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Determination of the Occurrence of Negative Impacts during Lowering of Sinking Wells Using the Fuzzy TOPSIS Method

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Abstract: Sinking wells belong to underground facilities. Large-diameter sinking wells are often constructed as retention basins and reservoirs for wastewater treatment plants, which is determined by the Urban Wastewater Treatment Directive. The directive obliges Member States to implement the principles of sustainable development, promoting sustainable sewage collection and treatment systems. When designing and constructing facilities using sinking well technology, contact between the structure and the ground must be considered. During the lowering of a sinking well into the ground medium, a number of negative impacts may occur and affect the sinking process, including excessive ground settlement outside the well, damage or destruction of adjacent objects, tilt of the well casing from the vertical, and uncontrolled sinking of the well casing. The aim of this paper is to determine the occurrence of negative impacts during the lowering of sinking wells. Determining the incidence of negative impacts could help to avoid pre-failure and emergency situations relating to sinking wells. A fuzzy TOPSIS method was used to determine the above.

Keywords: sinking well; multicriteria decision-making; fuzzy TOPSIS

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1. Introduction

Sinking wells are massive structures made of reinforced concrete. The sinking well consists of reinforced concrete coils, known as well steining. The last section is terminated by a cutting edge, which, once in position on the ground, edges through the soil medium as the excavated material is extracted from inside the well, allowing the well to sink into the ground without the use of additional weighting. The construction of a sinking well does not require a wide-space excavation. The drop well does not take up much space on the construction site. Large-diameter sinking wells have been used, among other things, as harbor jetties [1], sewage treatment facilities (pumping stations), storage reservoirs, municipal facilities, underground storage facilities, and launching and intermediate chambers for trenchless techniques. Currently, under Polish conditions, sinking wells are most often used as municipal facilities. This is justified, among other things, by Directive 91/271/EWG [2], which deals with the treatment of municipal wastewater. The Directive obliges Member States to implement the principles of sustainable development, to promote sustainable collection and treatment systems. Article 43 (1) of the Water Law [3] specifies the requirement of collective sewerage systems with urban wastewater treatment plants for agglomerations with more than 2000 RLM [4]. Rainfall should be separated from the sewerage system, as the introduction of rainwater into the river in large quantities can cause a risk to the watercourse. Therefore, the use of retention basins is recommended. Sewage pumping stations are constructed at sewage treatment plants. Facilities of this type can be constructed using diaphragm wall technology, sinking well technology, or the open method with protection of the excavation walls by means of casing, but sinking well technology is the most economical among those mentioned [5]. Sinking wells are underground facilities. The contact between the structure and the ground must be taken

into account when designing and constructing facilities using the sinking well technology. The likelihood of problems during construction should be taken into account, which is related to the need to determine the design assumptions for the subsoil [6]. The identification of the subsoil and the determination of subsoil properties are significant steps in the development of a construction project. Unfortunately, it is common practice in Poland to limit the cost of geotechnical investigations. The share of geotechnical documentation in the total investment cost is less than 0.02%. Therefore, it can be assumed that construction failures in Poland are often generated by the ground [7]. During the plunge of a sinking well into the ground medium, a number of negative impacts may occur, affecting the sinking process. Determining the incidence of negative impacts generated during the lowering of sinking wells could contribute to avoiding pre-failure and emergency situations in the future. Sinking wells can be constructed in areas with difficult soil and water conditions, i.e., in areas with silt, waterlogged soils, dust pits, floodplains, and depressions [8]. Facilities in difficult ground-water conditions and deep foundation levels are most often constructed as sinking wells with a circular cross-section. Facilities with shallower foundations are more often constructed as rectangular cross-sections. Wells with a circular cross-section are used more frequently because of the reduced friction when plunging into the ground medium. In addition, the contact area between the well and the obstacle is smaller in wells with a circular cross-section. In wells with a circular cross-section, there is less risk of the well deviating from the vertical when sinking into the ground than in a well with a rectangular cross-section. In wells with a rectangular cross-section, there is increased resistance at the corners of the walls during sinking into the ground, which can cause damage to the corners when the well is sinking into the ground [9]. The technology of the sinking well is adapted to different soil and water conditions. The stages of the technology are different for hydrated and non-hydrated soils. The course of the stages of sinking an abandoned well in non-watered soils is described in Figure 1.

