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BI-SERIAL CORRELATION OF CIVIL ENGINEERING BUILDING ELEMENTS UNDER CONSTANT TECHNICAL DETERIORATION

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Abstract:

The article presents a method of determining numerical relationships between defects occurring to some elements of the analysed structures, expressing their maintenance conditions, and the magnitude of their technical degradation. Unmeasurable (qualitative) variables, i.e. individual defects with dichotomous values, and measurable variables (quantitative), i.e. the extent of technical wear of particular structures, were identified. An attempt to numerically express the correlation between them was made. In the calculation of the strength of this relationship, the method of determination of the point bi-serial correlation coefficient for different types of properties. The significance of this coefficient for a typologically selected, nonprobability sample was investigated. The results obtained for this sample were extrapolated to a uniform population of pre-war tenement houses in Wrocław.

Keywords:

civil engineering buildings, correlation, defect, technical wear

INTRODUCTION

The article presents a statistical method of correlating various kinds of characteristics, i.e. occurring defects with a technical wear process of elements of over one hundred years old apartment buildings in typologically selected, nonprobability sample of tenement houses located in "Śródmieście", one of Wrocław districts, they were all built before 1914 and later were exposed to sudden and early damage resulting from warfare from 1944 to 9 May 1945 during the Festung Breslau defence [4], [5], [6], [7], [10].

The buildings are located in urban street routes which had not been changed for years. These inner city streets are of secondary importance. Among the buildings there are front buildings and annexes with modest architectural design and an economical functional standard. They were built of brick in longitudinal, most often three-bays construction systems.

The determined sample met the above mentioned criteria and was representative in one particular way of understanding representativeness [3]. It encompassed all values of variables which could be reconstructed on the basis of earlier conducted research, they were also collated and processed in a way enabling drawing conclusions on cause-effect relations between them and in the general population. Hence one can say that the sample, in which the required types of homogenous variables were classified, was typologically representative. Due to the fact that, apart from this the structure of the population and its properties were well investigated, such a selection of the sample can be considered purposeful.

1. THE GENERAL SCHEME OF THE CAUSE-EFFECT MODEL OF "DEFECT – TECHNICAL WEAR"

The general scheme of the cause-effect model of "defect – technical wear of structure elements" results from the synthesis of expert investigations of the selected sample described above [2], [5], [9]. At the broadest level of generalisation the scheme of the analysed model for any civil engineering building has the following form:

FACTORS	SYMPTOMS		CONSEQUENCES
⇓	↓ ⇓	↓	⇓
What causes sudden and accelerated destruction of civil engineering buildings?	Defects of structure elements	Technical wear process	What should be done with a civil engineering building?

Fig. 1. The general scheme of the cause-effect model of "defect – technical wear of structure elements"

Source: Author's own study

2. POINT, BI-SERIAL CORRELATION COEFFICIENT

The visual stage of determining the size of the defect symptoms of the elements of inner city tenement houses comprised identification of two types of variables:

- unmeasurable variables (qualitative), i.e. individual defects u_{ij};

- measurable variables (quantitative), i.e. the extent of technical wear of particular structures z_i.

The measured values of the extent of technical wear were classified as quantitative variables. The descriptive and notional analysis of the defects of elements of tenement houses in system analysis categories did not allow to accept them on the basis of conducted technical investigations (opinions, judgements and expert opinions) as measurable variables. The most significant drawback of the method of technical condition assessment used by the experts in the case of inner city tenement houses was the fact that it did not specify a defect in a numerical way. Even with the most faithful reconstruction of technical documentation and verification analysis, it was not possible to differentiate between a measurable value, e.g. "significant corrosion" of steel beams from "strong corrosion" of the same element or "heavy wear" of electrical installation from "heavy wear" of another element. Given such significant lack of precision in determining the size of elementary defects uij, a decision was made to determine the occurrence (or its lack) in a binary system, i.e. to assume that a defect of an element of a building would be identified at an elementary level and that it would be a dichotomous variable { u_j } = [0.1].

