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Budget Optimization for Maintenance of Bridges in Egypt

Hesham Abd Elkhalek, Sherif M. Hafez, Yasser M. El Fahham

Abstract**—**Allocating limited budget to maintain bridge networks and selecting effective maintenance strategies for each bridge represent challenging tasks for maintenance managers and decision makers. In Egypt, bridges are continuously deteriorating. In many cases, maintenance works are performed due to user complaints. The objective of this paper is to develop a practical and reliable framework to manage the maintenance, repair, and rehabilitation (MR&R) activities of Bridges network considering performance and budget limits. The model solves an optimization problem that maximizes the average condition of the entire network given the limited available budget using Genetic Algorithm (GA).

The framework contains bridge inventory, condition assessment, repair cost calculation, deterioration prediction, and maintenance optimization. The developed model takes into account multiple parameters including serviceability requirements, budget allocation, element importance on structural safety and serviceability, bridge impact on network, and traffic. A questionnaire is conducted to complete the research scope. The proposed model is implemented in software, which provides a friendly user interface. The framework provides a multi-year maintenance plan for the entire network for up to five years. A case study of ten bridges is presented to validate and test the proposed model with data collected from Transportation Authorities in Egypt. Different scenarios are presented. The results are reasonable, feasible and within acceptable domain.

Keywords**—**Bridge Management Systems (BMS), cost optimization condition assessment, fund allocation, Markov chain.

I. INTRODUCTION

BRIDGES are vital links in many transportation networks and represent a big capital investment for both governments and publics. Managing such important infrastructure is essential to keep the bridge network in healthy condition. In Egypt, bridges suffer major deterioration. Fund scarceness, high traffic, user needs, and other constraints make it a challenging task to decide which bridge need immediate repair or rehabilitation. That needs effective tools to be optimally handled. The consequences of delayed maintenance are higher user costs due to travel delays, accidents, vehicle operating costs, and even bridge failure.

The AASHTO defined *Bridge Management System* (BMS) as "A system designed to optimize the use of available resources for the inspection, Maintenance, Rehabilitation, and Replacement of bridges" [1]. The main components of a typical BMS are (a) Inspection, (b) inventory, (c) The Condition-Rating (d) Performance prediction, and (e) Cost Optimization [2]. Bridge inspections are conducted to determine the physical and functional condition of the bridge. Successful bridge inspection depends on proper planning, adequate tools and equipment, advanced technology, and the experienced inspection team. To evaluate the condition of bridges, performance measures are used. Bridge inventory data and inspection reports are used to provide the necessary data. Different Performance Measures for BMS includes; Condition Ratings (CR), Condition Index (CI), Sufficiency Rating (SR), health index, National Bridge Inventory Rating (NBI), Vulnerability Rating (VR), and load rating [3], [4].

Predicting the future deterioration is required to perform Life Cycle Cost Analysis. According to [5], approaches used in modeling bridge deterioration can be categorized as mechanical, deterministic, stochastic (Markov chain), and artificial intelligence models. Prioritization is used to rank bridges for maintenance activities. Bridges with high priority ranking indicate urgent need for repair actions. A common practice is to rank Bridges and Elements in the worst condition first regardless of their effect on the network and costs [6]. Such approach is known as “worst first”. However, it fails to account for the level of change in benefit for the funds expended and the network consideration. Another ranking approach is coupling a condition index and a strategic index [7].

Optimization represents the most modern and sophisticated approach for selecting the optimum maintenance schedule for bridge network. Many objectives can be considered in the problem such as minimizing maintenance cost and getting the highest return on the repair budget, maximizing bridge condition. Different Constraints could be considered including: budget limits, governmental and political constraints, user defined constraints, and performance constraints.

Related work in Egypt was initiated by [8] by developing a framework consists of three modules; database, structural analysis, and rating model. The framework considered steel bridges only. El-Kafory [9] introduced an approach to estimate the structural condition for the bridge flexural elements by calculating reliability index for shear and flexure failure modes. Abbas [10] introduced EBRMS based on the outcome of BRIME project in Europe, the framework prioritizes concrete bridges for maintenance and provides one-year plan.

This paper provides a bridge management tool called *E-BMS* to allocate the limited maintenance fund on bridges in transportation network to keep all bridges in the target level of performance within the available budget.

Hesham Abd Elkhalek, Professor, Sherif M. Hafez, Professor, are with the Structural Engineering Department, Alexandria University, Egypt (e-mail: heshamkhaleq@gmail.com, hafez0124027024@googlemail.com).

Yasser M. El Fahham, Teaching assistant & PhD candidate, is with the Structural Engineering Department, Alexandria University, Egypt (phone: 002-01093027131, e-mail: yelfahham@yahoo.com).

