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ANALYSIS OF THE TECHNICAL STATE FOR LARGE-PANEL RESIDENTIAL BUILDINGS USING ARTIFICIAL NEURAL NETWORKS

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Abstract. *This paper presents two new methods for analysis of a technical state of large-panel residential buildings.*

The first method is based on elements extracted from the classical methods and on data about repairs and modernization collected from building documentations. This is a new unique method. it is easy to use, does not need expertise. The required data could be extracted easily from building documentations. For better accuracy the data from building inspections should be applied (in Poland inspections are made every year).

The second method is based on extracted data processing by means of the artificial neural networks. This method could have lower accuracy but it is less prone to data errors.

1 INTRODUCTION

The considered general problem has been addressed by the Warsaw residential cooperatives. The management of the residential cooperatives requested the Faculty of Civil Engineering at the Warsaw University of Technology for proposals regarding a research on the technical state of buildings, especially built with the large-panel technology.

Today, assessment of the technical state of a building can be performed by one of many methods. These methods consider different number of analyzed details, require expertise, are based on expert's reports and their execution is time consuming. These methods show different deficiencies: labor-consumption, inaccuracy, lack of objectiveness and others. Even the most exact, but labor-consuming, "visual methods" are defective – two assessments for the same building, done by different specialists, can disagree. This is the result of differences in the condition assessment for a building element, particularly if it is hidden under paints, parquets, and other finishing layers. These elements can be evaluated indirectly only, through vision inspection of apparent flaws, cracks, delaminations etc. There is a need for new solutions which would help analyze current values of the technical state for many buildings and would allow for prediction of the future changes. Additionally, the new method should be easier to use.

2 CURRENT TECHNICAL STATE OF LARGE-PANEL BUILDING IN WARSAW (POLAND)

For about last fifty years, in Poland there have been built thousands of residential buildings made of prefabricated elements. Some of the buildings were repaired and modernized in insufficient degree, often occasionally only. It is now an important issue in Poland. After years of usage there is a question frequently asked: what is the technical state of these buildings? This is a serious technical as well as a social problem.

Following the inspection of nearly one hundred buildings (the data processed until now includes 68 buildings) in many Warsaw settlements and inspecting many more buildings from outside, it could be concluded that the technical state of most of these buildings is good. It is a result of the continuous conservation and planed repairing, especially for the last years. However, in many other cities in Poland the technical state of the residential buildings is worse and the process of modernization is at the beginning phase.

Fig. 1. Examples of large – panel residential buildings with old facade (Warsaw)

Many defects of buildings have been removed, particularly in cases made public as emergency or before emergency states. Many flaws were removed during the current repairs, many other during the exchange or modernization of wiring and plumbing, the exchange of windows, the repairs of loggias and balconies, the insulation of external walls. There are increasing numbers of buildings completely modernized. Unfortunately, there are still many buildings left in poor state.

Fig. 2. View of large – panel residential buildings with new facade (Warsaw)

