

## INTERDISCIPLINARY RISK ANALYSIS OF CONSTRUCTION INVESTMENT AND PROPERTY VALUE IN THE AREAS WITH MINING IMPACT

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### ABSTRACT

The scientific objective of this issue is to estimate the number and the significance of variables defined for particular functions, describing the nature, scope and type of impacts on buildings located in mining areas in terms of the technical condition of civil structures and costs of their possible protection and repair or modernisation. This publication analyses a problem of risk response as separate stages of a risk management process in investment projects being carried out in construction industry in the areas with mining impact. Specified and diagnosed variables are analysed in a selected respect, with particular emphasis on the assessment of the ultimate limit state and serviceability limit state of the tested civil structures. The prognostic knowledge of the process of protecting or repairing buildings on an active subsoil, within the assumed time range of the design use of the civil structures and the predicted mining impacts, is essential in an analysis of the form and scope of responses of the structures to adverse impacts and when estimating the cost of building interaction with the subsoil through the entire life cycle of the structure. The subject matter is interdisciplinary, covering both subjects in the field of engineering, as well as stochastic processes, econometrics and reliability of output data predicting the operational impact of mines in analysed urban areas.

**Key words:** area with mining impact, mining damage to building and civil structures, market and replacement value of the property, mining forecasts in the aspect of technical wear of the building

### INTRODUCTION

Currently, for areas intended for development in local development plans, market values of land properties are estimated according to the general legal and methodological guidelines applicable in Poland and Europe. Experts in this field specify values using valuation methods and techniques that best enable to include all variables which describe the property in question both directly and indirectly. Analysis of variables affecting the investment risk and market value of undeveloped and built-up land properties is described in numerous publications of the author (Gaszyński & Gwóźdz-Lasoń, 2005, 2007; Gwozdz-Lason, 2006,

2009a, 2009b, 2010a, 2010b, 2011, 2017a, 2019a, Kadela & Gwóźdz-Lasoń, 2021). In addition, they search for techniques best adapting results of all analyses, transformations and computational models in aim to describe the reality of the market in the sectors of civil engineering, construction industry, property appraisal and economics, what results in optimal estimations of the values sought. Due to the variability of the quantity and quality of available input data for individual analyses, as well as due to the variety of study objectives, the values sought are estimated in the aspect of all diagnosed investment risks of a construction project regarding the construction or renovation of buildings in areas affected by mine operations.

The most sought-after value of a construction investment is the market value, followed by the replacement value or the value of depreciated replacement costs, as well as the investment value and fair value of a given construction project. For land property together with its constituent parts (permanently connected with land and already existing or being at the design stage), are prepared in addition to typical appraisal studies determining the property market value property ownership rights, additional opinions or attachments to the main studies, which are a basis for establishing the costs of repairs, or strengthening or modernisation for a specific type of building, e.g. in mining areas, which are the subject of this study. Appraisals and studies defining the sought values of the examined construction project are based on the analysis of all construction, engineering, geotechnical, mining, legal and economic aspects affecting the time, cost and type and scope of the necessary additional renovation management of the facility, which is to ensure the assumed standard of serviceability and which affects the market value of the building erected on such mining areas. At the beginning all market attributes of a property are defined. Next, the necessary but not sufficient conditions that must be met to protect the existing or new building against adverse static and dynamic mining impact are analysed.

Nowadays, construction investments are carried out in areas with subsoil of unfavourable mechanical and physical parameters of the ground base, e.g.: floodplain-type, frost-susceptible or landslide subsoil, or the subsoil with static and dynamic mining exploitation discussed in this article (Gwóźdz-Lasoń, 2016b; Gwozd-Lason, 2017b, 2019b, 2019c; Kadela & Gwóźdz-Lason, 2021). The costs and time of implementation of all necessary additional protections and reinforcements of the subsoil and the buildings and structures placed on it quite significantly affect the value of the construction investment and its maintenance costs, and thus the value of the entire property.

One of the main points of appraisals or analyses is to examine the impact of the investment risk of a given construction project and diagnose all structural and functional hazards of the building (Fedorowicz & Fedorowicz, 2012; Myrczek, Juraszek & Tworek, 2020). The output data can be optimally extended with the results of the innovative technology of monitoring

of the analysed deformations and loads on the tested engineering objects, using fiber Bragg grating (FBG) and this method is being developed in the Department of Civil Engineering of the University of Bielsko-Biała (Juraszek, 2018, 2019).

