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Regression Model for Building Deterioration Prediction

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Abstract: *Deterioration models are an integral part of asset management used to predict future asset condition. One hundred buildings having different properties were audited to determine the level of degradation of building main elements and their deterioration causes which leads to different decisions for maintenance and repair. Data Analysis was then applied to find the correlation and regression between the elements deterioration symptoms and causes that lead to this deterioration. This paper has explored the main deterioration causes in the investigated buildings, and then regression equation for each deterioration symptoms was developed as a function of the deterioration causes that lead to this deterioration for each element. Then a matrix in excel sheet is designed to estimate the deterioration value where the user will input the values of deterioration causes according to the investigated symptoms of the building to come out with recommended decision for repairing or demolition .*

Keywords: *Asset management, Building deterioration, Deterioration models, Multiple linear regression model, SPSS Statistical Analysis.*

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I. Introduction

Building owners recognize the changing economic conditions; emphasize the importance of full utilization of existing structures rather than the increasing cost of new building so the need to evaluate the existing building stock is being recognized. According to Keshavarzrad [1], the first step in establishing an integrated asset management plan for buildings is establishment of an acceptable building hierarchy. The second step in developing an asset management (AM) plan for buildings requires an accepted condition monitoring plan. As the third step in proactive decision making, a good deterioration forecasting model is required at component level. In the final stage of an integrated AM plan, deterioration curves should be integrated with a decision making process, which will allow proactive decision making instead of the current reactive methods. Deterioration shows how each component of the asset will deteriorate according to time and used to forecast its future status.

Deterioration prediction of a building requires understanding of the deterioration of components of buildings and the resultant effect on a complete building. Deterioration prediction is a significant stage in whole life cycle of building management process [2] .In most of the asset management frame works, there is an evidence of forecasting deterioration which is used to evaluate serviceability and risks of failure. Balaras [4] stated that there is a number of parameters like the quality of construction and materials, the local weather conditions or the lack of maintenance, which can greatly influence this process.

The models used for prediction of deterioration trend can be classified in three categories; Deterministic models, statistical/stochastic models and Artificial Intelligence models [3]. Regression models forecast future building's condition from a set of explanatory variables via equations developed based on past data [5].

This paper aims to predict deterioration of elements and thus deterioration of building due to the existence of the determined symptoms and to enable early decision making beside the technical decision from a statistical perspective.

This study surveyed one hundred buildings to determine the level of degradation of building structural main elements: foundation, columns, slabs, beams and walls. The survey covers different governorates, locations, sizes, types, different elements deterioration symptoms and the main causes that lead to deterioration. SPSS program is used to analyze data and to find the regression between the structural elements deterioration symptoms and causes that lead to building deterioration. A Regression Model for Building Deterioration Prediction is then developed based on concluded regression equations of elements deterioration.

II. Methodology

This research is adopting the quantitative methodology through four phases; the first phase is surveying a hundred buildings using a survey form that was designed as part of this paper. The aim of that survey is exploring the current status of the buildings through identifying the structural elements deterioration, deterioration causes and required repairing. The data collection and analysis is followed in the second phase to analyze the surveyed data using SPSS software, where Data analysis includes testing the regression between deterioration Causes and Symptoms. Third phase is concerned with developing regression model for building deterioration prediction based on predicting element's deterioration and using a designed matrix in excel sheet to implement the model and estimate a value for building deterioration to be used as an indicator to make an initial decision for repairing or demolition. In fourth phase, a model validation is conducted.

III. Data Analysis

3.1. Data Collection

One hundred buildings were surveyed during the period from 2014 to 2016. Housing and building national research center was the source of data as it is the main governmental organization in Egypt responsible for buildings inspection. The survey form is divided into two sections: 1) Building general data (building type, location, Number of floors, age), and 2) Deterioration causes, recommendations (required repair), and Symptoms for deterioration for each structural element; Foundations, columns, slabs beams, and walls.

3.2. Sample Profile

The surveyed buildings included six types: schools, hospitals, Administrative buildings, hotels, service buildings, and others. Their percentage is distributed according to Fig. (1); where the administrative buildings represent the majority. The surveyed buildings cover most of the Governorates in Egypt; Cairo, Giza, Alexandria, Marsa-Matrouh, Hurghada, Beni Swef, Port Said, Tanta, Dakhlia, Monofia, Sharkia , Assuit, Kena, and Sohag. Moreover, only 30% are located as sea shore areas. Fig.(2) represents the buildings age, which ranges between 60's and 2000.The age of 26% of the surveyed buildings is larger than 50 years. 87% of the surveyed buildings range from 1-5 floors.