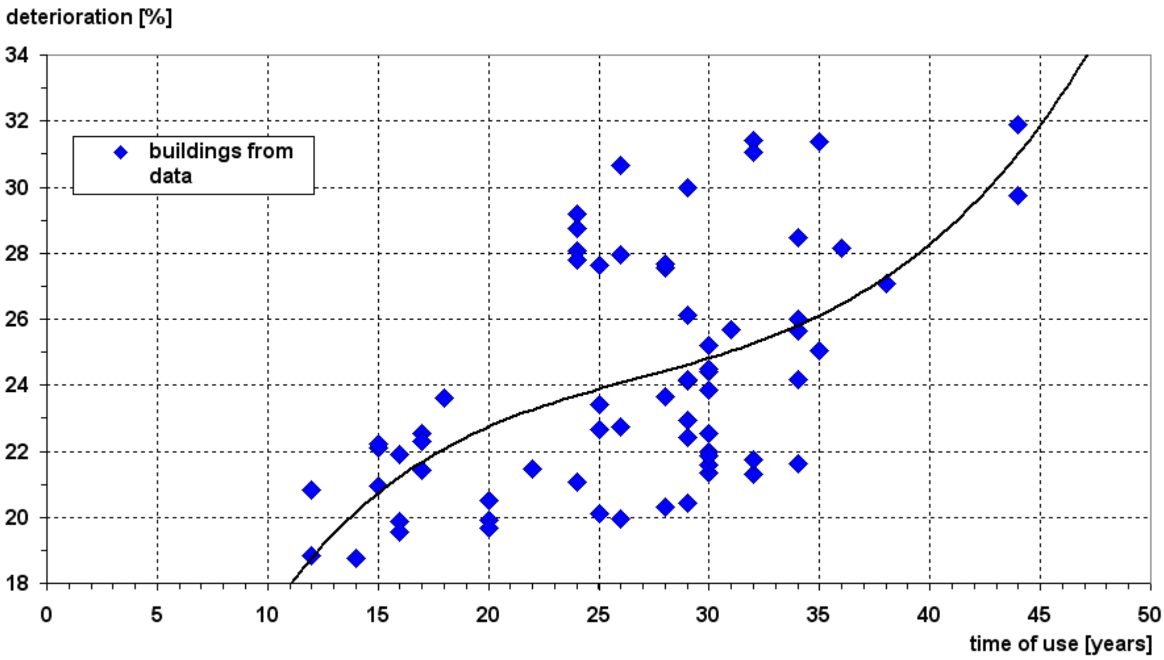

Fig. 3. Deterioration versus time since construction

3 DATA PROCESSING

All analyses presented here are based on the data obtained from housing cooperatives in Warsaw. They periodically examine their buildings with the general inspection at least ones every five years and the normal inspection every year.

The estimates of the technical state of buildings in many Warsaw settlements allow for drawing present trends and directions for future. They can help to improve the technical condition of buildings as well as to increase the satisfaction of their residents.

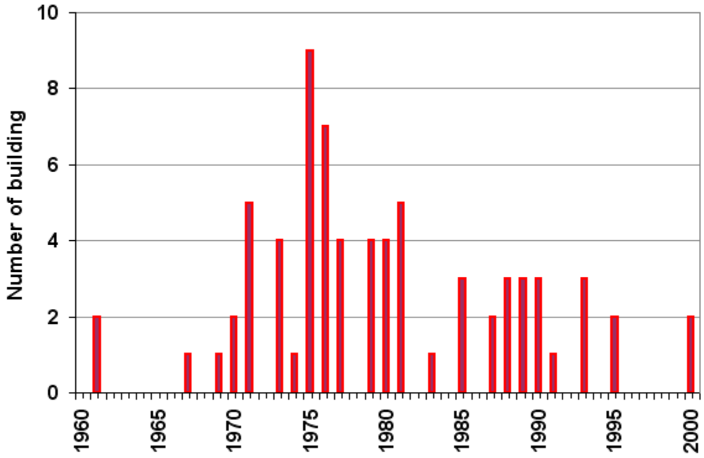

Fig. 4. Number of buildings versus year of construction. (units on Y axis)

A questionnaire was developed consisting of over 150 elements, collected as a result of analysis of engineering documentations, examining object's books, examination protocol, additional technical expertises, visual inspections of elevations and inside building, and photographic documentation.

Data from questionnaires have been imported to the MS Excel spreadsheet. This is a simple and powerful program for analysis. The data can be transformed, sorted, exported to other programs and imported back. For special cases the use of personally written programs in computer programming language -Visual Basic for Application is allowed.

In the next step a preliminary analysis of the collected data was performed with respect of the importance of information, the amount of data and its variation. The data input includes not only data about the technical state of buildings, but also other information such as about environment, type of maintenance, special events, repairs and modernizations. The information collected in the data base should allow performing miscellaneous analyses.