II. Overview of the Proposed Framework

Although several BMS have been developed, they require considerable efforts to insert the necessary data, which makes the process of managing bridges daunting task. In addition, sometimes these data are not available. Therefore, the proposed system aims to produce simple and efficient system for managing bridges in Egypt taking into account the limited budget and target level of performance of the network. It also represents a practical tool as it can be operated using the current available data without the need of previous history of inspection and maintenance practices. The proposed system is called "E-BMS" short for "Egyptian - Bridge Management system", just for clarification. The model is coded in C # implemented using *Visual Studio 2013* with and friendly user interfaces. Fig. 1 shows the main structure of the proposed E-BMS. The proposed E-BMS consists basically of four main models;

1. Database model,
2. Condition-rating model,
3. Deterioration model,
4. Optimization model.

III. Database Model

Database model includes the basic information and documents describing bridge configuration and network characteristics. It also contains the results of inspection reports. The structure and components of the database model is shown in Fig. 2. It is recommended to perform inspection according to AASHTO standards [3]. Inspection process is performed by inspection team; each person of the team has specific responsibility and must have specific level of education, qualifications, and training. While periodic inspection is performed to all bridges at shorter periods, the author prefers to perform detailed Inspection to all bridges of the network every 2-5 years according to the condition of network.

The bridge is divided within E-BMS into many components; (a) Substructure, (b) Superstructure, and (c) Miscellaneous. Each component is then subdivided into smaller parts called elements. The proposed E-BMS contains three lists stored in the database; (1) Element list, (2) Defect list, and (3) Repair methods list. The element list contains a Varity of elements that could be found in any concrete bridge.

The *Element list* is used to define the elements of each bridge. Thus, the inspector and E-BMS user can select any number of elements found in the *element list* to describe any bridge. The *Defect List* contains the most common defects observed in bridges in Egypt with the probable elements that can have these defects. This defect list works as defect catalog for bridge inspector to easily assign defects to each element in the bridge. *Repair methods list* contains the most common repair actions used to maintain concrete bridges where each defect observed at any element needs one or more repair techniques. According to the proposed system, each element is assumed to have up to four defects and one repair method for each defect. Assigning defects and suitable repair methods for each Condition States (CS) is the responsibility of the bridge inspector. Information of these lists is obtained from literature; [8], [10], [11]. Refinement and modifications are performed to these lists to best suit the condition and nature of bridges in Egypt. These modifications are performed according to the data obtained from "*General Authority for Roads, Bridges and Land Transport*" in Egypt.

IV. Condition-Rating Model

Condition Rating (CR) is used to describe the current status of a structure. A range of numerical values representing different levels of deterioration of bridge components or bridges are used. The condition is evaluated for each bridge element, then, for the entire bridge. According to *AASHTO* [11], each element has four condition states listed with qualitative descriptions and viable maintenance actions. Elements conditions and quantities are estimated during field inspection. Table I provides a definition of each condition state and feasible actions. Fig. 3 shows how to define quantities in the four Condition States, defects, repair methods, and repair cost within E-BMS during inserting element inspection data.

Measuring the condition of elements and bridges are determined by calculating Health index, which is a single number ranges from zero to 100. Zero corresponds to the worst possible health, and 100% for the best possible health. This method is similar to that used in the *Pontis* BMS with some modification in the weighting factor to best suit local conditions and available data in Egypt. The process is accomplished in two steps; Step one calculates the **Element Health Index** (EHI). Step two computes the entire **Bridge Health Index** (BHI) based on the weighted *EHI*. According to [12], the Health Index of an individual element (EHI) is calculated according to (1) as:

$$EHI = \frac{\sum_s K_s q_s}{\sum_s q_s} \text{ x } 100\ \% \tag{1}$$

The health index of the entire bridge (BHI) is evaluated as a weighted average of the Health Indexes of bridge elements based on element relative importance. It can be calculated by (2) as:

$$BHI = \frac{\sum_e H_e EIF_e}{\sum_e EIF_e} X\ 100\% \tag{2}$$

where; ***EHI***: the health index of an individual element, ***s***: the index of the condition state (4), q_s: the quantity of the element in the s^th condition state, k_s: a coefficient corresponding to the s^th condition state and reflects the level of deterioration. See Table II, ***BHI***: the health index of the entire bridge, H_e: the health index of an individual element (*EHI*), ***e***: the number of an element, EIF_e: *Element Importance Factor* of element *e*. It is a weighting factor representing the importance of each element to the structural safety and serviceability of a bridge.

