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Quantitative approach to project portfolio management: proposal for Slovak companies

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Abstract

Research background: Project portfolio optimization isa demanding process in the case of considering a large number of project intentions and has so far been the subject of research by many authors, especially foreign authors. However, the issue of project portfolio optimization is an area that is not sufficiently addressed by Slovak authors. This was the main impulse to create a specific mathematical model of integer programming with bivalent variables to optimize the company's project portfolio with the intention to reflect the specific requirements of Slovak companies.
Purpose of the article: The aim of the article is to propose a mathematical model of integer programming with bivalent variables to optimize the project portfolio with a focus on Slovak companies.

Methods: In accordance with the aim of the article, a questionnaire survey was carried out with the intention of identifying the criteria that are perceived by the managers of Slovak companies as important in the optimization of the project portfolio. These criteria were subsequently reflected in the mathematical model design using the mathematical programming method.
Findings & Value added: Based on a literature review aimed at the project portfolio optimization, we have found a gap in considering the compliance of project intentions and strategic objectives of the company within the optimization of the project portfolio. Based on the results of the questionnaire survey, the significance of the mutual compliance of project intentions with the strategic objectives of the company was confirmed from the point of view of Slovak companies. Given the fact that our aim was to create an innovative integer programming model with bivalent variables orientated to the conditions of Slovak companies, we included in the resulting model the criteria that were not considered within the scope of existing research in this area, and which are perceived as important by the Slovak companies.

Introduction

Managers of the companies must choose the best solution for their future development in every situation (Kliestik *et al.*, 2015, p. 5716). Otherwise, it is not even in relation to ensuring the effectiveness of project portfolio management, where optimization of the project portfolio is of great importance. If the company proceeds to the optimization phase in the project portfolio management process, it has a large number of optimization models to choose from. Each optimization model has its specific characteristics, advantages, or disadvantages, so it is not possible to unequivocally say which one is the best and most suitable. Project portfolio managers choose an optimization model based on their requirements as well as a nature and specifics of specific projects (Miricǎ, 2018, pp. 129–135; Hraskova & Bartosova, 2014, pp. 92–96).

In the area of project portfolio management, it is possible to solve a number of optimization models, which are aimed at optimizing a certain state according to a given criterion while meeting the restrictive conditions. The basic task of project managers is then to allocate limited resources among individual projects in order to achieve the goals set and to ensure value for the company (Salaga *et al.*, 2015, pp. 484–489). When respecting the restrictive criteria, it is necessary to design a project (projects) that would, for example, minimize overall execution time or costs (Ciszewski & Nowakowski, 2018, pp. 30–43). Optimization models may relate to whole projects or parts of projects, or to a set of projects, whereby the objective of optimization may be to select the most appropriate projects to meet the criteria (Cooper *et al.*, 2000, pp. 18–33). It is necessary to pursue how individual combinations of projects affect the changes of given criteria and what value they bring to the company (Cyrus & Vogel, 2018, pp. 57–93).

The aim of the article is to propose a mathematical model of integer programming with bivalent variables to optimize the project portfolio so that the proposed mathematical model reflects the practice of Slovak companies. For the purpose of ensuring the consistency of our proposed mathematical model and practice of Slovak companies, we conducted a questionnaire survey in order to find out the criteria they consider important in assessing project intentions. To achieve the aim of the article, a mathematical programming method applied to the creation of an integer programming model with bivalent variables to optimize the company's project portfolio was used.

The literature review summarizes the results of existing research in the field of project portfolio optimization. Research methodology describes the methods used and the data base necessary to fulfil the aim of the article. The results include the design of a mathematical model of bivalent programming to optimize the company's project portfolio based on the results of a questionnaire survey. In the discussion, we demonstrate the functionality and applicability of the proposed mathematical model in the conditions of Slovak companies based on its application in the LINGO 17.0 software. In the conclusions, we formulate the options for future research in this area.

Literature review

Project portfolio management has become an important factor in the success of long-term company's strategies and is related to the role of top managers who need to validate relevant investments and formulate objectives (Alexandrova, 2018, pp. 96–105). Therefore, top managers need to find the optimal combination of projects that can bring them maximum value.

The issue of project portfolio optimization has so far been studied by many authors. Liu and Zhang (2019, pp. 282–293) proposed a genetic algorithm to optimize the project portfolio with a flexible time horizon while respecting decision criteria such as risk, project time constraint, and reinvestment strategy.