The conclusions of these studies and analyses have an impact on the design or strengthening of the foundations, selection of the optimal type of designed structure, and also affect the type of building materials used for construction or renovation, the dimensions and architecture as well as the class and type of finishing of the building. The assumed initial data affect the optimal ranges of engineering reinforcements for identified and/or forecast unfavourable permanent and variable mining operations. The investment risk of an engineering structure generates a range of reinforcements and protections for the design values of limit states and the serviceability of the building. The entire package of tested initial data should be taken into account when assessing the value of the property located in the area in question, so that all diagnosed variables characterising the benefits and threats of the investment are translated into the cost plane of the construction project.

Current construction knowledge and industry experience increasingly requires appropriate analyses and calculations in ZSI – zero stage investment – for a construction or renovation and modernisation of a building or structure (Gwozd-Lason, 2016a). It is necessary to carry out an investment risk analysis for the established development conditions and for all the current and forecast threats to the construction investment, as established at the date of the analysis (Gwóźdz-Lasoń, 2019). Appropriate estimations and numerical simulations for the determined initial analyses of the initial data for a period of 15–20 years of the building or structure operation, indicating all critical elements of the facility which should be properly monitored (Parkasiewicz, Kadela, Bętkowski, Sieńko & Bednarski, 2017; Juraszek, 2018, 2019) and should be included in additional repairs, renovations, reinforcements or modernisations schedules aimed at securing the serviceability or ultimate limit states (Kwiatk (Ed.), 1997; Fedorowicz, 2006; Fedorowicz, 2008; Fedorowicz, Fedorowicz & Kadela, 2011; Fedorowicz & Fedorowicz, 2012; Kadela, Fedorowicz & Fedorowicz, 2015).

## APPROACHES, VALUATION METHODS AND TECHNIQUES

For the analyses of all the examined variables, a construction project consisting in the construction of a new secured building or renovation and strengthening of an existing building requires a selection of the appropriate approach and method of property valuation at the initial state and after construction, extension, renovation or modification of the property to achieve the assumed design data (Miedziałowski, 1994; Kwia-tek (Ed.), 1997; Gwóźdź-Lasoń, 2016a; 2017a; Liao et al., 2018; Kadeta & Gwozd-Lason, 2021). In the Polish real property market, the number of appraisals, analyses and expert opinions including the valuation of calculated and designed works as one of the items is systematically growing and forms the basis for the analysis of a construction investment at the beginning of a construction project. One of the strong impulses generating demand for this type of analyses is the issue of buildings in mining areas. For variables determining the conditions of a real estate in such an area, it is very important to choose the appropriate valuation method which complies with legal

and methodological guidelines and is able to take into account all important property attributes which can be translated into market or replacement values of a building or structure. Table 1 presents all valuation methods and techniques that are valid in Poland.

Research, analysis and estimates carried out in the last five years to determine the market value of the property with adverse mining impact result in a data package that can provide a set of information for valuation using a mixed approach (International Organization for Standardization [ISO], 2000; Polska Federacja Stowarzyszeń Rzeczoznawców Majątkowych [PFARM], 2000; Trojanek, Konowalczyk & Romian (Eds.), 2011, 2013). The mixed approach connects the sales comparison and the income approach. Both the properties similar to the valuated one and the profit provided by the property are considered. In mixed approach following methods are distinguished: the residual method, liquidation costs method and land estimate indicators (ground indicators) method. For the land estimate indicators method, data are constantly collected and simulations are carried out for various groups of representative data for the assumed types of properties. A detailed description of the variables and

**Table 1.** Approaches, methods and techniques for real property valuation, for valuation of a real property in mining damage areas

Approach	Method	Method
1. Comparative	1.1. Pair comparisons	–
	1.2. Average price adjustment	–
	1.3. Statistical market analysis	–
2. Profit-based	2.1. Investment	2.1.1. Simple capitalization 2.1.2. Discounted cash
	2.2. Profit	2.2.1. Simple capitalization 2.2.2. Discounted cash flow
3. Mixed	3.1. Residual	–
	3.2. Liquidation costs	3.2.1. Detailed 3.2.2. Merged elements 3.2.3. Index method
	3.3. Land estimate indicators (ground indicators)	–
4. Cost-based	4.1. Replacement cost	4.1.1. Detailed 4.1.2. Merged elements 4.1.3. Index method
	4.2. Substitution cost	4.2.1. Detailed 4.2.2. Merged elements 4.2.3. Index method

results obtained for the tested models will be included in subsequent publications. For the collection of properties with components existing or planned in the areas with mining impact, after analysing the technical condition of the building in terms of mining hazards and after analysing mining forecasts defining, among others, the mining category of the facility, the scope of additional protections and reinforcements or renovation and modernisation of buildings is determined both at present and for planned schedules of mining maintenance for the facilities. The residual method is applied to a property where building work is to be carried out. Property value is calculated as a difference in value after realisation of the works and the total cost of the works with consideration of investor's profit gained on the market. Technique can only be applied to when all of the following conditions are fulfilled:

