

DESIGN OPTIMISATION OF THE RESCUE DEVICE FOR THE ARGO PROFILING FLOAT - SWOT/TOWS ANALYSIS OF DESIGN VARIANTS

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ABSTRACT

Presented in this material is the development work carried out within the ARGO-Poland scientific consortium related to the design of rescue systems for ARGO profiling floats used for in situ exploration of the world ocean. The material below contains an excerpt from a multi-faceted analysis of the design solutions described in PHR 3(80)2022, providing a SWOT/TOWS analysis methodology and detailed results with conclusions.

Keywords: oceanology, underwater technology, unmanned underwater vehicles, mechanical engineering, automation and robotics.

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INTRODUCKTION

The Polish Hyperbaric Research Nr. 3(80)2022 published the material entitled "Rescue device concept for the Argo profiling float"[1], which describes the effects of development work carried out within the ARGO Poland consortium consisting of the Institute of Oceanology PAS, the Polish Naval Academy and the Institute of Geophysics of the Polish Academy of Sciences, as part of the Euro Argo European Research Infrastructure related to the global ocean observation system [3]. The subject of this work in the initial phase was the development of a concept for the Argo profiling rescue float device, which resulted in the development of several design variants of the device, outlined in the material referenced above. Subsequent research steps in this task consisted of selecting the optimum design for the device to be developed.

In a situation involving availability of several design concepts, the problem of selecting the right one from the point of view of the end-user of the design becomes a complex issue with multiple factors involved,

making it difficult to determine direct relationships between the components of the criterion function and those factors. Hence, such a problem is best solved by deciding on design solutions within an optimisation task mode. In the present case, the decision was taken to carry out the optimisation by performing a multi-faceted analysis of design variants (Fig. 1). Firstly, a SWOT/TOWS analysis of the initial concepts was undertaken, resulting in an assessment of each of the alternatives, from which the recommended option for implementation was identified as a result of this stage of the analysis. Then, the preliminary design concepts were subjected to analysis using the zero unitarization method, resulting in a ranking of the variants, which allowed the selection of the recommended solution obtained at this stage of the analysis. The two selected design variants were then subjected to an analysis of variant attractiveness and, on this basis, a recommended variant was selected for implementation [2].

The following material will present the SWOT/TOWS part of the analysis of design alternatives.

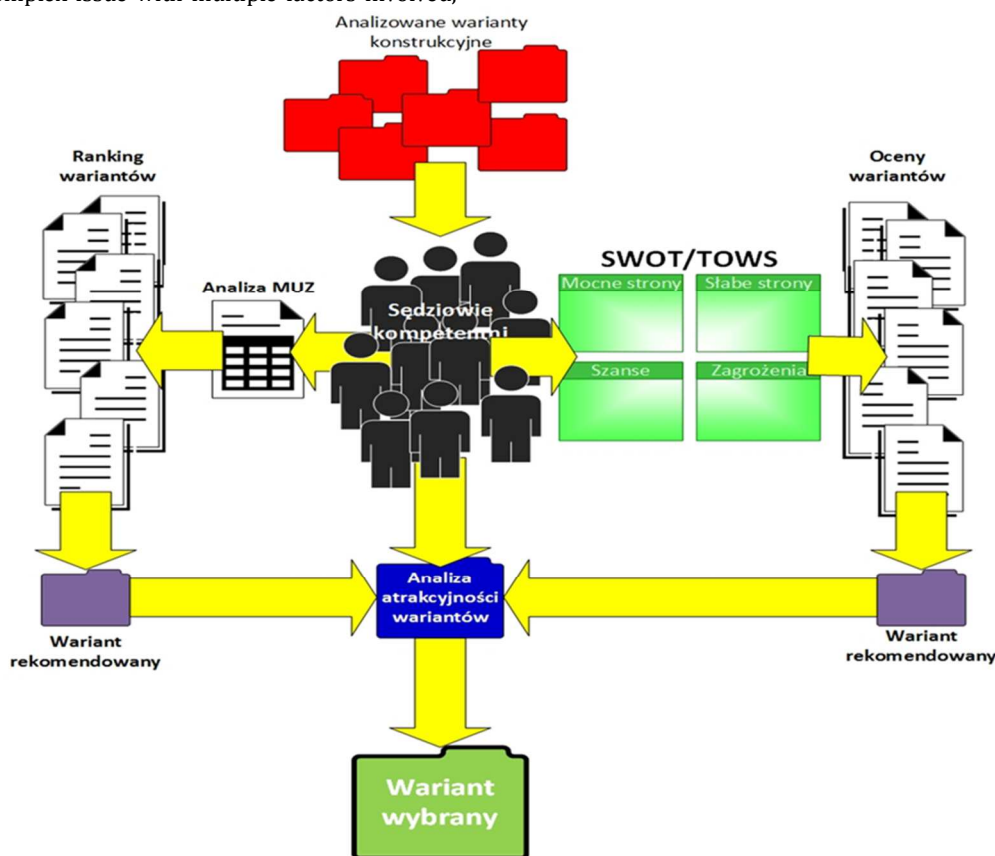


Fig. 1 A multi-faceted analysis of design options for the Argo profiling float rescue device [2].

DESIGN OPTIMISATION OF THE RESCUE DEVICE FOR THE ARGO FLOAT – SWOT/TOWS ANALYSIS METHODOLOGY OF DESIGN OPTIONS

The analysis is derived from K. Lewin's concept of force field analysis, developed in the 1950s, and allows facts to be organised to allow the understanding of data and its resulting consequences [2]. In this method, factors are defined in the following categories: strengths, weaknesses, opportunities and threats. In relation to the structural analysis, strengths represent all that the analysed design possesses and that enables it to achieve its defined goal function, weaknesses represent all that stands in the way of its achievement. Opportunities are all favourable solutions that can be used to achieve the expected results. Threats, on the other hand, are elements that have a negative impact on the operation and efficiency of the analysed solution. The SWOT analysis should provide answers to four key questions:

- Will the identified strengths allow opportunities to be exploited?

- Will the identified strengths overcome threats?
- Will the identified weaknesses prevent the exploitation of the opportunities?
- Will the identified weaknesses reinforce the impact of threats?

The SWOT analysis is complemented by its inverted version, the TOWS analysis, which should answer the following four questions:

- will opportunities amplify strengths?
- will threats weaken the strengths?
- will opportunities overcome weaknesses?
- will threats exacerbate weaknesses??

The combined SWOT and TOWS analysis allows the selection of a development strategy for the structure under consideration. The first step of the SWOT/TOWS analysis is to identify the factors and to complete the table as below:

Tab. 1

Results.

Strengths:	Weaknesses:
1....	1....
2....	2....
3....	3....
....	
n....	n....
Opportunities:	Threats:
1....	1....
2....	2....
3....	3....
....	n....
n....	

Given the rank of the defined factors from most important to least important, the 5 most important factors from each category are taken forward for further analysis. Each factor must then be described in detail and given weights representing their priority in a given category, with the sum of the weights in each category meeting the following condition:

$$\sum_{i=1}^n w_{ij} = 1,0 \quad (1)$$

where:

w_{ij} - weight of the i-th factor in the j-th category

The defined factors, together with their weights assigned to specific categories, are then tabulated:

Results.

