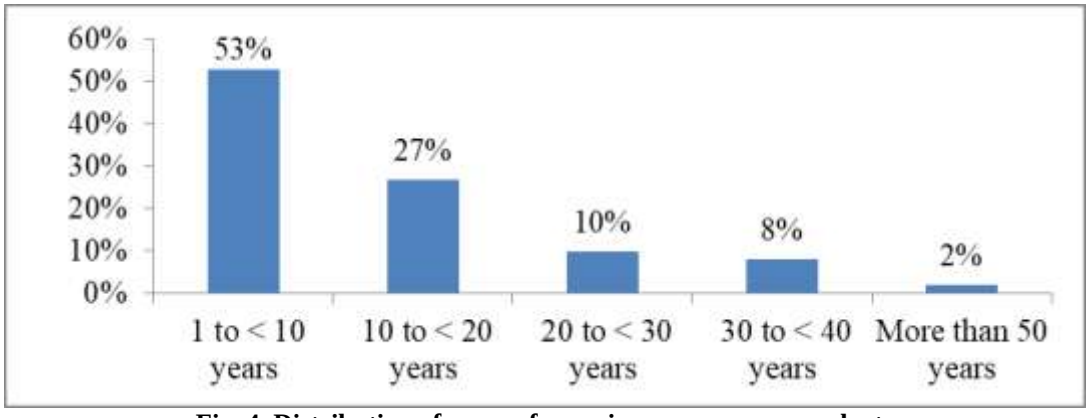

Fig. 4. Distribution of years of experience among respondents

The application of various tools in the decision-making process such as Pareto's principle is a very actual and essential aspect of the decision-making process [23].

Law of Pareto of the 80/20 law is found by an Italian economist, Vilfredo Pareto. Pareto stated that 80% outcome is the result from 20% income. 80% reaction is caused from 20% action, or 80% result comes from 20% effort [17].

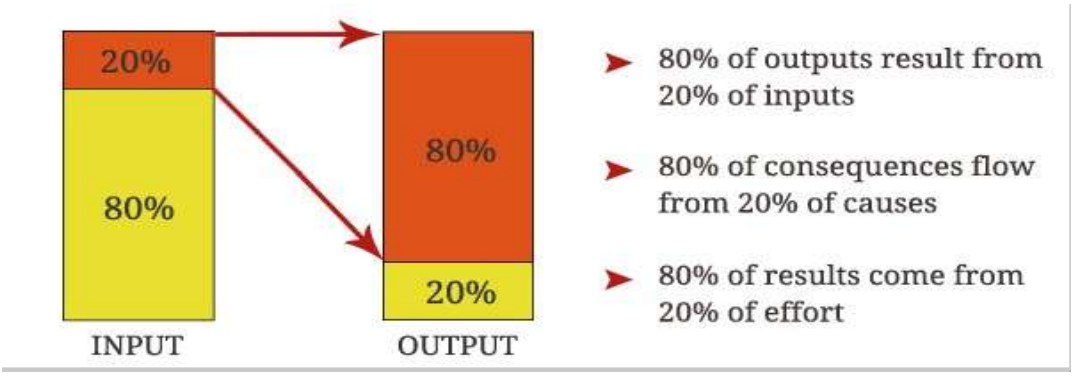

Fig. 5. "The 80/20 Principle" according to Pareto's Law

Before analyzing the results of the questionnaire, it was noted that 20% of the respondents were the most experienced in the bridges repair field and the questionnaire result should be more dependent on the answers of these experts, So, in the questionnaire analysis stage, this paper relied on the application of Pareto**'s** principle by using its benefits to improve the decision-making process.

V. CASE STUDY OF (MR&S) METHODS OF BRIDGES USING VALUE ENGINEERING

5.1 The pre-study phase:

The deterioration of existing bridges is a major problem in the operation of the nation's highway bridges. The number of bridges in Egypt approximately is 1,705 bridges as shown in table 2, the General Authority for Roads, Bridges and Land Transport (GRBLT) reported that bridge passed more than 40 years in service considered to be damaged occupied more than 60% of the whole [21].