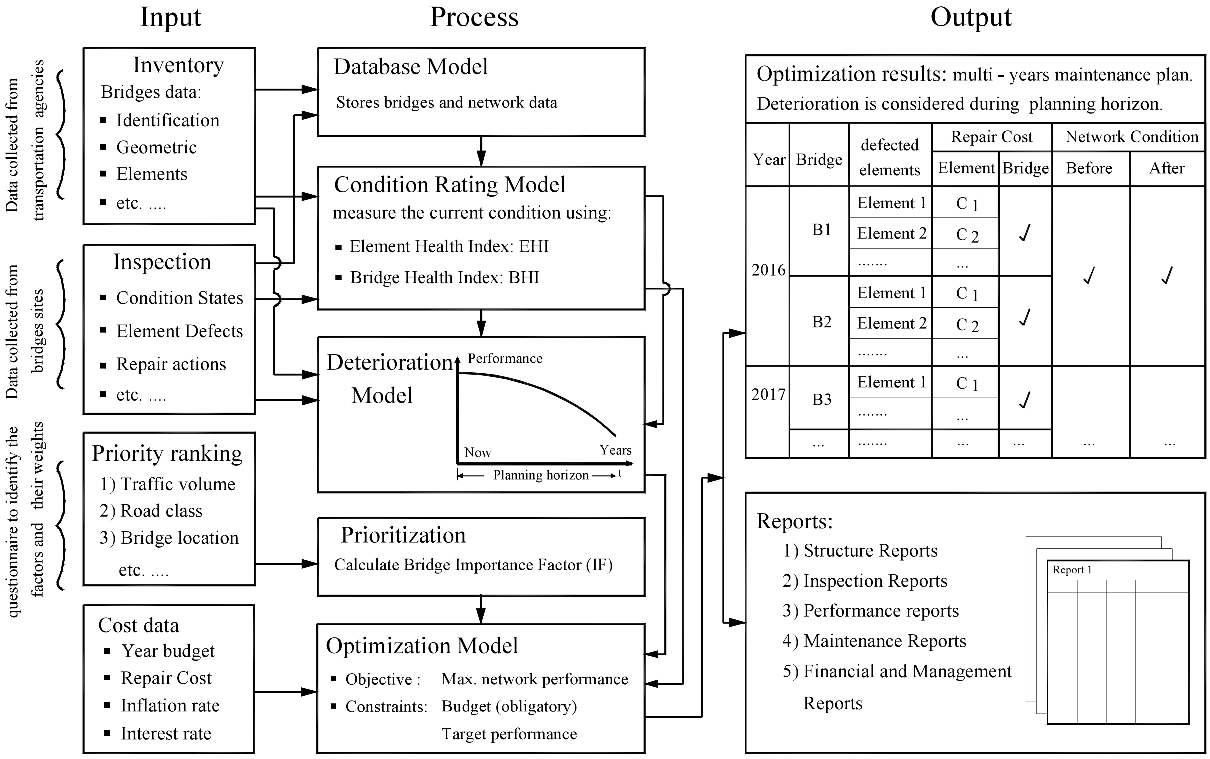

Fig. 1 Main structure of the proposed BMS

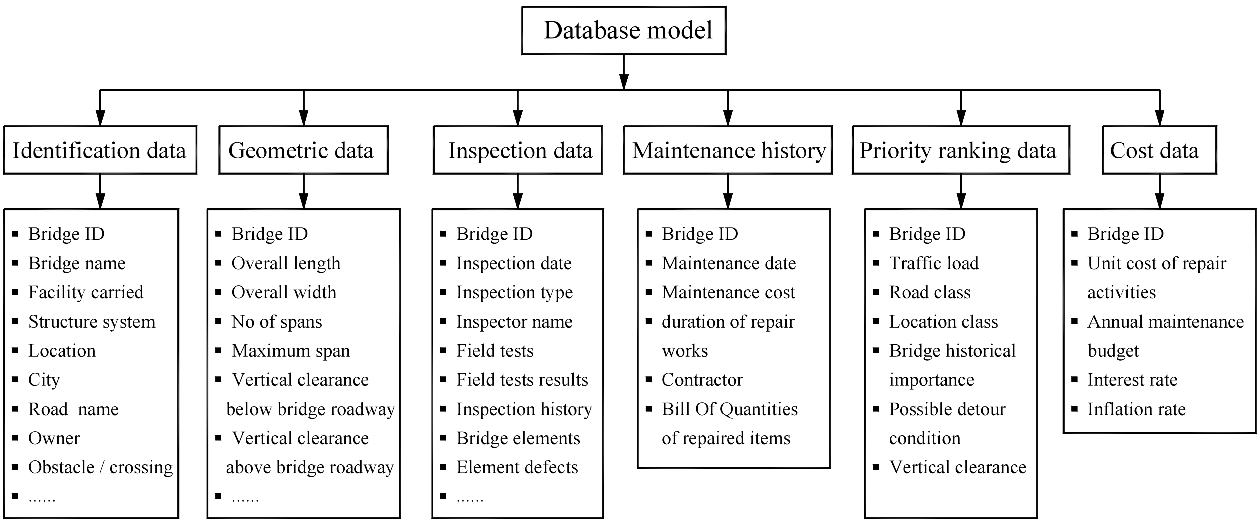

Fig. 2 Structure of the database model

A questionnaire is conducted to determine the value of ***EIF*** for each element in the bridge. Experts were asked to identify these weights for each element. The questionnaire is designed using five – points scale since this scale is convenient in questionnaire design, where 1 indicates less important while 5 indicates more important. The questionnaire was delivered to participants through direct interviews with the researcher to create better understanding of the research among the survey participants and clear any ambiguous point that could be found. The participants of the survey were professionals involved in the decision-making process in the maintenance departments at Egyptian transportation authorities, and Engineers who have experience related to bridges. 22 respondents have answered the questionnaire. Results are listed in Table III.