Strengths (S)		Weight	Weaknesses (W)		Weight
S1	.....	w_{ij}	W1	.....	w_{ij}
S2	.....	w_{ij}	W2	.....	w_{ij}
S3	.....	w_{ij}	W3	.....	w_{ij}
S4	.....	w_{ij}	W4	.....	w_{ij}
S5	.....	w_{ij}	W5	.....	w_{ij}
total		1,0	total		1,0
Opportunities (O)		Waga	Threats (T)		Waga
O1	.....	w_{ij}	T1	.....	w_{ij}
O2	.....	w_{ij}	T2	.....	w_{ij}
O3	.....	w_{ij}	T3	.....	w_{ij}
O4	.....	w_{ij}	T4	.....	w_{ij}
O5	.....	w_{ij}	T5	.....	w_{ij}
total		1,0	total		1,0

This is followed by eight cross-tabulations, which define the interactions between the factors in each category. Here, the fact that of an occurrence of interaction between factors is indicated by the number "1" or "0" by meeting the following condition (using the example of a potential relationship between a strength and a threat):

$$\text{if } S_i \supset T_i \Rightarrow v_i = 1 \quad (2)$$

$$\text{if } S_i \not\supset T_i \Rightarrow v_i = 0$$

where:

- S_i - strength
 T_i - threat
 v_i - interaction;
 $v_1 = 1$ – interaction occurs;
 $v_i = 0$ – interaction does not occur

In the next step, the total number of interactions for all analysed threats is calculated for the analysed strength.:

$$\Pi_{Si} = \sum_{i=1}^n v_i \quad (3)$$

where:

- Π_{Si} - number of interactions with a given strength S_i

On the basis of the number of interactions and the weight of the strength S_i the impact of this strength on the specific threat T_i is determined with formula:

$$q_{Si} = \Pi_{Si} \cdot w_{Si} \quad (4)$$

where:

- q_{Si} - impact of strength S_i on threat T_i

The calculated values of the product q_{Si} range from a minimum value to a maximum value. The rank (R) of the impact of the factor (from 1 to 5) is assigned in such a manner that for $q_{Si_{max}} R = 1$, and for $q_{Si_{min}} R = 5$. On this basis, the most impacting strength is identified. In the same cross table, a similar calculation is made by determining the most impacting strengths of the threat. The calculation method is the same, with the calculated indicators referring to the threats. The number of interactions of all strengths and threats is then totalled:

$$\sum_{i=1}^5 \Pi_{Si} = \Pi_{S1} + \dots + \Pi_{Si} \dots + \Pi_{S5} \quad (5)$$

$$\sum_{i=1}^5 \Pi_{Ti} = \Pi_{T1} + \dots + \Pi_{Ti} \dots + \Pi_{T5} \quad (6)$$

Similarly, the product summation is carried out:

$$\sum_{i=1}^5 q_{Si} = q_{S1} + \dots + q_{Si} \dots + q_{S5} \quad (7)$$

$$\sum_{i=1}^5 q_{Ti} = q_{T1} + \dots + q_{Ti} \dots + q_{T5} \quad (8)$$

The number of all interactions and the value of their products in the ratio of strengths to threats are obtained by summing equations (4); (5) and (6) and (7):

$$\sum_{i=1}^5 \Pi_{Si/Ti} = \sum_{i=1}^5 \Pi_{Si} + \sum_{i=1}^5 \Pi_{Ti} \quad (9)$$

$$\sum_{i=1}^5 q_{Si/Ti} = \sum_{i=1}^5 q_{Si} + \sum_{i=1}^5 q_{Ti} \quad (10)$$

The results of the calculations are tabulated as follows (Tab.3):

Tab. 3

Results.									
Strengths/Threats	Strength 1	Strength 2	Strength 3	Strength 4	Strength 5	Weight	Number of interactions	Product of weights and interactions	Rank
Threat 1	v_i	v_i	v_i	v_i	v_i	w_{Ti}	Π_{Ti}	q_{Ti}	2
Threat 2	v_i	v_i	v_i	v_i	v_i	w_{Ti}	Π_{Ti}	$q_{Ti_{max}}$	1
Threat 3	v_i	v_i	v_i	v_i	v_i	w_{Ti}	Π_{Ti}	q_{Ti}	3
Threat 4	v_i	v_i	v_i	v_i	v_i	w_{Ti}	Π_{Ti}	$q_{Ti_{min}}$	5
Threat 5	v_i	v_i	v_i	v_i	v_i	w_{Ti}	Π_{Ti}	q_{Ti}	4
Weight	w_{Si}	w_{Si}	w_{Si}	w_{Si}	w_{Si}		$\sum_{i=1}^5 \Pi_{Ti}$	$\sum_{i=1}^5 q_{Ti}$	
Number of interactions	Π_{Si}	Π_{Si}	Π_{Si}	Π_{Si}	Π_{Si}		$\sum_{i=1}^5 \Pi_{Si}$		
Product of weights and interactions	$q_{Si_{max}}$	q_{Si}	q_{Si}	q_{Si}	$q_{Si_{min}}$			$\sum_{i=1}^5 q_{Si}$	

cont. Tab. 3

Rank	1	2	4	3	5				
Interaction sum							$\sum_{i=1}^5 \Pi_{Si/Ti}$		
Product sum								$\sum_{i=1}^5 q_{Si/Ti}$	

Using equations from (1) to (10), eight relations are studied
 $S_i/O_i; O_i/S_i; S_i/T_i; T_i/S_i; W_i/O_i; O_i/W_i; W_i/T_i; T_i/W_i$ with
 the results recorded in tables as shown above.

The summary results of the cross-tabulations are represented in a table below (Tab.4):

Tab. 4

Results.

Combination	SWOT analysis results		TOWS analysis results		SWOT/TOWS summary	
	Sum of interactions	Sum of products	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths / Opportunities	$\sum_{i=1}^5 \Pi_{Si/Oi}$	$\sum_{i=1}^5 Q_{Si/Oi}$	$\sum_{i=1}^5 \Pi_{Oi/Si}$	$\sum_{i=1}^5 Q_{Oi/Si}$	$\Pi_{Si/Oi}$	$Q_{Si/Oi}$
Strengths/Threats	$\sum_{i=1}^5 \Pi_{Si/Ti}$	$\sum_{i=1}^5 Q_{Si/Ti}$	$\sum_{i=1}^5 \Pi_{Ti/Si}$	$\sum_{i=1}^5 Q_{Ti/Si}$	$\Pi_{Si/Ti}$	$Q_{Si/Ti}$
Weaknesses/Opportunities	$\sum_{i=1}^5 \Pi_{Wi/Oi}$	$\sum_{i=1}^5 Q_{Wi/Oi}$	$\sum_{i=1}^5 \Pi_{Oi/Wi}$	$\sum_{i=1}^5 Q_{Oi/Wi}$	$\Pi_{Wi/Oi}$	$Q_{Wi/Oi}$
Weaknesses /Threats	$\sum_{i=1}^5 \Pi_{Wi/Ti}$	$\sum_{i=1}^5 Q_{Wi/Ti}$	$\sum_{i=1}^5 \Pi_{Ti/Wi}$	$\sum_{i=1}^5 Q_{Ti/Wi}$	$\Pi_{Wi/Ti}$	$Q_{Wi/Ti}$

The values in the last two columns, i.e., for example, the sum of the interactions from the SWOT and TOWS analysis in the ratio of strengths to threats and the sum of their products, are calculated based on the equations:

$$\Pi_{Si/Ti} = \sum_{i=1}^5 \Pi_{Si/Ti} + \sum_{i=1}^5 \Pi_{Ti/Si} \quad (11)$$

$$Q_{Si/Ti} = \sum_{i=1}^5 Q_{Si/Ti} + \sum_{i=1}^5 Q_{Ti/Si} \quad (12)$$

The results of the calculations from the last two columns in the table above are then compiled into a strategy matrix:

Results.

Tab. 5

	Opportunities	Threats
Strengths	aggressive strategy (maxi-maxi)	Conservative strategy (maxi-min)
	$\Pi_{Si/Oi}; Q_{Si/Oi}$	$\Pi_{Si/Ti}; Q_{Si/Ti}$
Weaknesses	Competitive strategy (mini-maxi)	Defensive strategy (mini-mini)
	$\Pi_{Wi/Oi}; Q_{Wi/Oi}$	$\Pi_{Wi/Ti}; Q_{Wi/Ti}$

The decision to choose a particular strategy is indicated in the matrix by the maximum value of the sum of the number of interactions occurring, the supporting indicator being the sum of the products.