As shown in Table 2, surface bridges represent 65% of the total bridges in Egypt. Therefore, the case study of these bridges was chosen because it is the most prevalent in the country.

Table 2. Number of bridges in GARBLT

Bridge type	Number of bridges
Cable Stayed Bridge	2
Bridges over the Nile	31
Upper Bridge	475
Surface Bridge	1,106
Movable Bridge	91
Total	**1,705**

5.1.1 Information phase:

All necessary and possible information regarding the project were collected by visiting the site office and company directly to get all the project information.

❖ Project information:

- Project Name: I
- The Owner: General Authority for Roads, Bridges, and Land Transport (GARBLT).
- The Contractor: General Nile Company for Roads and Bridges (NC)
- Consultants: Nile Engineering Consulting Office (NECB),

Arabian Group Office (quality control consultant).

❖ Main Features of the Project:

- The project is a surface bridge crossing the highway, Egypt,
- The length of the bridge is around 200 m, and the width is 24 m (two lanes),
- The structural system: a concrete slab with main and secondary reinforced concrete beams stayed on concrete columns and the foundations are reinforced concrete piles.

The information includes criteria which have Impact on (M.R. &S.) of bridges, Alternatives available for maintenance and technical aspects of the projects. The data were collected through meetings, interviews, and questionnaire with the owner, consultants, and contractors.

The interviewees identified ten criteria which they considered important in the selection process. These criteria are Service life, Durability & Sustainability, Skilled labor, Constructability, Bridge location, Time of implementation, Relevant of the element, Bridge importance, Site & Environmental conditions and Ease of implementation.

Table 3. Criteria which have Impacted on (M.R. &S.) of bridges

Criteria	
Service life	Time of implementation
Durability & Sustainability	Relevant of the element
Skilled labor	Bridge importance
Constructability	Site & Environmental conditions
Bridge location	Ease of implementation

After answering these questions, the respondents were asked to rank the factors mentioned in the questionnaires from the most important (1) to the least important (10). The average rank was calculated. This process is important to know the most important factors, therefore, will be taken in to account on the study to compare the alternatives with respect to their importance. The parameters which will be selected for the VE study are shown in table (4).

Table 4. The studying criteria ranking

ID	Criteria	Ranking	ID	Criteria	Ranking
A	Service life	4	F	Site & Environmental conditions	3
B	Availability of raw materials	7	**G**	Bridge location	1
C	Constructability	2	**H**	Time of implementation	6
D	Durability& Sustainability	1	**I**	Bridge importance	5

5.1.2 Function analysis phase:

This phase includes the fast diagram FA for the strengthening technique by applying the FAST diagram procedure to understand the functions of the system and determining the scope of the study as shown in figure 6, 7. This made by identifying the objectives of the value study, the high order function, the basic function, the required secondary functions that help to achieve the basic function and so the low order function by using the how and why logic path technique which is; from the left to the right direction the function have to respond on the question of how to achieve the previous function for this function. And in the direction from the right to the left the function to have to respond on the question of why making its previous function. So it will be applied the FAST diagram on the strengthening technique to determine the items which help to improve the system through it to achieve this study its objective.

a. Function Analysis for the strengthening system:

