Analysis of implementation conditions under difficult geotechnical conditions using the SWOT analysis

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Abstract. Difficult and complex geological conditions are often an obstacle to the efficient implementation of construction works related to the erection of objects, in particular, earthworks and foundations. In the event of an additional occurrence of adverse weather conditions, there may be a delay in the final effect of the work and exceeding the construction costs. The article presents the stage of the implementation case in which these factors were compiled. The SWOT analysis was an element helpful in analyzing the situation and also allowing to make decisions regarding implementation. Through this analysis, the contractor identified the possible activities, including opportunities and strengths, which allowed for the development of a scenario. This is important because the lack of action would cause even greater delays and financial losses than those already existing.

1. Introduction

The subject of the analysis is the implementation example - the extension of the warehouse and production hall together with the accompanying infrastructure. In the course of implementation, the contractor encountered difficult ground conditions, which, combined with the adverse impact of atmospheric factors, resulted in a significant delay in construction and an increase in costs in relation to the ones provided for. It is important that the contract was a lump sum, which limited the possibility of the contractor increasing the amount of remuneration, and the delays that occurred constituted the attitude to calculating contractual penalties. It was reasonable to consider the various potential benefits and opportunities that the contractor could have used in such a complex situation. The analysis was based on the SWOT method. The SWOT analysis method is one of the widely known management support techniques by identifying the situation in order to develop possible scenarios for further action [1-4].

2. Weather factors and their impact on construction production

The influence of atmospheric factors on the execution of construction works, including earthworks is unquestionable [5]. In general, the seasonality of construction production is indicated in the context of its efficiency. It is noticed that the occurrence of unfavorable weather conditions, and in particular long and hard winter, lower noticeably the achieved result of construction production. This is mainly due to the technological dependence of construction processes, and in particular the need to apply specific regimes. Their vast majority concern wet processes such as concrete processes or works using wet mortars. The occurrence of negative temperatures significantly increases the risk of a decrease in the quality of these works or a drastic increase in the costs of these processes, which means that they are
not carried out under unfavorable conditions. In addition, the significant contribution of human labor, whose efficiency at low temperatures (as unfavorable conditions) is decreasing, is also significant. Examples of generalized data on the course of the winter season are presented in Table 1. Wpływ czynników atmosferycznych na realizację robót budowlanych, w tym robót ziemnych jest niekwestionowany [5-7].

### Table 1. Impact of weather conditions on the distribution of construction value in time

| Winter weather characteristics (minimum temperature) | Average annual construction output per quarter (in%) | Average annual construction output in relation to years with average winter (in%) |
|-------------------------------------------------------|-----------------------------------------------------|-----------------------------------------------------------------------------|
| Mild (up to -10°C)                                    | I.Q. 23    II.Q. 28  III.Q. 24  IV.Q. 25                      | 110                                                                         |
| Average (below -10°C to -15°C)                        | I.Q. 20    II.Q. 29  III.Q. 25  IV.Q. 26                      | 100                                                                         |
| High (below -15°C to -30°C)                           | I.Q. 13    II.Q. 30  III.Q. 27  IV.Q. 30                      | 90                                                                          |

In the case of earthworks and work on the ground, the impact of winter conditions is not as unfavorable as for sensitive processes, eg concreting. A much worse atmospheric factor is rainfall, which causes the substrate to blur, its plasticity, which is not conducive to both its carrying capacity and causes great difficulties in communication during the performance of other construction works [8-10].

### 3. Description of implementation conditions

Analyzed investment, during which the adverse weather conditions were compiled under difficult ground conditions, is the expansion of the warehouse and production hall within the existing logistics park near one of the largest centers in Poland (Wrocław-Bielany). The investment covered a plot of land with an area of 72.725 m², where the hall structure has been designed with a total area of 27,275 m² and 16,235 m² of paved areas (roads, parking lots). The total usable floor area of the expanded hall facility is 43,510 m². The designed extension part of the hall was placed on reinforced concrete, monolithic alloys. The foundations under the walls of the hall are of curtain (non-structural) character and are made of prefabricated reinforced concrete constituting the "finishing of the bottom" of the building. The newly designed building was deferred from the existing building due to the risk of the settlement difference between the new and existing building. A foundation wall / retaining wall is planned at the basement level change. External walls were designed up to the level of 2.4 m and to the level of 4.2 m in unloading docks as reinforced concrete prefabricated, while above - from the sandwich panel. The cover was also designed from a sandwich panel on a steel truss system. The building has a concrete floor (C25 / 30) reinforced with 17 cm thick scattered reinforcement and surface-hardened quartz based material.