DESIGN OPTIMISATION OF THE RESCUE DEVICE FOR THE ARGO FLOAT - SWOT/TOWS ANALYSIS OF DESIGN OPTIONS

SWOT/TOWS ANALYSIS OF THE DESIGN VARIANT FOR VOLUME EXPANSION BY MEANS OF PISTON DISPLACEMENT

Tab. 6

Strengths, weaknesses, opportunities and threats of the analysed design variant

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	Small device dimensions	0,3	W1	Need for relief valves	0,15
S2	Low cylinder weight	0,3	W2	Precision machining of internal surfaces	0,15
S3	Simple pneumatic supply	0,1	W3	Precision machining of external surfaces	0,15
S4	Simple electrical supply	0,1	W4	Freezing of the installation during air expansion	0,35
S5	Simple operating principle	0,2	W5	Need to secure the piston end position	0
			W6	Need to protect the cylinder outlet with a mesh	0
			W7	Mixed electrical/pneumatic supply	0,2
Summation		1,0	Summation		1,0
Lp	Opportunities (O)	Weight	Lp.	Threats (T)	Weight
O1	We do not significantly change the dimensions of the float	0,1	T1	Complicated cylinder design	0,15
O2	Low impact on standard floatation control system	0,3	T2	Possibility of leakage	0,15
O3	Uncomplicated design	0,1	T3	Locking the piston in the cylinder	0,2
O4	Greater structural reliability	0,3	T4	No impact of operation	0,35
O5	Stability of effects of use	0,2	T5	Possibility for the piston to move outside the cylinder	0
			T6	Foreign elements block the movement of the piston	0
			T7	Increased failure rate	0,15
Summation		1,0	Summation		1,0

Tab. 7

Do the identified strengths allow the opportunities to be exploited?

Strengths/ opportunities	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
O1	1	1	0	0	0	0,1	2	0,2	4
O2	1	1	0	0	0	0,3	2	0,6	2
O3	0	1	1	1	1	0,1	4	0,4	3
O4	0	0	1	1	1	0,3	3	0,9	1
O5	0	0	1	1	0	0,2	2	0,4	3
Weight	0,3	0,3	0,1	0,1	0,2	1	13	2,5	
Number of interactions	2	3	3	3	2		13		
Product	0,6	0,9	0,3	0,3	0,4			2,5	
Rank	2	1	3	3	4				
Sum of interactions							26		
Sum of products								5	

Tab. 8

Will opportunities amplify strengths?

Opportunities/ Strengths	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
S1	1	1	0	0	0	0,3	2	0,6	2
S2	1	1	0	0	0	0,3	2	0,6	2
S3	0	0	0	1	0	0,1	1	0,1	3
S4	0	0	0	1	0	0,1	1	0,1	3
S5	0	1	1	1	1	0,2	4	0,8	1
Weight	0,1	0,3	0,1	0,3	0,2	1	10	2,2	
Number interactions	of 2	3	1	3	1		10		
Product	0,2	0,9	0,1	0,9	0,2			2,3	
Rank	2	1	3	1	2				
Sum of interactions							20		
Sum of products								4,5	

Tab. 9

Will the identified strengths overcome the threats?

Strengths/ threats	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
T1	0	1	0	0	0	0,15	1	0,15	3
T2	0	1	1	0	0	0,15	2	0,3	2
T3	0	0	0	0	0	0,2	0	0	4
T4	0	0	0	0	0	0,35	0	0	4
T7	0	1	1	1	1	0,15	4	0,6	1
Weight	0,3	0,3	0,1	0,1	0,2	1	7	1,05	
Number interactions	of 0	3	2	1	1		7		
Product	0	0,9	0,2	0,1	0,2			1,4	
Rank	4	1	2	3	2				
Sum of interactions							14		
Sum of products								2,45	

Tab. 10

Do threats weaken the strengths?

Threats/ Strengths	T1	T2	T3	T4	T7	Weight	Number of interactions	Product	Rank
S1	1	0	0	0	0	0,3	1	0,3	3
S2	1	1	1	0	0	0,3	3	0,9	1
S3	0	1	0	0	0	0,1	1	0,1	4
S4	0	0	0	0	1	0,1	1	0,1	4
S5	1	0	0	0	1	0,2	2	0,4	2
Weight	0,15	0,15	0,2	0,35	0,15	1	8	1,8	
Number interactions	of 3	2	1	0	2		8		
Product	0,45	0,3	0,2	0	0,3			1,25	
Rank	1	2	2	3	2				
Sum of interactions							16		
Sum of products								3,05	

Tab. 11

Will the identified weaknesses prevent opportunities from being exploited?

Weaknesses/ Opportunities	W1	W2	W3	W4	W7	Weight	Number of interactions	Product	Rank
O1	0	0	0	0	0	0,1	0	0	4
O2	0	0	0	0	0	0,3	0	0	4
O3	0	1	1	0	0	0,1	2	0,2	3
O4	1	1	1	1	1	0,3	5	1,5	1
O5	1	1	1	1	1	0,2	5	1	2
Weight	0,15	0,15	0,15	0,35	0,2	1	12	2,7	
Number interactions	of 2	3	3	2	2		12		
Product	0,3	0,45	0,45	0,7	0,4			2,3	
Rank	3	2	2	1	3				
Sum of interactions							24		
Sum of products								5	

Tab. 12

Will opportunities overcome weaknesses?

Opportunities/ Weaknesses	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
W1	0	0	1	1	1	0,15	3	0,45	3
W2	0	0	1	1	0	0,15	2	0,3	4
W3	0	0	1	1	0	0,15	2	0,3	4
W4	0	0	0	1	1	0,35	2	0,7	1
W7	0	0	1	1	1	0,2	3	0,6	2
Weight	0,1	0,3	0,1	0,3	0,2	1	12	2,35	
Number interactions	of 0	0	4	5	3		12		
Product	0	0	0,4	1,5	0,6			2,5	
Rank	4	4	3	1	2				
Sum of interactions							24		
Sum of products								4,85	

Tab. 13

Will the identified weaknesses amplify the impact of the threats.

Weaknesses/ threats	W1	W2	W3	W4	W7	Weight	Number of interactions	Product	Rank
T1	1	1	1	0	0	0,15	3	0,45	4
T2	1	1	1	1	0	0,15	4	0,6	3
T3	0	1	1	1	0	0,2	3	0,6	3
T4	1	0	0	1	1	0,35	3	1,05	1
T7	1	1	1	1	1	0,15	5	0,75	2
Weight	0,15	0,15	0,15	0,35	0,2	1	18	3,45	
Number interactions	of 4	4	4	4	2		18		
Product	0,6	0,6	0,6	1,4	0,4			3,6	
Rank	2	2	2	1	3				
Sum of interactions							36		
Sum of products								7,05	

Tab. 14

Will threats amplify weaknesses?

Weaknesses/ threats	T1	T2	T3	T4	T7	Weight	Number of interactions	Product	Rank
W1	1	1	0	1	1	0,15	4	0,6	2
W2	1	1	0	1	1	0,15	4	0,6	2
W3	0	1	0	1	1	0,15	3	0,45	3
W4	1	0	1	1	1	0,35	4	1,4	1
W7	0	0	0	0	0	0,2	0	0	4
Weight	0,15	0,15	0,2	0,35	0,15	1	15	3,05	
Number of interactions	3	3	1	4	4		15		
Product	0,45	0,45	0,2	1,4	0,6			3,1	
Rank	3	3	4	1	2				
Sum of interactions							30		
Sum of products								6,15	

Tab. 15

Results.

COMBINATION	Results of the analysis SWOT		Results of the analysis TOWS		Summary overview	
	Sum of interactions	Sum of products	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths/Opportunities	26	5	20	4,5	46	9,5
Strengths/Threats	14	2,45	16	3,05	30	5,5
Weaknesses/Opportunities	24	5	24	4,85	48	9,85
Weaknesses/Threats	36	7,05	30	6,15	66	13,2

Tab. 16

Results.

	Opportunities	Threats
Strengths	Strengths amplify opportunities	Strengths do not eliminate risks
	Aggressive strategy	Conservative strategy
	46/9,5	30/5,5
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive loss	Defensive strategy
	48/9,85	66/13,2

**SWOT/TOWS ANALYSIS OF THE
DESIGN VARIANT OF VOLUME AUGMENTATION BY
MEANS OF FILLING OF THE BUOYANCY BAG**

Strengths, weaknesses, opportunities and threats of the analysed design variant.

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	Small device dimensions	0,2	W1	Flexible bags require the use of relief valves	0,1
S2	Small dimensions of the buoyancy bag	0,1	W2	High resilience of bag material required	
S3	Small casing dimensions	0,1	W3	Good workmanship of the bag required	0,1
S4	Simple operating principle	0,3	W4	Possibility of installation freezing during expansion	0,3
S5	The high metacentric system height	0,3	W5	Possibility of installation leaks	0,3
			W6	Complicated mixed electrical/pneumatic supply	0,2
			W7		
Summation		1,0	Summation		1,0
Lp	Opportunities (O)	Weight	Lp	Threats (T)	Weight
O1	Compact design of the rescue device	0,15	T1	Greater probability	
O2	Reduced compressed air requirements	0,2	T2	Bag burst	0,2
O3	Less likely	0,05	T3	Probability of not filling the whole bag	0,1
O4	Greater reliability	0,3	T4	Lack of effective action	0,3
O5	Good stability during ascent	0,3	T5	Loss of the Argo float	0,3
			T6	Higher failure rate	0,1
			T7		
Summation		1,0	Summation		1,0

Tab. 18

Do the identified strengths allow opportunities to be exploited?