After the determination of the type of the variables z_i and u_{ij}, an attempt was made to express correlations between them numerically (if they exist); i.e. to measure the influence of the defects occurring in the elements of the analysed buildings on the extent of the technical wear process. The calculation of the strength of this correlation was based on the method of pointwise determination of the bi-serial correlation coefficient of the measurable variable z_i and the dichotomous one u_{ij}, in notation it was generally marked as r(Z). It is one of few cases in statistics when properties of various types are correlated [1], [7], [8]. The correlation coefficient changes its value in the range of [-1,1]. The following values were determined for in groups of defects U for each elementary defect $u_{ij} = u_i$ (when j=1,2, ... ,m) and technical were Z:

- u_i – dichotomous variable assuming values 0 (u_{i0}) or 1 (u_{i1}); i = 1,2, ..., n;
- u_0 – number of observations of the variable u_i which were marked as 0;
- u_1 - number of observations of the variable u_i marked as 1;
- certainly $u = u_0 + u_1$ (if u is considered to be the number of all observations u_i), and:
- z_i – measurable variable; the values of this variable were divided into two groups depending on whether it assumed 0 or 1 values; i = 1,2, ..., n;
- z_{i0} – value of the property zi for units "i" in the case of which property u_{i0} occurred;
- z_{i1} - value of the property zi for units "i" in the case of which property u_{i1} occurred.

Next arithmetic averages were calculated for both groups:

$$\overline{z_0} = \frac{1}{u_0}\sum_{i=1}^{u_0} z_{i0} \tag{1}$$

$$\overline{z_1} = \frac{1}{u_1}\sum_{i=1}^{u_1} z_{i1} \tag{2}$$

as well as the standard deviation (determined for the r(Z) by a differently defined correlation):

$$d(Z) = \sqrt{\frac{u\sum_{i=1}^{u} z_i^{\,2} - (\sum_{i=1}^{u} z_i)^2}{u(u-1)}} \tag{3}$$

and as a result, on the basis of (1-3), the point, bi-serial correlation coefficient r(Z):

$$r(Z) = \frac{\overline{z_1} - \overline{z_0}}{d(Z)}\sqrt{\frac{u_1 u_0}{u(u-1)}} \tag{4}$$

The above presented way of associating the defects of the analysed elements of buildings with their technical wear, which enabled the determination of the direction and strength of this relationship, was used to examine the influence of the occurring defects on the technical wear process in the analysed elements of pre-war apartment houses [5], [7].

2.1. The examination of the significance of the point, bi-serial correlation coefficient on a sample of a recognized size

The analysis of the cause-effect model of "defect – technical wear of structure elements" for simultaneously collated 10 selected elements of buildings indicates significant differences of the strength of these relations within the same type of elementary defect u1 - u30 (Table 1). To compare the range of change in the correlation between defects and technical wear with the direction of the change of constituent probability ranges p(u)II, p(u)III, p(u)IV, the defects of the element corresponding with the building maintenance conditions II, III, and IV were collated in consolidated Table 1. The association values of the defects which showed the strongest correlation with technical wear, i.e. r(Z)>0,5 were marked.

Table 1. The collation of the range of probability change and correlations between defects and technical wear Ze, Zt*, Zt** of 10 selected elements of the analysed buildings

THE COLLATION OF THE REANGE OF PROBABILITY CHANGE AND CORRELATIONS BETWEEN DEFECTS AND TECHNICAL WEAR Ze, Zt*, Zt OF 10 SELECTED ELEMENTS OF INNER CITY APARTMENT BUILDINGS**