TABLE I
CONDITION STATE DEFINITIONS AND FEASIBLE ACTIONS

Level	Condition state			
	1	2	3	4
	Good	Fair	Poor	severe
Condition state Descriptions	No or minor defects; those not Affecting structural safety and serviceability of bridge.	minor defects, but do not weaken structural safety and serviceability of bridges.	failures and defects that currently develop and affect structural safety and serviceability	serious failures and defects that adversely affect structural safety and serviceability
Feasible actions	Do Nothing, Protect	Do Nothing, Protect, Repair	Do Nothing, Protect, Repair, Rehabilitate	Do Nothing, Rehabilitate, Replace Immediately

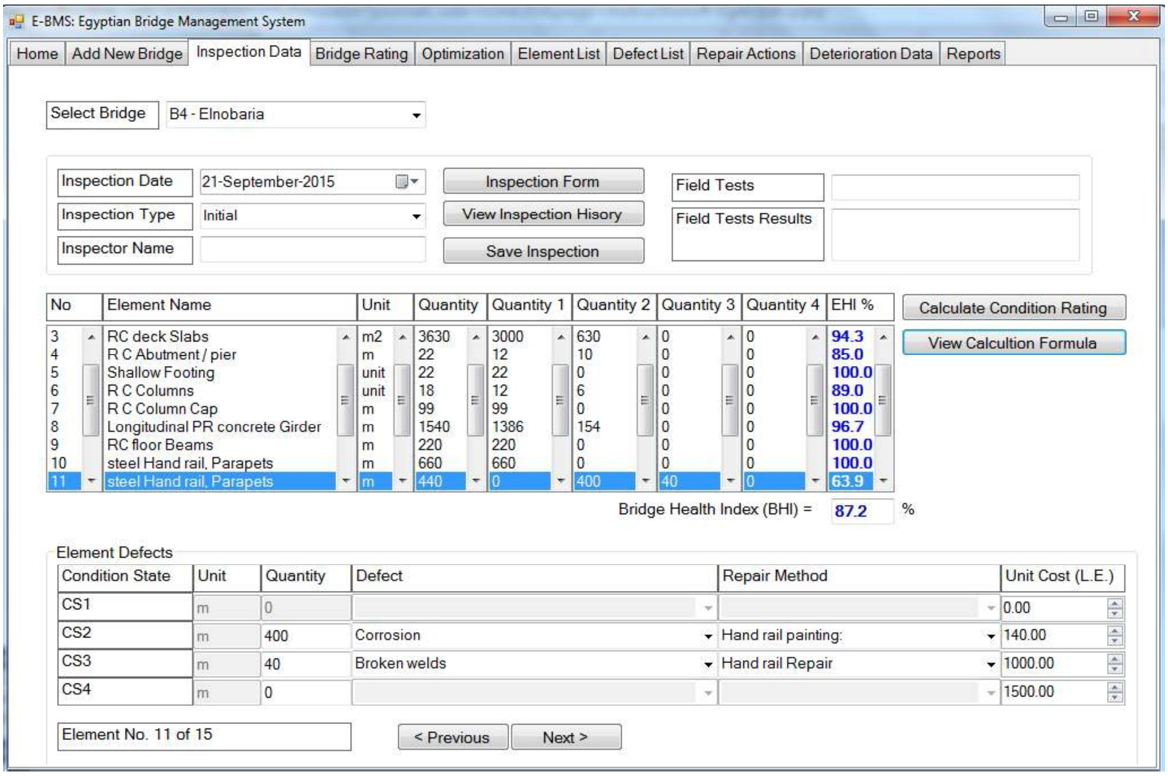

Fig. 3 Defining element inspection data

TABLE II
VALUES OF K_s COEFFICIENT

Condition State no	1	2	3	4
k_s	1.0	0.67	0.33	0

TABLE III
ELEMENT IMPORTANCE FACTOR (EIF)

Elements	EIF
Columns, abutments	1.0
Piles, pile caps, foundation, columns caps, main girders	0.90
Transversal girders, Floor beams, Slabs, Retaining walls, wing walls, Joints	0.70
Bearings, surface finish, asphalt, Lighting columns	0.60
Drainage system, Parapets, Handrail, Sidewalks, safety barriers, others	0.50