Strengths/ opportunities	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
O1	1	1	1	0	0	0,15	3	0,45	2
O2	0	1	0	0	0	0,2	1	0,2	4
O3	1	0	1	0	1	0,05	3	0,15	5
O4	0	0	0	1	0	0,3	1	0,3	3
O5	0	1	0	0	1	0,3	2	0,6	1
Weight	0,2	0,1	0,1	0,3	0,3	1	10	1,7	
Number of interactions	2	3	2	1	2		10		
Product	0,4	0,3	0,2	0,3	0,6			1,8	
Rank	2	3	4	3	1				
Sum of interactions							20		
Sum of products								3,5	

Tab. 19

Will opportunities amplify strengths?

Opportunities/ Strengths	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
S1	1	0	1	0	0	0,2	2	0,4	1
S2	1	1	0	0	0	0,1	2	0,2	3
S3	1	1	1	0	0	0,1	3	0,3	2
S4	0	0	0	1	0	0,3	1	0,3	2
S5	0	0	0	0	1	0,3	1	0,3	2
Weight	0,15	0,2	0,05	0,3	0,3	1	9	1,5	
Number interactions	of 3	2	2	1	1		9		
Product	0,45	0,4	0,1	0,3	0,3			1,55	
Rank	1	2	4	3	3				
Sum of interactions	18								
Sum of products	3,05								

Tab. 20

Will the identified strengths overcome the threats?

Strengths/ threats	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
T2	0	0	0	0	0	0,2	0	0	
T3	0	0	0	0	0	0,1	0	0	
T4	0	0	0	0	0	0,3	0	0	
T5	0	0	0	0	0	0,3	0	0	
T6	0	0	0	0	0	0,1	0	0	
Weight	0,2	0,1	0,1	0,3	0,3	1	0	0	
Number interactions	of 0	0	0	0	0		0		
Product	0	0	0	0	0			0	
Rank									
Sum of interactions	0								
Sum of products	0								

Tab. 21

Do the threats weaken the strengths?

Threats/ Strengths	T2	T3	T4	T5	T6	Weight	Number of interactions	Product	Rank
Number	of 1	1	1	1	0		4		
Product	0,2	0,1	0,3	0,3	0			0,9	
Rank	2	3	1	1	4				
Sum of interactions	8								
Sum of products	1,6								
Weight	0,2	0,1	0,3	0,3	0,1	1	4	0,7	
Number interactions	of 1	1	1	1	0		4		
Product	0,2	0,1	0,3	0,3	0			0,9	
Rank	2	3	1	1	4				
Sum of interactions	8								
Sum of products	1,6								

Tab. 22

Will the identified weaknesses prevent opportunities from being exploited?

Weaknesses/ Opportunities	W1	W3	W4	W5	W6	Weight	Number of interactions	Product	Rank
O1	0	0	0	0	0	0,15	0	0	4
O2	0	0	1	1	1	0,2	3	0,6	2
O3	1	0	0	0	0	0,05	1	0,05	3
O4	1	1	1	1	1	0,3	5	1,5	1
O5	0	0	0	0	0	0,3	0	0	4
Weight	0,1	0,1	0,3	0,3	0,2	1	9	2,15	
Number of interactions	2	1	2	2	2		9		
Product	0,2	0,1	0,6	0,6	0,4			1,9	
Rank	3	4	1	1	2				
Sum of interactions							18		
Sum of products								4,05	

Tab. 23

Will opportunities allow to overcome weaknesses?

Opportunities/Weaknesses	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
W1	1	1	0	1	0	0,1	3	0,3	4
W3	1	0	0	1	0	0,1	2	0,2	5
W4	0	1	0	1	0	0,3	2	0,6	2
W5	1	1	0	1	0	0,3	3	0,9	1
W6	0	1	0	1	0	0,2	2	0,4	3
Weight	0,15	0,2	0,05	0,3	0,3	1	12	2,4	
Number of interactions	3	4	0	5	0		12		
Product	0,45	0,8	0	1,5	0			2,75	
Rank	3	2	4	1	4				
Sum of interactions							24		
Sum of products								5,15	

Tab. 24

Will the identified weaknesses strengthen the impact of the threats?

Weaknesses/threats	W1	W3	W4	W5	W6	Weight	Number of interactions	Product	Rank
T2	1	1	0	0	0	0,2	2	0,4	3
T3	1	1	1	1	0	0,1	4	0,4	3
T4	1	1	1	1	0	0,3	4	1,2	1
T5	1	1	1	1	0	0,3	4	1,2	1
T6	1	1	1	1	1	0,1	5	0,5	2
Weight	0,1	0,1	0,3	0,3	0,2	1	19	3,7	
Number of interactions	5	5	4	4	1		19		
Product	0,5	0,5	1,2	1,2	0,2			3,6	
Rank	2	2	1	1	3				
Sum of interactions							38		
Sum of products								7,3	

Tab. 25

Will threats exacerbate weaknesses?

Weaknesses/threats	T2	T3	T4	T5	T6	Weight	Number of interactions	Product	Rank
W1	1	1	1	0	1	0,1	4	0,4	4
W3	1	1	0	1	1	0,1	4	0,4	4
W4	0	1	1	1	1	0,3	4	1,2	2
W5	1	1	1	1	1	0,3	5	1,5	1
W6	0	0	1	1	1	0,2	3	0,6	3
Weight	0,2	0,1	0,3	0,3	0,1	1	20	4,1	
Number of interactions	3	4	4	4	5		20		
Product	0,6	0,4	1,2	1,2	0,5			3,9	
Rank	2	4	1	1	3				
Sum of interactions							40		
Sum of products								8	

Tab. 26

Results.

COMBINATION	Results of the analysis SWOT	Results of the analysis TOWS	Summary overview		
	Sum of interactions	Sum of products	Sum of interactions	Sum of products	Sum of interactions of products
Strengths/Opportunities	20	3,5	18	3,05	38 6,55
Strengths/ Threats	0	0	8	1,6	8 1,6
Weaknesses/Opportunities	18	4,05	24	5,15	42 9,2
Weaknesses/ Threats	38	7,3	40	8	78 15,3

Tab. 27

Results.

	Opportunities	Threats
	Strengths enhance opportunities	Strengths do not eliminate risks
Strengths	Aggressive strategy	Conservative strategy
	38/6,55	8/1,6
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive loss	Defensive strategy
	42/9,2	78/15,3

SWOT/TOWS ANALYSIS OF THE DESIGN OPTION FOR VOLUME EXPANSION BY WATER CIRCULATION

Tab. 28

Strengths, weaknesses, opportunities and threats of the analysed design variant.

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	Likelihood of effective operation	0,3	W1	Two water pressure vessels required	
S2	Small dimension	0,3	W2	Emergency pump operation possible	0,3
S3	Single-circuit power supply	0,1	W3	Good build quality of buoyancy bags required	0,2
S4	Compact design	0,2	W4	Energy-intensive water pumping process	0,2
S5	Ease of restoring readiness for reuse	0,1	W5	The need for a protective basket	0,1
			W6	Complicated operating principle	0,2
			W7		
Summation		1,0	Summation		1,0
Lp	Opportunities(O)	Weight	Lp	Threats (T)	Weight
O1	Recovery of the ARGO float	0,3	T1	Greater likelihood of untightness	0,1
O2	Smaller buoyancy element to balance buoyancy of rescue device	0,2	T2	Lack of performance	0,3
O3	Greater reliability	0,2	T3	Probability of not filling the whole bag	
O4	Less chance of hooking	0,15	T4	Increased energy demand	0,1
O5	Simplified operation	0,15	T5	Possible damage to the bag	0,2
			T6	Higher failure rate	0,3
			T7		
Summation		1,0	Summation		1,0

Tab. 29

Do the identified strengths allow opportunities to be exploited?