- (i) existing conditions do not allow use of the sales comparison nor the income approach;
- (ii) the type and range of work is knowable;
- (iii) in the methods already adapted in the method data mapping the market condition are included.

When the costs of protecting, strengthening and renovating buildings exceed the replacement value of a new building, the decommissioning cost method is usually selected for the property valuation, where the value of the property is estimated as the cost of acquiring the land property less the cost of demolishing the components intended for demolition and in some cases the value of recyclable materials remaining after demolition is added. However, for appropriate designed protections and reinforcements ensuring appropriate use of the facility in the forecasted time interval of mining impact and for specific boundary values of land deformation indices for a given mining category, the property valuation is best done using the residual method.

Paragraph 15 of the Polish regulation on real estate appraisal and an appraisal report preparation (Rozporządzenie Rady Ministrów z dnia 21 września 2004 r. w sprawie wyceny nieruchomości i sporządzania operatu szacunkowego. Dz.U. 2004 nr 207 poz. 2109) specifies the information which should be analysed when using the residual method, which is the approach enabling the most accurate estimation of the required value in the aspect of all variables affecting the value

of a property in the analysed area with mining impact. The residual method is a mixed approach method that is used to determine the market value of a property if works involving construction, reconstruction, expansion, upward extension, alteration, assembly or renovation of a civil structure are to be carried out on the property. This is the main legal guideline reflecting the main need and purpose of property valuation in mining areas. Properties in these areas should always be strengthened, secured or refurbished in such a way that their load-bearing structure is an adequate protection against adverse mining impacts and that the proper renovation management of the building is guaranteed. The main methods for determining the value of planned renovation and modernisation works must be in accordance with the guidelines of the regulations: on the methods and basis for preparing estimations of construction cost and on the detailed scope and form of design documentation, technical specifications as well as the execution and acceptance of construction works, including the public procurement law. According to the legal acts, when calculating the value of a property, a balance of all project documentation information and industry price lists should be taken into account.

The residual method in accordance with § 16 of the mentioned legal regulation may be used if the following three conditions are met jointly: the existing conditions do not allow for the use of a comparative or income-based approach for the valuation of the property in question, the type and scope of works to be performed in accordance with the analyses and calculations carried out is known, and data reflecting the current market situation are taken into account in the elements of the appropriate approaches adopted for this method. It is also legally required for the appraisal report to provide a detailed justification that the specific method may be used in the form of a comprehensive analysis of the cumulative fulfilment of the above conditions. After valuation of the property using this method, the final results are very precise and provide a better basis for making an investment decision for a given construction or renovation, but this only happens when the initial data are properly diagnosed and calculated, allowing to estimate individual variables of the examined function of a given calculation model.

## VARIABLES OF THE FUNCTION ANALYSING THE USE OF FACILITIES IN AREAS WITH MINING IMPACT

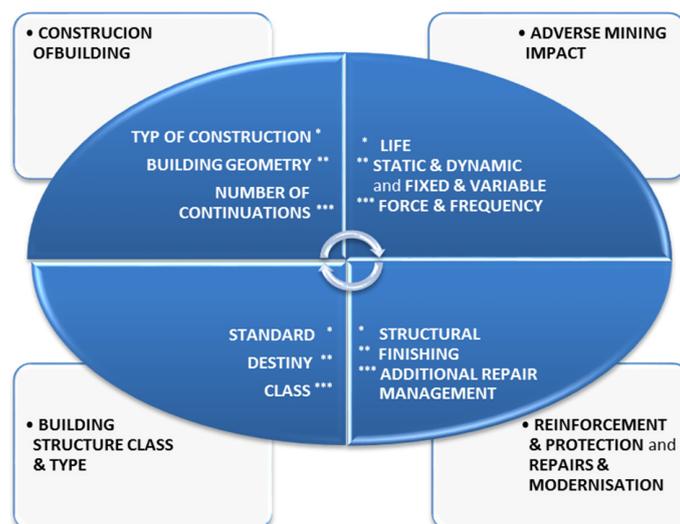
After a preliminary analysis of a given property and its qualification for the relevant collection, as well as after determining all the construction law guidelines and related regulations, the tasks are defined in the initial assumptions all the variables having an impact on the adverse geotechnical and mining impacts the analysed area supporting structure and the use of the analysed object. It is very important to analyse the guidelines included in local development plans for a given area, as well as the provisions of geological and mining law which specify design guidelines for determining the geotechnical foundation conditions for the facility and for its strengthening or renovation (Gwózdź-Lasoń, 2016a; Gwozdz-Lason, 2017a, 2019c). Appropriate classification of the initial data enable proceeding to the next step, in which the values of individual variables affecting the construction investment design, and thus its market and replacement value, are determined.

