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Research paper

Identification of threats affecting the risk of urban regeneration of post-industrial areas

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Abstract: One of the main problems of highly urbanized areas is progressively degrading land. This process is mainly caused by the closure of enterprises that have failed to adapt to the realities of the economy and the lack of investment. Post-industrial areas are usually large, diverse, and polluted complexes that may have historical and locational value. Currently, there is a growing interest among European city authorities in this type of land, which can be revitalized to create, i.e., leisure and recreation areas. The need to preserve cultural values, while adapting the space to the new reality, requires verification of risk factors affecting the urban regeneration process. In this article, the authors attempt to create a ranking of the risk factors of post-industrial area urban regeneration. A statistical analysis was conducted preceded by the collection of data in the form of assessments of the probability and severity of the identified urban regeneration risk factors. This ranking was created to identify the key factors for urban regeneration risk estimation. The analysis conducted revealed that the most significant urban regeneration risk factors are related to, i.e., poor technical condition of buildings and structures, environmental degradation, as well as logistical problems.

Keywords: ANOVA, brownfield, postindustrial areas, risk assessment, statistical analysis, urban regeneration

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1. Introduction

The issue of urban regeneration is characterized by different peculiarities depending on the type of area analyzed. Individual areas may also be subject to certain types of degradation to varying degrees. Therefore, to properly manage degraded areas, it is necessary first of all to look at their classification and characteristics. Based on their original purpose, degraded areas are divided into [1, 2]:

1. Residential areas,
2. Multifunctional complexes,
3. Areas associated with technical and industrial infrastructure: post-industrial (steel mills, cement plants, power plants), post-port, post-military, post-rail, post-mining (coal mines, salt mines, oil mines),
4. So-called urban wastelands.

The brownfields considered in this study are usually large, diverse, and contaminated complexes that sometimes have historical value.

With the Industrial Revolution, there were significant changes and transformations in the structure of societies and cities. More cities and industrial societies emerged as a result of settlements that developed near industrial plants, power plants, ports, or mines that opened to increase production. Therefore, areas where industry once developed commemorate the modernization and development of a country's economy in urban space. This is expressed in preserved buildings and urban complexes, many of which have high historical and aesthetic value [3, 4]. However, brownfield sites are a resource that has been little used for urban development in Central and Eastern European countries. These sites, although often showing massive destruction and high pollution, are just as often distinguished by their many advantages, showing great potential. The presence of brownfield sites affects, for example, the value of residential properties that are located in their vicinity [5]. Therefore, determining a rational strategy for their redevelopment is a complex task, requiring consideration of several different economic, social, physical, and environmental factors. Making such a decision has a long-term impact on the quality of life, ecological balance, and structure of cities [6–8].

The issue of brownfield urban regeneration has been discussed in the literature by many researchers. Burinskiene et al. [8] have developed a comprehensive set of criteria that contribute to the redevelopment of brownfield sites in urban areas. In their study, they focused on development strategies that include creating residential, green, commercial, recreational, and industrial sites or leaving the land as a reserve. They used expert evaluations along with a statistical method for measuring the level of agreement of their opinions combined with the Delphi method to determine the importance of criteria in groups of economic, social, physical, and environmental criteria.

Due to the nature of degraded areas, any action taken involves a high degree of risk and requires a wide range of analysis. Radziszewska-Zielina et al. [3] surveyed a group of experts associated with the Polish construction market, involved in the implementation of construction works. The authors showed that a major problem in the urban regeneration of brownfield sites is the lack of adequate solutions that support decision-making. Another impediment is also the lack of tools needed to assess the redevelopment potential of degraded sites. Tureckova et al. [7]

also pointed out the problem of the perception of brownfields. In their research, they showed that these areas are perceived negatively because they significantly affect the values of properties located in the immediate vicinity. Lenartowicz and Ostrega [9], on the other hand, presented the urban regeneration of post-industrial sites as a process of regeneration of physical space, natural and social environment, which involves the preservation of industrial heritage. Based on an analysis of the legal aspects of the protection and adaptation of industrial infrastructure in Poland, it was found that there is a lack of adequate links between legal regulations on industrial activity and the protection of historical monuments. In the following work, Ostrega and Cala [10] proposed a method for assessing the value of post-industrial landscapes using post-mining areas as an example. The authors paid special attention to the impact of mining activities on the development and expansion of the surrounding area.

Construction work conducted in urban redevelopment program areas is a special type of construction project. Very often in the course of redevelopment, many technical problems are encountered [11]. An important risk factor in such situations is the need to preserve the historic character of the object, which results, among other things, from the recommendations of the conservator of historic buildings, legal regulations, or the investor's vision [12]. As the research indicates [13], estimating the aging of buildings is essential when planning regeneration work. An additional source of risk is the difficulty in carrying out construction work often resulting from the location of these objects in dense urban areas [14]. The safety of the workers entrusted with the construction processes is also an important aspect of the implementation of redevelopment works [15].