Strengths/ Opportunities	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
O1	1	0	0	0	0	0,3	1	0,3	3
O2	1	1	0	1	0	0,2	3	0,6	1
O3	1	0	1	0	1	0,2	3	0,6	1
O4	1	1	0	1	0	0,15	3	0,45	2
O5	1	0	1	0	1	0,15	3	0,45	2
Weight	0,3	0,3	0,1	0,2	0,1	1	13	2,4	
Number of interactions	5	2	2	2	2		13		
Product	1,5	0,6	0,2	0,4	0,2			2,9	
Rank	1	2	4	3	4				
Sum of interactions							26		
Sum of products								5,3	

Tab. 30

Will opportunities amplify strengths?

Opportunities/ Strengths	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
S1	1	1	1	1	0	0,3	4	1,2	1
S2	0	1	0	1	0	0,3	2	0,6	2
S3	0	0	1	0	1	0,1	2	0,2	4
S4	0	1	0	1	0	0,2	2	0,4	3
S5	0	1	0	0	1	0,1	2	0,2	4
Weight	0,3	0,2	0,2	0,15	0,15	1	12	2,6	
Number interactions	of 1	4	2	3	2		12		
Product	0,3	0,8	0,4	0,45	0,3			2,25	
Rank	4	1	3	2	4				
Sum of interactions							24		
Sum of products								4,85	

Tab. 31

Will the identified strengths overcome the threats?

Strenghts/threats	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
T1	1	0	0	0	0	0,1	1	0,1	5
T2	1	0	0	0	0	0,3	1	0,3	3
T4	1	0	1	0	0	0,1	2	0,2	4
T5	1	1	0	0	0	0,2	2	0,4	2
T6	1	0	1	0	0	0,3	2	0,6	1
Weight	0,3	0,3	0,1	0,2	0,1	1	8	1,6	
Number interactions	of 5	1	2	0	0		8		
Product	1,5	0,3	0,2	0	0			2	
Rank	1	2	3	4	4				
Sum of interactions							16		
Sum of products								3,6	

Tab. 32

Do the threats weaken the strengths?

Threats/ Strengths	T1	T2	T4	T5	T6	Weight	Number of interactions	Product	Rank
S1	1	1	1	1	1	0,3	5	1,5	1
S2	0	0	0	0	0	0,3	0	0	3
S3	0	1	1	0	1	0,1	3	0,3	2
S4	0	0	0	0	0	0,2	0	0	3
S5	0	0	0	0	0	0,1	0	0	3
Weight	0,1	0,3	0,1	0,2	0,3	1	8	1,8	
Number interactions	of 1	2	2	1	2		8		
Product	0,1	0,6	0,2	0,2	0,6			1,7	
Rank	3	1	2	2	1				
Sum of interactions							16		
Sum of products								3,5	

Tab. 33

Czy zidentyfikowane słabości uniemożliwią wykorzystanie szans?

Weaknesses/ Opportunities	W2	W3	W4	W5	W6	Weight	Number of interactions	Product	Rank
O1	1	1	0	0	0	0,3	2	0,6	1
O2	1	0	1	1	0	0,2	3	0,6	1
O3	1	0	0	1	1	0,2	3	0,6	1
O4	0	0	0	1	0	0,15	1	0,15	2
O5	0	0	0	0	1	0,15	1	0,15	2
Weight	0,3	0,2	0,2	0,1	0,2	1	10	2,1	
Number interactions	of 3	1	1	3	2		10		
Product	0,9	0,2	0,2	0,3	0,4			2	
Rank	1	4	4	3	2				
Sum of interactions							20		
Sum of products								4,1	

Tab. 34

Will opportunities overcome weaknesses?

Opportunities/ Weaknesses	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
W2	1	0	1	0	0	0,3	2	0,6	1
W3	0	0	1	1	0	0,2	2	0,4	2
W4	1	0	0	0	1	0,2	2	0,4	2
W5	0	0	0	0	0	0,1	0	0	4
W6	0	0	0	0	1	0,2	1	0,2	3
Weight	0,3	0,2	0,2	0,15	0,15	1	7	1,6	
Number interactions	of 2	0	2	1	2		7		
Product	0,6	0	0,4	0,15	0,3			1,45	
Rank	1	5	2	4	3				
Sum of interactions							14		
Sum of products								3,05	

Tab. 35

Will the identified weaknesses strengthen the impact of the threats?

Weaknesses/ threats	W2	W3	W4	W5	W6	Weight	Number of interactions	Product	Rank
T1	1	1	0	0	0	0,1	2	0,2	3
T2	1	1	1	0	1	0,3	4	1,2	1
T4	0	0	1	0	1	0,1	2	0,2	3
T5	0	1	0	1	0	0,2	2	0,4	2
T6	1	1	0	1	1	0,3	4	1,2	1
Weight	0,3	0,2	0,2	0,1	0,2	1	14	3,2	
Number interactions	of 3	4	2	2	3		14		
Product	0,9	0,8	0,4	0,2	0,6			2,9	
Rank	1	2	4	5	3				
Sum of interactions							28		
Sum of products								6,1	

Tab. 36

Will threats exacerbate weaknesses?

Weaknesses/threats	T1	T2	T4	T5	T6	Weight	Number of interactions	Product	Rank
W2	1	1	0	0	1	0,3	3	0,9	1
W3	0	1	0	1	1	0,2	3	0,6	2
W4	0	0	1	0	0	0,2	1	0,2	4
W5	1	0	0	1	1	0,1	3	0,3	3
W6	0	1	1	0	1	0,2	3	0,6	2
Weight	0,1	0,3	0,1	0,2	0,3	1	13	2,6	
Number of interactions	2	3	2	2	4		13		
Product	0,2	0,9	0,2	0,4	1,2			2,9	
Rank	4	2	4	3	1				
Sum of interactions							26		
Sum of products								5,5	

Tab. 37

Results.

COMBINATION	Results of the SWOT analysis	Results of the TOWS analysis	Summary overview SWOT/TOWS
	Sum of interactions	Sum of products	Sum of interactions of products
Strengths/Opportunities	26	5,3	24
Strengths/ Threats	16	3,6	16
Weaknesses/Opportunities	20	4,1	14
Weaknesses/ Threats	28	6,1	26

Tab. 38

Results.

	Opportunities	Threats
Strengths	Strengths enhance opportunities	Strengths do not eliminate risks
	Aggressive strategy	Conservative strategy
	50/10,15	32/7,1
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive strategy	Defensive strategy
	34/7,15	54/11,6

**SWOT/TOWS ANALYSIS OF A DESIGN
VARIANT FOR VOLUME EXPANSION USING
FLEXIBLE HOSE FILLING**

Tab. 39

Strengths, weaknesses, opportunities and threats of the analysed design variant.

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	No relief valve required	0,2	W1	Good quality pneumatic installation required	0,2
S2	Simple operating principle	0,3	W2	Large size of the solution	
S3	Lighter weight than other variants	0,3	W3	Possibility of freezing the installation during air expansion	0,3
S4	Hose strength allows use to a depth of 500 m	0,2	W4	Complicated design of the hose container	0,3
S5			W5	Mixed air/electric power supply	
			W6	Pneumatic system leakage possibility	0,2
			W7		
Summation		1,0	Summation		1,0
Lp	Opportunities (O)	Weight	Lp	Threats (T)	Weight
O1	Reduced failure rate	0,3	T1	Occurrence of leaks	
O2	Effectiveness	0,3	T2	Increased possibility of hook-ups	
O3	Smaller buoyancy element to balance buoyancy of the device	0,2	T3	Lack of effective action	0,3
O4	Greater range of applications	0,2	T4	Lack of adequate buoyancy	0,2
O5			T5	Increased failure rate	0,2
			T6	Loss of float	0,3
			T7		
Summation		1,0	Summation		1,0

Tab. 40

Do the identified strengths allow opportunities to be exploited?

Strengths/ Opportunities	S1	S2	S3	S4	Weight	Number of interactions	Product	Rank
O1	1	1	0	1	0,3	3	0,9	1
O2	1	0	0	1	0,3	2	0,6	2
O3	0	0	1	1	0,2	2	0,4	3
O4	0	0	0	1	0,2	1	0,2	4
							0	5
Weight	0,2	0,3	0,3	0,2	1	8	2,1	
Number of interactions	2	1	1	4		8		
Product	0,4	0,3	0,3	0,8	0		1,8	
Rank	2	3	3	1	4			
Sum of interactions						16		
Sum of products							3,9	

Tab. 41

Will opportunities amplify the strengths?