The sought property values are specified for new, planned and existing buildings, which are to interact appropriately under adverse mining impact. Figure 1 presents a diagram of the conducted analysis of all significant variables affecting land properties and their

components in the form of buildings and structures located in the properties. The basic aspect investigated in the analyses is the investment risk of erecting or renovating a building in areas with the expected mining impact. The analysis of variables and their assignment to an appropriate group of data in individual computational models has a very significant impact on the final results to be developed and on the determination of final conclusions from expert opinions and appraisal reports. These are variables that directly or indirectly affect the effectiveness of investing in a given type of property on a given type of land with adverse impact on buildings and structures erected there, the forecasting the effects (e.g. financial, construction or environmental ones) of adopting or changing a local development plan, as well as estimating the mortgage lending value of property, taking into account all current and forecasted risks of construction investment and determining the property value for an individual investor's purposes.

### Structural variables of engineering structures

For facilities located in mining areas, apart from typical engineering facility wear patterns (resulting from the type of materials used for construction, the age of the building, renovation management history and the utility function of the building or structure), mining forecast



**Fig. 1.** The scope of variables for a property in terms of investment risk for the project of erecting or renovation and modernisation of existing buildings located in areas affected by mining (own work)

variables are analysed, in particular in terms of parameters affecting the location of the facility in subsequent stages of deformation when the facility undergoes five stages of the basin evolution. The technical wear of buildings is estimated based on the generally known and commonly used proportionality formula (Ross, Eytelwein and Unger) which assumes that all components of the property wear at the same rate in terms of individual structural and finishing elements of the buildings. Depending on the renovation management history of the buildings or structures, three main correlations are adopted in the calculations (1) – the linear formula of proportionality, (2) – Ross and Eytelwein formula and (3) – Ross and Unger formula:

$$S_z = 100 \cdot \frac{t}{T} \quad (1)$$

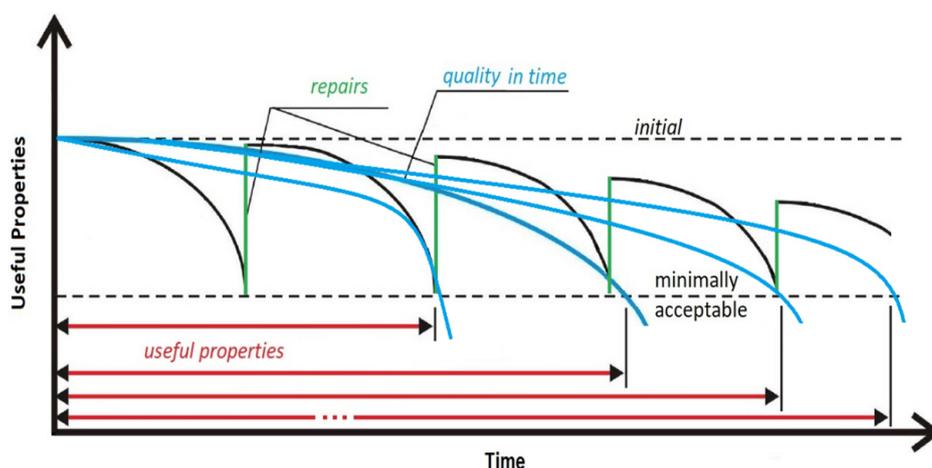
$$S_z = 100 \cdot \frac{t^2}{T^2} \quad (2)$$

$$S_z = 100 \cdot \frac{t \cdot (T+t)}{2 \cdot T^2} \quad (3)$$

where the first formula describes the wear of the building with improper maintenance, the second formula is for the renovation management at an average level, and the last one describes the wear for the properly maintained building. The patterns of technical wear are variables:  $t$  – the building age which is a period