In connection with the work of the investment, in January 2016, the ground floor survey was carried out on the plot on which the investment was located. In the indicated places, 25 ground exploratory holes were made up to a depth of 6.0 m in p.p.t. In total, 150.0 mb of soil layers were drilled. The excavated ground samples were subjected to macroscopic investigations while observing the groundwater table and measuring it. The degree of compaction of sandy soils was determined using a lightweight dynamic DPL probe. The ordinates of the area at the openings were connected to a working bench with a known height of 133.52 m above sea level. (floor level of the existing hall). Taking into account ground conditions and structural considerations, the footings and continuous footings were set at -0.80, -1.00, -2.20 m in relation to the comparative level of the hall. According to the tests carried out, the geotechnical category II was determined in the given area.

The area of the investment, in the area of plots covered by the investment, has been changed and raised by about 1.00 to 3.00 m. The layer of unpainted embankments and hummus caused that the
ordinates of the plot were higher than originally in the ordinate range 133.00 to 134.64 m. In the documented ground to a depth of 6.00 m below ground level. The presence of tertiary (Miocene) and Quaternary Pleistocene (Mid-Polish glaciation) moraine, water-glacial and anthropogenic Holocene deposits were found. The surface layer was a non-construct sand-block embankment covering places with hummus, with a total thickness of 0.50 - 3.00 m. Below, moraine deposits represented by sandy clays and clay sands often with an admixture of gravel and stones were drilled. Occurring sediments are silty and fine-grained sands as well as silty loams and tertiary clays. Tertiary sediments occur irregularly in the form of glaitectonic agglomerations. Groundwater with a free or electrified mirror was drilled in a part of the holes at a depth of 2.10-4.10 m.p. and its level stabilized on ordinates 130.00 - 131.50 m m.p. with a slope towards the south. The described condition of groundwater has been assumed as medium-low, so in a natural way, it will be subject to seasonal fluctuations resulting, on the one hand, from rainless periods, and on the other - with the occurrence of long periods of rainfall and spring thaw. As a guide, it can be assumed that in the maximum states the level of groundwater can rise by approx. 0.80 m above the state from January 2016. During intensive precipitation or spring thaw, water can stabilize in the roof of cohesive soils. Soil and water conditions in the examined area made it possible to lay the foundations of the designed object directly on mineral native soils, controlled embankments or thickened concrete slabs.

The described ground and water conditions, and above all weather conditions that occurred at the turn of the months of November and December, when the rainfall phenomena took a form significantly different from the average, and the persistent positive temperature in the following months caused a significant downtime for the implementation as well as the subcontractor itself and problems resulting in a significant delay in the completion of works. According to the work schedule, already at the stage of earthworks and foundations, the delay in implementation reached 58 days and constantly increased its value. Using the EVM methodology, characteristic indexes were defined, the interpretation of which was unfavorable. In addition, the analysis of prognostic indicators indicated a high probability of exceeding the deadline for the implementation of the investment, as well as exceeding the assumed investment budget without taking into account any penalties related to failure to meet the deadline.

\[ SV\% = 100 \times (BCWP - BCWS) / BCWS \]

where:
SV\% - schedule variance in percentage
BCWP – budget cost of work performed 220
BCWS – budget cost of work scheduled 370

\[ SV\% = 40.5\% \text{ (works are carried out 40.5\% slower than planned) } \]

\[ CV\% = 100 \times (BCWP - ACWP) / BCWP \]

where:
CV\% - cost variance in percentage
ACWP – actual cost of work performed

\[ CV\% = 36.36\% \text{ (the scope was completed 36.36\% above the budget) } \]

The analysis of these basic indicators allows unambiguous identification of irregularities in the course of the implementation process, the causes of which are directly ground conditions and unfavorable weather conditions. In order to analyze the situation, a SWOT analysis was carried out.
4. SWOT Analysis

Two possible situations were considered: difficult ground conditions in good weather conditions and difficult ground conditions in bad weather conditions. It should be noted that the conducted analysis was in fact related only to the second state, i.e., difficult ground conditions and bad weather conditions, however, to better identify the situation and develop an appropriate strategy, the analysis was also performed for potentially possible conditions.