Z2-FOUNDATIONS , Z3-UNDERGROUND WALLS , Z4-MASSIVE FLOORS OVER BASEMENTS , Z7-LOAD-BEARING WALLS , Z8-WOODEN FLOORS BETWEEN STOREYS , Z9-STAIRS, Z10-ROOF STRUCTURE, Z13-WINDOW WOODWORK , Z15-INTERNAL PLASTERS , Z20-ELEVATIONS		*probability of element defect corresponding with element maintenace conditions II, III, IV*						*point, bi-serial correlation coefficient of the observed technical wear (Ze) and the theoretical one (Zt*), (Zt**)*					
No.	*Defect name*	**p(u) II**		**p(u) III**		**p(u) IV**		**r(Ze)**		**r(Zt*)**		**r(Zt**)**	
		min	max	min	max	min	max	min	max	min	max	min	max
u1	MECHANICAL DEFECTS	**0,65**	**0,88**	**0,69**	**0,88**	**0,68**	**1,00**	**0,05**	**0,29**	**0,01**	**0,18**	**0,06**	**0,19**
u2	LEAKS	**0,88**		**0,92**		**1,00**		**0,26**		**0,19**		**0,20**	
u3	BRICK DAMAGES	**0,50**	**0,81**	**0,63**	**0,98**	**0,65**	**1,00**	**0,03**	**0,23**	**0,00**	**0,16**	**0,00**	**0,14**
u4	MORTAR DAMAGES	**0,50**	**0,63**	**0,63**	**0,95**	**0,88**	**1,00**	**0,28**	**0,30**	**0,00**	**0,09**	**0,00**	**0,11**
u5	BRICK DECAY	**0,42**	**0,83**	**0,65**	**0,89**	**0,64**	**0,80**	**0,01**	**0,17**	**0,00**	**0,08**	**0,00**	**0,09**
u6	MORTAR DECAY	**0,25**	**0,59**	**0,53**	**0,86**	**0,58**	**0,96**	**0,05**	**0,48**	**0,00**	**0,20**	**0,00**	**0,32**
u7	PEELING PAINT	**0,59**	**0,90**	**0,76**	**0,91**	**0,86**	**0,96**	**0,15**	**0,55**	**0,20**	**0,40**	**0,02**	**0,43**
u8	COMING OFF PAINT	**0,00**	**0,20**	**0,23**	**0,31**	**0,23**	**0,30**	**0,25**	**0,57**	**0,07**	**0,25**	**0,13**	**0,30**
u9	BRICK CRACKS	**0,06**	**0,65**	**0,30**	**0,83**	**0,28**	**0,55**	**0,01**	**0,11**	**0,00**	**0,24**	**0,00**	**0,15**
u10	PLASTER CRACKS	**0,25**	**0,75**	**0,44**	**0.86**	**0,29**	**1,00**	**0,03**	**0,63**	**0,03**	**0,44**	**0,03**	**0,60**
u11	WALL CRACKS	**0,00**		**0,10**		**0,20**		**0,21**		**0,00**		**0,00**	
u12	PLASTER SCRATCHES	**0,30**	**0,75**	**0,39**	**0,92**	**0,75**	**1,00**	**0,05**	**0,63**	**0,09**	**0,47**	**0,10**	**0,58**
u13	LOOSENING PLASTER	**0,00**	**0,44**	**0,14**	**0,57**	**0,63**	**0,95**	**0,09**	**0,81**	**0,09**	**0,33**	**0,25**	**0,56**
u14	FLAPPING PLASTER	**0,00**	**0,00**	**0,00**	**0,05**	**0,22**	**0,36**	**0,50**	**0,57**	**0,04**	**0,19**	**0,31**	**0,50**
u15	MOISTNESS	**0,00**	**0,78**	**0,02**	**0,95**	**0,56**	**1,00**	**0,07**	**0,84**	**0,04**	**0,41**	**0,16**	**0,59**
u16	SEEPAGE	**0,00**	**0,39**	**0,00**	**0,76**	**0,14**	**0,91**	**0,27**	**0,79**	**0,03**	**0,35**	**0,17**	**0,59**
u17	BIOLOGICAL CORROSION OF BRICK	**0,00**	**0,00**	**0,00**	**0,31**	**0,25**	**0,84**	**0,31**	**0,67**	**0,22**	**0,28**	**0,20**	**0,23**
u18	HOUSE FUNGUS	**0,00**	**0,00**	**0,00**	**0,08**	**0,00**	**0,63**	**0,38**	**0,60**	**0,02**	**0,18**	**0,23**	**0,48**
u19	MOULD AND DECAY	**0,00**	**0,00**	**0,00**	**0,04**	**0,00**	**0,22**	**0,34**	**0,49**	**0,02**	**0,11**	**0,09**	**0,39**
u20	TARNISH ON STEEL BEAMS	**0,06**	**0,13**	**0,60**	**0,82**	**0,70**	**0,91**	**0,42**	**0,54**	**0,13**	**0,31**	**0,19**	**0,22**
u21	SURFACE CORROSION OF STEEL BEAMS	**0,06**	**0,52**	**0,45**	**0,71**	**0,78**	**0,88**	**0,29**	**0,61**	**0,00**	**0,40**	**0,07**	**0,40**
u22	DEEP-SEATED CORROSION	**0,00**	**0,00**	**0,06**	**0,22**	**0,28**	**0,43**	**0,53**	**0,55**	**0,04**	**0,18**	**0,26**	**0,29**
u23	FLOODING	**0,00**		**0,00**		**0,09**		**0,45**		**0,09**		**0,31**	
u24	DYNAMIC SENSITIVITY OF FLOOR BEAMS	**0,59**		**0,70**		**0,50**		**0,00**		**0,00**		**0,00**	
u25	DEFORMATION OF WOODEN BEAMS	**0,30**		**0,43**		**0,38**		**0,12**		**0,00**		**0,00**	
u26	WOODWORK TWISTING	**0,41**		**0,81**		**0,93**		**0,42**		**0,20**		**0,32**	
u27	WOODWORK WARPAGE	**0,35**		**0,69**		**0,56**		**0,04**		**0,02**		**0,11**	
u28	DELAMINATION OF WOODEN ELEMENTS	**0,67**		**0,33**		**0,63**		**0,07**		**0,06**		**0,17**	
u29	PARTIAL INSECT INFESTATION OF WOODEN ELEMENTS	**0,00**	**0,08**	**0,02**	**0,10**	**0,09**	**0,19**	**0,28**	**0,45**	**0,00**	**0,20**	**0,18**	**0,51**
u30	TOTAL INSECT INFESTATION OF WOODEN ELEMENTS	**0,00**	**0,07**	**0,33**	**0,43**	**0,63**	**0,77**	**0,42**	**0,57**	**0,00**	**0,30**	**0,38**	**0,54**