Xiao *et al*. (2018, pp. 1–17) have proposed an improved multi-objective evolutionary algorithm based on decomposition and reference difference to optimize a software project portfolio with optimizing 2, 3, 4 objectives.

Vacik *et al*. (2018, pp. 107–123) proposed a method supporting decision-making by SME´s managers in selecting a project portfolio by using stochastic optimization. In optimizing the project portfolio, they emphasized the consideration of constraints and strategic compliance. Based on a case study, the authors confirmed the effectiveness of the chosen methodology for project portfolio optimization, which significantly contributes to the fulfilment of strategic goals and thus to the increase of the company's performance and shareholder value.

Multi-criteria stochastic portfolio optimization has been addressed by Gupta *et al*. (2008, pp. 1734–1755) using mathematical fuzzy logic programming, Huang (2007, pp. 396–405), which has addressed the optimization of a portfolio with stochastic yields based on fuzzy information and Ballestero *et al*. (2007, pp. 1476–1487) dealing with optimization under strict uncertainty conditions. Multi-criteria stochastic programming for project selection in the portfolio was applied by Abdelaziz *et al*. (2007, pp. 1811–1823), and Hanafizadeh *et al*. (2011, pp. 661–669) have optimized investment in selected sectors of the national economy using scenarios and the multi-criteria evaluation method. The issue of stochastic project portfolio optimization was also addressed by Golosnoy and Okhrin (2008, pp. 718–734). However, the difficulty of respecting project risk while optimizing portfolios using the above approaches does not give hope for their wider application in practice. One method of stochastic optimization is linear programming, which generally represents a mathematical method of solving tasks that makes it easier for managers to make optimal decisions.

A specific method of linear programming is integer programming with bivalent variables. Bivalent variables are of great importance as they regularly occur in many model formulations, especially in issues related to long-term and costly strategic decisions related to capital investment planning. Such a demanding strategic decision is also a decision on the composition of the optimum project portfolio with limited company resource availability. The application of bivalent programming to optimize the project portfolio was discussed by Fotr *et al*. (2013, pp. 71–88), who optimized project portfolio under certainty, as well as stochastic optimization for project risk. They took into account also the constraints on project resources. Other authors who have devoted themselves to bivalent programming in their publications are Doerner *et al*. (2006, pp. 830–841) and Tahri (2015, pp. 339–347), who also considered resource constraints as well as project risk in optimization.

Research methodology

In order to create a mathematical model of bivalent programming to optimize the project portfolio, a questionnaire survey was conducted to reflect the practice of Slovak companies in the design of the mathematical model. The questionnaire was distributed electronically via e-mail from September

2018 to December 2018 and was distributed to 12,429 companies in total. We received responses from 384 companies. The aim of the questionnaire survey was to find out the criteria that managers of Slovak companies consider to be the most important in assessing project intentions in the framework of project portfolio optimization.

Based on the results of the questionnaire survey, we will create a mathematical model of bivalent programming to optimize the company's project portfolio. In the case of multi-criteria optimization of the project portfolio, a complex situation arises where several restrictive criteria are taken into account simultaneously. When designing a mathematical model, we will follow the steps recommended by Sakal and Jerz (2003, pp. 1–336):

- Clear and comprehensible definition of the model's activities, the resources that enter the activities and the outcomes of the activities.
- Expressing constraints by linear equations or inequalities, whereas on the right side there is a limited available amount of input coefficient or the required amount of the issuing coefficient. On the left side, the needed amount of input coefficient is.
- Expressing the criterion of optimality in the form of an objective function.

For the purpose of this article, we use the mathematical programming method, integer programming, which represents a solution of linear models in which all or some variables are limited to an integer. Then, the general wording of the integer programming task is as follows:

$$Max\ (Min) \rightarrow \sum_{j=1}^{n} c_j x_j$$

$$\textstyle\sum_{j=1}^{n} c_{ij} x_j \ \leq \ b_i \tag{1}$$

$$x_j \ \in Z;\ j = 1, 2, \dots, n.$$

Where the coefficients of the right-hand sides, coefficients of the function and also the elements of the constraint matrix are integer. Under these conditions, it is the "Pure" integer linear programming, where all variables are integers. If the integer value constraint would apply only to some variables, it would be a mixed integer programming task.

A specific task of integer programming is integer programming with binary variables, otherwise called bivalent programming, developed by Ghasemzadeh *et al*. (1999, pp. 745–755). The only difference from the general role of linear programming is the nature of variables. In the case of bivalent programming, variables can only take values of 0 or 1, which means that some investments will be realized, i.e. they will be worth 1, or will not be realized and will be worth 0.