The SWOT analysis is based on a specific procedure consisting of five stages:

1. **Stage 1**: Identification of strategic factors
2. **Stage 2**: Qualification of positive or negative factors (Table 2 and Table 5)
3. **Stage 3**: Determining the strategic situation
4. **Stage 4**: Pairing "strong side = chance", "weak side = threat" (Table 3 and Table 6)
5. **Stage 5**: Aggregation of specific tasks and objectives into a general strategy (Table 4 and Table 7)

Contemplated scenario: difficult ground conditions and good weather conditions

**Stage 1 + 2**

| No  | Strengths                                      | Rating | No  | Weaknesses                           | Rating |
|-----|-----------------------------------------------|--------|-----|--------------------------------------|--------|
| 1   | Continuity of employment                      | 3      | 1   | Hardware operation                   | 5      |
| 2   | Moving around the construction site with building equipment | 4      | 2   | Exploitation of employees            | 3      |
| 3   | Retaining deadline for completion             | 5      | 3   | Maximizing the supply of mineral materials from the outside | 4      |
| 4   | Maximization of monthly processing            | 4      | 4   | Complicated execution of earthworks  | 3      |
| 5   | Contact with subcontracts                     | 3      | 5   | Necessity to hire subcontractors     | 3      |
|     |                                               |        |     |                                      | 19     |

| No  | Opportunities                                  | Rating | No  | Threats                              | Rating |
|-----|-----------------------------------------------|--------|-----|--------------------------------------|--------|
| 1   | Development of the hardware base               | 4      | 1   | Bad recognition of the subsoil       | 5      |
| 2   | Strengthening the company's reference          | 4      | 2   | Increase in the cost of carrying out earthworks | 4      |
| 3   | Larger cooperation opportunities on the market | 3      | 3   | High costs of additional works not included in the lump sum | 3      |
| 4   | Increasing buyer limits at suppliers           | 1      | 4   | Frequent failures of construction equipment | 4      |
| 5   | The gradual development of the company         | 3      | 5   | The necessity of using permanent dehydration during construction | 3      |
|     |                                               |        |     |                                      | 15     |

**Stage 3**

Identification of the strategic situation:

\[ \sum S > \sum W; \sum O < \sum T \] – situation “maxi – mini”

Calculation of the internal strength (SP) of the process:

\[ SP = \frac{\sum S}{\sum S + \sum W} = \frac{19}{19 + 18} = 0,5135 \]

Assessment of the strategic attractiveness (AS) of the process:
\[ AS = \frac{\sum O}{\sum O + \sum T} = \frac{15}{15 + 19} = 0.4412 \]

Determining the probability of strategic success (PSS):

\[ PSS = \frac{SP + AS}{2} = \frac{0.5135 + 0.4412}{2} = 0.4774 < 0.5 \]

Conclusion: The analyzed scenario is an unfavorable arrangement of external and internal conditions, unfavorable for success