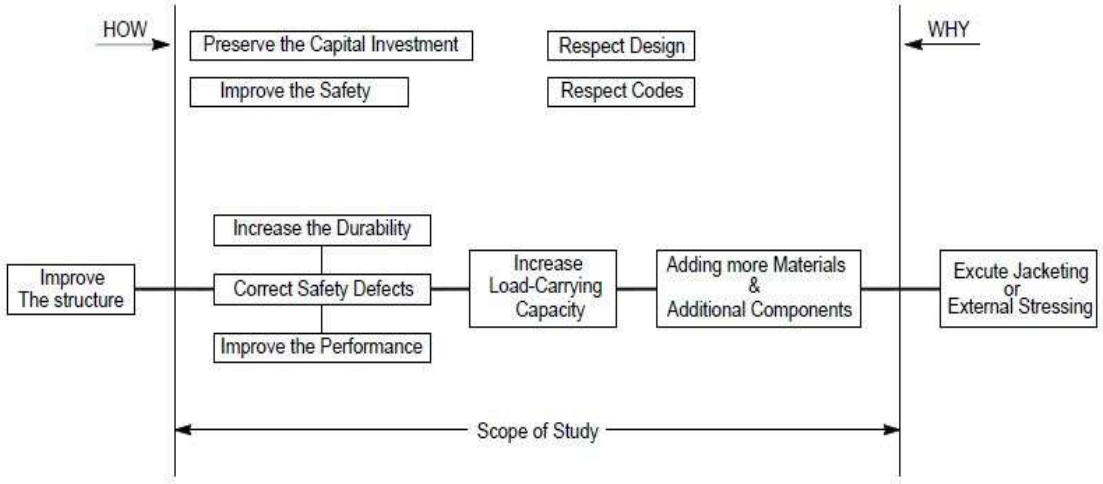

Fig. 6. The FAST diagram for the strengthening system

From the FAST diagram for the strengthening system it was found that; the high order function is: preserve the capital investment and improve the safety, the basic function is improving the structure and the low order function is: execute jacketing or external prestressing with some of the activities which laid under the critical path that helps to achieve the basic function.

b. Function Analysis for the slab topping system:

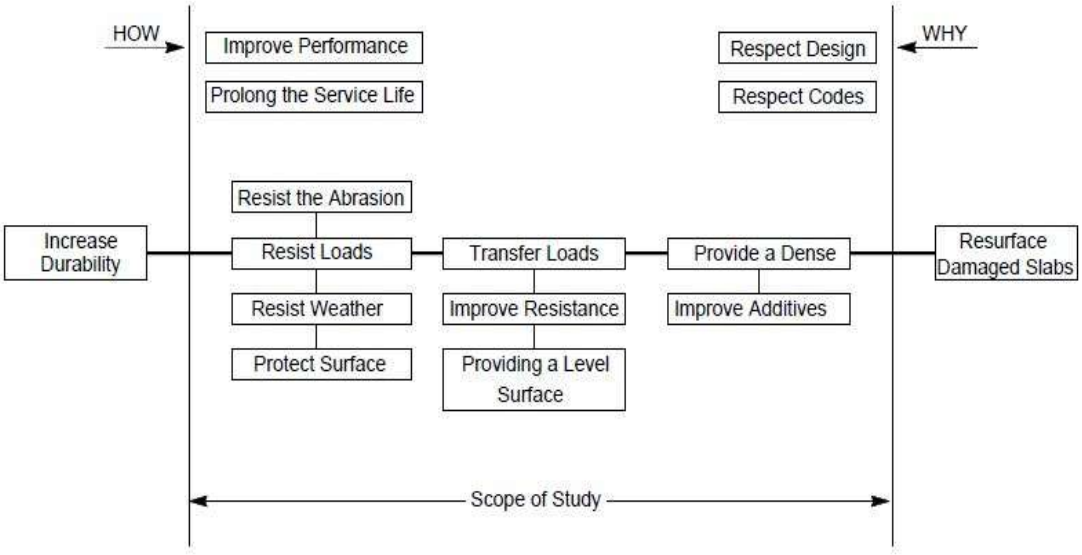

Fig. 7. The FAST diagram for the slab topping system

From the FAST diagram for the slab topping system, it was found that; The high order function is: improve performance; The basic function is: increase durability and the low order function is resurface damaged slabs with some of the activities which laid under the critical path that helps to achieve the basic function.

5.1.3 Creative Phase:

Now we have a full understanding of the project we can start with ideas or so-called creative and brainstorming. there are many creative ways to solve problems, but the most appropriate two methods for the field of value management:

1 - Analytical method: identify the problem and find a direct solution based on mathematical experiments and calculations and in the end we get only one solution.

2- Creative Method: It comes with several solutions that perform the desired purpose and usually there is one perfect solution to the problem.

The use of creative method represents the fundamental roots of the management value of this method has proved its worth [28].

