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PREDICTION OF BUILDING ELEMENTS DEGRADATION AND EVOLUTION OF THE REFURBISHMENT COSTS

BY
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A model of building elements degradation process is presented. The model is based on statistical data acquired in several EU countries. An estimation method for the refurbishment costs and evolution in time is also presented. The described techniques have been implemented in a computer program and the results have been validated. The work is part of the European Project Investimmo.

1. Introduction

Building refurbishment has become an important subject in the building sector ı Western Europe. In these countries, there is a balance between the two activities: onstruction of new buildings and refurbishing of the old ones. In order to suppo.. he latter, research has made significant advances offering the necessary tools. The ıost important is *Epiqr*, which resulted from an EU-Project in 1996. This paper escribes a prediction method for the degradation state of building elements and its omputer implementation using the theoretical model of *Epiqr*. The work is part of he European Project *Investimmo*.

2. Statement of the Problem

Epiqr is both an innovative software tool and an original method for assessing he building deterioration state, energy saving and indoor environment quality imrovement potential of residential buildings. The goal behind the development of *piqr* was to obtain a user-friendly instrument with which one could establish in short time the state of the building and consequently, the cost for retrofitting. n order to keep it simple but accurate enough, *Epiqr* defines a list of 50 standard uilding elements that a building can contain. To cover the large variety, each of he elements has several types. For example, element 39-Windows has four types: 9-1-Typical Window, 39-2-Wooden Window, 39-3-Plastic Window and 39-4-Metal Vindow. This allows a rapid survey of the construction (less than a day) in which ll elements are evaluated in a serial fashion.

When inspecting the element-type, a degradation state is assigned [1]. Also for the sake of simplicity, only four degradation states are available (Fig. 1):

a – perfect state (new element);
b – slight degradation;
c – significant degradation;
d – heavy deterioration, end of service.

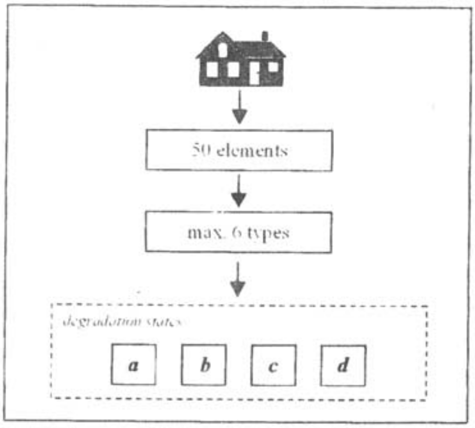


Fig. 1.– The *Epiqr* method.

However, *Epiqr* only makes a snapshot of the building at a given moment and does not take into account the dynamical aspect of the deterioration process. But the prediction of this process and thus the prediction of the refurbishment costs would be of great help for the large building owners. It would enable these owners to develop an investment strategy for the future, that optimizes the costs in terms of spatial and temporal distribution. This means that a software based on this prediction method could advise the owner when is the best moment to invest and in which building. Moreover, the standard subdivision in 50 elements makes possible a more precise direction of the funds.

3. Degradation State Prediction Model

Developing a model capable of predicting the degradation state of a building element means to determine four functions, $p_a(t)$, $p_b(t)$, $p_c(t)$ and $p_d(t)$, representing the probabilities of an element to be in each of the degradation states (a, b, c, d) at time, t. Also, at each moment, t, the following condition must be fulfilled:

$$p_a(t) + p_b(t) + p_c(t) + p_d(t) = 1. \tag{1}$$

3.1. Data Source

In order to determine the four functions information from three sources will be taken into account [2]:

a) survey data;
b) literature information;
c) expert opinion.

The *survey data* is the most important source of information. In an earlier phase of the Investimmo project, about 350 buildings from Germany, France, Switzerland, Denmark, Italy and Poland have been surveyed. During these surveys each element of the building has been inspected and information about it has been stored in a computer database: element number, type number, degradation state, diagnosis, element age.

Literature information concerns mainly the service life of building elements, which corresponds to state d as in *Epiqr* method. Unfortunately, this source offers no information on other states (a, b, c).

Expert opinion will provide the p_a, p_b, p_c, p_d functions based on experience. Experts will indicate how long a specific element will be in each of the four states, generating thus the four curves without any other influence.

3.2. Survey Diagrams and Curve Fitting

Data coming from the different surveys is stored in a database. When analysing an element, information for that element only is extracted from the database by a Matlab program. This program calculates the relative frequencies for a specific degradation state at a given age and displays them in a bar chart (Fig. 2).