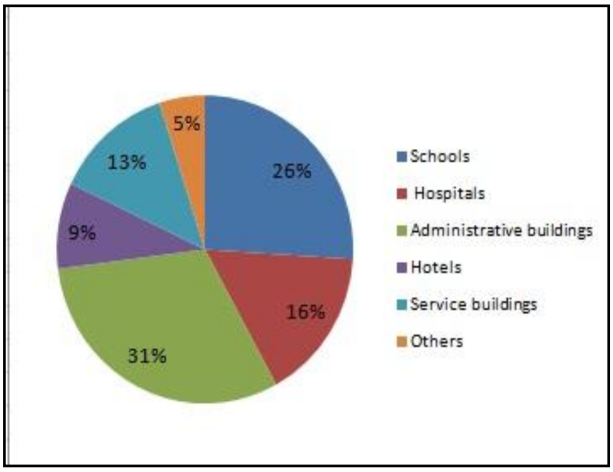

Fig. (1): Buildings Type

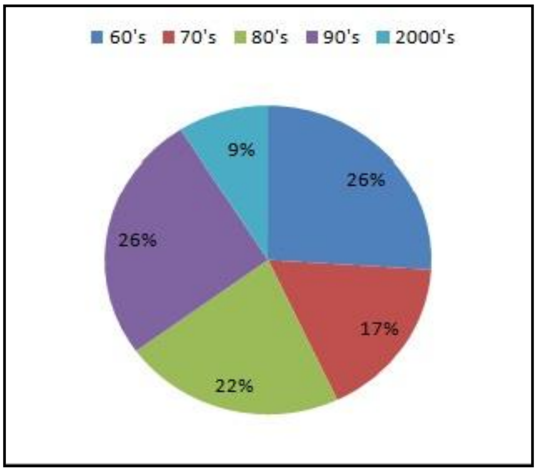

Fig.(2): Buildings Age

3.3. Current Status of Surveyed Buildings

Second section of the survey form has discussed the current status for surveyed buildings; where it addresses the current deterioration problems, the causes of deterioration, Deterioration Symptoms of structural elements, and the recommended decisions for repair. The study has classified the Deterioration Symptoms surveyed to seven Symptoms: Cracks, Construction faults (Irregular surface, Bug Holes), Disintegration (Scalling, Dusting , Weathering), Distortion of movement (Buckling, Deflection, Settling, Tilting), Seepage (Discoloration, Efflorescence, Corrosion, Leakage), Erosion (Abrasion, Cavitation) and Spalling. The study also classified the causes surveyed to six causes: bas sewage, bad insulation, bad concrete used (no quality control), non conformity with codes, increase of loads, and no maintenance. The analysis of the data revealed that the most deterioration causes are because of bad sewage and bad insulation causes, while the choice of "no maintenance" represents the least reason. Also the cracks were the most symptom that appear for all elements followed by erosion and seepage.

IV. Building regression model

4.1. Regression Model

A model is developed using regression analysis to clarify the relationship between the element's deterioration symptoms (as dependent variable)and causes (as independent variables) using SPSS software. Fig.(3) displays the proposed symptoms, and causes which clarify the regression relation between them. Where there are six causes and seven symptoms for each of the structural elements. The building's deterioration is evaluated based on the deterioration of its main elements**.**