The drilling of a sinking well in non-waterlogged ground is not particularly problematic. The excavated material should be excavated evenly around the perimeter of the well, without allowing the well to deviate from the vertical. In sandy soils, the excavated material should be removed from the inside of the well, whereas in compact soils, the excavated material can be removed from the inside of the well and from under the edge. The tilting of the well from the vertical should be corrected as soon as the tilting occurs [10]. Correction of the deviation of the well from the vertical may be carried out by increasing the excavated material from the side opposite to the tilted edge.

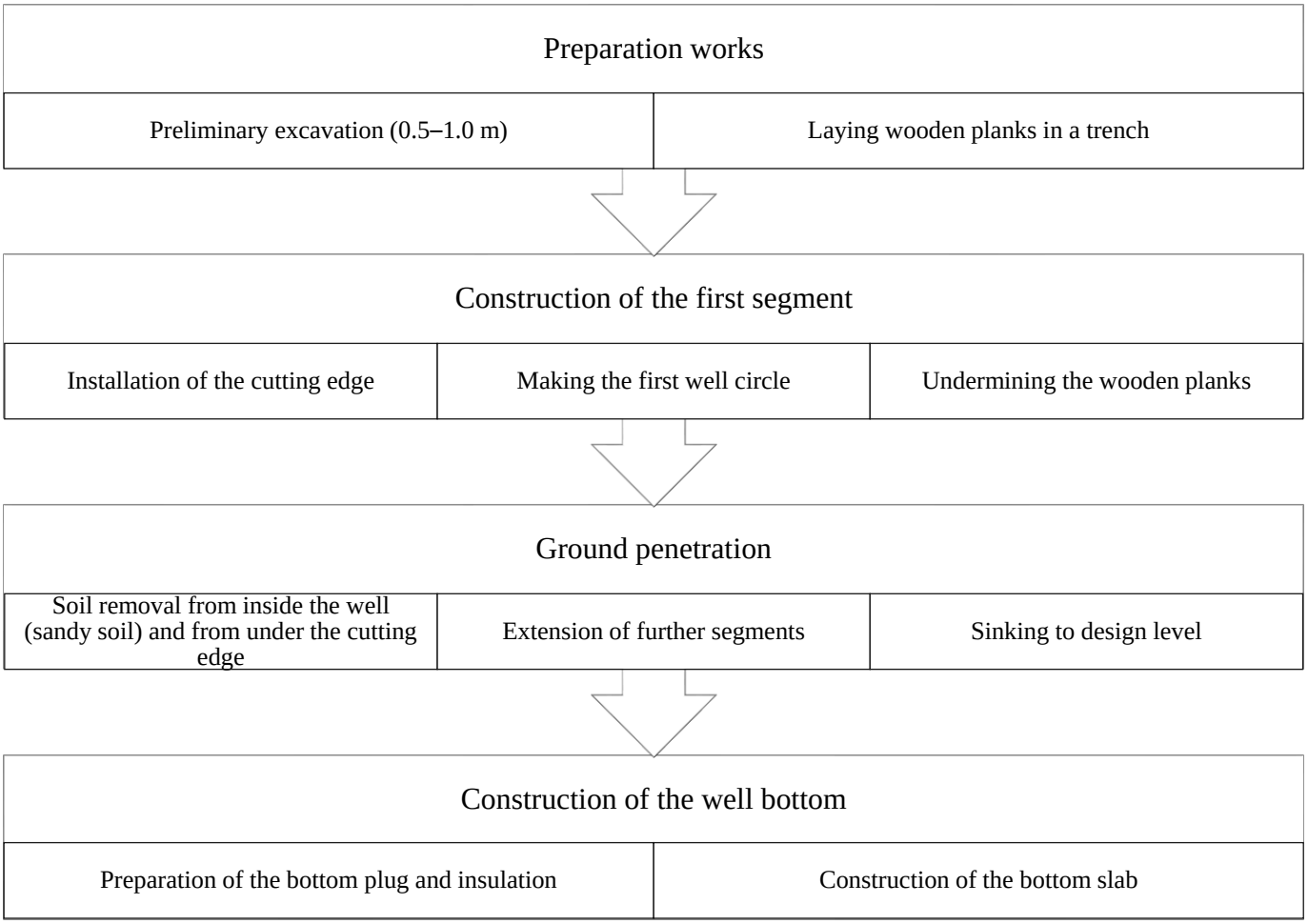

Figure 1. Sinking well plunging stages for non-aqueous soils.