from the building occupancy permit date to the date of determining the wear, and  $T$  – the value of the assumed designed useful life of the building or structure. The values of individual formulas result in the percentage of the facility technical wear. Technical wear illustrates the technical condition of the engineering structure and evaluates the suitability of the facility for the intended functional use. The calculated property wear determines the percentage of reduction in the value of the property resulting from technical, functional (use-related, economic) and environmental reasons, and it mainly results from the wear of materials which the property is built of, as a result of the structure operation in transferring static and dynamic loads. Progressive wear may be stopped by appropriate renovation or modernisation of the structure, or by appropriate protection and strengthening of the structure so that the facility operation does not approach the areas of ultimate and serviceability limit states of the building. The main components of the function determining the technical wear of a property affecting the speed and form of wear include:

- type of structure (brick, reinforced concrete, wooden, aluminium, steel, mixed),
- type of material from which the building or structure was made of,
- primary and secondary age of the facility,
- design and construction standard of workmanship for the building or structure,



**Fig. 2.** Analysis of the property condition, from the maximum value of a new structure to the minimum allowable ultimate and serviceability limit states of the building, as time variables and value variables of technical wear for assumed periods of use and for the assumed renovation and modernisation management (own work)

- the use of the property,
- renovation management of the facility.

The scope of the impact of these coefficients on the final result of the wear calculations of the facility varies and depends on the classified group of analysed properties. Figure 2 shows the technical wear of the engineering facility, including the impact of periodic repairs, modernisations and renovations, especially comprehensive renovations carried out in accordance with the schedule of property renovation management designed using critical path method. This approach of the use increases the technical, physical and functional quality as well as its standard – which extends its life and maintains its standard at the expected level.

Individual investor’s specialised mining and geotechnical analysis of the property is required to fully assess the technical condition of buildings that are part of the property in mining impact areas.

### Mining impact variables

For a structure located in areas with current or forecast mining operations, in addition to typical variables affecting the wear and damage, unfavourable mining impacts, both constant and variable, as well as static and dynamic ones, are an additional factor. When analysing the value of property for a construction investment, the forecasted adverse mining impact – as a function of the time of impact, mining and geotechnical category, type and size of horizontal deformation, slope and radius of land curvature – significantly affects the condition of the facility and the scope of protection, reinforcements and renovations that should be performed, and hence on the market value of the property in the selected calculation model.

Currently in Poland there are no legally defined variables that classify subsoils in terms of the impact of mining operations on buildings and structures existing or planned in this area. Table 2 describes the

**Table 2.** Categories of areas with mining impact and suitability of areas with mining impact for development (Główny Instytut Górnictwa [GIG], 2000)

Area category	Slope	Radius of curvature	Horizontal deformation	USEFULNESS as building land	Remarks
–	$T$ [mm·m <sup>-1</sup> ]	$R$ [km]	$\varepsilon$ [mm·m <sup>-1</sup> ]	–	
0	$T \leq 0.5$	$ R  \geq 40$	$ \varepsilon  \leq 0.3$	yes	No protection of the structure is necessary.
I	$0.5 < T \leq 2.5$	$40 >  R  \geq 20$	$0.3 <  \varepsilon  \leq 1.5$	limited	Facility with more intensive than the typical renovation management, carried out for the purpose of removing visual, easy to remove, structurally harmless mining damage.
II	$2.5 < T \leq 5.0$	$20 >  R  \geq 12$	$1.5 <  \varepsilon  \leq 3.0$	limited	Properly designed facility protection and awareness of the intensive renovation of the facility, necessary to remove typical, visual, non-structurally-critical mining damage, are required.
III	$5.0 < T \leq 10$	$12 >  R  \geq 6$	$3.0 <  \varepsilon  \leq 6.0$	limited	Properly designed facility protection and awareness of very intensive renovation of the facility, necessary to remove damages resulting from mining impact, are required.
IV	$10 < T \leq 15$	$6 >  R  \geq 4$	$6.0 <  \varepsilon  \leq 9.0$	very limited	Properly designed extensive facility protection and awareness of a need for extremely intensive renovation of the facility, as well as the probability of occurrence of mining interactions that may affect the serviceability limit states of the facility and its supporting structure, are required.
V	$15 < T$	$4 >  R $	$9.0 <  \varepsilon $	none	Very high probability of mining impacts that will affect the ultimate and serviceability limit states of the structure, and the occurrence of discontinuous terrain deformations that could cause the facility to collapse.