Stage 4

Table 3. Strategy type – CONSERVATIVE

| Threats | Strategy | Strategy type - CONSERVATIVE „maxi – mini” |
|----------|----------|------------------------------------------|
| 1. Bad recognition of ground conditions | 1. Continuity-Employment | I Despite the information about poor ground and water conditions, we are not able to predict the composition of uncontrolled embankments, the surprising occurrence of peat bogs can significantly hinder the movement around the site, soft plastic clay completely eliminates wheeled vehicles from participation in robots. It is necessary to designate appropriate technological routes and properly perform them because favorable weather conditions will allow us to effectively maintain the path through the entire investment. |
| 2. Moving around the construction site with construction equipment | 2. Moving around the construction site with construction equipment | II Due to the large number of construction equipment, and therefore rapid progress in earthworks, processing in a given month should reach high amounts, but due to complicated ground conditions, the need for surface drainage or chemical improvement of the land, the costs of such works as double-deck construction, therefore, the profits will be very small. However, with appropriate experience and risk, we are able to scrupulously strive for success by segregating mineral materials and selectively arranging them depending on the purpose of the areas concerned. |
| 3. High costs of additional works not included in the lump sum | 3. Retaining the deadline for implementation | III To keep the deadline for the investment, we are forced to incur additional costs due to poor recognition of uncontrolled land of anthropogenic origin, our task is to provide adequate documentation to the investor to prepare an annex to the contract for additional quantities of works, eg utilization of buried debris, hummus removal from the hall platform in areas not explored by a geologist |
| 4. Maximizing monthly processing | 4. Maximizing monthly processing | IV Due to the maximum equipment usage, we must be aware of continuous equipment failures, so it is essential to have a full-time mechanic at the construction site. |
| 5. Contact with subcontractors | 5. Contact with subcontractors | V With a high groundwater table, we should not save on the drainage of a permanent construction site by installing drainage with a pumping station, we are able to prevent a complete stoppage of earthworks, therefore, we protect ourselves from exceeding the deadline for completion of works. |
| | | VI With a high groundwater table, we should not save on the drainage of a permanent construction site by installing drainage with a pumping station, we are able to prevent a complete stoppage of earthworks, therefore, we protect ourselves from exceeding the deadline for completion of works. |
### Stage 5

**Table 4.** Conservative maxi-mini results

| Strategy | Strategic options |
|----------|-------------------|
| - CONSERVATIVE „maxi – mini” | Re-testing for ground verification |
| | Extending contacts at subcontractors |
| | Employment of a mechanic for construction machines |
| | Investment in new construction machines to avoid more frequent breakdowns |
| | Investment in own drainage system to cut additional costs |
| | Making risky decisions while carrying out earthworks |
| | Taking care of technological paths and their proper construction |
| | Prevention of downtime due to machine breakdowns, strengthening the composition of subcontractors |

Contemplated scenario: difficult ground conditions and bad weather conditions

### Stage 1 + 2

**Table 5.** Stage 1 and 2 for given scenario

| Lp | Strengths | Rating | Lp | Weaknesses | Rating |
|----|-----------|--------|----|------------|--------|
| 1  | Hardening the substrate through frost | 5  | 1 | Maximizing the supply of mineral materials from the outside | 5  |
| 2  | Ability to service machines on the construction site during rainfall | 2  | 2 | Complicated execution of earthworks | 4  |
| 3  | Possibility of regeneration breaks for employees | 2  | 3 | Breaks in conducting works during atmospheric precipitation | 4  |
|    | | | 4 | Lack of proper control of works (geotechnical investigations) | 2  |
|    | | | 5 | Big risk of decisions | 5  |
|    | | | | | 20 |
| 9  |                      |      | | | |
| 4  | Increasing buyer limits at suppliers | 3  | 1 | Failure to meet the deadline for implementation due to weather | 5  |
| 5  | Strengthening the company’s reference | 5  | 2 | The need for permanent drainage during construction | 3  |
| 3  | Good condition of the staff | 2  | 3 | Lack of continuity of employment | 2  |
| 4  | Investment in soil dewatering and drying tools | 2  | 4 | Bad soil recognition | 5  |
| 5  | Building a solid experience of the supervisory staff | 3  | 5 | Increase in additional costs | 4  |
|    | | | | | 15 |
| 15 |                      |      | | | 19 |

### Stage 3

Identification of the strategic situation:

\[ \sum S < \sum W; \sum O < \sum T \] – situation “mini – mini”

Calculation of the internal strength \((SP)\) of the process:

\[ SP = \frac{\sum S}{\sum S + \sum W} = \frac{9}{9 + 20} = 0.3103 \]
Assessment of the strategic attractiveness (AS) of the process:

\[ AS = \frac{\sum O}{\sum O + \sum T} = \frac{15}{15 + 19} = 0.4412 \]

Determining the probability of strategic success (PSS):

\[ PSS = \frac{SP + AS}{2} = \frac{0.3103 + 0.4412}{2} = 0.3758 < 0.5 \]

Conclusion: The analyzed scenario is an unfavorable arrangement of external and internal conditions, unfavorable for success