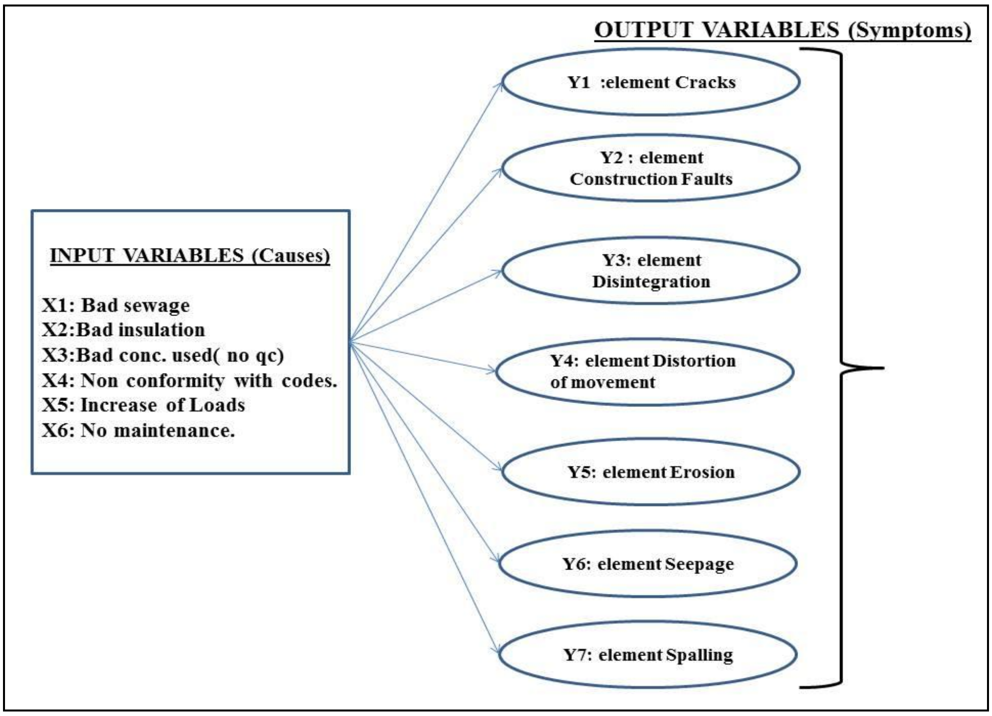

Fig. (3) :Variables of Building's Element Deterioration Model

4.1.1. Multiple Linear Regression Model

Multiple linear regression is a theoretical assumption; that for every one-unit change in the independent variable, there will be a consistent and uniform change in the dependent variable. Scatter plot is a way to pursue the hypothesis of linear relation between dependent and independent variables. The multiple linear regressions determine the equation of the line that best describes that relationship. This equation can be used to predict values of the dependent variable from values of the independent variables. According to Kerali [6] in the linear deterioration model, the rate of deterioration is independent of the existing degree of deterioration of the concrete. This perspective is appropriate for this study, where the current surveyed buildings are exposed to problems which have the same symptoms such as Cracks, Construction faults, Disintegration, Distortion of movement, Seepage, Erosion and Spalling.

There are four important statistics that should be conducted to attend in a multiple linear regression model. First, the F statistic tests which determine whether the model as a whole predicts the dependent variable or no. Second, the regression coefficients that measure the strength and direction of the relationships. Third, for each of these regression coefficients, there is a significance score, which measures the likelihood that the relationship revealed in the coefficients can be attributed to random chance. Each coefficient is then interpreted as the predicted change in the value of the dependent variable for a one-unit change in the independent variable after accounting for the effects of the other variables in the model. Finally, the adjusted R square statistic measures the model's overall predictive power and the extent to which the variables in the model explain the variation in the dependent variable. Furthermore, Collinearity must be checked to avoid the peculiar regression results. So, the final model will exclude the insignificant independent variables, as well as the highly correlated independent variables to each other [7] . Fabbozzi [8], stated that Stepwise exclusion regression method is applied for the purpose of determining the suitable independent variables to be included in a final regression model to conclude the final equation for each dependent value as following:

$$\mathbf{Y = A+B_1X_1+ B_2X_2+B_3X_3 + \ldots +Std. Error (€)} \qquad (4.1.1.a)$$

Where, **€ = 0** , **Y**: Predicted value of Y (Dependent variable/ Residual values), **A**: constant, **B:** coefficient of independent variable, and **X :** is independent variables.

4.1.2. Regression Analysis

The Regression analysis model is a relationship between the element deterioration symptoms (as dependent variable) and causes (as independent variables) , which are developed using SPSS software. The final regression equations for each element may only involve some of the causes because others are statistically insignificant. Using SPSS software, the multi linear regression model is carried out using stepwise method; to come out with the following equations for each element.

The regression model was done to get the regression equation for each element's deterioration. According to Ens[9]; there are common measures that should be examined to get the final regression:

- Reasonable and significant parameter values,
- Plot of residuals,
- R^2 and Any assumptions.

Following the previous measures, the regression analysis is proceeded for all dependent and independent variables. Therefore, to explain how the statistical regression analysis is done, the foundation cracks will be explained as an example to determine the regression equation of it.

The regression is conducted as foundation cracks(Y_1) is dependent value, and the following are the independent variables : (X_1: Bad sewage , X_2:Bad insulation , X_3:Bad conc. used(no qc) , X_4: Non conformity with codes , X_5: Increase of Loads , and X_6: No maintenance).The subsequent statistics (from Table 1 to Table 5) are evaluated to examine if these independent variables together could predict the value of dependent variable, and if the relation is statistically significant .

To examine the hypothesis of linearity between dependent and independent variables; Visual inspection of scatter diagram of each dependent variable and the independent variable is conducted for checking the linearity[8]. The scatter plot in Fig.(4) shows that the data points tend to flow from the lower left-hand corner of the graph to the upper right. Also, there is a significant positive correlation of this dependent and independent variables; where P-value = 0.000 (Correlation is significant at the 0.01 level (2-tailed)). The linear regression determines the equation of the line that best describes that relationship. This equation can be used to predict values of the dependent variable from the values of the independent variable.