2. Literature Review

2.1. Sinking Wells

This article [11] presents methods for plunging sinking wells with rectangular and circular cross-sections, identifying good practice during completion. Four cases of well sinking implementation were analyzed, with attention paid to controlling the verticality of the well sinking. A number of tips are provided to help control the correct progression of the well sinking into the ground. The article [12] presents an example of monitoring a large-diameter well that was performed in the UK. Monitoring of subsidence and tilting of the well was carried out during the sinking of the well. Valuable information was provided for improving the design of sinking wells and the future monitoring of sinking. Sinking and subsidence monitoring was also carried out in article [13]. The article [14] presented procedures to mitigate the occurrence of some of the difficulties during the completion of sinking wells. It was pointed out that improper sinking of wells can cause additional costs and delays. The aspect of performing soil testing prior to completion and soil monitoring during the sinking of the well was highlighted.

2.2. Negative Impacts

On the basis of a thorough analysis of abandoned well implementation cases, consultation with experts involved in the implementation of facilities using sinking well technology, own observations and an analysis of the literature, the successive stages of well sinking were reconstructed, and the possibility of irregularities at each stage of well sinking was analyzed. A variety of well-sinking conditions and a wide range of factors were analyzed in

detail. After considering the above data, the following negative impacts occurring during well sinking were identified:

- excessive ground settlement outside the well,
- damage/destruction of adjacent objects,
- tilts of the well casing from the vertical,
- horizontal displacement of the well casing,
- uncontrolled sinking of the well casing,
- damage to the well casing structure (i.e., cracking, scratching),
- damage to the base of the well casing (damage to the bottom and cutting edge),
- detachment of the well bottom ring (prefabricated well),
- well bottoming out (only after the well bottom has been completed),
- freezing of the chamber shell to the ground medium,
- well casing hanging,
- total destruction of the well.

The aforementioned negative impacts were identified as a set of decision options, which were subjected to a frequency of occurrence determination in the following analysis. The negative impacts affect the well-sinking process in different ways. Some of the above impacts contribute only to minor delays in the ongoing work and are mostly reversible. Other impacts, on the other hand, can cause irreversible damage and pre-failure or emergency situations. It is not always easy to determine the cause of negative impacts. There are usually many interdependencies involved in causing negative impacts.

Excessive ground settlement outside the well—on the outside of the well casing, ground settlement, i.e., vertical and horizontal ground displacement, occurs during caving. This is a naturally occurring phenomenon when the well is cased. The problem arises when the displacements are too large. This is when there is a risk of damage/damage to neighboring structures and infrastructure. Displacements will be greater if a lowering of the groundwater table is used in the development area. This is due to the depression funnel created during the drainage of the area. The cause of increased displacements may be due to improper excavation of the ground masses. Increased subsidence will also occur if there is an uneven load on the well construction.

Damage/damage to neighboring facilities—pre-failure or emergency condition. Destruction and damage in the near neighborhood of the sinking well, as described above, is also related to excessive ground settlement. Damage to neighboring infrastructure can occur when the ground is improperly excavated.

Deflection of the well casing from the vertical—deflection of the well structure caused by incorrect actions during the sinking of the well. Deviations must be corrected on an ongoing basis. The maximum permissible deviation is 10 cm.

Horizontal displacement of the chamber shell—the maximum allowable displacement of the chamber is 2 cm.

Uncontrolled sinking of the chamber shell—uncontrolled, too rapid sinking of the chamber into the ground medium. This can result in the well sinking below the designed level.

Damage to the structure of the chamber shell (i.e., cracking, scratching)—can result, among other things, from improper excavation of the ground mass.

Damage to the base of the well jacket (damage to the bottom and knife)—can be caused by the well encountering an obstacle in the ground, i.e., an erratic boulder, tree root, or old installation. Damage can also occur when the wooden beams are removed from under the well knife, just before the structure is plunged.

Detachment of the lower well ring (prefabricated well)—can be caused by the well encountering an obstacle in the ground, i.e., an erratic boulder, tree root, or old installation. Damage can also occur when the wooden beams are removed from under the well knife, just before the structure is plunged.