V. DETERIORATION MODEL

Deterioration models predict the future deterioration. This research considers the deterioration of the bridge element to be a **Markov process**, which are extensively used to forecasts the future condition of an element, based on its current condition states and transition probability matrix. Any element can exist in one of four environments **(Benign, Low, Moderate, Severe),** which describe different weather or operating conditions. [3]. Each environment has one transition probability matrix. Thus, four matrices have to be feed to the E-BMS for each element. These matrices are obtained from literature. Generating Transition probability matrices is out of the scope of this study because of the lack of historical data and past inspection records for Egyptian bridges. The general form of a deterioration transition probability matrix (P) is presented in Table IV [13].

TABLE IV
GENERAL FORM OF A TRANSITION PROBABILITY MATRIX

		To state			
		1	2	3	4
From state	1	P_{11}	P_{12}	P_{13}	P_{14}
	2	0	P_{22}	P_{23}	P_{24}
	3	0	0	P_{33}	P_{34}
	4	0	0	0	1

Each element *pi,j* in this matrix represents the probability that the condition of a bridge element will change from state *i* to state *j* during a certain time interval called the transition period which always one year. If the initial condition vector *P*(0) that describes the present condition of a bridge element is known, then, the future condition vector *P*(t) at any year *t* can be obtained as [14]:

$$\sum_{j=1}^{n=4} p_{ij} = 1 \tag{3}$$

$$p_{ij} \geq 0$$

$$P(t) = p(0) \times p^t \tag{4}$$

$$p(0) = [q_1 \quad q_2 \quad q_3 \quad q_4] \tag{5}$$

where; ***P* (0)**: the present or initial condition vector of a bridge element, ***P* (t)**: the future condition vector at year *t*, P^t: transition probability matrix to the power *t* (where *t* is the year number), w_i: the quantity of an element in condition state *i*, *i*=1, 2, 3, 4

VI. OPTIMIZATION MODEL

This section contains the core processes of the proposed framework by incorporating two basic issues; prioritization and optimization. Prioritization aims to give bridges higher possibility of being selected according to the bridge impact on network, while optimization searches for the best solution of maintenance fund allocation.

TABLE V
IMPORTANCE FACTOR MEASUREMENT SUMMARY

Factor	Weight (w_i)	Reference
1) Traffic volume	0.155	[6], [10], [15]
2) Rood class	0.135	[6], [8], [10], [15]
3) Bridge location class	0.127	[10]
4) Possible detours	0.113	[16]
5) Historical importance	0.092	[10], [15]
6) Defense Considerations	0.106	[10], [15]
7) Width condition	0.088	[10], [15]
8) Vertical clearance	0.096	[10], [15]
9) % Trucks	0.088	*This factor is added as recommended by the pilot survey*

A. Prioritization

The importance of a bridge to the road network, as well as the impact of the loss of bridge service to traffic, are other factors that must be considered in deciding which bridges to be repaired. The ***importance factor*** (IF) is developed for this purpose. IF is a single indicator ranges from zero for less importance to 100 for the most important bridges. Many parameters are taken into account to determine the bridge importance factor (IF). These include strategic, functional, operational, and economical factors. These factors are collected from literature. Besides, a confirmation of these parameters is conducted using a questionnaire to determine the factors affecting the importance factor (IF) and their priority weights in the calculation formula. Table V illustrates these factors.

The bridge *importance factor* (IF) is therefore determined for each bridge using the previous factors by multiplying the *Weight* (w_i) by the *Factor Measurement* (f_i) as shown in (6):

$$IF = \sum_{i=1}^{9} w_i * f_i \tag{6}$$

where; w_i: weight of factor $i, \sum_{i=1}^{9} w_i = 1$; f_i: Factor Measurement fi ={0.25 to 1.0}

B. Improvement After Repair

The condition of elements after performing specific type of repair improves to certain level. In the real world, some repair actions do not necessarily make the element condition as good as new. Determining the condition after repair represents a challenge task in Bridge Management systems, as it requires accurate improvement models that are based on real data. The technique used in this study is similar to that used in [17], [18]. It is assumed that when doing nothing to a bridge element, no improvement will happen in its condition. Protection or Minor maintenances will enhance the condition to 78% of the initial new condition. Major repairs will raise the element condition to 89% of the initial new condition. Finally, replacement or reconstruction will reset the element to the initial new state (100%). The values of improvements in Table VI were confirmed by expert judgment throughout questionnaire. Table V provides an example of how the after repair condition (EHI_{After}) of an element is calculated based on the previous approach.