The equation of the shown reference line equals to Y = 0.167x + 0

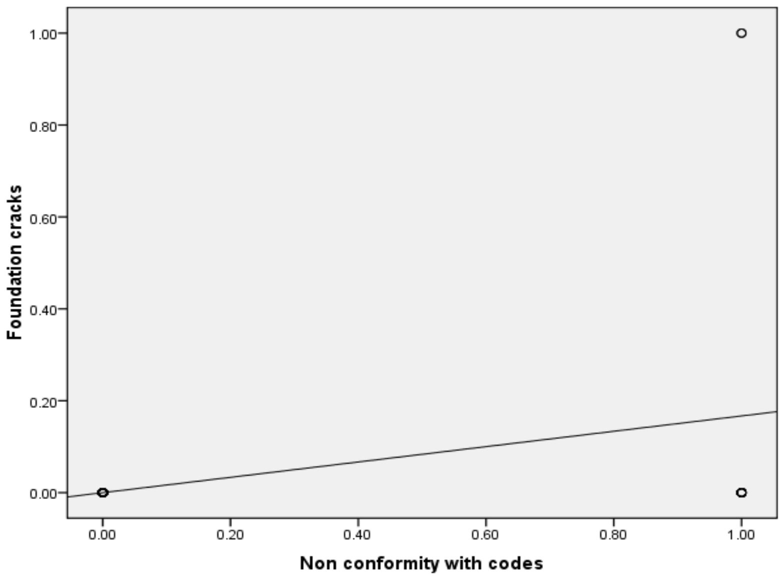

Fig. (4) :Scatter Plot of Foundation Cracks and Non Conformity with Codes

Using the stepwise exclusion regression method; the all independent variables are included at the beginning, then the insignificant variables are removed one after another, also the statistics of Collinearity Diagnostics using SPSS is used to check the collinearity. Therefore, Table (1) summarizes the excluded independent variables (Bad sewage, Bad insulation, Bad conc. used (no qc), Increase of loads, and No maintenance) , which are excluded based on two those examinations correlation and collinearity. Whether, they are not significantly correlated with foundation cracks (dependent variable) or there is a collinearity between independent variables, the collinearity would be tested to examine the correlation between them, then exclude those having the least adjusted R square. So, finally the regression equation of foundation cracks contains only one significant independent variable the "Non conformity with codes" as will be clarified in Table 2.

Table (1) : Excluded Variables from the regression model for Dependent Variable: Foundation cracks

Model	Beta In	T	Sig.	Partial Correlation	Collinearity Statistics		
					Tolerance	VIF	Minimum Tolerance
1 Bad sewage	-.097[a]	-1.038	.302	-.105	.996	1.004	.996
Bad insulation	-.097[a]	-1.036	.303	-.105	.979	1.022	.979
Bad conc. used (no qc)	-.060[a]	-.608	.545	-.062	.891	1.122	.891
Increase of loads	.092[a]	.940	.349	.095	.901	1.109	.901
No maintenance	.000[a]	.000	1.000	.000	.996	1.004	.996

a. Predictors in the Model: (Constant), Non conformity with codes

Table (2) illustrates that the regression coefficient is positive (0.167) ; it means that the more "non conformity with codes" , the higher "foundation cracks" , and the relationship is statistically significant(sig.= 0.000). It is reasonable that non conformity with codes will result in foundation cracks. The result constitutes the final regression model as shown in Table (2). Therefore, the final regression equation is formed as following:
Y_1: Foundation cracks = $Y_1=0.167\ X_4$

Table (2) : Regression Coefficients for Dependent Variable: Foundation racks

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	6.716E-17	.014		.000	1.000		
	Non conformity with codes	0.167	.040	.387	4.153	**0.000**	1.000	1.000

The ANOVA table tests whether the model as a whole is significant. In other words, it tests if the independent variables, taken together, predict the dependent variable better than just predicting the mean for everything. In Table (3) The P-value (Sig. column) for the Regression model is 0.000 (less than0.001), which means that the model is highly significant. Moreover, it can be concluded that the model can predict the foundation crack.

Table (3) : ANOVA Test for Dependent Variable: Foundation cracks

Model		Sum of Squares	df.	Mean Square	F	P-value (Sig.)
1	Regression	.293	1	.293	17.248	**0.000[a]**
	Residual	1.667	98	.017		
	Total	1.960	99			

a. Predictors: (Constant), Non conformity with codes

For Table (4); the adjusted R square statistic explores how good is the model, it measures the regression model's usefulness in predicting outcomes – indicating how much of the dependent variable's variation is due to its relationship with the independent variable(s). It ranges from one to zero, an adjusted R square of 1 means that the independent variable explains 100% of the dependent variable's variation and it entirely determines its values. Conversely, an adjusted R square of 0 means that the independent variable explains none of the variation in the dependent variable it has no explanatory power whatsoever [7] and [8] . The table of Model Summary (Table 4) shows that Adjusted R Square is 0.141; more than zero. This means that the independent variable explains 14% of the dependent variable's variation and it entirely determines its values.