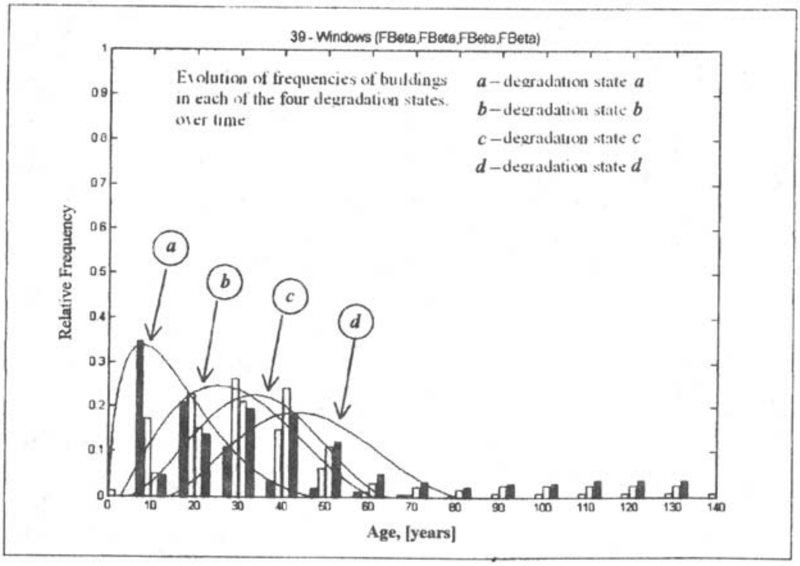


Fig. 2.- Relative frequencies for element 39-Windows, in all four degradation states (a, b, c, d).

Next, a function is used to model the evolution of the frequencies over time. This function is the *beta probability density function*, available also in the Matlab library:

$$y = f(x|a,b) = \frac{1}{B(a,b)} x^{a-1}(1-x)^{b-1} I(0,1)x,$$

where $B(...)$ is the Beta function and $I(0,1)$ is the indicator function that ensures that only x values between (0,1) have nonzero probability. This function is fitted four times for the four degradation states, a, b, c and d. The *lsqcurvefit* Matlab function, which is based on the least squares algorithm, is used to this purpose. It returns the parameters of the beta probability density function and also a value that estimates how good the fit is. The four resulting curves (Fig. 2) estimate the frequencies of the building elements given the degradation state and the element age.

Based on these four curves, the probability curves are determined (Fig. 3). These estimate the likelihood for a specific element with a specific age to be in a certain degradation state.

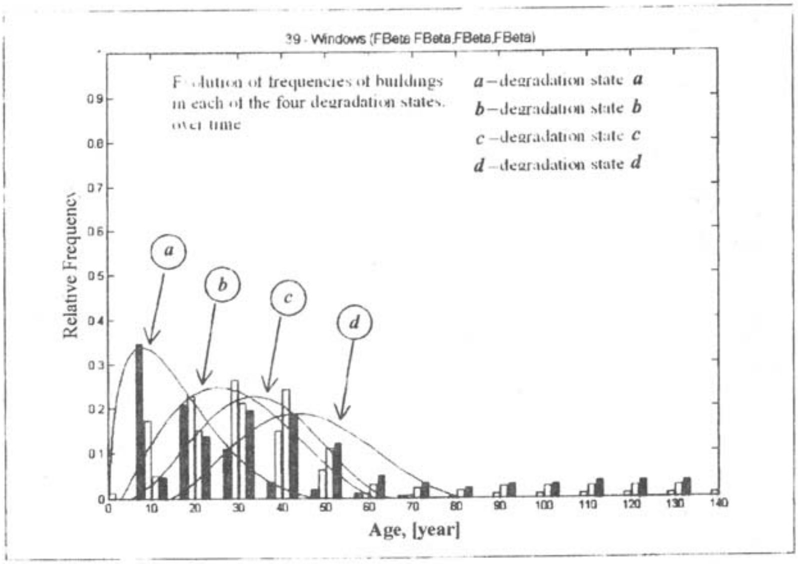


Fig. 3. Probability for element 39-Windows, in all four degradation states (a, b, c, d).

At the same time, the condition (1) is fulfilled.

In the example presented in Fig. 3, element 39-Windows has at age 20 years the following probabilities to be in each of the four states:

$$p_a(t) = 0.34; \quad p_b(t) = 0.38; \quad p_c(t) = 0.23; \quad p_d(t) = 0.05.$$

The probability curves are determined for each of the 50 building elements. This way, the evolution of the element is estimated using a statistical instrument and by summing the effects one can assess the evolution of the entire building.

4. Prediction of the Refurbishment Costs

The calculation of the refurbishment costs is based also on the model set by *Epiqr*. That is, with each degradation state $(a, b, c$ or $d)$ of an element, a list of works is associated. These are necessary works in order to bring the element from its current state into state a (perfect condition). Works for all elements in all degradation states are stored in a separate database, which is used when refurbishment costs are computed. To calculate the costs for the entire building, individual per element costs, for all 50 elements, must be summed.