Source: Author's own study

Observations of such a significant difference in the correlation between the measurable variable zi and the dichotomous one u_i led to the examination of the significance of this correlation conducted on a sample of 95 to 102 measurements of 10 selected elements of the buildings. The research on the significance of the correlation coefficient r(Z) was conducted in the same way as in the case of the Pearson and Spearman tests [1], [3], [4], [8], using the statistics "t-student" defined as follows:

$$t = r(Z)\sqrt{\frac{u-2}{1-[r(Z)]^2}} \tag{5}$$

when the number of the degrees of freedom is equal to df=u-2. As a result the accurate probability p(r) of obtaining the same value for the statistics t as the one obtained on the basis of the representative sample was calculated. It was also assumed the null hypothesis H_0 (r(Z)=0) against the alternative hypothesis H_1 (r(Z)≠0) is valid and apart from this the double-sided area of the criterion was determined. The probability p(r) corresponds with the observed level of significance. As a matter of fact in the case of properties of various types, it would not be a mistake to adopt the level of significance at 10%. However, However, because the author wanted to decisively distinguish the defects which had the most influence on the extent of technical wear in construction elements, it was assumed that if p(r)<0.05 then the analysed correlation is actually significant, and when 0.05≤p(r)<0.10 then one can assume that there is a tendency to the relationship in question. Table 2 presents the values of point, bi-serial association coefficients r(Z), the highlighted values are the ones which have the strongest correlation (at the significance level of 5%) and the ones which show a tendency for interrelation between the defect and the extent of technical wear of the elements of the analysed buildings.

Table 2. The result of the research on the cause-effect correlation between defects and technical wear of 10 selected building elements

