"An Asset Management System for Maintenance and Repair of Educational Buildings"

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Abstract:

Infrastructure renewal has been a focus of attention around the world. This paper provide a comprehensive asset management framework to support the efficient planning of maintenance and repair strategies for educational buildings, which outlines a database system using neural network tools to evaluates the performance of the school, using last repair data and predicte detrioration of the target school.A new approach is presented to restruct the inspection efforts and condition assessment process to help the decision maker make the right choices between long-term alternatives related to the maintenance, repair and capital renewal for the Egyptian educational authorities. A prototype of the framework has been developed to facilitate school maintenance and has been tested on different Educational Organization.

Key words: "Framework","Educational Organizations", "Asset Management", "Maintenance Planning and Repair Strategies".

1.INTRODUCTION:

Infrastructure renewal has been a focus of attention worldwide. Municipal and federal authorities are increasingly recognizing the need for life cycle cost analysis of infrastructure projects, in order to facilitate proper prioritization and budgeting of maintenance operations. (El-Behairy, H. 2007). Property managers are faced with many challenges regarding when and how to inspect, maintain, repair, renew, and replace a diverse set of existing facilities in a cost effective manner.(D.J Vanier 2004).
Currently, the public infrastructure including highways, bridges, pipelines, mass transit, water supply, energy and wastewater treatment facilities, education and healthcare buildings are deteriorating rapidly due to their ancient age, over capacity, extensive use and insufficient maintenance. While Educational Buildings represent a great challenge due to their diverse components that have different repair requirements. It is essential, therefore, to establish an effective maintenance/repair strategy in order to keep Educational Buildings sufficiently safe and serviceable throughout their service lives..

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Most of the schools and educational buildings that were built in the 1950s and 1960s, for example, are now more than 45 years old and need extra care.Therefore, improving the asset

management process for them is expected to provide substantial benefits for one of the largest infrastructure sectors.
Rugless,J. 1993, defined condition assessment as a process of systematically evaluating an organization's capital assets in order to project repair, renewal, or replacement needs that will preserve their ability to support the mission or activities they were assigned to serve. This relationship challenges to establish an indicator of the condition of the building components so that unnecessary inspection visits can be avoided and inspection can be limited to the items that show conflicting information.
Traditionally in Egypt, a condition assessment for a building is performed through visual inspection by experts in specific building systems, e.g., architecural, structural, electrical, and mechanical. Locally from field visits, there is no tools to predict the future condition for buildings components to save inspection efforts, and prevent suddenly inexpected deterioration.
The literature shows that some efforts has been made to speed up the current process of field inspection of buildings. A condition assessment system is performed primarily to facilitate the ranking of all the components of all assets according to the amount of needed repair. Four main steps are needed(Figure 1).

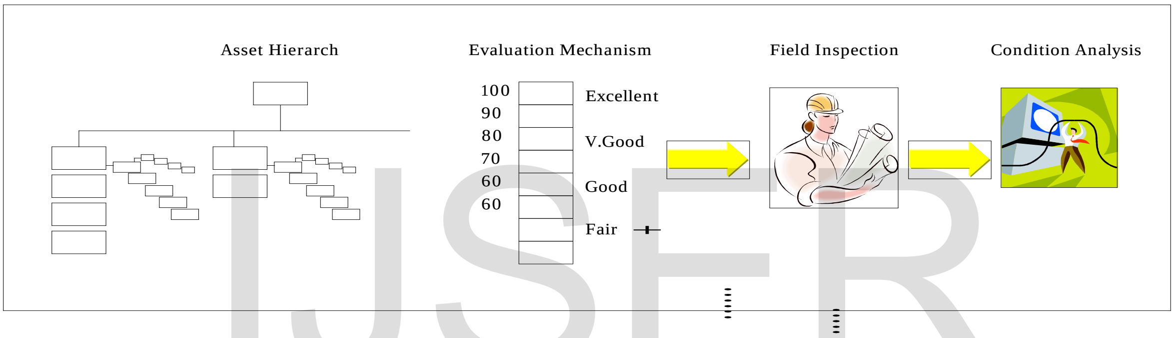

Figure 1" Main Aspects Of The Condition Assessment Process"