categories of mining areas with the boundary values of land deformation indicators. From the point of view of the usefulness of the analysed area for construction purposes, it could be concluded that only areas classified as zero category are suitable for development without any additional protection. Areas of Categories I–III are suitable for founding engineering structures after meeting the relevant conditions set out in the guidelines of the local development plan, development conditions and the initial assumptions of the acceptable investment risk which is calculated for a given type of structure with appropriate safeguards. For the development of areas in Category IV of mining impact areas, the estimated costs of additional structure protections against mining impact, in addition to higher costs of building renovation management, additional insurance costs and high investment risk in some cases exceed the typical investment cost in Category 0 of mining impact area. Areas of Category V, on the other hand, are not suitable for construction of civil structures. Table 2 illustrates the usefulness of mining areas for development and defines the scope of building reinforcements and protections, mainly at the design stage of new construction projects.

Bearing in mind the provisions applicable in Poland, the geotechnical category of the entire civil structure or its individual parts is determined by the designer of the structure based on geotechnical soil tests, the scope of which is agreed with the specialised geotechnical works contractor. In terms of the adopted classification, three geotechnical categories of civil structures are distinguished. The area analysed in the article in which adverse mining impact in the form of unfavourable

discontinuous deformations and dynamic impacts is present or will occur in the predicted time, is an area with complex terrain conditions, and thus all the analysed cases of buildings or structures located on mining damages are classified in the third geotechnical category. The analysed variables regarding the construction of buildings directly or indirectly affect the group of mining impact variables. Various numbers of underground and above-ground floors of buildings as well as various ranges of permanent and variable loads transferred by the structures to the active subsoil and the bearing capacity values significantly affect the variables generated by mining operations. The building resistance to mining ground deformations is the facility structure's ability to take over the effects of continuous and discontinuous soil deformations when all boundary conditions are met. Facilities react differently to deformations and dynamic impacts of mine operations due to the range of other variables that affecting the technical condition of the building. The degree of adverse impact mainly depends on the engineering and construction characteristics of the building. The classification of civil structures depends on its resistance to mining impacts (Table 3).

In Poland, it is legally permissible to exceed the serviceability limit state of a civil structure in mining areas with respect to deformations, damages and vibrations, but only if the first limit state, i.e. the ultimate limit state of the structure, is met. Exceeding the second limit state is reflected in the way the given engineering structure is used (Kwiatk (Ed.), 1997; Fedorowicz, 2006; Fedorowicz, 2008; Fedorowicz, Fedorowicz & Kadela, 2011; Fedorowicz & Fedorowicz, 2012; Kadela, 2013; Kadela, Fedorowicz &

**Table 3.** Classification of buildings and structures in areas with mining impact

Feature of the civil structure	Classification
1. Shape of the facility	1.1. Compact
	1.2. Superficial
	1.3. Linear
2. Susceptibility of the facility to deformation with the ground deformation	2.1. None – rigid structure
	2.2. Deformable – plastic structure
	2.3. Deformable – plastic-elastic structure
3. Maintaining structural safety and serviceability	3.1. Resistant structure
	3.2. Conditionally resistant structure
	3.3. Non-resistant structure

Fedorowicz, 2015; Gwóźdz-Lasoń, 2016; Gwozdź-Lason, 2017, 2019; Parkasiewicz, Kadela, Bętkowski, Sieńko & Bednarski, 2017; Instytut Techniki Budowlanej [ITB], 2000, 2003, 2006).

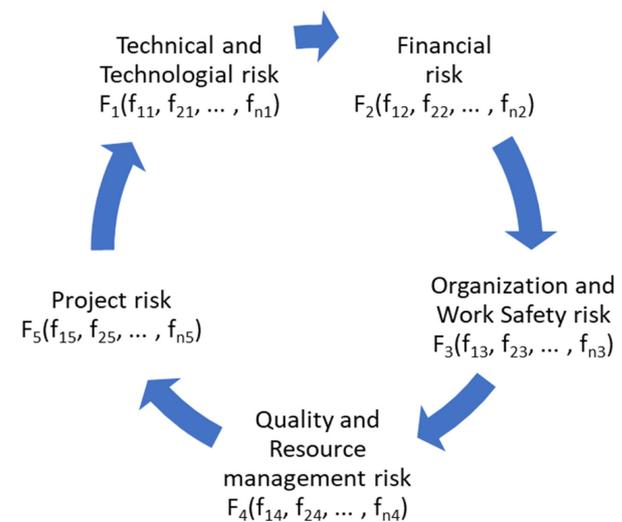
For the types of properties analysed in this publication, the limit states of structures are randomly influenced by mining impacts, constituting a very unfavourable load combination exceeding the allowable design values, and thus requiring additional design reinforcements and structural protections which translate into additional renovation and modernisation costs and increase the risk of such construction investment. The adverse impact of mining operations significantly affects the process of determining the property market. The results of calculations and analyses of the soil deformation values and the impacts taken over by buildings constitute one of the main aspects generating the size, scope and method of strengthening and protecting the structures of new buildings as well as the scope of repair, renovation or modernisation of existing buildings. The cost of renovation or reinforcement is calculated for the optimal scope of protection or repair of the facility, as well as for the optimal technology for the implementation of construction works on the basis of repair management properly foreseen for the forecasted mining impacts.