Considering the above, the article aims to establish a ranking of technical risk factors in brownfield urban regeneration projects, preceded by a statistical analysis of the significance of P and S scores for two groups of respondents. Using two independent groups of respondents (experts and residents) has been considered in the context of verifying the concordance of the assessments. The ranking itself is created to highlight the key risk factors in the context of urban regeneration risk estimation.

The research adopts an interdisciplinary approach grounded in psychology as well as behavioral economics to support the solution of a construction project management problem.

2. Research method

The conducted statistical analysis was preceded by data collection in the form of probability (P) and severity (S) assessments of the occurrence of identified urban regeneration risk factors. For this purpose, the survey technique was used. Despite its advantages, such as low survey cost, reduced bias that may result from individual interviewer characteristics, greater accessibility of respondents (larger sample), and anonymity, it is worth noting some of the disadvantages of this approach.

The survey technique, as a method of collecting data based on a pre-created risk factor register, is sometimes criticized because of the subjectivity of the assessments. Moreover, while the expert survey is useful for ranking risk factors, it may not be sufficient for decision-making. This is because it is difficult to obtain a meaningful assessment of the level of risk without recourse to a more detailed analysis of the variables involved in a given situation, especially in terms of causal inference of interconnected events [16]. Therefore, risk assessment and management is also a topic frequently addressed by researchers [17]. So is developing methods to reduce the negative impact of risk factors on the construction project [18]. It is worth noting, however, that in the case of urban regeneration, we are dealing with a project initiated by social needs articulated in the framework of widely conducted public consultations. The survey, on the relevance of risk factors, conducted among residents, is therefore intended to reflect the identification of socially relevant risks [19]. Furthermore, the prevailing trend in studies reveals a lack of substantial distinctions between the evaluations of professionals and the questionable knowledge of laypeople. Haigh and List [20], among others, note, at most, a heightened inclination among experts towards a phenomenon termed myopic loss aversion. Meanwhile Kahneman and Tversky [21], prominent researchers in the field of behavioral economics, specializing in decision-making under uncertainty, note among respondents an excessive caution (desire to avoid loss) when risking the loss of something one already owns, while a lack of caution when seeking gains.

3. Urban regeneration of a brownfield site – a case study

A special case of post-industrial areas are whole city districts which, in addition to industrial structures, also have residential or service functions. An example of this type of structure is Letnica – a district of Gdansk. Despite its convenient location, it suffered from economic stagnation, infrastructural, spatial, and social problems.

One of Letnica's major problems was technical degradation. The workers' housing complex, built at the turn of the 19th and 20th century, and the infrastructure before the urban regeneration began, was in a very poor technical condition. The houses were built as one-storey buildings without basements, with wooden ceilings, roofs covered with tar paper, less often with tiles, without sewage, gas, and heating installations. Most buildings used for heating coal cookers, bottled gas, and electricity. The poor technical condition of the buildings was complemented by a lack of sanitary facilities. All these factors contributed to a very low standard of housing and a very low level of housing stock value.

More than 60% of all the district's buildings had cultural values that were deteriorating and disappearing due to the lack of restoration efforts. The need for intervention was also supported by the lack of rainwater drains. Together with high groundwater levels and fairly high rainfall, this caused waterlogging streets, central heating, as well as sogginess and molding buildings that, as a consequence, did not meet thermal standards. An additional problem was the lack of connection of buildings to district heating networks, which resulted in heating the buildings with solid fuel and thus exposing residents to so-called low emissions. All buildings required thermo-modernization works and, due to the lack of renovation works, their technical condition was bad or very bad. The road infrastructure and pavement surfaces were also in poor technical condition.

3.1. Technical difficulties in the context of the construction process phases

Urban regeneration determines arising numerous and specific risks. It includes problems of a technical nature, related to management and organization, and problems related to so-called external factors [22, 23]. Despite the significant role of non-investment (social) tasks, research shows that the risk of urban regeneration is predominantly dependent on activities of an investment nature. For this reason, the study focuses on technical problems against the background of the different phases of the construction process, dividing them into groups A, B, and C.

3.1.1. Group A – diagnosis of the intervention area

Among the problems of Group A (initiation and preparation stage), the following were highlighted:

1. Degradation of buildings and infrastructure,
2. Historical building value,
3. Quality of project assumptions preparation.