The paper present a framework model, which aims to integrate maintenance data to facilitate efficient inspection planning and to improve the condition assessment process (for capital replacement purposes) for the inter-related building components.
The challenge for this paper was inherent in the current process: the lack of integration between maintenance/repair and capital renewal functions, the need for efficient inspection planning, and the need for less-subjective condition assessment. The proposed model focuses to decrease field inspection and condition assessment for educational buildings.
The framework has developed a deterioration model that uses Neural tools to predict different repair strategies along the planning horizon. This means decision-makers can, with minimal efforts, produce short and long term capital improvement plans while ensuring coordination and proper timing of rehabilitation activities on all networks, thus maximizing the effectiveness of the funds available.
However, the proposed developments can also be applied to other infrastructure buildings such as offices, hospitals, shopping malls, etc..

2.SYSTEM DESCRIPTION:

The proposed framework includes the development of a classification mechanism for condition evaluation, a predictive model to predict future deterioration, a repair model to select best repair scenario, and a planning horizon implemented with budget due to repair selection. Figure 2 shows the main process for the proposed framework.

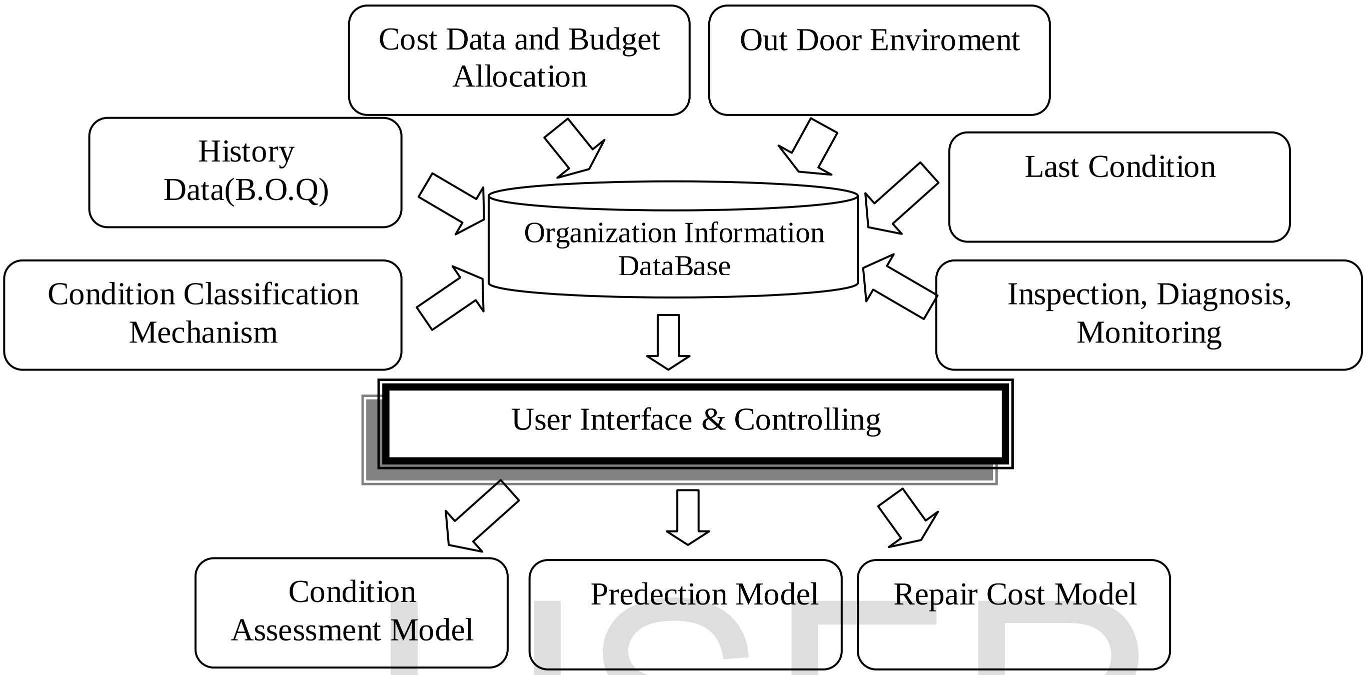

Figure 2 "Main Process For The Proposed Framework".