Opportunities/ Strengths	O1	O2	O3	O4	Weight	Number of interactions	Product	Rank
S1	1	1	0	0	0,2	2	0,4	3
S2	1	1	0	0	0,3	2	0,6	2
S3	0	0	1	0	0,3	1	0,3	4
S4	1	1	0	1	0,2	3	0,6	1
							0	5
Weight	0,3	0,3	0,2	0,2	1	8	1,9	
Number interactions	of 3	3	2	2		10		
Product	0,9	0,9	0,4	0,4	0		2,6	
Rank	1	1	2	2				
Sum of interactions						18		
Sum of products							4,5	

Tab. 42

Will the identified strengths overcome the threats?

Strengths/threats	S1	S2	S3	S4	Weight	Number of interactions	Product	Rank
T3	0	0	0	0	0,3	0	0	2
T4	0	0	1	1	0,2	2	0,4	1
T5	1	0	0	1	0,2	2	0,4	1
T6	0	0	0	0	0,3	0	0	2
							0	2
Weight	0,2	0,3	0,3	0,2	1	4	0,8	
Number interactions	of 1	0	1	2		4		
Product	0,2	0	0,3	0,4	0		0,9	
Rank	3	4	2	1	4			
Sum of interactions						8		
Sum of products							1,7	

Tab. 43

Do threats weaken the strengths?

Threats/ Strengths	T3	T4	T5	T6	Weight	Number of interactions	Product	Rank
S1	0	0	1	0	0,2	1	0,2	3
S2	0	0	1	0	0,3	1	0,3	2
S3	0	1	0	1	0,3	2	0,6	1
S4	0	0	1	0	0,2	1	0,2	3
							0	4
Weight	0,3	0,2	0,2	0,3	1	5	1,3	
Number interactions	of 0	1	3	1		5		
Product	0	0,2	0,6	0,3	0		1,1	
Rank	4	3	1	2	4			
Sum of interactions						10		
Sum of products							2,4	

Tab. 44

Will the identified weaknesses prevent opportunities from being exploited?

Weaknesses/ Opportunities	W1	W3	W4	W6	Weight	Number of interactions	Product	Rank
O1	1	1	1	1	0,3	4	1,2	1
O2	1	1	1	1	0,3	4	1,2	1
O3	0	0	0	0	0,2	0	0	3
O4	0	1	0	1	0,2	2	0,4	2
							0	3
Weight	0,2	0,3	0,3	0,2	1	10	2,8	
Number interactions	of 2	3	2	3		10		
Product	0,4	0,9	0,6	0,6	0		2,5	
Rank	3	1	2	2	4			
Sum of interactions						20		
Sum of products							5,3	

Tab. 45

Will opportunities overcome the weaknesses?

Opportunities/ Weaknesses	O1	O2	O3	O4	Weight	Number of interactions	Product	Rank
W1	1	1	0	0	0,2	2	0,4	2
W3	1	1	0	0	0,3	2	0,6	1
W4	1	1	0	0	0,3	2	0,6	1
W6	1	1	0	0	0,2	2	0,4	2
						0	0	3
Weight	0,3	0,3	0,2	0,2	1	8	2	
Number interactions	of 4	4	0	0	0	8		
Product	1,2	1,2	0	0	0		2,4	
Rank	1	1	2	2	3			
Sum of interactions						16		
Sum of products							4,4	

Tab. 46

Will the identified weaknesses strengthen the impact of the threats?

Weaknesses/ threats	W1	W3	W4	W6	Weight	Number of interactions	Product	Rank
T3	1	1	0	1	0,3	3	0,9	2
T4	0	1	1	1	0,2	3	0,6	4
T5	1	1	1	1	0,2	4	0,8	3
T6	1	1	1	1	0,3	4	1,2	1
							0	5
Weight	0,2	0,3	0,3	0,2		14	3,5	
Number interactions	of 3	4	3	4		14		
Product	0,6	1,2	0,9	0,8	0		3,5	
Rank	4	1	2	3	5			
Sum of interactions						28		
Sum of products							7	

Tab. 47

Will threats exacerbate weaknesses?

Weaknesses/threats	T3	T4	T5	T6	Weight	Number of interactions	Product	Rank
W1	1	0	1	1	0,2	3	0,6	2
W3	0	0	1	1	0,3	2	0,6	2
W4	0	0	0	0	0,3	0	0	3
W6	1	1	1	1	0,2	4	0,8	1
							0	3
Weight	0,3	0,2	0,2	0,3	1	9	2	
Number of interactions	2	1	3	3		9		
Product	0,6	0,2	0,6	0,9	0		2,3	
Rank	2	3	2	1	4			
Sum of interactions						18		
Sum of products							4,3	

Tab. 48

Results.

COMBINATION	Results of the SWOT analysis	Results of the TOWS analysis	Summary overview SWOT/TOWS			
	Sum of interactions	Sum of products	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths/Opportunities	16	3,9	18	4,5	34	8,4
Strengths/ Threats	8	1,7	10	2,4	18	4,1
Weaknesses/Opportunities	20	5,3	16	4,4	36	9,7
Weaknesses/ Threats	28	7	18	4,3	46	11,3

Tab. 49

Results.

	Opportunities	Threats
Strengths	Strengths enhance opportunities	Strengths do not eliminate risks
	Aggressive strategy	Conservative strategy
	34/8,4	18/4,1
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive strategy	Defensive strategy
	36/9,7	46/11,3

**SWOT/TOWS ANALYSIS OF THE
DESIGN VARIANT CONSISTING IN THE
MODIFICATION OF THE MASS BY DISCARDING THE
CONCRETE BALLAST**

Tab. 50

Strengths, weaknesses, opportunities and threats of the analysed design variant.

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	Compact design	0,2	W1	Concrete ballast	0,1
S2	Generating a constant buoyant force	0,3	W2	Large number of wires and electrical connections	0,2
S3	Simplicity of operation	0,3	W3	Complex ballast release system	0,3
S4	Additional protection for the float when hitting the bottom	0,1	W4	Susceptibility to overgrowth of external moving parts	0,3
S5	Low device weight	0,1	W5	The release module is flooded after activation	0,1
			W6		
			W7		
Summation		1,0	Summation		1,0
Lp	Opportunities (O)	Weight	Lp.	Threats (T)	Weight
O1	No hooking	0,2	T1	Environmental pollution by a concrete element	0,1
O2	Operating reliability	0,3	T2	Failure rate - loss of tightness of elements	0,2
O3	Effectiveness of operation	0,3	T3	Potential jamming of the release pin	0,3
O4	No damage to the float	0,1	T4	Immobilisation of ballast	0,2
O5	Less impact on float performance	0,1	T5	Disposable device	0,2
			T6		
			T7		
Summation		1,0	Summation		1,0

Tab. 51

Do the identified strengths allow opportunities to be exploited?

Strengths/ opportunities	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
O1	1	0	0	0	0	0,2	1	0,2	2
O2	0	1	1	1	0	0,3	3	0,9	1
O3	0	1	1	1	0	0,3	3	0,9	1
O4	0	0	0	0	0	0,1	0	0	4
O5	0	0	0	0	1	0,1	1	0,1	3
Weight	0,2	0,3	0,3	0,1	0,1		8	2,1	
Number of interactions	1	2	2	2	1		8		
Product	0,2	0,6	0,6	0,2	0,1			1,7	
Rank	2	1	1	2	3				
Sum of interactions							16		
Sum of products								3,8	

Tab. 52

Will opportunities amplify the strengths?

Opportunities/ Strengths	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
S1	1	0	0	0	0	0,2	1	0,2	3
S2	0	1	1	0	1	0,3	3	0,9	1
S3	0	1	0	0	0	0,3	1	0,3	2
S4	0	0	0	0	0	0,1	0	0	4
S5	0	0	0	0	0	0,1	0	0	4
Weight	0,2	0,3	0,3	0,1	0,1		5	1,4	
Number interactions	of 1	2	1	0	1		5		
Product	0,2	0,6	0,3	0	0,1			1,2	
Rank	3	1	2	5	4				
Sum of interactions							10		
Sum of products								2,6	

Tab.53

Will the identified strengths overcome the threats?