Through this phase is determined the alternatives for each item of those items under study, taking into account the special considerations required availability and characteristics that have been realized through the scope of study from the fast diagram of each item. So it will be as following:

A. For the Strengthening:

In the repair and strengthening field, there are many types of materials that may be used, but there are four types of methods that may be fit with the considerations that have been observed. These are:

1. Reinforced Concrete Jacketing,
2. Fiber Reinforced Polymer Composite Jacket,
3. Steel Jacketing,
4. External prestressing (for beams).

B. For the slab topping system:

There are a lot of mixes of concrete used in the topping system. These alternatives are;

1. Topping with ferrocement,
2. Topping with High Strength Concrete,
4. Topping with fiber concrete,
5. Topping with self-compacted Concrete.

The function of this phase only to find alternatives and then an assessment is made in the next phase.

5.1.4 Evaluation Phase:

In this phase were applied the breakdown analysis for each item for the items under study. Through this procedure will work analysis for each one of the alternatives identified in the previous phase for each item under the study in its individual components and determine its price based on market prices and on previous experiences;

a. Cost analysis for strengthening alternatives:

It was analyzed each alternative of the four alternatives to determine its components and determine the price of each of them and thus the total cost is determined for each one of them.

Table 5. Cost analysis and for strengthening alternatives

Type of strengthening	Components	Cost/ Item/$	Total Cost/Item
Reinforced Concrete Jacket	1-Remove the concrete cover and clean the steel bars. 2- Coat the steel bars with an epoxy material. 3- Drill and clean holes + inject epoxy. 4- Fixing the steel reinforcement. 5- Mixing and pouring. 6- Workmanship. 7- Profits and taxes.	5 $ 200 $ 88 $ 6350 $ 1600$ 5650 $ 5570 $	19463 $
Fiber Reinforced Polymer Composite Jacket	1-Remove the concrete cover and clean the steel bars. 2- Coating the steel bars with an epoxy material. 3- Coating with mortar. 4- Coating with an appropriate epoxy material. 5- Installing the FRP laminates and wraps. 6- Workmanship. 7- Profits and taxes.	5 $ 200 $ 80 $ 1200 $ 6000 $ 300 $ 2900 $	10900 $
Steel Jacket	1-Remove the concrete cover and clean the steel bars. 2- Coating the steel bars with an epoxy material. 3- Coating with mortar. 4- Installing the steel jacket. 5- Apply anti-corruption. 6- Workmanship. 7- Profits and taxes.	5 $ 200 $ 80 $ 13380 $ 1200 $ 8000 $ 9150 $	32015 $
External prestressing	1- Drill, clean and grouting the holes. 2- Fixing the anchorages and supports 3- Install and stress tendons. 4- Workmanship. 5- Profits and taxes.	5 $ 2000 $ 7000 $ 4100 $	18340 $

b. Cost Analysis for slab topping alternatives:

It was analyzed each alternative of the five alternatives to determine its components and determine the price of each of them and thus the total cost is determined for each one of them.

Table 6. Cost Analysis for slab topping alternatives

Type of Topping	Components	Cost/ m2/$	Total Cost/m2
Topping with Ordinary Reinforced Concrete	C.A = 0.8 F.A = 0.4 Cement = 400 Kg/m3 Water = 150 kg/m3 R. steel = 200 kg/m3 Mix + Pouring =17.50$/m3	2.50 $ 35 $ 0.50 $ 26.50 $ 163 $ 17.50 $	245 $
Topping with Ferrocement Concrete	C.A = 0.8 F.A = 0.4 Cement = 400 Kg Water = 200 kg/m3 Metal mesh+ Mortar R. steel = 200 kg/m3 Mix + Pouring =	7 $ 2.50 $ 24 $ 0.50 $ 2 $/m2 177 $ 150 $	365 $
Topping with High Strength Concrete	C.A = 0.8 F.A = 0.4 Cement = 600 Kg/m3 Water = 150 kg/m3 C.A= 90 Kg/m3 R. steel = 185kg/m3 Mix + Pouring =	7 $ 2.50 $ 35 $ 0.50 $ 26.50 $ 163 $ 17.50 $	252 $
Topping with Steel Fiber Concrete	C.A = 0.8 F.A = 0.4 Cement = 400 Kg Water = 200 kg/m3 Steel fiber =5 kg/m3 R. steel = 200 kg/m3 Mix + Pouring =	7 $ 2 $ 23.50 0.50 $ 14 $ 176 $ 15 $	238 $
Topping with Self-Compacted Concrete	C.A = 0.8 F.A = 0.4 Cement = 400 Kg/m3	7 $ 2 $ 20.50 $	224 $