3.SYSTEM ANALYSIS:

3.1 System Condition Assessment Classification:

The proposed condition assessment system uses a Relative Condition Index RCI to be used to arrange schools into three categories, each represent current condition. The Relative Condition Index RCI use maintenance history data for each item and make a relation between different factors affecting items deterioration .
The condition index effected by school capacity and school area related to maintenance quantity, which is an index to know student maintenance quantity per area. In the proposed approach it is a choosen index to indicate student/m^2 and its required maintenance.
Equation (3.1) represent the represented maintenance index quantity at year (i) for item(j) multiplied by school capacityat at year (i) and divided by school area using the following equation:

$$\mathbf{Q_{ij}} = \frac{MQij*SCi}{SA} \qquad (3.1)$$

Where : $\mathbf{Q_{ij}}$ = maintenance index at year i for item j
MQ_{ij}= maintenance quantity at year (i) for item j.
SC=school capacity(number of student per classes) at year (i).
SA= school area m^2.

The Relative Condition Index is then determined for each school item equation (3.2):

$$\mathbf{RCI_j} = \frac{\mathbf{Qij - Qj\,min}}{\mathbf{Qj\,max - Qj\,min}} * \mathbf{100} \qquad (3.2)$$

Where RCI_{ij} = Relative Condition Index for item j

Q_{ij} = the calculated maintenance index at year i for item j

Q_{jmin} = minimum maintenance index for item j

Q_{jmax}. = maximum maintenance index for item j

Once the Relative condition index is determined, its represent the instant condition for each component.The system categorized the condition into three categories: figure 3 represent the scale for relative condition.

Good Condition: which index varies from 0 to 35%.

Fair Condition: which index varies from 35 up to 70%.

Critical Condition: which index varies upper than 70%.

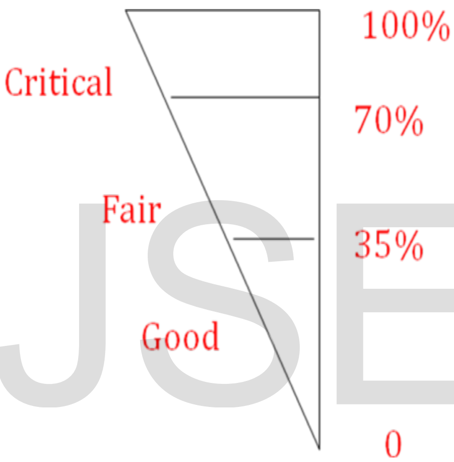

Figure 3 "Scale for Relative Condition Index".

3.1.1 Instance Repair Selection System:

Since it is possible to inspect some of the defects but not all, it is necessary to decrease the inspection efforts by using the previous calculated Relative Condition Index.

The proposed model advise the inspection department to inspect the critical items first and have the first priority at instance, while the Good condition can be delayed later. Then, it can easly prioritize the defect items to be repaired.

For Fair conditions need another tool to specify the repair time to predict the proper time to be repaired. Based on the inspection results, the deterioration model parameters can be updated to express the deterioration process more accurately.

3.2 Predicted Repair Selection System:

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In this section, the model use the Artificial Neural Network ANN to create an intelligent facility to predict item condition and inspection planning (based on the reactive-maintenance history),and determine specific time for repair the Fair items using specific factors.
Many factors are related to deterioration of the school: current capacity versus permissible capacity in terms of the number of pupils. If the current enrolment capacity exceeds the permissible capacity of the school, the building would deteriorate faster because of overuse. Similarly, the type of school, i.e., elementary versus secondary, also affects the school's overall condition. It has been reported that secondary schools tend to have a higher rate of vandalism and accidental damage compared to elementary schools .
The demographics of the students, such as their age, gender, and financial background also affect the deterioration of the building. Among other factors affecting the condition of school are the level of maintenance and the type of neighbourhood (residential, commercial, or industrial).
Studing proposed system factors affectinfg school condition are:

- Type of school (elementary, secondary, etc).
- Age or major year of renovation of school.
- Size (enrolment capacity).
- Gieographical and external environment.
- Last maintenance repair data M**Q.**

The model parameters can be updated and Mentenance Repair & Replacement policies are selected every year using the updated deterioration models.
The data used for network training, testing, and validation are: the calculated Q& RCI from previous section to present the maintenance data, average school intensity, type of school,geographic data, and the Age is the most important factor that affect the deterioration prediction calculation.