The results of statistical analyses, based on the assumed econometric model of the impact of the studied factors affecting the technical and functional condition of a facility in the aspect of variables influencing the market value of the property, indicate the importance of individual attributes and their impact on the property value (Kadela & Gwóźdz-Lasoń, 2021). The main factors affecting the actual and forecasted mining impacts on construction sites in individual areas indicate the greatest impact of the ‘exploitation gate’ and ‘exploitation factor’ variables in a given area, with the ‘dispersion factor’ and adopted ‘computational model’ variables being the next significant impacts. The last group of variables includes variables analysing the impact of ‘random factors’, ‘expert values’ and ‘periphery parameters’ of mining impact. Mining forecasts of adverse impacts on the subsoil and civil structures affect variables that generate greater than average costs of protection, reinforcements and renovations of the construction investment, in order to ensure adequate

comfort of use of the facility, which requires conducting renovation management of facilities much more frequently than typically, including the options of necessary modernisation and repairs of buildings in accordance with the planned schedules.

### Real estate investment risk in areas with mining impact

This research was made by analysis of every each information from the experts who have had experience in high rise of building construction projects in the mining areas. It was made to obtain recommended corrective actions needed for controlling material cost variance, the variables used in this research consist of cause of the variable and corrective action variable to anticipate the variance of risk class of construction investment in the areas with mining impact (Fig. 3).



**Fig. 3.** Risk class:  $f_{1i}$  – lowest risk (1);  $f_{2i}$  – low risk (2);  $f_{3i}$  – satisfactory risk (3);  $f_{4i}$  – high risk (4);  $f_{ni}$  – the highest risk (5); final class decisions (own work)

The analysed action taken is referred to the cause and effect of the construction investment design, and adverse mining impact variances. The causes of cost variances and their corrective actions in construction, materials and mining impact managements can be grouped into:

- planning and scheduling,
- external factors mining impact,
- organisation and personnel (experts),

- procurement and delivery – typical materials for market and replacement by a new value of buildings on areas with mining impact,
- quality assistance – quality control,
- usage structure – subsoil contact issues,
- change of order or type of reinforcement, protection, repairs or modernisation,
- monitoring and control.

Corrective action data acquired from the expert are analysed with method which is a qualitative approach used to provide prediction of future incident tendencies. The goal of this method is to combine four analysis aspect of variables for a property in terms of investment risk for the project of erecting or renovation and modernisation of existing buildings locates in areas affected by mining. Corrective action towards the cause of time and renovation cost.

Risk probability matrix analysis uses the judgment of risk variables to determine the risk priority and classifying risks. The process is consists in finding out a risk having the highest influence to the failure of a project. Corrective actions are applied to the causes of variance by observing the risk factor, both the highest and lowest risk factor, in an effort to prevent deviation in analysis of management aspects. A full understanding of the issues, assumptions made for the investment (financial, design, technology, engineering, circle economy) and field problems (geotechnology, mining, environment) is required before recommending remedial actions and creating investment risk variables. Research shows that the cause of analysis of cost variance, risk ranking and recommended corrective actions can be organised into a knowledge base which can be developed into a computerized knowledge base management system. This prototype knowledge base management system will yield output in terms of recommended corrective action to cost variance. Recommendation well depend on factors which have the highest risk ranking. Corrective actions towards the cause of variance are recommended by observing the risk leaver of material cost variance.