Flooding of the well (only after the bottom of the well has been concreted in)—when a well is completed in hydrated ground (after the bottom of the well has been concreted in), the well may float if the weight of the object is less than the buoyancy of the water.

Freezing of the well casing to the ground medium—can occur during the execution of works in sub-zero temperatures, when using prolonged stoppages in the sinking of the well.

Well casing hanging—during sinking, the well steining can become wedged in the ground. The reason for the well becoming wedged may be the presence of cohesive soil in the upper part of the well casing and loosened non-cohesive soil in the lower part. The cohesive soil in the upper layer clamps the well casing, making the sinking of the well difficult. Hanging of the well casing can also occur if the weight of the well is too low. The well casing can also become wedged as a result of encountering an erratic boulder or other large element present in the ground. Sagging of the well casing can also be caused by the use of downtime, when operating in sub-zero temperatures.

Total destruction of the well—destruction of the well casing or a well with a completed bottom, making it impossible to continue sinking the well or to use it.

3. Research Methodology

3.1. Study Area

Multi-criteria decision-making methods have been proposed to determine the incidence of negative impacts. The issues addressed in this thesis are complex and multi-faceted, so proposing a multi-criteria decision-making (MCDM) method is appropriate. Multi-criteria decision-making methods have found application in many fields. Previous work [15] has applied the fuzzy TOPSIS method to supplier selection in the furniture industry. In his work, Anbarkhan [16] proposed an innovative approach to sustainability assessment in software engineering using the fuzzy TOPSIS method. MCDM is often applied in the construction industry. Wang and Ying used a hybrid combination of MCDM methods to investigate the function of AI tools in the construction industry. The application of the methods in traffic and underground construction can also be cited. MCDM methods, i.e., AHP, TOPSIS, and PROMETHEE, were used, among others, in the selection of the optimal route (bypass) [17]. To determine the incidence of negative impacts occurring during the lowering of sinking wells, the authors proposed the use of fuzzy TOPSIS methods combined with expert analysis. The authors chose to use the fuzzy TOPSIS method because it has found application in decision-making problems that imprecisely define the decision issue or imprecisely specify the preferences of the decision-maker (expert). This is when the expert cannot precisely determine the levels of fulfilment of particular criteria by the decision options under analysis, or when there are partially uncertain consequences of the options for certain issues. In the above-mentioned cases, the fuzzy TOPSIS method can be used to describe the phenomenon and model the preferences. For the purpose of carrying out the study, the course of lowering a sinking well was reconstructed, and the possibility of irregularities occurring at each stage of sinking the well was analyzed. Numerous cases of sinking wells and various sinking conditions were studied. A previous literature analysis was also used. As a result of the literature analysis, only some of the negative impacts occurring during the lowering of a sinking well were identified. The greater part was identified during the analysis of the sinking stages and in the case studies. In the next step, experts were consulted to gather their opinions on the frequency of the negative impacts. The experts selected to give their opinions had many years of experience in execution and design work with the sinking well method. Due to the niche nature of the topic addressed in this study, there are few companies dealing with sinking wells. Accurately verifying the experience and knowledge of the companies' staff was virtually impossible. Determining the population size was problematic in this case. Taking this into account, the determination of a random sample was abandoned, and it was decided to determine a purposive (non-probabilistic) sample. Multi-criteria methods require the participation of experts, which obliged the authors of the article to carry out an expert analysis. The

selection of experts was guided by relevant execution and design experience in the field of large-diameter sinking-well construction. Persons who have been working on the subject for years were selected. The experience of the experts was verified accordingly. The final sample was defined as a panel of five independent experts. The experts verbally assigned the incidence of negative impacts using a linguistic rating scale. The linguistic ratings were successively converted into numerical values, assigned based on the established rating scale. MCDM methods were proposed to determine the incidence of negative impacts. The problem addressed in this thesis is complex and multifaceted, so proposing MCDM methods was appropriate. The complex decision-making problem proposed in this thesis involves the consideration of information of a difficult-to-measure nature; therefore, the introduction of fuzzy logic elements into the analysis was proposed. The ratings assigned by the experts were written in the form of triangular fuzzy numbers of type −1 [18].