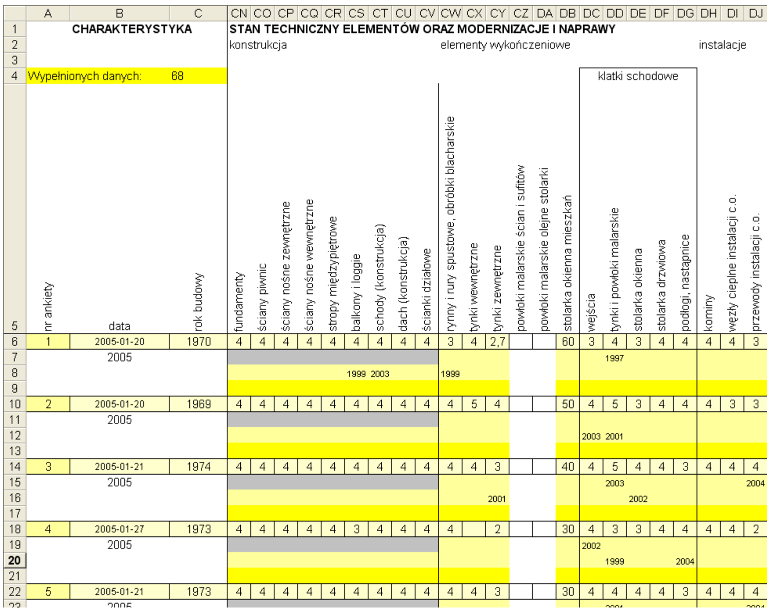

Fig. 5. Example fragment of data in MS Excel (data in Polish)

4 NEW METHODS

4.1 Estimation of the technical state of a building using data about repairs

The estimate described below was made as a response to the current problems and the requirements for calculating the value of the technical state of a building. The following general assumptions have been made:

- existing time method is imprecise,
- existing visual method requires an expert and an expensive expertise, in consequence many estimates are conducted by persons with insufficient knowledge and experience,
- there is a need for a method, which would allow for assessment of the technical state for many buildings with good accuracy without participation of an expert,
- the method should be advantageous to residential cooperatives,
- the method should be feasible for people with basic training, not only for experts.

The presented method is based on elements extracted from the classical methods [2] and on the data about repairs and modernization collected from the building documentation. According to the author's best knowledge, the following approach has not been applied before for large-panel and large-block buildings.

The technical state [Z] of a building is calculated as a sum of several groups [Z_n] of elements defining the technical state (such as cold and hot water plumbing, gas, electricity, external and internal walls, ceilings, foundations, windows, doors, finishing details and others).

$$Z = \sum_n Z_n \tag{1}$$

For every group of elements we calculate the value of the element deterioration [Z_{nt}] per weighted coefficient [w] (which depends on the rate of the cost of the group of elements to the whole cost of the building).

$$Z_n = Z_{nt} \cdot w \tag{2}$$

The value of an element deterioration [Z_{nt}] is calculated following one of three formulas:

A. If the state of the group of elements was estimated as poor during last examination:

$$Z_{nt} = 100 \cdot \frac{t}{T} \tag{3}$$

t – time interval since overall repair or since the end of construction,

T – predicted life time for this element.

B. If the state of the group of elements was estimated as average during last examination:

$$Z_{nt} = 100 \cdot \frac{t \cdot (t + T)}{2 \cdot T^2} \tag{4}$$

C. If the state of the group of elements was very good:

$$Z_{nt} = 100 \cdot \frac{t^2}{T^2} \tag{5}$$

The deterioration in this method depends on:

- time, which has passed since last repair of element or time which has passed since construction (easy to be determined),

- estimate of the state of element groups which can be determined on basis of yearly controls.

For this method it is possible to determine the range of variation dependent on the time which has passed since construction. The boundary values of parameters were selected as the values which are admissible, safe for the building, take into account the plumbing and wiring ageing, and are acceptable from the economical point of view. The better estimates (below the range) can be obtained as a result of modernization or earlier repairs. On the contrary worse results (above the range) can be received as a result of risky repair politics, design flaws, extensive degradation. The range of variation of the deterioration value for an example building is presented in Fig. 6.