Table (4) : Model Summary for Dependent Variable: Foundation cracks

Mode	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.387[a]	.150	**0.141**	.13041	.150	17.248	1	98	**0.000**

a. Predictors: (Constant), Non conformity with codes

The same procedures are followed for each element to finally get the following regression equations from equation (4.1.2.a) to equation (4.1.2.w) :

Foundation

Y_1: Foundation cracks = Y_1=0.167X4 (4.1.2.a)
Y_2: Foundation construction fault = $Y_2=0.074X_3$ (4.1.2.b)
Y_3: Foundation disintegration = $Y_3=0.083X_4$ (4.1.2.c)
Y_4: Foundation distortion of movement = $Y_4=0.125+0.292X_4$ (4.1.2.d)
$Y_{5:}$ Foundation erosion = $Y_5= 0.074X_3$ (4.1.2.e)

Columns

Y_5: Column erosion = $Y_5= 0.383+0.259X_2$ (4.1.2.f)
Y_6: Column seepage = $Y_6 = 0.021+0.413X_2$ (4.1.2.g)

Beams

Y_1: Beams cracks $Y_1=0.621+0.189X_1$ (4.1.2.h)
Y_4: Beams distortion of movement = $Y_4=0.205+0.202X_3$ (4.1.2.i)
Y_6: Beams seepage = $Y_6=0.064+0.144X_2$ (4.1.2.j)
Y_7: Beams spalling= $Y_7= -0.027+0.109X_2+0.157X_4$ (4.1.2.k)

Slabs

Y_1: Slabs cracks = $Y_1= 0.897+0.103X_1$ (4.1.2.l)
Y_2: Slabs construction fault = $Y_2=0.045+0.288X_4$ (4.1.2.m)
Y_3: Slabs disintegration = $Y_3=0.466+0.225X_1$ (4.1.2.n)
Y_4: Slabs distortion of movement = $Y_4=0.568+0.348X_4$ (4.1.2.o)
Y_5: Slabs erosion = $Y_5= 0.411+0.384X_2-0.289X_4$ (4.1.2.p)
Y6: Slabs seepage = $Y_6=0.413+0.260X_1+0.336X_2$ (4.1.2.q)
Y_7: Slabs spalling = $Y_7=0.149+0.210X_2$ (4.1.2.r)

Walls

Y_1: Walls cracks = $Y_1= 0.596+0.234X_2$ (4.1.2.s)
Y_3: Walls disintegration = $Y_3=0.113+0.553X_6$ (4.1.2.t)
Y_6: Walls seepage = $Y_6=0.340+0.433X_2$ (4.1.2.v)
Y_7: Walls spalling = $Y_7=0.052+0.615X_6$ (4.1.2.w)

According to regression analysis, there are two major notes; it can be noticed that there are some symptoms that have failed to formulate a regression equation with independent variables for some elements; such as columns cracks, beams erosion, walls construction fault, etc. This can be explained that there is a collinearity between the correlated independent variables which is reasonable. Also, it is noticed that there is only one independent variable(X_5 : increase of loads) which has no significant effect on any of dependent variables; that is because there are only 5 cases from the total of 100 buildings surveyed stated that the cause of deterioration was the increase of loads. Therefore, its effect cannot be significant on the elements deterioration.

4.1.3. Building Deterioration Prediction Model

According to Zhang [10], the condition of the element is a composite measure of a number of deterioration symptoms. The Regression analysis model revealed that there is a relationship between the deterioration symptoms (as dependent variable) and causes (as independent variables) for each element. Based on experts review from the survey; the symptoms are classified in a scale according to their severity as follows: Distortion of Movement, Seepage, Cracks, Erosion, Spalling, and Disintegration, Construction Faults. A scale from1 to 7 is given to the weight of severity with 7 as a maximum and 1 as a minimum severity. Therefore the deterioration of each element can be calculated as the following equation:

$$Y_{element} = \sum W_{symptoms} * Y_{symptoms\ for\ each\ element} \quad (4.1.3.a)$$

Where $\mathbf{W}_{symptoms}$ is the weight of the severity of the deterioration symptoms and $\mathbf{Y}_{symptoms}$ is the independent variable for each elements' symptoms.

$$\mathbf{Y_{element} = 7Y_4 + 6Y_6 + 5Y_1 + 4Y_5 + 3Y_7 + 2Y_3 + 1Y_2} \quad (4.1.3.b)$$

According to equation (4.1.3.b), the equation of each element deterioration will be formulated as shown in the following equations:

$$\mathbf{Y_{Foundation} = 0.875 + 0.37\,X_3 + 3.045\,X_4} \quad (4.1.3.c)$$
$$\mathbf{Y_{Columns} = 1.658 + 3.514\,X_2} \quad (4.1.3.d)$$
$$\mathbf{Y_{Beams} = 4.843 + 0.945\,X_1 + 1.191\,X_2 + 1.414\,X_3 + 0.471\,X_4} \quad (4.1.3.e)$$
$$\mathbf{Y_{Slabs} = 14.007 + 2.525\,X_1 + 4.182\,X_2 + 1.568\,X_4} \quad (4.1.3.f)$$
$$\mathbf{Y_{Walls} = 5.402 + 3.768\,X_2 + 2.951\,X_6} \quad (4.1.3.g)$$