3.2. Fuzzy Numbers

A fuzzy set A of type −1 in the space X (with any number of elements), is defined as a set of ordered pairs:

$$A = \{(x, \mu A(x));\ x\ \in\ X\}, \tag{1}$$

where μA: $X \rightarrow [0, 1]$ to each element $x \in X$ assigns a degree of membership to the fuzzy set A:

- $\mu_A(x) = 0$ element x does not belong to set A,
- $\mu_A(x) = 1$ element x belongs to set A,
- $0 < \mu_A(x) < 1$ the element partially belongs to set A.

The fuzzy set theory is a generalization of the classical model of the membership of a point to a set. The values of the characteristic function are in the interval [0, 1]. The fuzzy set theory allows for the introduction of uncertainty and imprecision.

Triangular fuzzy numbers (Figure 2) are a type of membership function described by three values, i.e., a left-hand constraint (l), a vertex (m), and a right-hand constraint (u).

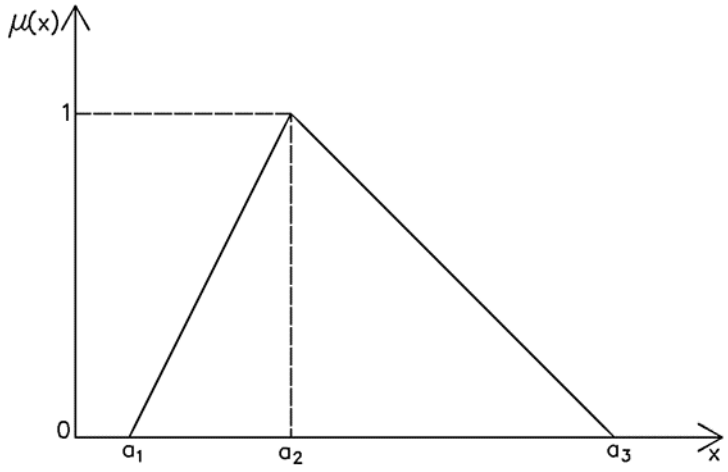

Figure 2. Triangular fuzzy number.

Triangular fuzzy numbers represent the degree of membership and take on a triangular shape [19]. The membership function for a triangular fuzzy number is defined as follows [20]:

$$(x) = \begin{cases} 0\ jeli\ x < l \\ \frac{x-l}{m-l}\ jeli\ l \le x \le m \\ \frac{u-x}{u-m}\ jeli\ m \le x \le u \\ 1\ jeli\ x > u \end{cases} \tag{2}$$

Arithmetic operations performed on fuzzy numbers with parameters $\tilde{a} = (l_a, m_a, u_a)$, $\tilde{n} = (l_n, m_n, u_n)$ may be defined as follows:

$$\tilde{a}(+)\tilde{n} = (l_a + l_n, m_a + m_n, u_a + u_n) \quad (3)$$

$$\tilde{a}(-)\tilde{n} = (l_a - l_n, m_a - m_n, u_a - u_n) \quad (4)$$

$$\tilde{a}(\times)\tilde{n} = (l_a \cdot l_n, m_a \cdot m_n, u_a \cdot u_n) \quad (5)$$

$$k(\times)\tilde{a} = (kl_a, km_a, ku_a) \quad (6)$$

$$\tilde{a}(/)\tilde{n} = (l_a / l_n, m_a / m_n, u_a / u_n) \quad (7)$$

$$max\left(\tilde{a}, \tilde{n}\right) = (max(l_a \cdot l_n), max(m_a \cdot m_n), max(u_a \cdot u_n)) \quad (8)$$

$$min\left(\tilde{a}, \tilde{n}\right) = (min(l_a \cdot l_n), min(m_a \cdot m_n), min(u_a \cdot u_n)) \quad (9)$$

The use of fuzzy numbers is justified when the information collected is imprecise or has been determined using linguistic expressions. Determination of preferences by experts is vague and difficult to estimate using a numerical value. Preferences can be determined using linguistic expressions [19,21–24]. The linguistic rating scale facilitates the formulation of opinions and evaluations of phenomena that are difficult to measure in a natural human way, under conditions of incomplete information. Linguistic expressions are converted into fuzzy numbers. An example of the assignment of triangular fuzzy numbers to the corresponding linguistic values is shown in Table 1 [19].