To carry out such an analysis, repair and reactive-maintenance records for a sample of 25 schools were obtained from the Egyptian Educational Building Authority. Two types of data were collected from the schools: (1) general data from geographic departments which included information about the school type (elementary or secondary), construction year, area (in square metres), classes capacity and location which simply defineted as (center south, away, sea); and (2) Specific data from repair department which contained previous repair work data, including work description, code, quantity of repair, unit cost, and repair cost. Data was collected for the last three repair plan to ensure consistency in the conclusions to be drawn from one year to the next. (Acquiring the specific data was a highly extensive task due to the size and the confidential nature of the data).
Figure 4 shows the schools input data : average repair maintenance for the last three repair plan, the age till this year from the construction date, type of school, loacation of school, the calculated relative index, average schools intensity, and school area per student all thgese factors through one defected item.
These data represent the training data so the ANN to learn the relation between the school age and the condition index with respect to school capacity and location. Therefor, the trained network was used to predict the future item condition.

district	eduction	area/student	average intensity	اعمال الدرج و التكسيات	age	Relative Index
sea	prim	3.7	43.4	100	15	0.02
center	prim	4.6	25.3	1900	13	0.29
center	sec	2.9	43.7	1600	13	0.25
center	prim	2.1	40.5	2340	13	0.36
center	prim	4.0	26.6	2200	15	0.34
sea	sec	8.3	61.2	50	11	0.01
sea	sec	2.5	45.0	50	12	0.77
sea	prim	7.7	23.5	1185	14	0.18
south	sec	11.5	31.5	4410	13	0.68
south	prep	4.7	48.5	430	12	0.07
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4 "School Input Data" .

Figure 5 shows a sample output for the training data to predict the relative condition index according to the relation with the influent factors.

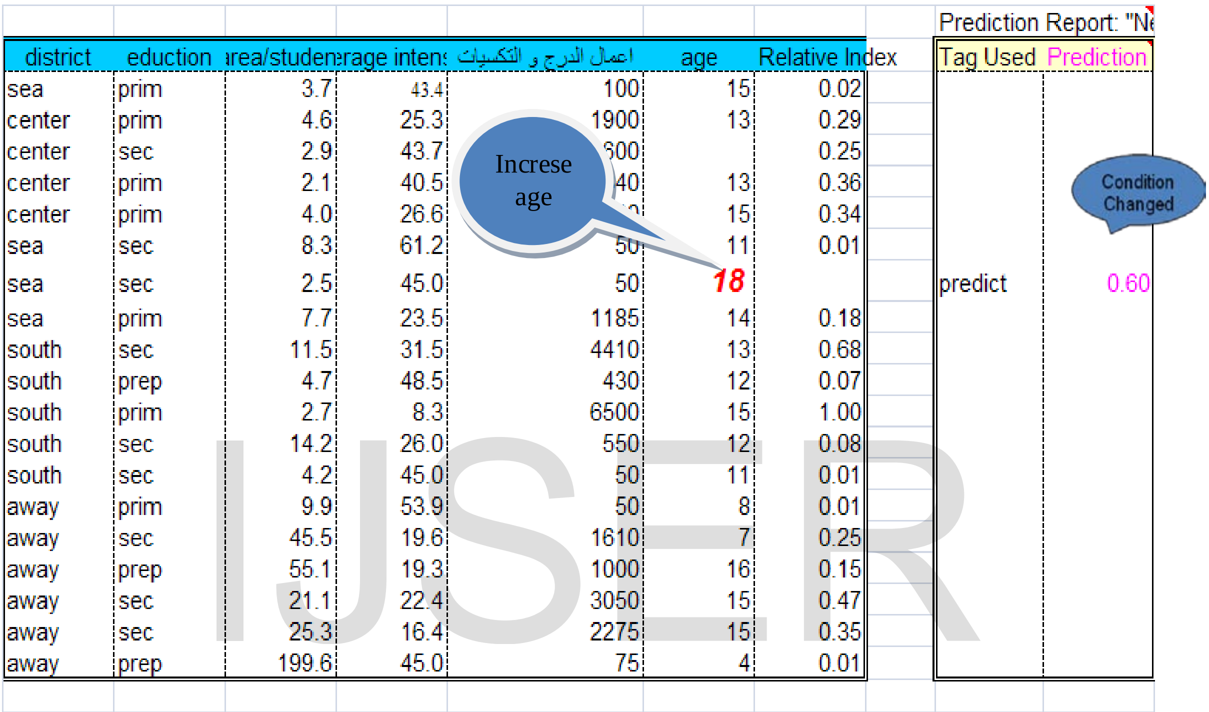
							Train-Test-Predict Report for "Net Trained			
district	eduction	area/student	average intensity	اعمال الدرج و التكسيات	age	Relative Index	Tag Used	Prediction	Good/Bad	Residual
sea	prim	3.7	43.4	100	15	0.02	train			
center	prim	4.6	25.3	1900	13	0.29	train			
center	sec	2.9	43.7	1600	13	0.25	predict			
center	prim	2.1	40.5	2340	13	0.36	test	0.29	Good	0.07
center	prim	4.0	26.6	2200	15	0.34	test	0.29	Good	0.05
sea	sec	8.3	61.2	50	11	0.01	train			
sea	sec	2.5	45.0	50	12	0.77	train			
sea	prim	7.7	23.5	1185	14	0.18	test	0.16	Good	0.02
south	sec	11.5	31.5	4410	13	0.68	train			
south	prep	4.7	48.5	430	12	0.07	train			
south	prim	2.7	8.3	6500	15	1.00	train			
south	sec	14.2	26.0	550	12	0.08	train			
south	sec	4.2	45.0	50	11	0.01	train			
away	prim	9.9	53.9	50	8	0.01	train			
away	sec	45.5	19.6	1610	7	0.25	train			
away	prep	55.1	19.3	1000	16	0.15	test	0.15	Good	0.00
away	sec	21.1	22.4	3050	15	0.47	train			
away	sec	25.3	16.4	2275	15	0.35	train			
away	prep	199.6	45.0	75	4	0.01	train			