	Water = 100 Litter/m3 C.A= 90 Kg/m3 R. steel = 200 kg/m3 Mix + Pouring =	0.50 $ 9 $ 176 $ 9 $	
Topping with Polymer Concrete	C.A = 0.8 F.A = 0.4 Cement = 400 Kg/m3 Water = 200 kg/m3 C.A= 15 Kg/m3 R. steel = 200 kg/m3 Mix + Pouring =	7 $ 2 $ 23.50 $ 0.50 $ 5 $ 176 $ 15 $	229 $

Next will apply the weighted evaluation matrix; this to determine the best alternative that will be fit with the objective of the study. In this technique, the idea that would be evaluated by comparing the alternatives with the esthetics factors criteria, each one to the others (criteria scoring matrix – upper part of the table), and the second to evaluate the chosen alternative to each criterion or aesthetics factors decided in the lower part of the table. The analysis matrix is designed to take the criteria and weights developed and to establish a format for evaluation of the response of various alternatives against the criteria. Total weighted evaluation score aid the decision maker in the selection of the best alternative. The input data consist of the criteria and weights taken from the criteria weighted process form, and the alternatives developed up to this point. After listing the input data, the present way and each alternative are then evaluated against each criterion and ranked as the following:

* Excellent: 5 * Very Good: 4
* Good: 3 * Fair: 2
* Poor: 1

So it will compare the criteria which selected previously and study the alternatives of each item of the VE study by the weighted evaluation matrix (the strengthening method, the slab topping).

i. Weighted Evaluation Matrix for strengthening alternatives:

When applying the quantifying quality matrix on the strengthening methods by comparing each alternative with the non-measure criteria found have a high-value index when applying the value equation (VI= Q/C).

Table 7. Weighted evaluation matrix for strengthening alternatives

(A) Service life	A										
(B) Availability of raw materials	a/1	B									
(C) Constructability	c/1	c/2	C								
(D) Durability& Sustainability	d/1	d/2	c/d	D							
(F) Site & Environmental conditions	a/f	f/1	c/1	d/1	F						
(G) Bridge location	g/1	g/2	c/g	d/g	g/1	G					
(H) Time of implementation	a/1	b/h	c/2	d/2	f/1	g/2	H				
(I) Bridge importance	a/i	i/1	c/1	d/1	f/i	g/1	i/1	I			
Weight	4	1	9	9	4	9	1	3			
% of the total	10	3	23	23	10	23	3	7.5	Q	C $	Vi = Q/C
Reinforced Concrete Jacket	4.5	4.5	4.5	4.5	4.5	4	4	4			
	45	13.5	103.5	103.5	45	92	12	30	444.50	19463	0.023
Steel Jacket	4	5	4	3	4	3.5	4	4			
	40	15	92	69	40	80.5	12	30	378.50	32015	0.012
Fiber Reinforced Polymer Composite Jacket	4	4.5	5	4.5	4	4.5	5	4.5			

	40	13.5	115	103.5	40	103.5	15	33.75	464.25	10900	0.042
External stressing	4	3	4	4	4	4	4	4			
	40	9	92	92	40	92	12	30	407	18340	0.022

From the evaluation phase, it is clear that the most appropriate alternative in this case study is the Fiber Reinforced Polymer Composite Jacket (CFRP).

ii. Weighted Evaluation Matrix for slab topping alternatives:

When applying the quantifying quality matrix on the slab topping methods by comparing each alternative with the non-measure criteria found have a high-value index when applying the value equation
(VI= Q/C)