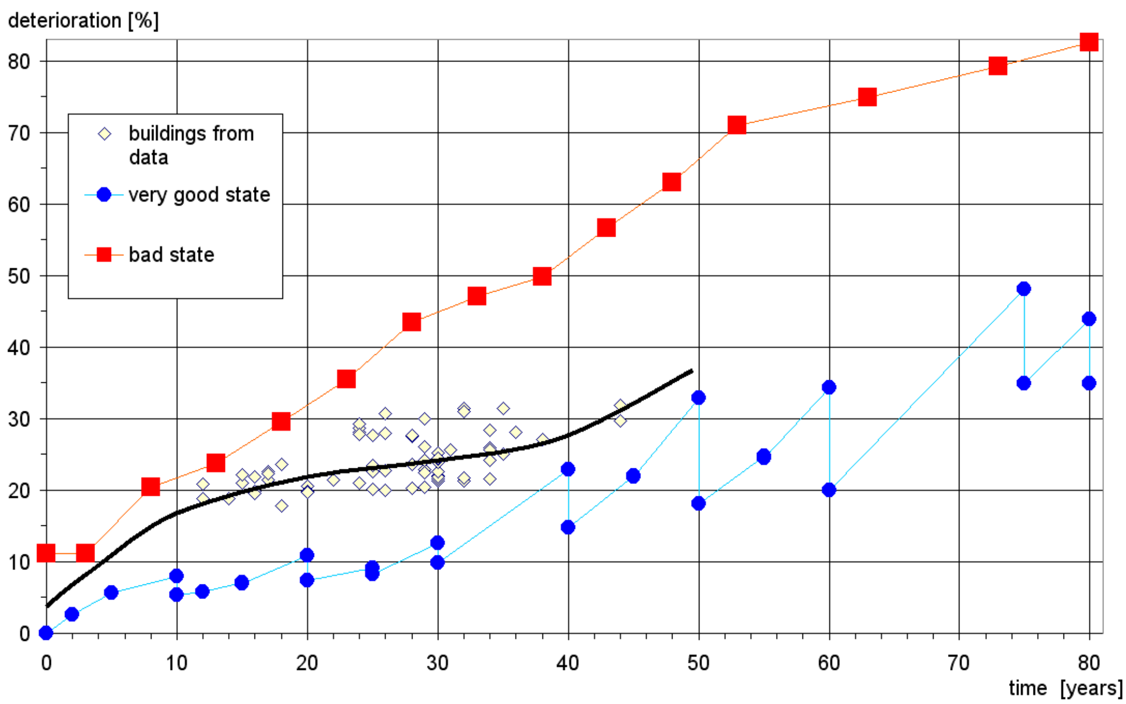

Fig. 6. Range of variation of building deterioration versus time which has passed since construction

It is possible to estimate the variation for each year of the building use. This will determine possible values of building deterioration and its range of variation according to the formula:

$$S_p = Z_{\max} - Z_{\min} \tag{6}$$

where: Z_{min} - minimal deterioration, Z_{max} - maximum deterioration.

Next we define a formula for the degree of repairs realization for a given building:

$$R = \frac{S_p}{Z - Z_{\min}} \tag{7}$$

where: Z - value of deterioration for a given building.

Presented above ratio could be a point of reference at planning repair work sequence for a group of buildings or for comparing building values. This is a simple and objective method for the determination if the building is used correctly, as well as if it is abandoned.

4.2 Estimate the technical state of building using artificial neural networks.

This method is based on the extracted data processing by means of the artificial neural networks. The aim is to learn the artificial neural network configurations for a set of data containing values of the technical state and information about building repairs for last years (or other information and building parameters) and next to analyze new buildings by the instructed neural network. The second profit from using artificial neural networks is the reduction of number of parameters. Instead of more then 40 parameters describing building, about 6-12 are usually sufficient for satisfactory accuracy.

The algorithm for obtaining results from artificial neural networks (ANN) consists of:

1. preparing full database in MS Excel,
2. selection of data for the next step of analysis,
3. data normalization for use in net – changing range of values from <0,N> to <0,1>,
4. selecting components from the records,
5. sorting and selecting records for groups of data: for training, for cross validation, for testing,
6. choosing the type of artificial neural net, selecting topology,
7. teaching net, verifying results,
8. repeating steps (5,6,7) for optimization of the network architecture,
9. analyzing new data with the optimal net.

Table and graph below present results for the net build in architecture 14-3-1.