The deterioration of a building is dependent on the deterioration of all elements in the building. Based on experts review from the survey; The structural importance of the main elements were specified to be 30 % columns, 25 % foundation, 25 % beams, 15 % slabs and 5% walls. Therefore the deterioration of a building can be calculated as the following equation:

$$\mathbf{Y_{Building}} = \sum \mathbf{W_{element}} * \mathbf{Y_{element}} \quad (4.1.3.h)$$

Where $\mathbf{W_{element}}$ is the structural importance of each element. Therefore, the building deterioration can be calculated according to equation (4.1.3.i) as following:

$$\mathbf{Y_{Building} = 0.30Y_{Columns} + 0.25Y_{Foundation} + 0.25Y_{Beams} + 0.15Y_{Slabs} + 0.05Y_{Walls},} \quad (4.1.3.i)$$

Using the values of equations from equation (4.1.3.c) to equation (4.1.3.g) to substitute their values in equation (4.1.3.i), the building deterioration equation is then calculated as shown in Equation (4.1.3. j):

$$\mathbf{Y_{Building} = 4.298 + 0.615\,X_1 + 2.168\,X_2 + 0.446\,X_3 + 1.114\,X_4 + 0.148\,X_6,} \quad (4.1.3.\,j)$$

Equation (4.1.3. j) represents the relation between the building deterioration and the deterioration causes; in case of having all symptoms existing. Therefore, the parameters of this equation are not always fixed for all applied cases; some of them may not exist regarding to its deterioration level. So, this study has developed a matrix as a methodology to formulate this equation for any case in a simple way through substituting in it. The matrix is applied in excel sheet where element symptoms are represented in rows, and causes are represented in columns as shown in Fig.(6-a) , Fig.(6-b).

The developed building deterioration model is used to estimate the deterioration value and to indicate how much construction defects (causes) affect the element deterioration and consequently the building deterioration. Moreover, it is able to recommend the needed action plan according to the estimated deterioration value.

V. Model Implementation

The developed model aims to predict deterioration of elements and thus deterioration of building due to the existence of the determined symptoms. Therefore, to estimate the building deterioration; the user will proceed with the following processes that are represented in the model flow chart as shown in Fig.(5).

First, for any investigated case, the user will detect the elements deterioration symptoms using visual inspection. Then, by reviewing the regression equations of each element, the user can predict the causes that lead to this deterioration. The next step, Using the designed matrix in the excel sheet; substitute for the predicted causes(X) by 0 or 1. Zero for not existing causes and 1 for existing. The matrix is designed as a substitution for equations from (4.1.3.b) to (4.1.3.i). Then the value of building deterioration ($Y_{Building}$) will be estimated automatically. It will equal to 4.298 for a building in best conditions, and 8.789 in the worst conditions as represented in Fig. 6. Therefore, the building deterioration value will range from 4.298 To 8.789. Based on the estimated deterioration value; the model comes out with one of two recommendations; repairing or demolishing. The model suggests two limits for recommendation action plan as follows: From 4.298 to 6.544(as an average point) the building needs repair, and from 6.544 to 8.789 the building should be demolished. These limits are provided as a guide from a statistical perspective beside the technical decision; it gives a hand / indicator before laboratory tests.

The developed model is applicable for all building types, but limited for only significant symptoms in the regression model.