Strengths/threats	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
T1	0	0	0	1	0	0,1	1	0,1	1
T2	0	0	0	0	0	0,2	0	0	2
T3	0	0	0	0	0	0,3	0	0	2
T4	0	0	0	0	0	0,2	0	0	2
T5	0	0	0	0	0	0,2	0	0	2
Weight	0,2	0,3	0,3	0,1	0,1		1	0,1	
Number interactions	of 0	0	0	1	0		1		
Product	0	0	0	0,1	0			0,1	
Rank	2	2	2	1	2				
Sum of interactions							2		
Sum of products								0,2	

Tab. 54

Do threats weaken the strengths?

Threats/ Strengths	T1	T2	T3	T4	T5	Weight	Number of interactions	Product	Rank
S1	0	0	0	0	0	0,2	0	0	2
S2	0	0	0	0	0	0,3	0	0	2
S3	0	0	0	0	0	0,3	0	0	2
S4	1	0	0	1	0	0,1	2	0,2	1
S5	0	0	0	0	0	0,1	0	0	2
Weight	0,1	0,2	0,3	0,2	0,2		2	0,2	
Number interactions	of 1	0	0	1	0		2		
Product	0,1	0	0	0,2	0			0,3	
Rank	2	3	3	1	3				
Sum of interactions							4		
Sum of products								0,5	

Tab. 55

Will the identified weaknesses prevent opportunities from being exploited?

Weaknesses/ Opportunities	W1	W2	W3	W4	W5	Weight	Number of interactions	Product	Rank
O1	0	0	0	0	0	0,2	0	0	2
O2	1	0	0	0	0	0,3	1	0,3	1
O3	1	0	0	0	0	0,3	1	0,3	1
O4	0	0	0	0	0	0,1	0	0	2
O5	0	0	0	0	0	0,1	0	0	2
Weight	0,1	0,2	0,3	0,3	0,1		2	0,6	
Number of interactions	2	0	0	0	0		2		
Product	0,2	0	0	0	0			0,2	
Rank	1	2	2	2	2				
Sum of interactions							4		
Sum of products								0,8	

Tab. 56

Will opportunities overcome the weaknesses?

Opportunities/Weaknesses	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
W1	1	1	1	0	0	0,1	3	0,3	1
W2	0	0	0	0	0	0,2	0	0	2
W3	0	0	0	0	0	0,3	0	0	2
W4	0	0	0	0	0	0,3	0	0	2
W5	0	0	0	0	0	0,1	0	0	2
Weight	0,2	0,3	0,3	0,1	0,1		3	0,3	
Number of interactions	1	1	1	0	0		3		
Product	0,2	0,3	0,3	0	0			0,8	
Rank	2	1	1	3	3				
Sum of interactions							6		
Sum of products								1,1	

Tab. 57

Will the identified weaknesses strengthen the impact of the threats?

Weaknesses/threats	W1	W2	W3	W4	W5	Weight	Number of interactions	Product	Rank
T1	1	0	0	0	0	0,1	1	0,1	4
T2	0	1	0	0	0	0,2	1	0,2	3
T3	0	0	1	1	0	0,3	2	0,6	1
T4	0	0	1	1	0	0,2	2	0,4	2
T5	0	0	0	0	1	0,2	1	0,2	3
Weight	0,1	0,2	0,3	0,3	0,1		7	1,5	
Number of interactions	1	1	2	2	1		7		
Product	0,1	0,2	0,6	0,6	0,1			1,6	
Rank	3	2	1	1	3				
Sum of interactions							14		
Sum of products								3,1	

Tab. 58

Will threats exacerbate the weaknesses?

Weaknesses/threats	T1	T2	T3	T4	T5	Weight	Number of interactions	Product	Rank
W1	1	1	0	0	0	0,1	2	0,2	2
W2	0	1	0	0	0	0,2	1	0,2	2
W3	0	0	0	0	0	0,3	0	0	4
W4	0	0	1	1	0	0,3	2	0,6	1
W5	0	0	0	0	1	0,1	1	0,1	3
Weight	0,1	0,2	0,3	0,2	0,2		6	1,1	
Number of interactions	1	2	1	1	1		6		
Product	0,1	0,4	0,3	0,2	0,2			1,2	
Rank	5	1	2	3	4				
Sum of interactions							12		
Sum of products								2,3	

Tab. 59

Results.

COMBINATION	Results of the analysis SWOT	Results of the analysis TOWS	Summary overview	
	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths/Opportunities	16	3,8	10	2,6
Strengths/ Threats	2	0,2	4	0,5
Weaknesses/Opportunities	4	0,8	6	1,1
Weaknesses/ Threats	14	3,1	12	2,3
			26	6,4
			6	0,7
			10	1,9
			26	5,4

Tab. 60

Results.

	Opportunities	Threats
Strengths	Strengths enhance opportunities	Strengths do not eliminate risks
	Aggressive strategy	Conservative strategy
	26/6,4	6/0,7
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive strategy	Defensive strategy
	10/1,9	26/5,4

**SWOT/TOWS ANALYSIS OF THE
DESIGN VARIANT CONSISTING OF MASS CHANGE
BY REJECTION OF LEAD BALLAST**

Tab. 61

Strengths, weaknesses, opportunities and threats of the analysed design variant.

Lp	Strengths (S)	Weight	Lp	Weaknesses (W)	Weight
S1	Compactness of the design	0,2	W1	Lead ballast	0,2
S2	Generation of constant buoyant force	0,3	W2	Complex release system	0,3
S3	Protection of the bottom elements of the float	0,1	W3	Susceptibility to overgrowth of external elements	0,2
S4	Low weight of the device	0,2	W4	High energy requirements	0,1
S5	Simplicity of operation	0,2	W5	Complicated shape of the ballast to be cast	0,2
			W6		
			W7		
Summation		1,0	Summation		1,0
Lp	Opportunities (O)	Weight	Lp	Threats (T)	Weight
O1	No hooking	0,2	T1	Environmental pollution	0,1
O2	Reliability of operation	0,3	T2	Failure rate	0,3
O3	Uninterrupted operation of the float measuring elements	0,2	T3	Immobilisation of ballast	0,3
O4	Less impact on float performance parameters	0,1	T4	Limited operational time	0,1
O5	No damage	0,2	T5	Lack of effective operation	0,2
			T6		
			T7		
Summation		1,0	Summation		1,0

Tab. 62

Will the identified strengths allow opportunities to be exploited?

Strengths/ opportunities	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
O1	0	0	0	0	0	0,2	0	0	4
O2	0	0	0	1	1	0,3	2	0,6	1
O3	0	0	0	0	0	0,2	0	0	4
O4	1	0	0	1	0	0,1	2	0,2	3
O5	0	1	1	0	0	0,2	2	0,4	2
Weight	0,2	0,3	0,1	0,2	0,2		6	1,2	
Number of interactions	1	1	1	2	1		6		
Product	0,2	0,3	0,1	0,4	0,2			1,2	
Rank	3	2	4	1	3				
Sum of interactions							12		
Sum of products								2,4	

Tab. 63

Will opportunities amplify the strengths?

Opportunities/ Strengths	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
S1	1	0	0	0	0	0,2	1	0,2	2
S2	0	1	0	0	0	0,3	1	0,3	1
S3	0	0	0	0	1	0,1	1	0,1	3
S4	0	0	0	1	0	0,2	1	0,2	2
S5	0	0	1	0	0	0,2	1	0,2	2
Weight	0,2	0,3	0,2	0,1	0,2		5	1	
Number interactions	of 1	1	1	1	1		5		
Product	0,2	0,3	0,2	0,1	0,2			1	
Rank	2	1	2	3	2				
Sum of interactions							10		
Sum of products								2	

Tab. 64

Will the identified strengths overcome the threats?

Strengths/threats	S1	S2	S3	S4	S5	Weight	Number of interactions	Product	Rank
T1	0	0	0	0	0	0,1	0	0	
T2	0	0	0	0	0	0,3	0	0	
T3	0	0	0	0	0	0,3	0	0	
T4	0	0	0	0	0	0,1	0	0	
T5	0	0	0	0	0	0,2	0	0	
Weight	0,2	0,3	0,1	0,2	0,2		0	0	
Number interactions	of 0	0	0	0	0		0		
Product	0	0	0	0	0			0	
Rank									
Sum of interactions							0		
Sum of products								0	

Tab. 65

Do threats weaken the strengths?