Table 1. Linguistic terms with assigned triangular fuzzy numbers.

Linguistic Terms	Triangular Fuzzy Number
Very low	(0; 0; 1)
Low	(0; 1; 3)
Medium low	(1; 3; 5)
Medium	(3; 5; 7)
Medium high	(5; 7; 9)
Large	(7; 9; 10)
Very large	(9; 10; 10)

Source: [19].

A linguistic scale, defined by triangular membership functions [25], was used to assess the negative impacts occurring during the lowering of the sinking wells. A scale including five linguistic categories was introduced (Table 2), described by triangular membership functions (Figure 3).

Table 2. Five-point linguistic rating scale.

Assessment of the Intensity of Impact	
Linguistic Terms	**Triangular Fuzzy Number**
Rare	(0, 0, 1)
Unlikely	(0, 1, 2)
Medium probability	(1, 2, 3)
Likely	(2, 3, 4)
Almost certain	(3, 4, 4)

Source: own compilation based on [26].

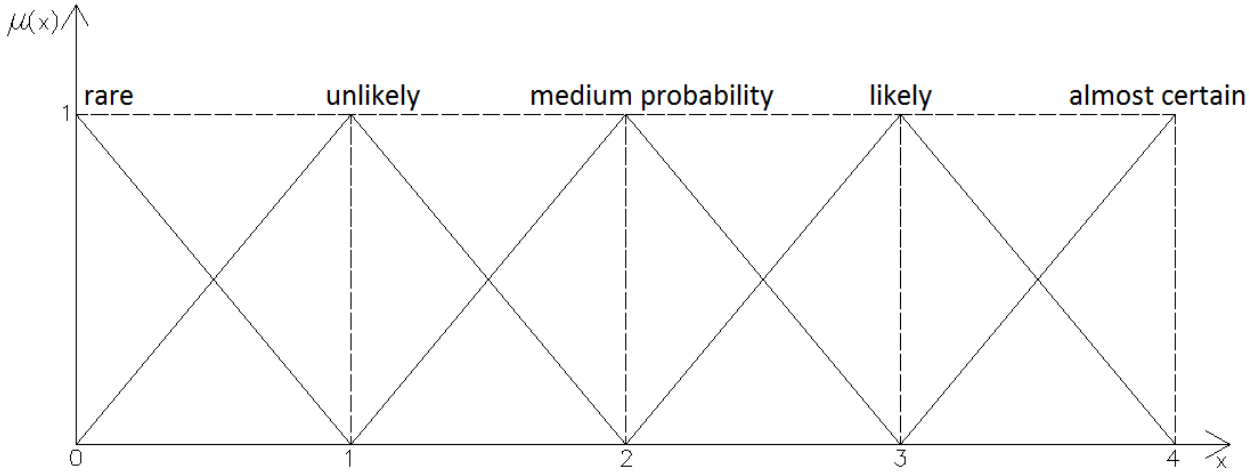

Figure 3. Triangular fuzzy numbers with assigned linguistic terms. Own source based on [25,26].

3.3. Fuzzy TOPSIS

The fuzzy TOPSIS method was developed by Hwang and Yoon [27]. The method involves determining the ideal and anti-ideal solutions and then calculating the distances of the decision alternatives from the ideal and anti-ideal solutions. The TOPSIS method has often been used in the construction industry, including to assess the fire resistance of residential houses and reduce fire safety risks. Ji and Luo applied the TOPSIS method to assess and predict the development of prefabricated buildings [28]. In this study, a fuzzy extension of the TOPSIS method was applied.

The analysis using the fuzzy TOPSIS method starts with the determination of a fuzzy decision matrix, in which the evaluations should be written in the form of triangular fuzzy numbers $\widetilde{a}_{jk} = \left(l_{jk},\ m_{jk},\ u_{jk}\right)$, with a triangular membership function $\mu_{\widetilde{a}_{jk}}(x) \in [0,\ 1]$. The evaluation of the impact intensity can be determined as shown in Table 2.

The rows of the fuzzy decision matrix correspond to the decision options analyzed, while the columns contain the experts' evaluations.