THE RESULTOF THE RESEARCH ON THE CAUSE-EFFECT CORRELATION BETWEEN DEFECTS AND TECHNICAL WEAR OF 10 SELECTED ELEMENTS OF INNER CITY APARTMENT BUILDINGS											
POINT, BI-SERIAL CORRELATION COEFFICIENT r(Z)i BETWEEN THE MEASUREBLE VARIABLE (zi) AND DYCHOTOMOUS VARIABLE (ui) IN A SAMPLE OF 95 < U < 102		foundations	underground walls	massive floors over basements	load-bearing walls	wooden floors between storeys	stairs	roof structure	window woodwork	internal plasters	elevations
No.	*Defect name*	r(Z)2	r(Z)3	r(Z)4	r(Z)7	r(Z)8	r(Z)9	r(Z)10	r(Z)13	r(Z)15	r(Z)20
u1	MECHANICAL DEFECTS						0,05		0,29	0,09	0,28
u2	LEAKS								0,26		
u3	BRICK DAMAGES	0,13	0,23	0,08	**0,19**		0,03				
u4	MORTAR DAMAGES		0,28		0,30						
u5	BRICK DECAY	0,14	0,07	0,00	**0,17**						
u6	MORTAR DECAY		0,05		0,09					0,47	0,48
u7	PEELING PAINT									0,15	0,55
u8	COMING OFF PAINT									0,25	0,57
u9	BRICK CRACKS	0,05	0,01	0,05	0,11						
u10	PLASTER CRACKS		0,03		0,03					0,30	0,63
u11	WALL CRACKS				0,21						
u12	PLASTER SCRATCHES				0,12	0,05				**0,18**	0,63
u13	LOOSENING PLASTER					0,09				0,67	0,81
u14	FLAPPING PLASTER									0,57	0,50
u15	MOISTNESS	0,70	0,74	0,58	0,56	0,07		0,43	0,83	0,70	0,84
u16	SEEPAGE	0,64	0,52	0,67	0,46	0,27	0,59	0,50	0,74	0,61	0,79
u17	BIOLOGICAL CORROSION OF BRICK	0,36	0,31		0,67						
u18	HOUSE FUNGUS					0,45				0,38	0,60
u19	MOULD AND DECAY	0,49	0,43		0,34				0,49	0,41	0,56
u20	TARNISH ON STEEL BEAMS			0,42			0,54				
u21	SURFACE CORROSION OF STEEL BEAMS			0,29			0,61				
u22	DEEP-SEATED CORROSION			0,55			0,53				
u23	FLOODING			0,45							
u24	DYNAMIC SENSITIVITY OF FLOOR BEAMS					0,00					
u25	DEFORMATION OF WOODEN BEAMS					0,12					
u26	WOODWORK TWISTING								0,42		
u27	WOODWORK WARPAGE								0,04		
u28	DELAMINATION OF WOODEN ELEMENTS							0,07			
u29	PARTIAL INSECT INFESTATION OF WOODEN ELEMENTS						0,38	0,28	0,45		
u30	TOTAL INSECT INFESTATION OF WOODEN ELEMENTS					0,43		0,57	0,42		
	number of degrees of freedom:	100	93	93	100	100	100	100	100	97	100

Source: Author's own study

2.2. Extrapolation of the sample results on a uniform population of civil engineering buildings

All the examined samples of 10 selected elements of inner city tenement houses are statistically significant (u>30), moreover they constitute from 15.8% to 17.0% of the general population of 600 buildings [9]. An analogous methodology of research could define a general population in of civil engineering buildings from the widest perspective. For the purpose of the extrapolation of the results of the above defined sample on the whole population and determination of confidence intervals for a point, bi-serial correlation coefficient of the general population, the author used the approximation to normal distribution N(0.1). It was assumed that each confidence level covers the real value r (an estimator in the correlation coefficient population calculated on the basis of the sample) with probability 1-p(r)=0,95. For the so assumed value of the distribution function $\Phi(x)=0.95$ in the normal distribution of average equal to 0 and standard deviation of 1, the value of the statistics, which in each analysed case was x=1.96, was read. In the general population the correlation coefficient g(Z) is defined by the lower and upper limit of the confidence interval [3], [8], [11]:

$$r(Z)_d < g(Z) < r(Z)_g \tag{6}$$

hence:

$$r(Z)-x\frac{1-[r(Z)]^2}{\sqrt{u}} < g(Z) < r(Z)+x\frac{1-[r(Z)]^2}{\sqrt{u}} \tag{7}$$

It was assumed that the square estimator r(Z) corresponds with such percentage of the general population that the obtained data can be referred to the confidence level of 95%.

CONCLUSIONS FROM THE RESEARCH ON THE INFLUENCE OF OCCURING DEFECTS ON THE EXTENT OF TECHNICAL WEAR

The results of the examined cause-effect correlation “defect-technical wear” in a representative sample of inner city apartment buildings erected using traditional methods over one hundred years ago allow to formulate the following conclusions (Tables 1 and 2):

a) as expected the direction of the correlation is right-sided (positive) for all 10 examined building elements, however, the correlation strength between the occurring defects and their technical wear shows a significant range (from 0.00 to 0.84);

b) as a rule the factor which has the greatest influence on the technical wear of the elements of the analysed buildings are defects caused by water and moisture penetration – on average 0.54, it should also be mentioned it is always a significant correlation;

c) the technical condition of each examined element indicates the influence of its defects, e.g.:

   – defects of wooden parts (floor beams, stair treads, rafter framing, window woodwork) attacked by biological pests - $r(Z)\cong0.42$;

   – mechanical defects of the structure and texture, here significance relates only to these elements in which these defects can be the reason for progressive influence on new defects (cumulative ones), e.g. construction walls in basements and in overground parts as well as plasters on the interior and exterior (but not on foundations or massive basement floors);

d) defects resulting in the loss of the original shape of wooden elements should be considered insignificant; an exception here would be window woodwork twisting, with a correlation of 0.42, because this defect results in a loss of the use value of window woodwork.