TABLE VI
AFTER - REPAIR CONDITION CALCULATION (EXAMPLE OF PAVEMENT)

	Element: pavement	Quantity (m2)	Repair action	Improvement in condition (%)	EHI	EHI_{After}
Condition states	CS1	80	Do nothing	0.0	63.4 %	92.3 %
	CS2	60	Protect	78		
	CS3	20	Repair	89		
	CS4	40	Replace	100		

EHI: the current *Element Health Index* of the element before repair, it is calculated as discussed earlier, EHI_{After}: The Element Health Index after performing the necessary repair activities and calculated as:

$$EHI_{After} = \frac{q_1*100+q_2*78+q_3*89+q_4*100}{q_1+q_2+q_3+q_4}\ \% \tag{7}$$

C. Optimization Process

Optimization model represents a decision - making model where the selection of proper maintenance activities for bridges network is modeled as quality maximization of network given the limited annual budget. The main criteria for selecting the maintenance plan are as:

1) The least - cost repair strategy that maximizes the average condition of the whole network.
2) Elements with higher EIF are more eligible to be selected
3) Bridges with higher Importance (IF) receive higher priority of maintenance
4) The total cost of maintenance works should not exceed the annual available budget

The system performs the following steps to get the optimal maintenance plan:

1. Calculate for each element; the values of *Element Health Index* (**EHI**), *Cost Index* (**CI**), and *initial repair cost* (**C_0**).
2. Calculate for each bridge, the values of *Bridge Health Index* (**BHI**) and *Importance Factor* (**IF**).
3. A reference value is set for ***BHI***; this value represents the target minimum performance of bridges ($BHI_{ref.}$). All bridges with ***BHI*** below this value are considered to need maintenance, repair, or rehabilitation activities and will be included in the optimization process. The remaining bridges are excluded because they satisfy the minimum level of performance specified by transportation agency. However, the not-selected bridges may be selected the next years when excessive deterioration occurs.
4. For bridges selected in step 3, a reference value for element condition is set ($EHI_{ref.}$). All elements with ***EHI*** below this value are considered to need maintenance, repair, or rehabilitation activities and will be included in the optimization process these elements are put into a list called "Eligible elements list", the remaining not-selected elements are excluded.
5. Operate the Genetic algorithm (GA) optimization process for elements in "Eligible elements list" selected in step 4.

It should be noted that the minimum level of performance used in the proposed algorithm is not an obligatory constraint where it can be violated if the available budget is not sufficient. Instead, it is set as target objective to reduce the size of the problem by eliminating bridges and elements whose conditions greater that the target performance.

D. Problem Formulation

The formulation of the bridge maintenance optimization problems aims to represent the objective functions and constraints of the optimization process mathematically. Element-level formulation is used in this study. That means that the proposed system treats the bridge network as a large number of elements, each element has defined characteristics (e.g. condition, defects, and repair cost). The study takes the trend of Element-level formulation to concentrate on the condition of each individual element rather than the condition of the whole bridge. The formulation of the problem is similar to *0-1 knapsack problem,* which restricts the number x_i of repair activity *i* to zero or one; One if element *e* is selected and zero otherwise. [19]. Applying the previous definition, the objective function and constraints will be as follows:

Maximize the overall condition (average BHI of all bridges)

Subject to: total maintenance and repair cost ≤ annual budget.

$$\text{Maximize: } z_1 = \mathrm{H_t} \tag{8}$$

$$\text{Subject to: } C_t \leq B_t \tag{9}$$

$$H_t = \frac{\sum_{i=1}^{N} BHI_{it} * IF_i * BC_i}{\sum_{i=1}^{N} IF_i * BC_i} \tag{10}$$

$$BHI_{it} = \frac{\sum_e EHI_{et} * EIF_e}{\sum_e EIF_e} \tag{11}$$

$$C_t = \sum_{t=1}^{5} \sum_{i=1}^{N} \sum_{e=1}^{E} \boldsymbol{C}_{tie} * X_e \tag{12}$$

where; $\boldsymbol{H_t}$ = average performance of the entire bridge network at year ***t***, $t = \{1, 2, 3, 4, 5\}$, $\boldsymbol{BHI_{it}}$: *Bridge Health Index of bridge i* at year *t* after applying repair actions for the selected elements in that bridge, $\boldsymbol{EHI_{et}}$: current *Element Health Index* for not – repaired elements at year *t*, = *After repair Element Health Index* for repaired elements (EHI_{after}) at year *t*, $\boldsymbol{EIF_e}$: *Element Importance Factor* of element *e*, $\boldsymbol{IF_i}$: *Importance Factor* of bridge *i*, $\boldsymbol{BC_i}$: the estimated Budget cost of bridge *i* or the construction cost, $\boldsymbol{C_t}$: the total repair Cost of the network during year *t*, $\boldsymbol{C_{tie}}$: Repair cost of element *e* in bridge *i* at year *t*, $\boldsymbol{X_e}$: variable, 1 if element *e* is repaired and zero otherwise $X_e \in \{0,1\}$, for *i* = 1, 2,.., *E*, ***N***: the total number of bridges in the network, ***E***: the Total number of elements in bridge *i*, $\boldsymbol{B_t}$: the available budget at year *t*

The term $\boldsymbol{BC_i}$ (Budget cost of bridge *i*) used in (10) is introduced to account for the size of the bridge because the bridge size can be reflected by the construction cost. Therefore, bridges with bigger sizes will have higher impact on the average condition of the entire network.