The next step of the analysis is to normalize the values of the matrix according to the formulas:

$$\text{for the "profit" criterion: } \widetilde{z}_{jk} = \left(\frac{l_{jk}}{\underset{i}{maxu_{ik}}},\ \frac{m_{jk}}{\underset{i}{maxu_{ik}}},\ \frac{u_{jk}}{\underset{i}{maxu_{ik}}}\right) \tag{10}$$

$$\text{for the "cost" criterion: } \widetilde{z}_{jk} = \left(\frac{\underset{i}{minu_{ik}}}{u_{jk}},\ \frac{\underset{i}{minu_{ik}}}{m_{jk}},\ \frac{\underset{i}{minu_{ik}}}{l_{jk}}\right) \tag{11}$$

The next step is to create a normalized weighted decision matrix. The weights are entered according to the formula:

$$\widetilde{r}_{ij} = w_j \widetilde{z}_{ij},\ \text{for } i = 1,\ \ldots,\ m;\ j = 1,\ \ldots,\ n. \tag{12}$$

The next step in the analysis using the FUZZY TOPSIS method is to determine a fuzzy weighted ideal and anti-ideal solution, according to the formulas below:

$$\text{ideal solution } f_k(\widetilde{a}^{+}) = \widetilde{v}_k^{+} = \underset{i}{max}\ \widetilde{r}_{ik} \tag{13}$$

$$\text{anti-ideal solution: } f_k(\widetilde{a}^{-}) = \widetilde{v}_k^{-} = \underset{i}{\min}\ \widetilde{r}_{ik} \quad \text{for } i = 1,\ldots,\ m;\ j = 1,\ \ldots,\ n. \tag{14}$$

$$d_j^+ = \sum_{k=1}^{n} d\left(\widetilde{r}_{jk}, \widetilde{v}_k^+\right), \; j = 1, 2, \ldots, m \tag{15}$$

$$d_j^- = \sum_{k=1}^{n} d\left(\widetilde{r}_{jk}, \widetilde{v}_k^-\right), \; j = 1, 2, \ldots, m \tag{16}$$

Finally, the value of the synthetic evaluation measure is determined, and a hierarchy of evaluations is carried out.

$$S_j = \frac{d_j^-}{d_j^+ + d_j^-}, \; for \; j = 1, 2, \ldots, m \tag{17}$$

4. Results of the Analysis

In the first stage of the analysis, the experts determined the incidence of negative impacts arising during the lowering of the sinking well. Ratings, assigned by experts, were given based on a five-point linguistic rating scale (Table 1). Subsequently, the ratings were normalized and given weights according to 10–12 formulas. The decision options and criteria after normalization and weighting are shown in Table 3.

Table 3. Ratings after normalization and consideration of weights.

Decision Options					
Ground settlement	0.06	0.00	0.19	0.04	0.19
	0.13	0.00	0.25	0.08	0.25
	0.19	0.03	0.25	0.11	0.25
Damage/destruction of neighboring objects	0.00	0.00	0.06	0.04	0.06
	0.06	0.00	0.13	0.08	0.13
	0.13	0.03	0.19	0.11	0.19
Tilts	0.13	0.00	0.06	0.08	0.13
	0.19	0.00	0.13	0.11	0.19
	0.25	0.03	0.19	0.15	0.25
Horizontal displacement	0.06	0.00	0.06	0.00	0.00
	0.13	0.00	0.13	0.04	0.06
	0.19	0.03	0.19	0.08	0.13
Uncontrolled sinking	0.13	0.00	0.00	0.04	0.00
	0.19	0.00	0.00	0.08	0.00
	0.25	0.03	0.06	0.11	0.06
Damage (cracking, scratching)	0.06	0.00	0.00	0.04	0.00
	0.13	0.00	0.00	0.08	0.00
	0.19	0.03	0.06	0.11	0.06
Damage of the cutting edge	0.00	0.00	0.00	0.08	0.00
	0.00	0.03	0.00	0.11	0.06
	0.06	0.05	0.06	0.15	0.13
Detachment of the bottom ring	0.00	0.00	0.00	0.08	0.00
	0.06	0.00	0.00	0.11	0.00
	0.13	0.03	0.06	0.15	0.06
Well bottoming	0.06	0.00	0.00	0.00	0.00
	0.13	0.00	0.00	0.04	0.00
	0.19	0.03	0.06	0.08	0.06
Freezing	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.04	0.00
	0.06	0.03	0.06	0.08	0.06
Hanging	0.13	0.00	0.00	0.08	0.13
	0.19	0.00	0.06	0.11	0.19
	0.25	0.03	0.13	0.15	0.25
Total destruction	0.00	0.00	0.00	0.00	0.00
	0.06	0.00	0.00	0.04	0.00
	0.13	0.03	0.06	0.08	0.06

Subsequently, a fuzzy weighted ideal and anti-ideal solution had to be determined according to Formulas (13) and (14). The ideal and anti-ideal solutions are shown in Table 4.