One of the more significant problems of a technical nature was the poor quality of design assumptions preparation, which (generalizing) resulted from negligence and inadequate recognition of the building's technical condition. In the case of the Letnica urban regeneration, one could observe, i.a. incorrectly adopted geological assumptions for one of the buildings. The original refurbishment project for this building assumed soil parameters different from the actual ones (angle of internal friction of 34° instead of the actual 31°). Inaccuracies were also found in the soil type definition – after re-testing, it turned out that the soil had a lower bearing capacity than the documentation indicated. Furthermore, quicksand resources were discovered in the area. An additional problem turned out to be the higher-than-originally-assumed load on the foundations resulting from the change in floor construction from timber to reinforced concrete, which had not been taken into account in the design. The accumulation of all these factors could have contributed to the building catastrophe. Due to the advancement of the interior and façade works and, above all, the historical and cultural value of the building, it was decided to save the building by using 238 foundation micropiles. Their use was justified by the change in the slab structure, but also by the new functional layout affecting the positioning of the partition walls differently than before. All these factors resulted in a 60% increase in the load on foundations. These irregularities imposed changes to the material-financial investment scope and the construction project, delaying the works by about six months and significantly increasing costs. Other problems include:

1. Incorrectly adopted cleaning technology for the facades of the renovated buildings (technology change caused a significant delay and generated additional costs),
2. Underestimation of tender estimates,
3. Inventory deficiencies.

3.1.2. Group B – planning and execution of the investment process

The planning and particularly execution stage is especially sensitive. For this reason, among the problems of Group B stand out:

1. Problems and design flaws,
2. Logistical difficulties,
3. Problems with works execution,
4. Problems with safety and proper supervision.

An essential element in the planning and execution of complex construction projects is establishing a schedule ensuring that the activities of multiple parties are coordinated and that the production capacities of individual contractors are effectively utilized. In the case of uncommon activities, however, the precise timing of individual tasks and the entire project is very difficult.

In the course of the research, it was observed that Letnica experienced numerous problems with project coordination, resulting in increased costs and longer project implementation. It is worth noting that the vast majority of these problems resulted from the excessive accumulation of works carried out simultaneously, e.g. the incorrect overlapping schedules of refurbishment works in buildings with the schedules of reconstruction and modernization of adjacent streets. In addition, the following problems were identified:

– paving and consolidation of the road surface near the renovated buildings caused scratches to walls,
– piling for new buildings in the direct vicinity of the regenerated area resulted in uneven settlement and torsion of buildings undergoing renovation; pile driving technology had to be changed into drilled piles.

3.1.3. Group C – maintenance

Among the problems of Group C were: *Maintenance after urban regeneration.* The maintenance problems result mainly from the need to sustain the effects of urban regeneration (so-called institutional sustainability). Difficulties in this area may result, i.e., from inadequate supervision of technical reviews by managing authorities. On the other hand, the lack of social acceptance and consent to the new situation after urban regeneration may contribute to returning pathologies and secondary degradation of renovated resources.

3.2. Risk factors assessment

The risk factors' identification process was based mainly on the analysis and evaluation of documentation related to the preparation and implementation of selected urban regeneration projects in Gdańsk. Extensive literature studies conducted for the doctoral dissertation [24] of one of the co-authors were also used to gather the complete list of risk factors. The final version of the risk register was also consulted with the experts involved in the urban regeneration process in Gdańsk.

The assessment of risk factors is based on the indication of estimated P and S levels for identified risk factors by two independent groups of respondents. For this purpose, the survey technique was used. The assessment was based on *P* and *S* qualitative scales (Table 1, Table 2). The *P* and *S* assessment (by residents – *Rs*, expert group – *E*) was used to create a ranking of risk factors. Using two independent groups of respondents has been considered in the context of verifying the concordance of the assessments. This concordance was confirmed using the Student's *t*-test.

Table 1. The rating scale for the *P* of risk factors occurrence (own study)

Level	**Description**	**Estimated probability**
1	Fairly unlikely	(0%; 10%⟩
2	Rare	(10%; 25%⟩
3	Possible	(25%; 50%⟩
4	Likely	(50%; 75%⟩
5	Almost certain	(75%; 100%⟩

Table 2. The rating scale for the potential *S* of risk factors occurrence (own study)

Level	**Description**
1	Negligible possible minimal increase in time and costs without significant impact on the scope and quality of the project
2	Marginal slight increase in duration, possibly compensated by time reserves and a slight increase in project costs (within 5%); impact on scope and quality of minor works
3	Medium unavoidable increase in duration and project costs (within 5÷10%); impact on scope and quality of more substantial works
4	Critical unavoidable significant increase in duration and cost of the project (within 10÷20%); unacceptable impact on the scope and quality of the relevant works
5	Catastrophic unavoidable significant increase in duration and cost of the project (over 20%); scope and quality of works not allowing for operation

*The study includes approximate percentages.