Table 8. Weighted evaluation matrix for slab topping alternatives

(A) Service life	A										
(B) Availability of raw materials	a/1	B									
(C) Constructability	c/1	c/2	C								
(D) Durability& Sustainability	d/1	d/2	c/d	D							
(F) Site & Environmental conditions	a/f	f/1	c/1	d/1	F						
(G) Bridge location	g/1	g/2	c/g	d/g	g/1	G					
(H) Time of implementation	a/1	b/h	c/2	d/2	f/1	g/2	H				
(I) Bridge importance	a/i	i/1	c/1	d/1	f/i	g/1	i/1	I			
Weight	4	1	9	9	4	9	1	3			
% of the total	10	3	23	23	10	23	3	7.5	Q	C $	Vi = Q/C
Topping with Ordinary Reinforced Concrete	3.5	5	4	3.5	4	3.5	3.5	3.5			
	35	15	92	80.5	40	80.5	10.5	26.25	379.75	245	1.55
Topping with ferrocement concrete	3	4	4	3	3.0	3.5	4	3			
	30	12	92	69	30	80.5	12	22.5	348	365	0.95
Topping with High Strength Concrete	4	4.5	4.5	4	4.5	4	4.5	4			
	40	13.5	103.5	92	45	92	13.5	30	429.5	252	1.70
Topping with steel fiber concrete	4	4.5	3.5	4.5	3.5	4	4	4.5			
	40	13.5	80.5	103.5	35	92	12	33.75	410.25	238	1.723
Topping with self-compacted Concrete	3.5	5	4	3.5	4	3.5	3.5	3.5			
	35	15	92	80.5	40	80.5	10.5	26.25	379.75	224	1.69
Topping with polymer concrete	4	3.5	3.5	4	3.5	4	3	4			
	40	10.5	80.5	92	40	92	9	30	394	229	1.720

From the evaluation phase, it is clear that the most appropriate alternative in this case study is Topping with steel fiber concrete.

5.1.5 Development Phase:

Improve the selected alternatives into fully supported recommendations. Develop technical and economic supporting data to demonstrate the benefits and feasibility of the desirable concepts, Develop team recommendations including long-term and interim solutions and generate cost and/or time-saving based on proposed solutions.

5.1.6 Presentation Phase:

In value engineering presentation phase oral as well as the written report is put up to the management/finance department for approval, mentioning the cost of the project after the application value engineering is considerably less **[29]**.

VI. CONCLUSION

1- From the cost analysis for strengthening methods, it is obvious that the savings that can be achieved from using the estimated system by comparing its total cost with the total cost of the system implemented are equal to 178 $ per cubic meter of concrete.
2- From the cost analysis for slab topping methods, it is obvious that the savings that can be achieved from using the estimated method by comparing its total cost with the total cost of the system implemented are equal to 14000 $ in this case study.
3- 39% of the respondents didn't have a specific methodology to select the appropriate maintenance system and even the respondents who have one couldn't specify this methodology which reflects that there is no good planning for these projects.
4- 63% of the respondents didn't believe that the current maintenance and repair methods available for bridges are sufficient.
5- Using FAST diagram technique during the project study gives a good chance to identify the items which will need to be inspected.
6- The necessity of teaching value engineering in universities to establish the concept and importance of VE and to improve our merit in the construction market.

VII. RECOMMENDATIONS FOR FUTURE STUDIES:

In order to perform the work done in this research, some more topics may be achieved:

1- Expand the current research to include new advanced repair methods which are not yet used in the Middle East.
2- Implementing the Value Engineering technique for other deteriorated elements in the reinforced concrete bridges like expansion joints.
3- Apply VE principles on the other bridges types such as railways bridges, steel bridges, and pedestrian bridges.
4- Upgrading the research to include the substructure as well (foundations, piers, and bearings). This will be more helpful in deciding the most appropriate construction method.

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M.O.Abo El-Naga" Evaluation of Bridges' Maintenance Systems Alternatives Using Value Engineering In Developing Countries (Case Study)" American Journal of Engineering Research (AJER), vol.8, no.07, 2019, pp.77-90