**Stage 4**

**Table 6.** Strategy type - DEFENSIVE

| Environment | Strategy | Strategy type - DEFENSIVE „ maxi – mini” |
|-------------|----------|--------------------------------------|
| Threats     | Strengths| Lp | Tasks:                                                        |
| 1. Failure to meet the deadline for implementation due to the weather | Adverse weather with unfavorable ground in the ground compels us to invest in specialized equipment, only caterpillar machines are involved, transport means are only haulers, we need maximum the amount of equipment in the short time of freezing temperatures. |
| 2. Necessity to use permanent drainage during construction | High level of groundwater forces us to drain the permanent work area, which makes difficult to deep excavations or construction of embankments, these works are getting longer, and the marauding rain fills the holes and forcing us to continuous deep drainage, complicated organization of earthworks requires constant supervision of the manager and large financial expenditures (eg chemical drying of low-bearing soils, refining of materials, layer stabilization). |
| 3. Lack of continuity of employment | Continuous breaks force us to reduce the labor force to minimize the investment costs, unfortunately, we are forced to keep people in the store when the right weather arrives to start working at full speed immediately, often extending working time to extreme values. |
| 4. Poor recognition of the ground surface | The occurrence of poorly loadable soils, peatlands and uncontrolled embankments, compels us to invest in mineral materials from the mine in huge quantities, we should properly gin the grounds from the construction with purchased sand to reduce costs. Due to the maximum equipment usage, we must be aware of continuous hardware failures, therefore it is necessary to have a full-time mechanic at the construction site. |
| 5. Increase in additional costs | It is in our interest to re-examine the entire scope of works to be carried out, in order to properly plan the order of earthworks, we need to designate paths to move construction equipment, we will not be able to verify our work by |

| Threats | Strategy |
|---------|----------|
| 1. Failure to meet the deadline for implementation due to the weather | Adverse weather with unfavorable ground in the ground compels us to invest in specialized equipment, only caterpillar machines are involved, transport means are only haulers, we need maximum the amount of equipment in the short time of freezing temperatures. |
| 2. Necessity to use permanent drainage during construction | High level of groundwater forces us to drain the permanent work area, which makes difficult to deep excavations or construction of embankments, these works are getting longer, and the marauding rain fills the holes and forcing us to continuous deep drainage, complicated organization of earthworks requires constant supervision of the manager and large financial expenditures (eg chemical drying of low-bearing soils, refining of materials, layer stabilization). |
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| 5. Increase in additional costs | It is in our interest to re-examine the entire scope of works to be carried out, in order to properly plan the order of earthworks, we need to designate paths to move construction equipment, we will not be able to verify our work by |
geotechnics, we should do work in accordance with acquired professional experience and take a chance to work in unfavorable weather conditions.

| Stage | VII |
|-------|-----|
| Without risk we will not be able to carry out the scope of works on time, our decisions will depend on the success of the entire investment, without earthworks the assembly of the whole structure will not be possible, therefore we should hire the best earthwork engineers who will help you make risky decisions. |

### Table 7. Defensive mini-mini results

| Strategy type | Strategic options |
|---------------|-------------------|
| „mini – mini“ | Re-testing for ground verification |
| DEFENSIVE     | Extending contacts at subcontractors |
|               | Employment of qualified supervisory staff |
|               | Readiness to maximize equipment and employees |
|               | Awareness of additional costs, saving on materials |
|               | Tightening large merchant limits at suppliers |
|               | Investment in own drainage system to cut additional costs |
|               | Making risky decisions while carrying out earthworks |
|               | Taking care of technological paths and their proper construction |
|               | Prevention of downtime for atmospheric reasons, strengthening the composition of subcontractors |

### 5. Conclusions

In the implementation of earthworks, the key factors affecting the effect of the conducted works are primarily soil and water conditions and weather factors. While before carrying out the work, a number of ground soil tests and examinations are performed - in the case of large implementations, the test results are usually verified at the implementation stage. Then it turns out whether the assumptions made on the basis of the geological surveys carried out are true. The second factor - weather conditions are much less predictable. It can be based on historical data, however, the variability of climate and weather in recent years often indicates weather anomalies that can effectively hinder construction works. Compilation of these two factors with a disadvantage to the contractor can effectively stop the progress of works, contributing to the increase of unforeseen costs. The approach based on the SWOT analysis presented in the article allows to identify the situation in which the contractor found himself, to develop a strategy of action, and thanks to them, minimize the negative effects of the above-mentioned factors on implementation of the work.

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