Two groups of respondents were surveyed – experts (construction managers, road and installation work managers, investor supervision inspectors, conservators, officials of the Revitalization Department in Gdansk, lecturers specializing in urban regeneration issues – 10 people; experts' sample size) and residents of Gdansk from revitalized areas (229 people – residents' sample size).

The product of P and S of risk factors allowed the risk level (rank – R) to be defined using the so-called risk matrix. Its reflection is the assessment of risk levels with the interpretation presented in Table 3.

Table 3. Risk level assessment (own study)

Risk level	Description
1÷7	Low risk mitigation is not required
8÷12	Medium actions required to reduce risk during project implementation once symptoms are observed
13÷25	High unacceptable; corrective action required before commencing investment or change in the performance of certain tasks

3.3. Similarity analysis of scores for independent samples – Student's *t*-test

A similarity analysis was conducted for two independent groups of respondents. Its purpose was to show the convergence of scores assigned by the two groups and also to confirm the average value of E-scores on a larger random sample. They were asked to assess both P and S of the occurrence of adverse events related to the construction activities performed as part of the urban regeneration. Given the research hypothesis (similarity in the mean scores for both groups of respondents), a statistical measurement method was adopted in the form of Student's t-test for independent samples and the two-sample F-test for variance, preceded by a one-way ANOVA. The calculations were performed in MS Excel using the data analysis module. They present analogously for each of the eight risk groups. As statistical inference using the above tests is applicable only for variables with a normal or near-normal distribution, this condition was verified for the assessments of each of the risk groups studied.

The presented statistical inference is based on the assumption of representativeness and randomness in terms of the selection of interviewees. The representativeness condition is based on the size and diversity (e.g. in terms of gender, place of origin, age, level of knowledge, specialization) of the surveyed groups. It can therefore be assumed that the sample structure, in both cases, is consistent with the population. In the case of residents, the random nature is determined by the fact that individuals participating in the survey were selected independently of the characteristics under study and each person had a P different from zero to be in the sample. Meanwhile, the experts were selected mainly from among specialists originating from the Gdansk construction community.

Due to the research nature (separate P and S assessment), a total of 16 comparisons were made using the aforementioned tests (Student's t-test, F-test).

3.3.1. P-score similarity analysis for independent samples

An example of a *P*-score similarity analysis for risk group No. 1.1.1.0. (according to Table 4) is presented below.

Table 4. The mean *P*-score values [%] for eight groups of technical risk factors (own study)

Id.	Description	*Rs*[%]	*E*[%]
1.1.1.0.	Group I – Degradation of buildings and infrastructure	61.175	61.400
1.1.1.1.	Poor technical condition of buildings and structures related to technical infrastructure; environmental degradation		
1.1.1.2.	High level of environmental contamination (air, water, and land)		
1.1.1.3.	Lack of technical infrastructure facilities on site		
1.1.1.4.	Lack of valid technical documentation of the facility/plan of underground networks		
1.1.1.5.	Impeded conditions for making inventory and applying technical expertise		
1.1.2.0.	Group II – Historical building value	49.686	62.500
1.1.2.1.	Non-standard security features and technologies required		
1.1.2.2.	Archaeological investigation required		
1.1.3.0.	Group III - Quality of project assumptions preparation	40.118	40.750
1.1.3.1.	Negligent preparation of project assumptions		
1.1.3.2.	Inadequate identification of subsoil properties and groundwater conditions		
1.1.3.3.	Misdiagnosis of the building structure's performance under complex and abnormal loads		
1.1.3.4.	Inadequate recognition of building/structural elements' technical condition		
1.1.3.5.	Poor expertise quality		
1.1.3.6.	Renovation works to be scoped in an inhabited building - inability to perform opencast / in situ surveys		
1.2.1.0.	Group IV – Problems and design flaws	37.500	28.250
1.2.1.1.	Calculation biases		
1.2.1.2.	Insufficient experience, low qualifications of the designer		
1.2.1.3.	Inappropriate standards and guidelines adopted		
1.2.1.4.	Incorrect design assumptions		
1.2.1.5.	Incorrectly applied loads (structural and functional layout of the facility change)		
1.2.1.6.	Negligent preparation of project documentation		