## RESULTS AND DISCUSSION

All discussed variables of the examined functions of building condition in an area of mining impact on the market values of the building and on the investment

risk of a given construction project were analysed from the interdisciplinary standpoint. Legal guidelines applicable in Poland and relevant normative guidelines as well as industry standards provide the opportunity to estimate the value of property located on mining damages with the application of an appropriate investment risk factor for the assumed scope of strengthening of the engineering structure, its renovation or modernisation. The results of the market value calculations for the analysed group of properties, using the discussed mixed approach for the analysed variables describing in detail the buildings and mining impacts, very well illustrate the market value of the properties and replacement values of necessary reinforcements, protections or renovations of buildings. Conclusions from the examined groups provide information about the extreme importance of initial assumptions for a given calculation model. Unrealistic or contradictory parameters for individual coefficients result in outcomes that go beyond the assumed confidence intervals. Such results are less likely than the results of estimates and calculations when using the comparative or income-based approach without calculating the importance of the analysed coefficients.

## CONCLUSIONS

Conclusions from the already completed projects for the computational models built provide information about very good risk assessment results for individual types of construction investments. In my opinion, the most important issue is the proper process of analysing the output data. Each stage of the construction, renovation or modernisation process of a building in areas with an additional negative impact of mining exploitation requires the analysis of data in classified groups. Data analysis has a significant impact on the end result – the success of the project or its failure. Depending on the scale and complexity of the problem to be solved using data analytics, the optimal approach and method as well as appropriate computational tools should be selected. The investment risk for the variable examining the influence of the technical condition of a building is very well estimated when the data on the structure and conducted renovations and modernisations, as well as on the class and type of building

materials constituting the buildings is true. Confirmed in construction logs and facility books. If the output is derived from unconfirmed statements, then for such a variable the impact weight on the risk calculations must be adjusted accordingly. The presented investment risk analysis takes into account the weights of individual variables, influencing, among others on the geotechnical and mining impact of the analysed area. If a variable of the impact on the investment risk is created from the adverse impact of mining exploitation, the input data for its estimation are crucial. In realizable projects there were the output data from the documentation plus the data from in situ tests create a variable with the maximum value of the weight, which will adequately affect the estimated investment risk, but there were also only output data from mining forecasts and, unfortunately, even with a high weight for this variable, the risk was not counted. At the same time, using only calculations according to outdated guidelines without verification gives a data set for analysis that is not fully true. The estimated infestation risks in terms of individual variables depend on the quantity and quality of data for statistical calculations of the selected method.

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## **INTERDYSCYPLINARNA ANALIZA RYZYKA INWESTYCJI BUDOWLANYCH I WARTOŚCI NIERUCHOMOŚCI NA OBSZARACH Z WPŁYWEM EKSPLOATACJI GÓRNICZEJ**

### **STRESZCZENIE**

Naukowym celem niniejszego artykułu jest oszacowanie liczby zmiennych ryzyka inwestycyjnego, zdefiniowanych dla poszczególnych funkcji opisujących charakter, zakres i rodzaj oddziaływań eksploatacji górniczej na budynki w aspekcie stanu technicznego obiektów budowlanych i kosztów ich wzmocnienie, ewentualnej ochrony oraz naprawy lub modernizacji. W niniejszej publikacji analizowany jest problem reakcji na ryzyko jako klasyfikowanych odrębnych etapów procesu zarządzania ryzykiem w projektach inwestycyjnych realizowanych w branży budowlanej na terenach górniczych. Wyprecyzowane i zdiagnozowane zmienne są analizowane w wybranym aspekcie, ze szczególnym uwzględnieniem oceny stanu granicznego nośności i użyteczności badanych obiektów budowlanych. Prognozowana eksploatacja górnicza oraz badania in situ kreują wytyczne, które oddziałują na zabezpieczanie lub remonty budynków na podłożu czynnym w założonym czasie użytkowania projektowanych obiektów budowlanych. Odpowiednia baza danych dla przewidywanych oddziaływań górniczych jest niezbędna w analizie formy i zakresu reakcji konstrukcji na niekorzystne oddziaływania oraz przy szacowaniu kosztów interakcji budynku z podłożem przez cały cykl życia konstrukcji. Tematyka ma charakter interdyscyplinarny, obejmuje zarówno przedmioty z zakresu inżynierii, jak i procesów stochastycznych, ekonometrii oraz ilości i jakości danych wyjściowych prognozujących oddziaływanie eksploatacyjne kopalń na analizowanych obszarach miejskich.

**Słowa kluczowe:** obszar oddziaływania górniczego, szkody górnicze obiektów budowlanych i cywilnych, wartość rynkowa i odtworzeniowa nieruchomości, prognozy górnicze w aspekcie zużycia technicznego budynku