Figure 5 Trained School Input Data .

The prediction framework model make many loops to identify the next condition for each item, it begins by increasing one year, two,three……, till the condition changed.figure 6 shows some trial neural output

							Prediction Report: "Ne	
district	eduction	rea/studen	rage inten	اعمال الدرج و التكسيات	age	Relative Index	Tag Used	Prediction
sea	prim	3.7	43.4	100	15	0.02		
center	prim	4.6	25.3	1900	13	0.29		
center	sec	2.9	43.7	1600		0.25		
center	prim	2.1	40.5	2340	13	0.36		
center	prim	4.0	26.6	2200	15	0.34		
sea	sec	8.3	61.2	50	11	0.01		
sea	sec	2.5	45.0	50	14		predict	0.32
sea	prim	7.7	23.5	1185	14	0.18		
south	sec	11.5	31.5	4410	13	0.68		
south	prep	4.7	48.5	430	12	0.07		
south	prim	2.7	8.3	6500	15	1.00		
south	sec	14.2	26.0	550	12	0.08		
south	sec	4.2	45.0	50	11	0.01		
away	prim	9.9	53.9	50	8	0.01		
away	sec	45.5	19.6	1610	7	0.25		

Same Condition



district	eduction	area/studen	rage inten	اعمال الدرج و التكسيات	age	Relative Index
sea	prim	3.7	43.4	100	15	0.02
center	prim	4.6	25.3	1900	13	0.29
center	sec	2.9	43.7	600		0.25
center	prim	2.1	40.5	40	13	0.36
center	prim	4.0	26.6	[illegible]	15	0.34
sea	sec	8.3	61.2	50	11	0.01
sea	sec	2.5	45.0	50	18	
sea	prim	7.7	23.5	1185	14	0.18
south	sec	11.5	31.5	4410	13	0.68
south	prep	4.7	48.5	430	12	0.07
south	prim	2.7	8.3	6500	15	1.00
south	sec	14.2	26.0	550	12	0.08
south	sec	4.2	45.0	50	11	0.01
away	prim	9.9	53.9	50	8	0.01
away	sec	45.5	19.6	1610	7	0.25
away	prep	55.1	19.3	1000	16	0.15
away	sec	21.1	22.4	3050	15	0.47
away	sec	25.3	16.4	2275	15	0.35
away	prep	199.6	45.0	75	4	0.01

Tag Used	Prediction
predict	0.60

Figure 6 "Neural Output Iterative Loops" .