Continued on next page

Table 4 – *Continued from previous page*

Id.	Description	*Rs*[%]	*E*[%]
1.2.1.7.	Drawing mistakes		
1.2.1.8.	Poor organization of design processes		
1.2.2.0	Group V – Logistical difficulties	46.258	38.167
1.2.2.1.	Simultaneous refurbishment of buildings and infrastructure		
1.2.2.2.	Difficulties in organizing the storage space required for construction materials and equipment		
1.2.2.3.	Maneuvering heavy equipment in confined spaces		
1.2.2.4.	Lack of access to the building due to infrastructure works		
1.2.2.5.	Demolition of buildings adjacent to the renovated ones		
1.2.2.6.	Existence of infill buildings (potential for drainage damage)		
1.2.3.0.	Group VI – Problems with works execution	46.726	37.583
1.2.3.1.	Changes in technical design due to insufficient object recognition		
1.2.3.2.	Insufficient engineering knowledge resulting in design discrepancies		
1.2.3.3.	Defective works execution in terms of scope and quality of materials used, labor, organization of works, timeliness, efficiency, etc.		
1.2.3.4.	Inadequate qualifications of the contracting company		
1.2.3.5.	Contractor negligence		
1.2.3.6.	Suspension or works disruption		
1.2.4.0.	Group VII – Problems with safety and proper supervision	40.052	30.875
1.2.4.1.	Failure to comply with H&S regulations - works suspended until eliminated; accident on site		
1.2.4.2.	Considerable distances between line works - difficult supervision		
1.2.4.3.	Lack of technical supervision over the quality and progress of works		
1.2.4.4.	Lack of safeguards and danger zone marking in the vicinity of working plants and machinery		
1.3.1.0.	Group VIII – Maintenance after urban regeneration	48.412	35.833
1.3.1.1.	Improper use of the facility during the warranty and quality guarantee period		
1.3.1.2.	Insufficient seasoning time for renovated buildings imposed by the need to accommodate residents		
1.3.1.3.	Leakage, failure of water and sewage systems; problem with rainwater drainage		

Group 1.1.1.0. – degradation of buildings and infrastructure

The *P*-score similarity analysis for group 1.1.1.0. was preceded by verification of the normality of the distribution using charts which were developed for each risk group separately for both Rs and E scores. Given the size of the sample, the distribution of the studied variable tends toward normal only for Rs scores (Fig. 1). *P*-scores for the *E* are concentrated around the central and most frequently repeated responses. Moreover, according to PN-ISO 2854, even if the *P* distribution of the observed variable deviates slightly from the accepted norm, but the number of samples is not too small (there are between 5 and 10 observations), the tests used in the statistical analysis give approximate results, and their accuracy is sufficient for the most practical situations.

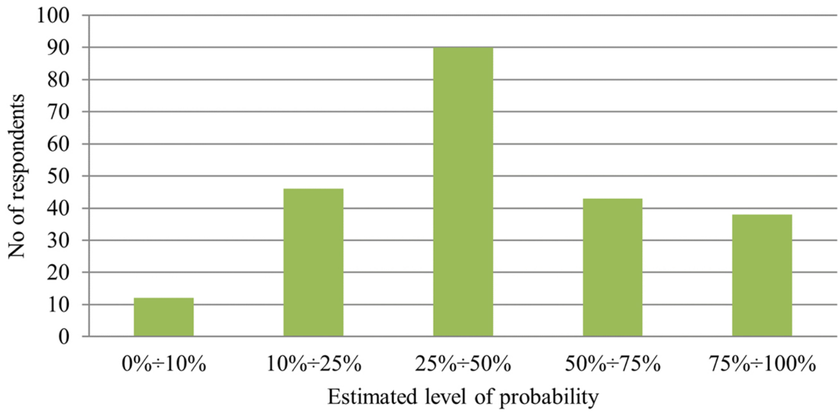

Fig. 1. Chart showing the P distribution of Rs' scores about risk group no 1.1.1.0.

To prove the equality of *P*-scores for both studied groups, one-way ANOVA was applied (Table 5, Table 6) taking, as a differentiating factor, the level of knowledge of each group. The following hypotheses were proposed:

– Hypothesis '0': the mean *P*-score values for both groups are equal;
– Hypothesis '1': the mean P-score values for both groups are different.

Based on Table 5 and Table 6, it can be concluded that the difference between the means for both groups is not statistically significant, as the critical value of the *F*-test (3.881) is greater than the calculated value (0.001), and $p = 0.975 > \alpha = 0.05$. Therefore, there is no basis for rejecting the "0" hypothesis – the specificity of the group of respondents does not affect the mean values.

Table 5. One-way ANOVA – data

Groups	Observations	Sum	Mean	Variance
Rs	229	14009	61.2	498.689
E	10	614	61.4	79.156

Table 6. One-way ANOVA – calculation results

Source of variance	***SS***	***df***	***MS***	***F***	***p*-value**	***F*-test**
Between groups	0.487	1	0.486	0.001	0.975	3.881
Within groups	114413.413	237	482.757	–	–	–
Total	114413.900	238	–	–	–	–

**SS* – variability of the tested characteristic in the sample (sums of squares of deviations of the tested characteristic from the mean value); *df* – degrees of freedom numbers; *MS* – mean squares; F – the calculated value of the statistic for the F-test; $p-$value – probability value; $F-$test – critical value.