E. Genetic Algorithm (GA)

GA has been used widely to solve complex and non-linear optimization problems. The complexity of the proposed problem grows exponentially with the increase in number of bridges and elements, making traditional optimization techniques not able to handle such a huge problem. [17], [20]. A genetic algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution. The algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Over successive generations, the population "evolves" toward an optimal solution. The chromosomes in GAs represent number of candidate solutions. Possible chromosomes encodings are binary, permutation, value, and tree encodings. For the Knapsack problem, the binary encoding is used where every chromosome is a string of bits, 0 or 1. Fig. 4 presents the flow chart of solving the problem using Genetic Algorithm.

The feasibility of a solution means that it satisfies the budget constraints. However, the traditional GA operators are blind to constraints of an optimization problem [21]. To enforce GA on eliminating infeasible solutions at each generation, a penalty on objective function is set. That means that if a solution is not feasible, then the algorithm modifies its fitness to be zero. That diminishes the probability of that solution to be selected in the next generation. And reduces the efforts wasted in evaluating infeasible solutions. The selection of individuals in GA is based on the principle of survival of the fittest. It is important for the optimization process to set the GA parameters in order to generate solutions of high quality (high fitness). Many trial calculations are generated during the development of the model to get the best parameter setting. The analysis is performed using a Population size of 100 and Number of generations of 200.

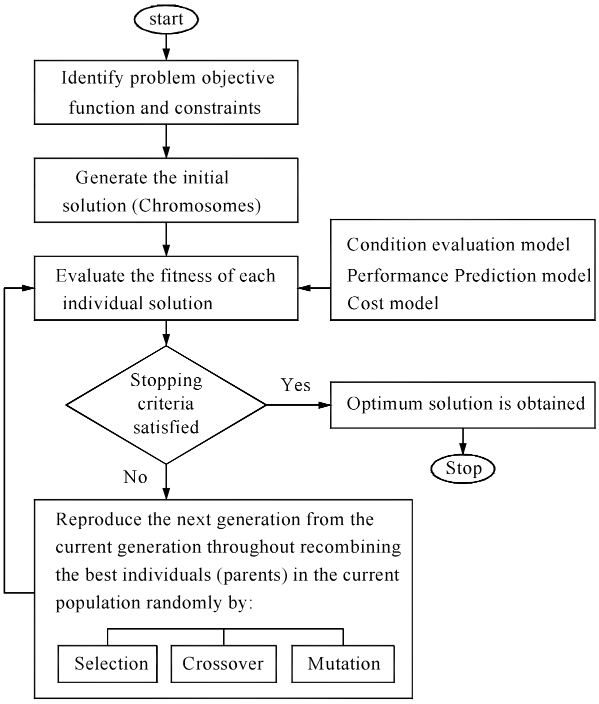

Fig. 4 Flow chart of problem solving using Genetic Algorithm

VII. Validation and Testing Using Case Study

The developed framework is verified throughout a case study of ten real Bridges in Egypt. The aim is to implement the E-BMS and test its applicability. The chosen bridges have different types, traffic load, size, and location in order to check the reliability and feasibility of the proposed system. Different scenarios are assumed to test the proposed system. Each scenario has its own budget, objective, and target performance. Table VII provides a description of the case study scenarios.

Sample results of different scenarios are presented. All results are reasonable, acceptable and feasible as they satisfy problem constrains. The Average running time of the optimization for the case study network is 9 *seconds*, which is considerably small. This time depends basically on the size of the network. In scenarios 1, 2, 3, and 4, performance maximization problem is solved using different budget limits at each scenario to get one – year maintenance plan. While a multi – year maintenance plan is produced in Scenario 5.

TABLE VII
Description of the Case Study Scenarios

Scenario	Planning year	Target performance (%)		Budget (LE)
		$BHI_{ref.}$	$EHI_{ref.}$	
Scenario 1	2016	95	95	1,000,000
Scenario 2	2016	95	95	2,000,000
Scenario 3	2016	95	95	3,000,000
Scenario 4	2016	95	95	4,500,000
Scenario 5	2016 2017 2018	95	95	1,000,000 1,000,000 1,000,000

The algorithm selects bridge elements that maximize the fitness function; these elements have high *EIF* and are located on more - important bridges. More bridge elements are selected for maintenance and repair works as more fund became available. The current Average condition of the network was 90.55% (before repair); this condition is enhanced when the available maintenance budget has increased as shown in Fig. 5 which provides the average network condition corresponding to different repair costs. The fund is not enough to repair all defected elements in scenarios 1, 2, and 3 with annual budget of 1000000, 2000000 and 3000000 LE respectively. While in scenario 4, the budget is 4500000 LE, which is sufficient to repair all defected bridges; therefore, all bridges and elements with health index less than or equal to 95% (the reference value) are selected for maintenance. Analysis is performed using interest rate of 9%, inflation rate of 10%, and 20 - years planning horizon.