The extrapolation of the results of the analysed cause effect correlation "defect – technical wear" based on a representative sample of inner city apartment buildings on the general population of 600 buildings leads to the following conclusions (Table 2):

- at least one correlation coefficient g(Z) occurs in each of the examined elements, it can represent moderate strength of the analysed relationship ($0.45=r(Z)_d<g(Z)<r(Z)_g=0.70$) or quite strong - ($0.60=r(Z)_d<g(Z)<r(Z)_g=0.80$); very strong correlation ($g(Z)>r(Z)_d=0.80$) has not been found;
- as a rule correlations representing at least moderate strength always show defects caused by water and moisture penetration; only in the case of interior and exterior plasters also individual mechanical defects of their structure and texture can also be considered moderate and quite strong;
- for the adopted confidence level of 95%, the value of moderate strength can refer to 34-48% of the general population and quite strong populations it is 49-71%.

REFERENCES

1. Baer D. E., *An introduction to latent variable models in the social sciences*, University of Western Ontario, Ontario 1993.
2. Czapliński K., Marcinkowska E., *Typologia starych budynków mieszkalnych ze względu na potrzebę ich odnowy*, Konferencja Naukowo - Problemowa: Techniczne i organizacyjne metody rewaloryzacji budowli, Wrocław -Szklarska Poręba 1993, p. 126-134.
3. Greń J., *Modele i zadania statystyki matematycznej*, PWN, Warszawa 1976.
4. Kendall M. G., *Rank correlation methods*, Griffin, London, Londyn 1955.
5. Konior J., *Influence of apartment houses' maintenance on their deterioration*, Archives of Civil Engineering, XLIV, 2, 1998, p. 36-47.
6. Konior J., *Decision assumptions on building maintenance management. Probabilistic methods*, Archives of Civil Engineering, L, 3, 2006, p. 52-61.
7. Konior J., *Korelacja różnego rodzaju cech elementów budowlanych,* Konferencja Naukowo - Techniczna: Inżynieria procesów budowlanych. Wrocław - Karłów, 2006, p. 125-131.
8. Morrison D. F., *Multivariate Statistical Methods*, McGraw - Hill Book Company, Nowy Jork 1990.

9. Praca zbiorowa, *Badanie oraz ocena stanu technicznego i celowości poddania remontowi kapitalnemu budynków mieszkalnych we wrocławskiej dzielnicy Śródmieście*, Raporty serii "U" Instytutu Budownictwa Politechniki Wrocławskiej, Wrocław 1984-90.
10. Praca zbiorowa pod redakcją Olega Kaplińskiego, *Metody i modele badań w inżynierii przedsięwzięć budowlanych.* PAN, KILiW. Warszawa 2007, p. 225-243.
11. Zając K., *Zarys metod statystycznych*, PWE, Warszawa 1988.

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Assoc. Prof. Jarosław KONIOR, PhD, Eng. – Wrocław University of Science and Technology, Faculty of Civil Engineering, Department of Technology and Management in Construction. He is a cofounder of the largest design-management company in Poland. He is an experienced expert in the management of international construction projects and the Polish investment process in the construction business. The author of publications related to the assessment of the technical conditions of buildings and modern management methods of investment projects. A propagator of 3D engineering design, the BIM based approach and Revit. He obtained the award of the Minister of Infrastructure for his participation in a joint publication under Oleg Kapliński's supervision titles "Metody i modele badań w inżynierii przedsięwzięć budowlanych" [Research Methods and Models in Engineering Projects] PAN, KILiW. Scientific interests: research methodology in construction process engineering, management procedures and quality systems in design and investment supervision, discounted techniques in cost simulations and financial controlling of investments, multi-criteria feasibility studies in construction projects, qualitative and quantitative evaluation of engineering structures and phenomena using the probabilistic approach and the fuzzy sets calculus, multi-discipline and multi-criteria expert research on engineering structures representing differentiated typological samples.

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