The next step was to evaluate the difference between mean P-scores, which was conducted using a two-tailed Student's t-test (Table 7). The following research hypotheses were established:

– Hypothesis '0': the mean P-scores for both groups are equal;
– Hypothesis '1': the mean P-scores for both groups are different.

Table 7. The two-sample Student's t-test assuming equal variances

	Rs	***E***
Mean	61.2	61.4
Variance	498.689	79.156
Observations	229	10
Total variance	482.757	–
Difference of means according to hypothesis	0	–
Df	237	–
t-Stat	–0.032	–
$P(T \leq t)$ one-tailed	0.487	–
Test T one-tailed	1.651	–
$P(T \leq t)$ two-tailed	0.975	–
Test t two-tailed	1.970	–

Since the comparisons were made between the assessments of two groups of respondents, the conclusions of the Student's t-analysis look analogous to those observed for the one-way ANOVA, so again, at the significance level of $\alpha = 0.05$, there is no reason to reject the null hypothesis of equality of means (results of testing the null hypothesis for the one-way ANOVA and the two-samples Student's t-test assuming equal variances are analogous, so the one-way ANOVA was omitted for the other risk groups). However, it is necessary to verify the assumption of the equality of variances so a complementary F-test was performed (Table 8), assuming the hypotheses:

– Hypothesis "0": variances for both groups are equal;
– Hypothesis "1": variances for both groups are different.

Table 8. The two-sample F-test for variance

	Rs	***E***
Mean	61.2	61.4
Variance	498.689	79.156
Observations	229	10
df	228	9
F	6.300	–
$P(F \leq f)$ one-tailed	0.003	–
F-test one-tailed	2.728	–

The F-test established that the variances for both groups (residents and experts) are significantly different ($p = 0.003 < \alpha = 0.05$, the critical value of the one-tailed F-test – 2.728 is lower than the calculated value – $F = 6.300$). Therefore, the “0” hypothesis should be rejected in favor of the alternative one. The primary reason for the difference in variances is the *Rs* sample size, therefore it cannot be ruled out that with a larger sample size E, the two variances would be equal. However, rejection of the equality of variances hypothesis makes it necessary to run the Student’s t-test again – this time assuming unequal variances (Table 9). The definition of the hypotheses in the Student’s t-test remains the same.

Table 9. The two-sample Student’s t-test assumes unequal variances

	Rs	***E***
Mean	61.2	61.4
Variance	498.689	79.156
Observations	229	10
Difference of means according to hypothesis	0	
df	15	
t-Stat	–0.071	
$P(T \leq t)$ one-tailed	0.472	
Test T one-tailed	1.753	
$P(T \leq t)$ two-tailed	0.944	
Test t two-tailed	2.131	

The probability of the null hypothesis being true for a two-tailed two-sample Student’s t-test assuming unequal variances is 0.944, and the critical value of the two-tailed t-test (2.131) is higher than the calculated value (–0.071), so the earlier assumption of equality of means can be affirmed.

The similarity of P-score analyses for the remaining risk groups is presented in Table 10 (only one of the 8 risk groups revealed a lack of equality of mean P-scores at the significance level $\alpha = 0.05$ – risk group 1.3.1.0.). Therefore, it should be concluded that most of the average P-scores for the different risk groups are statistically equal to each other, which was confirmed by conducting additional calculations presented in Table 11 and Table 12.

Table 10. The Student's t-test with two samples assuming equal variances (two-tailed; significance level $\alpha = 0,05$) – collective data for 8 risk groups)

Risk group No	Mean		Variance		Observations		p-Value	t-Stat calculated value	F-Test critical value	Equality of means
	Rs	***E***	***Rs***	***E***	***Rs***	***E***				
1.1.1.0.	61.175	61.400	498.689	79.156	229	10	0.975	–0.032	1.970	YES
1.1.2.0.	49.686	62.500	571.506	540.278	229	10	0.098	–1.661	1.970	YES
1.1.3.0.	40.118	40.750	440.422	368.279	228	10	0.926	–0.093	1.970	YES
1.2.1.0.	37.500	28.250	363.732	306.667	229	10	0.133	1.506	1.970	YES
1.2.2.0.	46.258	38.167	336.946	145.494	229	10	0.169	1.379	1.970	YES
1.2.3.0.	46.726	37.583	254.432	261.644	229	10	0.077	1.773	1.970	YES
1.2.4.0.	40.052	30.875	554.699	286.128	229	10	0.225	1.217	1.970	YES
1.3.1.0.	48.412	35.833	336.508	263.735	229	10	0.034	2.131	1.970	NO