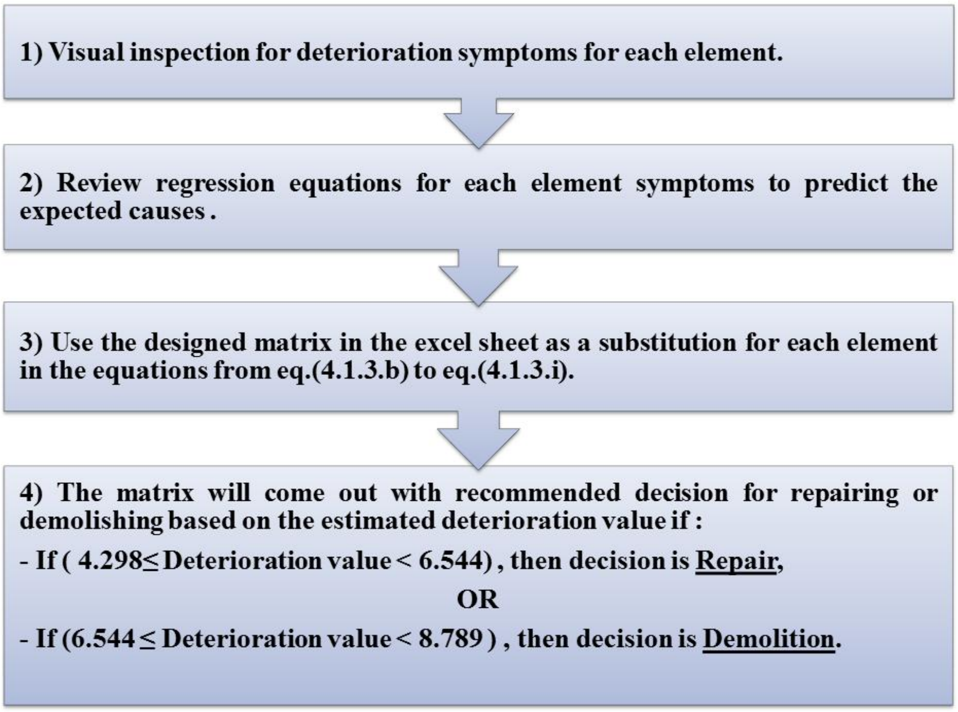

Fig.(5): the Building Deterioration Prediction Model Flowchart

VI. Model Validation

A case study is selected for model validation. The case study is a hospital built in 70's in Cairo. As a result of visual inspection, the deterioration symptoms are documented as following:

- For columns: cracks , erosion, seepage, and spalling
- For beams: cracks, distortion of movement, erosion and spalling
- For slabs: cracks, disintegration, distortion of movement and seepage
- For walls: cracks and distortion of movement
- For foundation, no symptoms exist.

The documented deterioration symptoms will help the user to decide which cause will be entered. To apply the model, the following steps have been proceeded as followings:

1. First step is substitution in the regression equations which is represented in the matrix for each element as shown in Fig.(7) ; Zero for not existing causes and 1 for existing .

The following causes are predicted based on defined symptoms: For columns: Bad insulation (X_2) is the cause. For beams: Bad sewage(X_1), Bad insulation (X_2), Bad concrete used (X_3), and Non conformity with codes (X_4) are the causes. For slabs: Bad sewage(X_1), Bad insulation (X_2) and Non conformity with codes (X_4) are the causes. For walls: Bad insulation (X_2) is the cause. Therefore, the causes for the building deterioration are Bad sewage(X_1), Bad insulation (X_2), Bad concrete used (X_3), and Non conformity with codes (X_4). In brief, based on element regression model; for this case it can be predicted that there are four causes X1, $X_{2,}$ $X_{3,}$ and $X_{4.}$

2. Second step is estimating the deterioration building value by substituting in the model represented in the matrix. The deterioration value is estimated to be **7.247**.
3. Third step is coming up with the suggested recommendation based on the designed range. Regarding to the estimated deterioration value where (6.544 **<7.247**<8.789); the decision will be demolition.

By reviewing the technical decision taken for this case study according to the investigated data; the technical decision was found demolition.

By implementing the developed regression model for the selected case study; it is found that the developed model is applicable and the expected outcomes are validated with actual status.

	CONSTANT	X1: Bad sewage	X2:Bad insulation	X3:Bad conc used(no qc.	X4: Non conformity wz codes	X5: Increase of Loads	X6: No maintenance	Σ $Y_{element}$
Y1 :Cracks					0.167			0.167
Y2 : Construction Faults				0.074				0.074
Y3: Disintegration					0.083			0.083
Y4: Distortion of movement	0.125				0.292			0.417
Y5: Erosion				0.074				0.074
$Y_{Foundation}$	0.125	0	0	0.148	0.542	0	0	4.29
Y5: Erosion	0.383		0.259					0.642
Y6: Seepage	0.021		0.413					0.434
$Y_{columns}$	0.404	0	0.672	0	0	0	0	5.172
Y1 :Cracks	0.621	0.189						0.81
Y4: Distortion of movement	0.205			0.202				0.407
Y6: Seepage	0.064		0.144					0.208
Y7: Spalling	-0.027		0.109		0.157			0.239
Y_{beams}	0.863	0.189	0.253	0.202	0.157	0	0	8.864
Y1 :Cracks	0.897	0.103						1.000
Y2 : Construction Faults	0.045				0.288			0.333
Y3: Disintegration	0.466	0.225						0.691
Y4: Distortion of movement	0.568				0.348			0.916
Y5: Erosion	0.411		0.384		-0.289			0.506
Y6: Seepage	0.413	0.261	0.336					1.010
Y7: Spalling	0.149		0.21					0.359
Y_{Slabs}	2.949	0.589	0.93	0	0.347	0	0	22.288
Y1 :Cracks	0.596		0.234					0.83
Y3: Disintegration	0.113						0.553	0.666
Y6: Seepage	0.340		0.433					0.773
Y7: Spalling	0.052						0.615	0.667
Y_{Walls}	1.101	0	0.667	0	0	0	1.168	12.121