Multilayer perceptron net (MLP)	
input	14 parameters
output	1 parameter (Z)
topology of network	14-3-1
training	momentum method
data package for training	37
data package for cross validation	11
data package for testing	11
error for training data, MSE	$1{,}067 \cdot 10^{-6}$
error for cross validation data, MSE	$18803 \cdot 10^{-6}$
error for testing data, MSE	$226 \cdot 10^{-6}$

Tab. 1. Important parameters of multilayer network

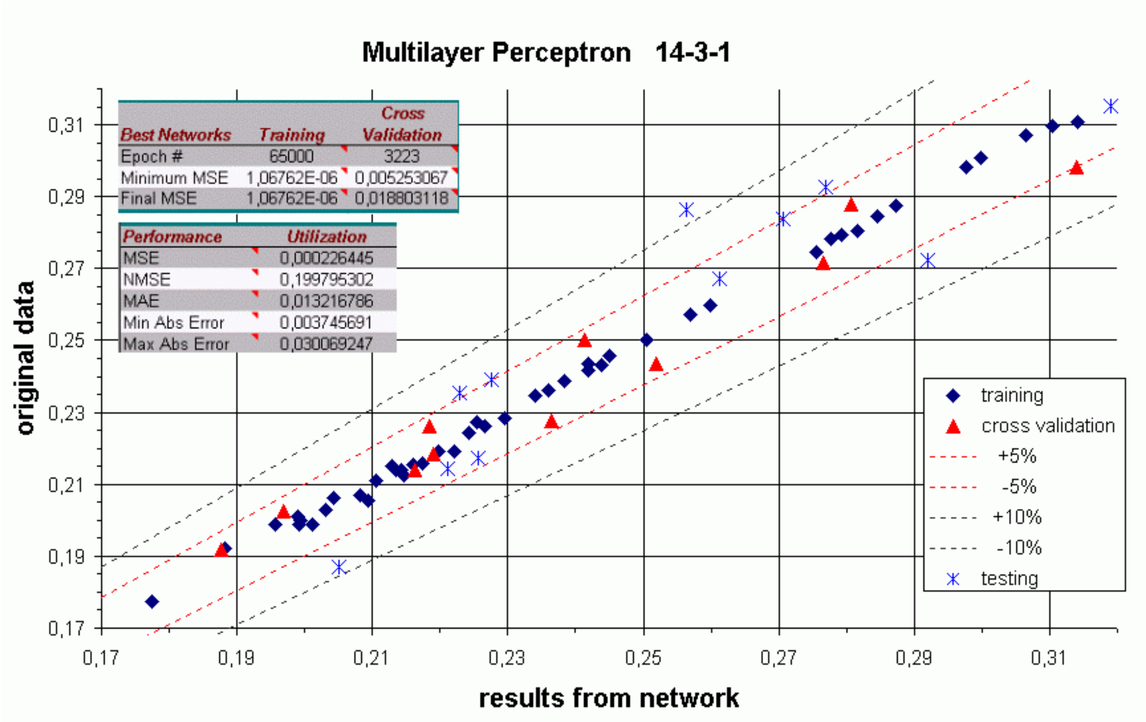

Fig. 7. Results for network architecture 14-3-1

It seems that until now there has been published only one work [1] dedicated to the definition the technical state of buildings, based on artificial methods. This paper presents analysis of buildings inhibited for long time (constructed before 1918), built of small elements (bricks), often with timber structure of ceilings and roofs. The approach presented here for large-panel residential buildings is new.

5 SUMMARY

Estimating the technical state of buildings using data about repairs:

- is easier to use comparing to the older methods because deterioration is calculated on formulas dependent only on time since last full repairing or since end of construction and on predicted life time for this element. The old methods are based on deterioration defined for each element by a specialist,
- is more objective, than time methods or visual methods. It does not require exact value identification of deterioration for each building element during the control. As the experience indicates, if the range of an element state value is smaller (only three values for this method), the results describing deterioration are more repeatable,
- in practice, presented method can give comparable results even if it is used by a person who is not an expert. The existing visual method requires estimation of deterioration value done by an expert and in many cases necessitates an expensive expertise,
- it is fast and simple, the needed data can be obtained from building documentations.

Estimating technical state of building using artificial neural networks:

- has lower accuracy,
- can work on incomplete data,
- is more resistant to errors in data,
- needs small range of data as an input,
- MLP is type of net, which gives good results, the error is not significant,
- it can be applied as one from many methods for estimating technical state.

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