Threats/ Strengths	T1	T2	T3	T4	T5	Weight	Number of interactions	Product	Rank
S1	0	1	0	0	0	0,2	1	0,2	1
S2	0	0	0	0	0	0,3	0	0	2
S3	0	0	0	0	0	0,1	0	0	2
S4	0	0	0	0	0	0,2	0	0	2
S5	0	0	0	0	0	0,2	0	0	2
Weight	0,1	0,3	0,3	0,1	0,2		1	0,2	
Number interactions	of 0	1	0	0	0		1		
Product	0	0,3	0	0	0			0,3	
Rank	2	1	2	2	2				
Sum of interactions							2		
Sum of products								0,5	

Tab. 66

Will the identified weaknesses prevent opportunities from being exploited?

Weaknesses/ Opportunities	W1	W2	W3	W4	W5	Weight	Number of interactions	Product	Rank
O1	0	0	0	0	0	0,2	0	0	2
O2	1	1	1	1	1	0,3	5	1,5	1
O3	0	0	0	0	0	0,2	0	0	2
O4	0	0	0	0	0	0,1	0	0	2
O5	0	0	0	0	0	0,2	0	0	2
Weight	0,2	0,3	0,2	0,1	0,2		5	1,5	
Number of interactions	1	1	1	1	1		5		
Product	0,2	0,3	0,2	0,1	0,2			1	
Rank	2	1	2	3	2				
Sum of interactions							10		
Sum of products								2,5	

Tab. 67

Will opportunities overcome the weaknesses?

Opportunities/Weaknesses	O1	O2	O3	O4	O5	Weight	Number of interactions	Product	Rank
W1	0	1	0	0	0	0,2	1	0,2	1
W2	0	0	0	0	0	0,3	0	0	2
W3	0	0	0	0	0	0,2	0	0	2
W4	0	0	0	0	0	0,1	0	0	2
W5	0	0	0	0	0	0,2	0	0	2
Weight	0,2	0,3	0,2	0,1	0,2		1	0,2	
Number of interactions	0	1	0	0	0		1		
Product	0	0,3	0	0	0			0,3	
Rank	2	1	2	2	2				
Sum of interactions							2		
Sum of products								0,5	

Tab. 68

Will the identified weaknesses strengthen the impact of the threats?

Weaknesses/threats	W1	W2	W3	W4	W5	Weight	Number of interactions	Product	Rank
T1	1	0	0	0	0	0,1	1	0,1	3
T2	0	1	0	0	0	0,3	1	0,3	1
T3	0	0	1	0	0	0,3	1	0,3	1
T4	0	0	0	1	0	0,1	1	0,1	3
T5	0	0	0	0	1	0,2	1	0,2	2
Weight	0,2	0,3	0,2	0,1	0,2		5	1	
Number of interactions	1	1	1	1	1		5		
Product	0,2	0,3	0,2	0,1	0,2			1	
Rank	2	1	2	3	2				
Sum of interactions							10		
Sum of products								2	

Tab. 69

Will threats exacerbate the weaknesses?

Weaknesses/threats	T1	T2	T3	T4	T5	Weight	Number of interactions	Product	Rank
W1	1	0	0	0	0	0,2	1	0,2	2
W2	0	1	0	0	0	0,3	1	0,3	1
W3	0	0	1	0	0	0,2	1	0,2	2
W4	0	0	0	1	0	0,1	1	0,1	3
W5	0	0	0	0	1	0,2	1	0,2	2
Weight	0,1	0,3	0,3	0,1	0,2		5	1	
Number of interactions	1	1	1	1	1		5		
Product	0,1	0,3	0,3	0,1	0,2			1	
Rank	3	1	1	3	2				
Sum of interactions							10		
Sum of products								2	

Tab. 70

Results.

COMBINATION	Results of the analysis SWOT		Results of the analysis TOWS		Summary overview	
	Sum of interactions	Sum of products	Sum of interactions	Sum of products	Sum of interactions	Sum of products
Strengths/Opportunities	12	2,4	10	2	22	4,4
Strengths/ Threats	0	0	2	0,5	2	0,5
Weaknesses/Opportunities	10	2,5	2	0,5	12	3
Weaknesses/ Threats	10	2	10	2	20	4

Tab. 71

Results.

	Opportunities	Threats
Strengths	Strengths enhance opportunities	Strengths do not eliminate risks
	Aggressive strategy	Conservative strategy
	22/4,4	2/0,5
Weaknesses	Weaknesses offset opportunities	Weaknesses exacerbate threats
	Competitive strategy	Defensive strategy
	12/3	20/4

CONCLUSIONS OF THE SWOT/TOWS ANALYSIS FOR THE DESIGN VARIANTS REVIEWED

The designs of the rescue device for the Argo profiling float described in publication [1], i.e.:

- Variant 1 (W1) - volume augmentation by means of piston displacement,
- Variant 2 (W2) - volume augmentation by means of filling the buoyancy bag,
- Variant 3 (W3) - volume increase by water circulation,
- Variant 4 (W4) - volume increase by means of filling the flexible hose,
- Variant 5 (W5) - weight change by discarding concrete ballast,
- Variant 6 (W6) - weight variation by discarding lead ballast, were subject to a multifaceted analysis (Fig. 1).

The panel of competent judges involved three designers with years of experience in the design of submersible equipment and two specialists with less experience or covering other areas of expertise, whose task was to generate difficult-to-predict or even surprising negative factors related to the functioning of the designed device. The competent judges, in the course of the SWOT/TOWS analysis, generated the strengths, weaknesses of the constructions analysed as well as opportunities and potential threats; and assigned them the corresponding weights. The results of these activities are presented in Tables: Tab. 6, Tab. 17, Tab. 28, Tab. 39, Tab. 50 and Tab. 61. Using these tables, the competent judges assessed the presence of interactions between the various factors, which was then the basis for performing the calculations according to the methodology presented in section 1. The results of the calculations are summarised in tables: for Variant 1 (W1) in Tab. 7 to Tab. 15; for Variant 2 (W2) in Tab. 18 to Tab. 26; for Variant 3 (W3) in Tab. 29 to Tab. 37; for Variant No. 4 (W4) in Tab. 40 to Tab. 48; for Variant No. 5 (W5) in Tab. 51 to Tab. 59; for Variant No. 6 (W6) in Tab. 62 to Tab. 70. The results of the SWOT/TOWS analysis for Variants W1; W2 and W4 (Tab. 16; Tab. 27 and Tab. 49 respectively) clearly demonstrate that in the case of these solutions, their weaknesses amplify the potential threats, while opportunities do not compensate for weaknesses. The sum of the interactions

of weaknesses and threats for these variants were: for W1 - 66.0; for W2 - 78.00; and for W4 - 46.00, respectively. In the case of variant W3, the results of the analysis show that, as for variants W1, W2 and W4, the weaknesses of the structure amplify the threats, but unlike in those variants, here the strengths of the structure can amplify the opportunities (Table 38). The SWOT/TOWS analysis of variants W5 and W6 clearly indicates that in their case the strengths reinforce their opportunities, while in both cases the weaknesses can amplify the threats (Tab. 60 and Tab. 71).

The results of the SWOT/TOWS analysis highlight that of the six preliminary design concepts analysed for the ARGO rescue device, those related to volume change may not guarantee the correct operation of the device being designed.

In the next research step, the optimisation of the designed device was carried out by means of a zero-unitisation analysis and the attractiveness of the *urządzenia* solutions, a description of which will be the subject of the next publication.

The development work described in this material is being carried out as part of the Argo Polska scientific consortium comprising the Institute of Oceanology Polish Academy of Sciences in Sopot, the Institute of Geophysics Polish Academy of Sciences in Warsaw

and the Polish Naval Academy in Gdynia (Department of Underwater Works Technology). At the same time, Argo-Poland is a member of the EURO-Argo ERIC European research infrastructure, being a component of the global world ocean observation network based on Argo autonomous floats. The task carried out by the

Department of Underwater Works Technology at the Polish Naval Academy in this project consists in the development of the design, construction and verification in laboratory conditions and real life rescue systems for Argo profiling floats.

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