Table 11. Verification of assuming the equality of variances – two-sample F-test for variance (one-tailed test; significance level $\alpha = 0.05$)

Risk group No	p-Value	F calculated value	F-Test critical value	Equality of variances
1.1.1.0.	0.002	6.300	2.728	NO
1.1.2.0.	0.513	1.058	2.728	YES
1.1.3.0.	0.417	1.196	2.728	YES
1.2.1.0.	0.423	1.186	2.728	YES
1.2.2.0.	0.083	2.316	2.728	YES
1.2.3.0.	0.418	1.028	2.728	YES
1.2.4.0.	0.138	1.276	2.728	YES
1.3.1.0.	0.368	1.276	2.728	YES

Table 12. The two-sample Student's t-test assuming unequal variances is the consequence of rejecting the hypothesis of equality of variances in the F-test – Table 11 (two-tailed test; significance level $\alpha = 0.05$)

Risk group No	p-Value	t-Stat calculated value	F-Test critical value	Equality of means
1.1.1.0.	0.944	-0.071	2.131	YES

The Student's t-test, assuming unequal variances (Table 12) revealed a result consistent with the Student's t-test assuming equal variances (Table 10). The equality of means for risk group 1.1.1.0. was therefore confirmed.

3.3.2. S-score similarity analysis for independent samples

An example analysis of the similarity of S-scores for risk group No. 1.1.1.0. (as shown in Table 4) was performed analogously to the similarity analysis of P-scores.

Based on the conducted calculations it should be noted that, in 2 of 8 risk groups, inequality of mean S-scores was observed. However, most of the mean S-scores for each risk group are equal to each other. Due to the equality of variances in the F-test, it was not necessary to conduct a Student's t-test for unequal variances.

3.4. Risk factors ranking

As a consequence of risk factors assessment, using Table 3, a risk factor ranking relating to urban regeneration risk of a technical nature was developed (Table 13). The ranking presented includes only those risk factors where the experts ultimately assessed the level of risk as high or medium. These factors should be considered crucial in the assessment of urban regeneration risk.

Table 13. The technical risk factors ranking for E (high – H and medium – M risk level)

Id.	Risk level	Risk factor
1.1.1.1.	H	Poor technical condition of buildings and structures related to technical infrastructure; environmental degradation
1.1.2.1.	M	Non-standard security features and technologies required
1.2.2.1.	M	Simultaneous refurbishment of buildings and infrastructure
1.1.1.5.	M	Impeded conditions for making inventory and applying technical expertise
1.1.3.1.	M	Negligent preparation of project assumptions
1.1.2.2.	M	Archaeological investigation required
1.1.3.4.	M	Inadequate recognition of building/structural elements' technical condition
1.2.3.5.	M	Contractor negligence
1.1.1.4.	M	Lack of valid technical documentation of the facility/plan of underground networks
1.2.2.3.	M	Maneuvering heavy equipment in confined spaces
1.1.3.5.	M	Poor expertise quality
1.1.3.6.	M	Renovation works to be scoped in an inhabited building - inability to perform opencast / in situ surveys
1.2.3.1.	M	Changes in technical design due to insufficient object recognition
1.1.1.3.	M	Lack of technical infrastructure facilities on site
1.1.1.2.	M	High level of environmental contamination (air, water, and land)
1.3.1.2.	M	Insufficient seasoning time for renovated buildings imposed by the need to accommodate residents

4. Conclusions

The need for urban regeneration and redevelopment of brownfield sites is driven primarily by environmental (reduction of the impact of pollution located on the site), economic (possibility to use existing facilities, infrastructure, favorable location), and social (brownfield sites constitute an unwelcoming neighborhood, are perceived as dangerous places) considerations. For this reason, the urban regeneration process must be preceded by an in-depth analysis of the impact of risk factors to minimize the likelihood and severity of various types of hazards emerging.

As a result of the research, a ranking of urban regeneration risk factors was developed identifying major causes of disruption to construction tasks. These include:

- poor technical condition of buildings and structures related to technical infrastructure; environmental degradation,
- simultaneous refurbishment of buildings and infrastructure (logistical problems),
- tight schedule and limited time for construction processes,
- problems with communication and flow of up-to-date and reliable information.