Table 4. Ideal and anti-ideal solutions.

Decision Options					
$\tilde{a}^{+}$	0.13	0.00	0.19	0.08	0.19
	0.19	0.03	0.25	0.11	0.25
	0.25	0.05	0.25	0.15	0.25
$\tilde{a}^{-}$	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.04	0.00
	0.06	0.03	0.06	0.08	0.06

Subsequently, the distances of each alternative (negative impacts) from the ideal and anti-ideal solution were calculated, taking into account the Formulas (15)–(17), and the value of the synthetic evaluation measure was determined. The results of the calculations and a ranking indicating the frequency of the negative impacts arising during the sinking of the sinking well are given in Table 5.

Table 5. Distances of options from the ideal and anti-ideal solutions and synthetic evaluation measure.

Decision Options	d_j^+	$d_j^+ + d_j^-$	S_j	Rank
Excessive ground settlement	0.05083	0.05370	0.94665	1
Damage/destruction of objects	0.01372	0.03417	0.40167	4
Tilts	0.03732	0.04469	0.83508	2
Horizontal displacement	0.01302	0.03818	0.34106	5
Uncontrolled sinking	0.01503	0.06021	0.24956	6
Damage (cracking, scratching)	0.00656	0.05370	0.12221	7
Damage of the cutting edge	0.00432	0.05510	0.07845	9
Detachment of the bottom ring	0.00411	0.05641	0.07294	10
Well bottoming	0.00586	0.05510	0.10633	8
Freezing	0.00000	0.06161	0.00000	12
Hanging	0.03276	0.04859	0.67416	3
Total destruction	0.00130	0.05641	0.02308	11

The result of the fuzzy TOPSIS analysis is a ranking of the incidence of the negative impacts arising during the lowering of the sinking well.

5. Conclusions

Sinking wells are used in sustainable wastewater collection and treatment systems. A number of negative impacts can occur during the lowering of a sinking well structure into the surrounding ground. The issue of determining the occurrence of negative impacts arising during the lowering of a sinking well is complicated and multifaceted. The application of MCDM methods in the present work seems appropriate. In this paper, a fuzzy TOPSIS method is introduced, which is suitable for use in decision-making problems with an imprecisely defined decision problem and imprecisely defined decision-maker preferences. A case study of sinking wells, an analysis of the various conditions and stages of sinking wells, and a literature analysis made it possible to identify the negative impacts that occur during the lowering of a sinking well. As a result of expert consultation, data were extracted to assess the incidence of negative impacts arising during the lowering of sinking well. The fuzzy TOPSIS method is a powerful MCDM method that can be used to determine the incidence of negative impacts arising during the lowering of a sinking well, by identifying ideal and anti-ideal solutions, determining the distance of decision options from ideal and anti-ideal solutions, and prioritizing and ranking. In this study, the method was used to determine the incidence of negative impacts arising from the lowering of a sinking well. Determining the incidence of negative impacts arising during

the lowering of a sinking well could help to avoid pre-failure and emergency situations in the future. The ranking of the frequency of negative impacts showed that excessive ground settlement around the well is the impact that most frequently occurs during well plunging. Also, deviation of the well from the vertical and sagging of the well casing are common during sinking construction. The decision-maker should also take into account the possibility of damage or destruction of neighboring structures, horizontal displacement, and uncontrolled collapse. Negative impacts that occur occasionally are damage to the well casing (cracking and scratching), flooding, knife damage, and coil detachment. The least frequent negative impacts were complete destruction of the well and freezing of the well casing to the surrounding soil. In future studies, the authors would like to extend the initiated analysis of negative impacts occurring during the lowering of a sinking well by identifying cause–effect relationships between negative impacts and establishing a cause–effect relationship structure.

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