$Y_{Building}$ = 8.789

DEMOLITION

Fig.(6-a): Designed matrix for buildings deterioration model (the worst case)

	CONSTANT	X1: Bad sewage	X2:Bad insulation	X3:Bad conc used(no qc.	X4: Non conformity wz codes	X5: Increase of Loads	X6: No maintenance	Σ $Y_{element}$
Y1 :Cracks								0
Y2 : Construction Faults								0
Y3: Disintegration								0
Y4: Distortion of movement	0.125							0.125
Y5: Erosion								0
$Y_{Foundation}$	0.125	0	0	0	0	0	0	0.875
Y5: Erosion	0.383							0.383
Y6: Seepage	0.021							0.021
$Y_{columns}$	0.404	0	0	0	0	0	0	1.658
Y1 :Cracks	0.621							0.621
Y4: Distortion of movement	0.205							0.205
Y6: Seepage	0.064							0.064
Y7: Spalling	-0.027							-0.027
Y_{beams}	0.863	0	0	0	0	0	0	4.843
Y1 :Cracks	0.897							0.897
Y2 : Construction Faults	0.045							0.045
Y3: Disintegration	0.466							0.466
Y4: Distortion of movement	0.568							0.568
Y5: Erosion	0.411							0.411
Y6: Seepage	0.413							0.413
Y7: Spalling	0.149							0.149
Y_{Slabs}	2.949	0	0	0	0	0	0	14.007
Y1 :Cracks	0.596							0.596
Y3: Disintegration	0.113							0.113
Y6: Seepage	0.340							0.34
Y7: Spalling	0.052							0.052
Y_{Walls}	1.101	0	0	0	0	0	0	5.402

$Y_{Building} = 4.298$

REPAIR

Fig. (6-b): Designed matrix for buildings deterioration model (the best case)

.Fig.(7) : Model Validation (Applied in designed Matrix as excel sheet)

Member		CONSTANT	X1: Bad sewage	X2:Bad insulation	X3:Bad conc used(no qc)	X4: Non conformity wz codes	X5: Increase of Loads	X6: No maintenance	Σ $Y_{element}$
Foundation	Y1 :Cracks					0			0
	Y2 : Construction Faults				0				0
	Y3: Disintegration					0			0
	Y4: Distortion of movement	0.125				0			0.125
	Y5: Erosion				0				0
	$Y_{Foundation}$	0.125	0	0	0	0	0	0	0.875
Columns	Y5: Erosion	0.383		0.259					0.642
	Y6: Seepage	0.021		0.413					0.434
	$Y_{columns}$	0.404	0	0.672	0	0	0	0	5.172
Beams	Y1 :Cracks	0.621	0.189						0.81
	Y4: Distortion of movement	0.205			0.202				0.407
	Y6: Seepage	0.064		0					0.064
	Y7: Spalling	-0.027		0.109		0.157			0.239
	Y_{beams}	0.863	0.189	0.109	0.202	0.157	0	0	8
Slabs	Y1 :Cracks	0.897	0.103						1.000
	Y2 : Construction Faults	0.045				0			0.045
	Y3: Disintegration	0.466	0.225						0.691
	Y4: Distortion of movement	0.568				0.348			0.916
	Y5: Erosion	0.411		0		0			0.411
	Y6: Seepage	0.413	0.261	0.336					1.010
	Y7: Spalling	0.149		0					0.149
	Y_{Slabs}	2.949	0.589	0.336	0	0.348	0	0	20.99
Walls	Y1 :Cracks	0.596		0.234					0.83
	Y3: Disintegration	0.113						0	0.113
	Y6: Seepage	0.340		0					0.34
	Y7: Spalling	0.052						0	0.052
	Y_{Walls}	1.101	0	0.234	0	0	0	0	6.572

$Y_{Building}$ = 7.247

DEMOLITION

VII. Conclusion

Developing buildings deterioration model using regression analysis based on predicting the causes of elements deterioration and coming up with a recommendation was the aim of this study. Using SPSS software, the Regression analysis revealed a relationship between the element deterioration symptoms (as dependent variable) and deterioration causes (as independent variables). Regression equation for each deterioration symptoms was developed as a function of the deterioration causes that lead to this deterioration for each element. This study has designed a matrix in excel sheet; as a way to simplify the model implementation, where the user will input the values of deterioration causes according to the investigated symptoms of the building to come out with recommended decision for repair or demolition as a support tool for maintenance technical decision before doing any technical tests . For further research; it is recommended to computerize the developed model and link the recommended decision with the building asset database as a step to develop an expert system for asset management.

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