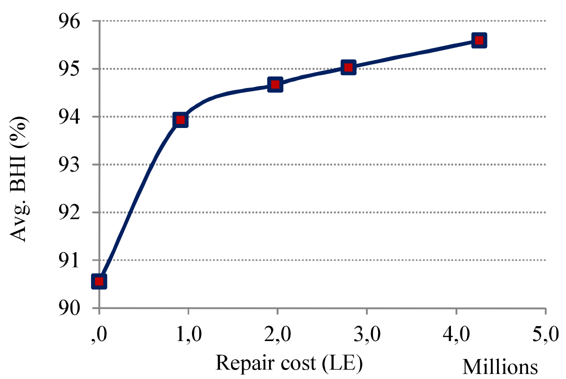

Fig. 5 Results of different budget scenarios

The results of scenario 5 are organized in Fig. 6, which displays the repair cost of each bridge during the three years. In order to evaluate the performance of the maintenance plans developed for Scenario 5 under the performance maximization, the network performance curve and deterioration curve of both Scenario 5 maintenance plans and No – maintenance are displayed in Fig. 7. The network performance curve displays the network average BHI values before treatment and after treatment for each year of the three

- year maintenance plan produced in Scenario 5. It is noted that the average BHI of the networks enhances due to spending the maintenance budget. However, the trend of the performance declines each year where it starts by 90.55% and ends by 89.27%, this is because the bridges is deteriorating continuously at a rate may be higher that the rated of improvement due to maintenance activities performed to the network. In other words, some maintenance works like minor repair raises the condition of the bridge to some degree but not to 100%.

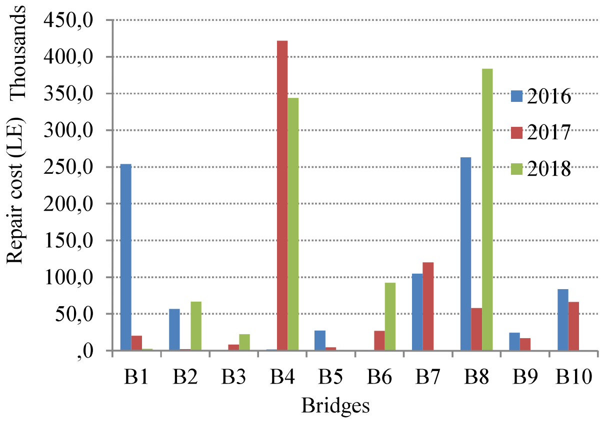

Fig. 6 Repair Costs of each bridge (Scenario 5)

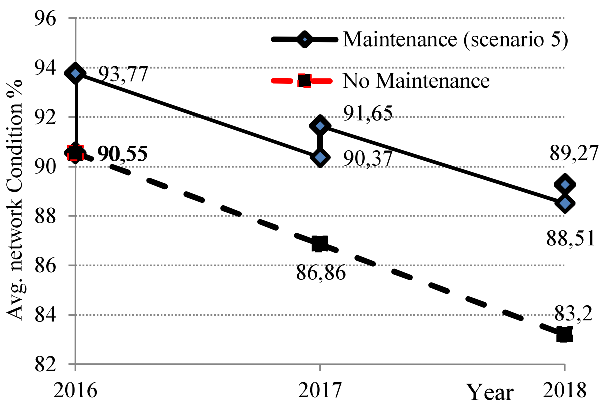

Fig. 7 Performance of network under performance maximization (Scenario 5)

VIII. Conclusion

The objective of this research is to develop a framework that allocates the limited maintenance budget to competing bridges in network. The problem is formulated as quality maximization. The impact of the bridge on transportation network is considered by introducing the Importance Factor (IF). Deterioration is predicted using Markov Chain model. Computerized software is developed to implement the model. Preparing the input data for most BMS software like PONTIS is truly a time-consuming process [22]. As a result, the authors tried to provide a practical tool called **E-BMS** that could be operated within the available data to manage the maintenance process of bridges in Egypt. The methodology proposed herein is general, and can be applied to all aspects of concrete bridge management. Future improvements can include; producing Transition Probability Matrices for all elements to best suit the condition in Egypt, including user and failure costs, and producing more accurate improvement model that estimate the after repair condition.

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