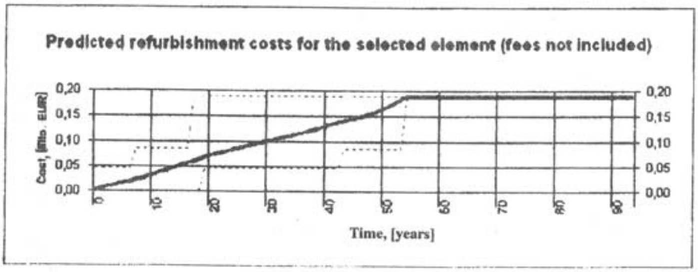
The prediction of the refurbishment costs takes into account all four probabilities of an element at a given time:

$$C = p_a(t)c_a + p_b(t)c_b + p_c(t)c_c + p_d(t)c_d,$$

where: C is the cost for refurbishing an element; p_a, p_b, p_c, p_d – probabilities for all four degradation states; c_a, c_b, c_c, c_d – refurbishment costs from each state.

However, the costs are zero when the element is in state a, therefore $c_a = 0$ for any element. Fig. 4 presents the evolution of the costs for element 39. The dotted lines depict the maximum and the minimum costs corresponding to the best and the worst evolution of the degradation process.

a



b

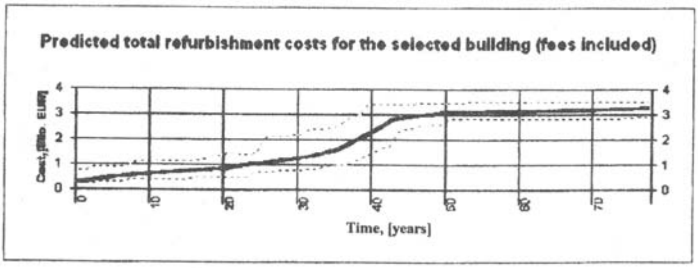


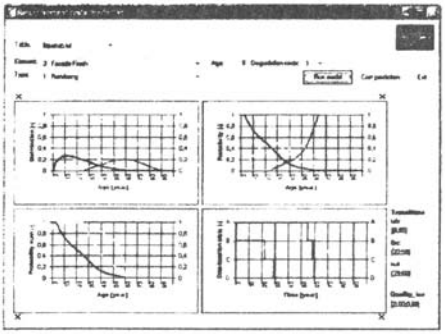
Fig. 4.– Prediction of refurbishment costs per element (a) and for the entire building (b).

By adding up the costs for all elements of the building, the total refurbishment costs are calculated.

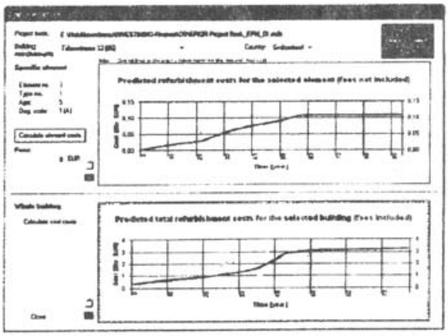
5. The Investimmo-Finance Software System

The model has been implemented in a computer program named Investimmo-Finance [3]. This was written in VisualBasic and processes input data in *Epiqr*-format according to the described method.

The main window is shown in Fig. 5. The user selects the element and the element type, current degradation state and age. The program then computes the frequency, probability, cumulated probability and transition curves. Next the refurbishment costs are calculated based on the cost database and, finally, the costs for the entire building are computed. The results are displayed in graphical form but also as a table, which can be exported to Excel.



a



b

Fig. 5.– Main window of Investimmo-Finance (*a*); results window (refurbishment costs) (*b*).

6. Conclusions

The presented method was not designed to replace the expert and make decisions based exclusively on statistical data. Instead it is thought to assist the persons involved, to make a consistent investment plan that takes into account the physical degradation process of building elements. In the EU not only the commercial management and the subordinated rent/sales managers, but also the technical management and subordinated stakeholders are involved into the financial planning process. In addition to the prediction offered by the described system, several other factors will be assessed when making a decision: rental income, sales income, operating expense, interest rates, short-term and long-term financial strategies, etc.

The prediction model is based on the assumption of a normal degradation process. It cannot take into account cataclysmic phenomena as earthquake, flood, fire, etc., as these are impossible to predict.

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REFERENCES

1. W e t z e l C., *Optimierung des zukünftigen Instandhaltungsbedarf*. BundesBauBlatt, **52**, 28-33 (2003).
2. * * * *Investimmo. EU-Contract N GRD1-2000-25139*, 2000.
3. L a i r J., B a u e r M., W e t z e l C., D o l o c a A., *A Predictive Model for Future Deterioration of Building Elements*. Management of Durability in the Building Process. Milan, June 24-26, 2003.

EVOLUŢIA FENOMENULUI DE DEGRADARE A ELEMENTELOR DE CONSTRUCŢIE ŞI A COSTURILOR DE REABILITARE

(Rezumat)

Se prezintă un model care descrie fenomenul de degradare a elementelor de construcţie. Modelul are la bază date statistice achiziţionate în mai multe ţări din Uniunea Europeană. Este descrisă, de asemenea, o metodă pentru estimarea costurilor de reabilitare şi a evoluţiei acestora în timp. Tehnicile prezentate au fost implementate într-un program de calcul, iar rezultatele au fost validate practic. Lucrarea este parte a proiectului Investimmo, finanţat de Uniunea Europeană.