3.3 Optimum Repair Scenario:

At this stage, selecting the best repair plan has been modeled to reach a desirable condition with minimum repair cost. A mathematical comparison method developed to identify yearly instant repair, and the next 4 year and adding the budget constraints. The model ranked all schools related to each item than ranked condition for each item for each school separately.

Table 3.1 shows the output for each year items condition categorized into the three defined group, while table 3.2 shows the output for each school items condition.

Years	Item I	Item II	Item III…..n
2012	Critical School 1	Critical School 1	Critical School 1
2012	Critical School 2	Critical School 2	Critical School 2
2012	Critical School 3	Critical School 3	Fair School 3
2012	Critical School 4	Fair School 4	Fair School 4
2013	Fair School 5	Fair School 5	Good School 5
2013	Fair School 5	Fair School 5	Good School 5
2013	Fair School n	Fair School n	Good School n

Table 1 "Years Items Output Condition".

School\Condition	School 1	School 2	School 3
Critical	Item 1(year i)	Item 1(year i)	Item 1(year i)
	Item 2(year i)	Item 2(year i)	Item 2(year i)
	Item n(year i)	Item n(year i)	Item n(year i)
Fair	Item 3(year i)	Item 3(year i)	Item 1(year i)
	Item 4(year i)	Item 3(year i)	Item 2(year i)
	Item n(year i)	Item n(year i)	Item n(year i)
Good	Item 5(year i)	Item 5(year i)	Item 5(year i)
	Item 6(year i)	Item 6(year i)	Item 6(year i)
	Item n(year i)	Item n(year i)	Item n(year i)

Table 2 "Schools Output Ranking Condition"

Table 1 represent the condition output for for each iyem through its life service after ranking, while table 2 represent school items condition and its related years.

The following steps are then utilized:

- Calculate cost for critical items.
- Calculate cost for fair condition items that is must to be done at this year and cannot be delayed.
- Add yearly budget constraints.
- Compare the previous calculations(figure 7):
    - If the budget satisfy repair plan without addition , then the decision can be taken for to repair these items.
    - If there is more budget the model can add more items that have least priority in the plan horizon.
    - If the needed repair budget is more the available, the organization must provide more buget to prevent failure or unexpected action due to instant conditions.

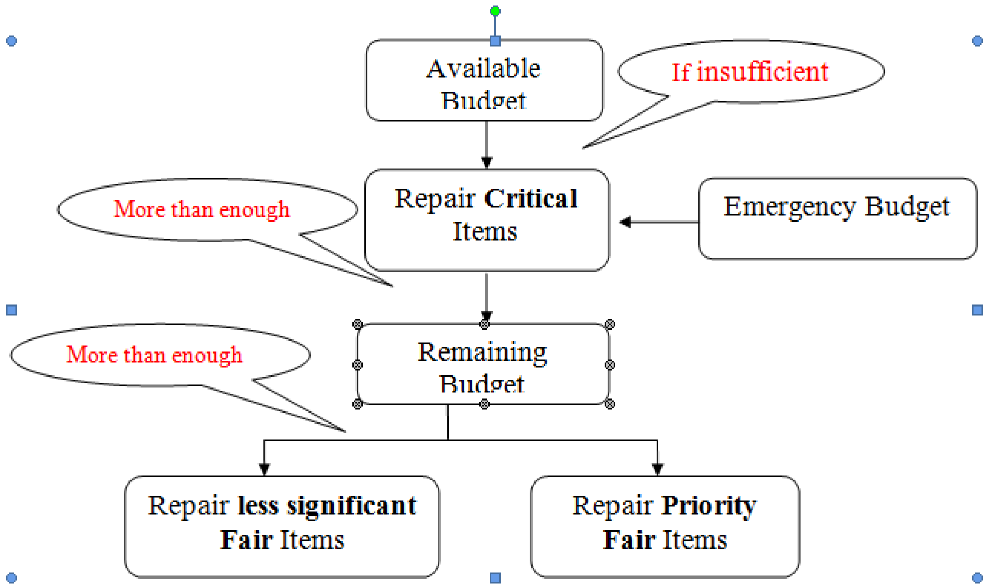


Figure 7 "Repair Budget Allocation Strategy"

Finally, the system develop a life cycle cost model for school network,considering the deterioration model, least cost repair strategies, budget limits. The model has optimum repair strategy for each year in the plan and the next during the planning horizon and there related budget. Table 3 represent the final report after constrain the budget limit with the require repair items.