Considering the experts' experience and knowledge, it was assumed in advance that the experts' assessment of threats affecting the risk of urban regeneration of post-industrial areas would be crucial. However, the authors have decided to confront it with the assessments of residents to verify whether the two assessments are similar. The conducted statistical analysis in most cases (81.25% – 13/16 cases) confirmed a convergence of the average P and S scores of the identified risk factors for both groups of respondents. Therefore it can be concluded that the resulting ranking reflects the actual level of relevance of individual risk factors for the urban regeneration of the post-industrial area. Moreover, as mentioned in subsection 3.3.1, only one of the 8 risk groups revealed a lack of equality of mean P-scores at the significance level $\alpha = 0.05$. Therefore, it should be concluded that most of the average P-scores for the different risk groups are statistically equal to each other. Thus, it was possible to establish a reliable ranking of technical risk factors in brownfield urban regeneration projects, considering the decreasing impact of risk factors on the magnitude of project risk.

The authors' further research is to expand the scope of the analysis by including additional groups of post-industrial areas urban regeneration problems, related to external factors as well as management and organization.

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Identyfikacja zagrożeń wpływających na ryzyko rewitalizacji miejskiej terenów poprzemysłowych

Słowa kluczowe: analiza wariancji, obszary poprzemysłowe, rewitalizacja, zarządzanie ryzykiem

Streszczenie:

Jednym z głównych problemów obszarów wysoce zurbanizowanych jest pojawianie się terenów, które ulegają stopniowej degradacji. Proces ten spowodowany jest przede wszystkim likwidacją przedsiębiorstw, które nie zdołały przystosować się do realiów gospodarki oraz brakiem nakładów inwestycyjnych. Obszary poprzemysłowe to zwykle duże, zróżnicowane i zanieczyszczone kompleksy związane głównie z przemysłem lekkim i ciężkim posiadające często walory historyczne i lokalizacyjne. Obecnie zauważa się wzrost zainteresowania władz europejskich miast tego typu terenami, które mogą zostać zrewitalizowane, tworząc m.in. miejsca wypoczynku i rekreacji. Szczególnym przypadkiem obszarów poprzemysłowych są całe dzielnice miast, które oprócz struktur przemysłowych pełnią także funkcje mieszkaniowe czy usługowe. Przykładem tego rodzaju struktury jest Letnica, będąca dzielnicą Gdańska. Pomimo dogodnej lokalizacji, występowały tu stagnacja gospodarcza, problemy infrastrukturalne, przestrzenne i społeczne. Jednym z poważniejszych problemów Letnicy była degradacja w wymiarze technicznym. Zespół robotniczej zabudowy mieszkaniowej, wzniesiony na przełomie XIX i XX wieku, oraz infrastruktura przed rozpoczęciem rewitalizacji znajdowała się w bardzo złym stanie technicznym. Ponad 60% wszystkich budynków dzielnicy posiadała wartości kulturowe, które ulegały stopniowemu niszczeniu i zanikały ze względu na brak działań renowacyjnych. Konieczność zachowania wartości kulturowych, a jednocześnie przystosowania przestrzeni do nowej rzeczywistości, zmusza do weryfikacji zagrożeń mających wpływ na proces rewitalizacji. W artykule autorzy podejmują próbę utworzenia rankingu zagrożeń rewitalizacji obszaru poprzemysłowego. Przeprowadzono analizę statystyczną poprzedzoną zebraniem danych w postaci ocen prawdopodobieństwa oraz skutków zaistnienia zidentyfikowanych czynników ryzyka rewitalizacji. Ranking ten utworzono w celu wskazania czynników, które są kluczowe w kontekście szacowania ryzyka rewitalizacji. Biorąc pod uwagę przeprowadzoną analizę statystyczną należy stwierdzić, że powstały ranking odzwierciedla rzeczywisty poziom istotności poszczególnych czynników ryzyka rewitalizacji obszaru poprzemysłowego. Wyniki przeprowadzonych badań wskazują ponadto, iż zakłócenia w realizacji zadań budowlanych spowodowane są m.in. następującymi przyczynami:

- napięty harmonogram i ograniczony czas realizacji procesów budowlanych,
- problemy z komunikacją i przepływem aktualnych oraz wiarygodnych informacji,
- realizacja nietypowych robót i unikatowych rozwiązań,
- problemy logistyczne wynikające z jednoczesnej obecności na placu budowy inwestora, wykonawcy, podwykonawcy, mieszkańców dzielnicy.

Genezą większości zaistniałych problemów okazał się brak dogłębnej analizy źródeł i czynników ryzyka. Niektóre spośród przyczyn skutkujących opóźnieniami działań podejmowanych na placu budowy i zwiększeniem kosztów, były efektem niemożliwych do przewidzenia błędów popełnionych na etapie planowania. Pozostałe spowodowane były tzw. “czynnikiem ludzkim”, przejawiającym się między innymi zaniedbaniami, niedopatrzeniami, brakiem kompetencji oraz przekazywaniem nieaktualnych i nie w pełni zweryfikowanych informacji.

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