Limited Budget

Years	Items Condition	Budget	Emergency Budget
2012	Critical		
	Critical		
	Fair		
2013	Fair		
	Fair		
	Good		

Table3 "Budget Time Schedule".

3.4 Network Level Optimum Repair Allocation

After choosing best repair strategy for each school for the planning horizon, the model can calculate and submit best network level strategy for schools ubder consideration.

Figure 8 shows the project and network level for schools repair strategy.

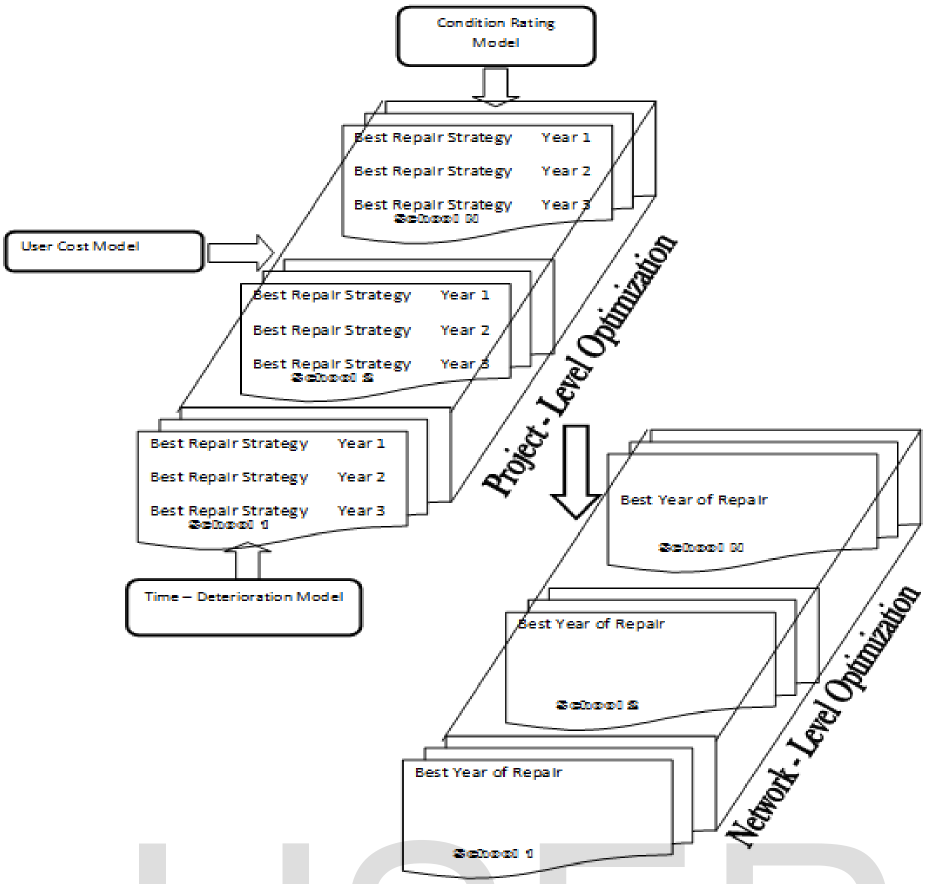
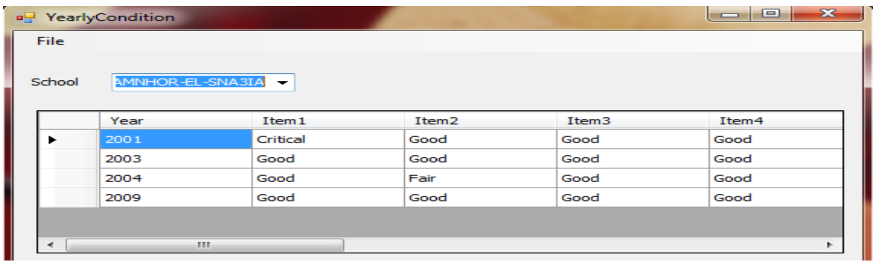


Figure 8 Project And Network Level Schools Repair Strategy

4. Sample for Prototype Outputs

Figure 9 shows a sample for a school item condition data. For this school item 1 is critical and repaired at year 2001 then for the next 3 repairing time is still good item until year 2009.



Year	Item1	Item2	Item3	Item4
2001	Critical	Good	Good	Good
2003	Good	Good	Good	Good
2004	Good	Fair	Good	Good
2009	Good	Good	Good	Good

Figure 9 A School Item Condition

The model predict item for next year at 2010 (figure 10) shows that there is no change for condition, and so for year 2011,2012. By asking the Egypt Educational Building Authority about this school and the updated repair data, and reply there isnt any change or repair work done there for the last 4 years, and no complaint about this school for year 2013.

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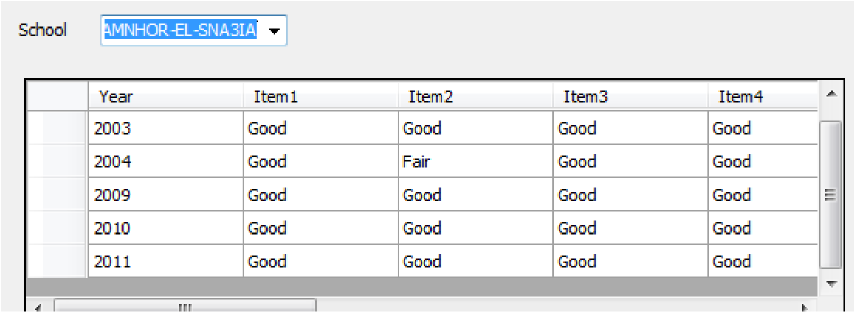

Figure 10 A School Prediction Data Output

Figure 11 shows that the condition begin to change for year 2014, and this confirm the authority result.

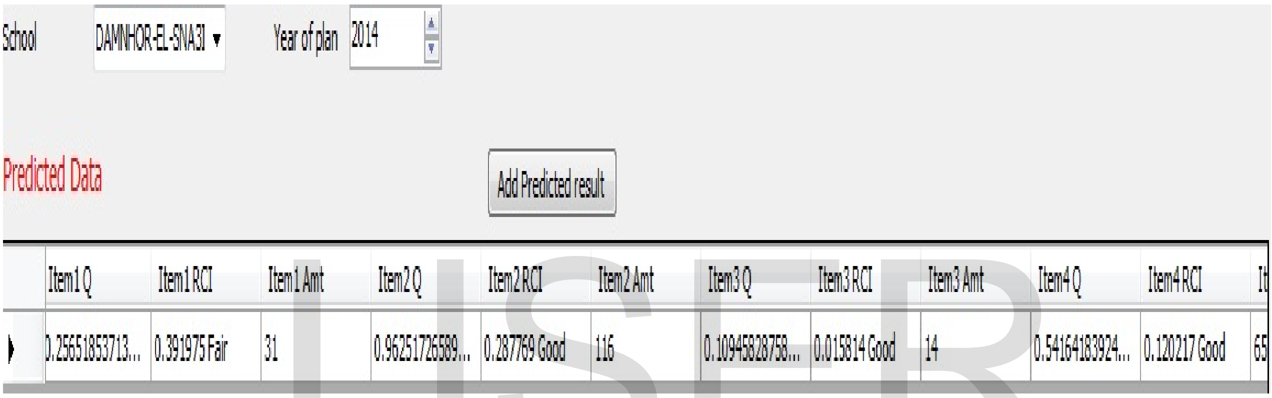

Figure 11 A School Prediction Output changed Condition

The use of the Prototype has greatly improved the quality of information available on schools by establishing the condition of each segment according to various criteria. For example, the ability to create different improvement scenarios and compare results between scenarios helps refine proposed solutions and flesh out the planning of public works.
In other words, decision-makers want to manage the risk of major breaks occurring over several years and to plan improvements before the level of risk becomes too high. In the same vein, the evaluation of life-cycle cost will also provide valuable information to technical personnel and decision-makers.

5. Conclusion:

In this paper a dynamic approach has been introduced . The proposed approach depends on accurate condition assessment of the asset inventory, considering component deficiencies. For each building component, the condition assessment data is used to generate a dynamic deterioration model, which is then used in a repair selection model. The repair selection model determines , for each year of the planinig horizon, the cheapst repair strategy that raises the condition of the component to a user defined minimum acceptable level. Predicting the deterioration has been demonstrated, that the developed ANN model, with only the most influential parameters as input parameters, can predict damage degree accurately and instantly.

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