By solving the bivalent programming model, we get such a selection of projects in a portfolio that maximizes the total value of the portfolio and it is possible to realize such a portfolio within specified limiting criteria. The condition for the bivalent programming model is also the additivity of the selected economic criterion in the objective function so that its value can be summed up through individual projects. Such a condition of additivity meets e.g. NPV, profit, as these are absolute indicators, the condition does not meet the relative indicators such as profitability index, internal rate of return, etc. (Fotr & Soucek, 2011, pp. 1–416). The general formulation of the bivalent programming task is as follows:

$$Max\ (Min) \rightarrow \sum_{j=1}^{n} c_j x_j$$

$$\textstyle\sum_{j=1}^{n} c_{ij} x_j \ \leq \ b_i \tag{2}$$

$$x_j = 0\ or\ 1;\ \ j = 1, 2, \dots, n.$$

By following the steps in the previous section, the procedure for creating a mathematical model of bivalent programming will have the following characteristics. In the case of project portfolio optimization, we will always assume a situation in which project managers, together with top managers, are considering a large number of project intentions. Each project intention is characterized from the point of view of its inputs, activities as well as outputs and other areas mentioned in the project intention proposal. The second step is to define the limiting criteria of the mathematical model. As mentioned above, we will be focused on the criteria that were evaluated by companies in the questionnaire survey. The criteria and their evaluation are shown in Table 1.

The restrictive criteria, together with the characteristics of the linear inequalities they will possess, will be as follows:

1. Budget – information on the amount of the necessary budget (or costs) for individual project intentions will be taken from the prepared project intentions. The budget of the individual project intentions will represent the left side of the inequality and the budget available will be part of the right side of inequality.

2. Human resources needed – information on the need for human resources for individual project intentions will also be taken from the drafted project intentions. The human resources needed to implement the individual project intentions will stand on the left side of the inequality and the available human resources will stand on the right side of the equation.

In addition to the aforementioned limiting criteria, which reflect the practice of Slovak enterprises, it is necessary to take into account the relationship between project intentions when optimizing the project portfolio. It is necessary to include in the restrictive criteria any of the relationships between project intentions that may arise:

1. Project intentions can be mutually supportive and, therefore, one project intent cannot be realized without the project intent of the other. In such a case, two situations may arise after the optimization of the project portfolio, either both project intentions will be implemented or no one.
2. Project intentions may be mutually exclusive, that is, there may be two situations, no project intent, or only one of the project intentions will be implemented.
3. Project intentions are independent, which means the realization of one project intent does not depend on the implementation of the second project intent. In such a case, there may be three situations where neither project intent will be implemented, only one of them will be implemented or both project intentions will be implemented.

The final step in creating a mathematical model of bivalent programming is to express the optimality criterion in the form of an objective function. One of the following three variants will be considered as the criterion of optimality:

1. NPV will be the net present value generated by all realized projects, with the aim of optimizing the project portfolio to maximize the net present value of the project portfolio.
2. Compliance with strategic objectives of the company, whereby the value of the compliance of individual project intentions with the strategic objectives of the company can be obtained by using the Hiller scoring model (see Hiller, 2002) (Table 2) and specifically based on the values of absolute strategic importance (ASB) of the individual project intentions. The aim of project portfolio optimization will then be to maximize the value of the absolute strategic importance of the project portfolio. As part of studying the literature aimed at optimizing the project portfolio, we have noticed that none of the authors considered the relationship between strategic objectives and project intentions in the context of optimization. It is, therefore, our aim to include this aspect in the optimization of the project portfolio and to monitor its significance in this pro-

cess. The importance of including this aspect in the optimization of the project portfolio is also confirmed by the resulting normalized weight of this criterion, calculated on the basis of the average values assigned to the criterion by the managers of the companies in the questionnaire survey.

3. Success – we get the value of success for individual project intentions by using the proposed fuzzy logic system (Valjaskova, 2019, pp. 121–130). The linear equation will include the success values of each project intent, and the aim of optimizing the project portfolio will be to maximize the success of the project portfolio.

We have given the characteristics of the mathematical model we have created, but we do not consider these characteristics to be fixed. This means that it is possible to implement optimization with various objective functions. Managers may first consider a purpose function that aims to maximize net present value. Subsequently, the absolute strategic importance of the project portfolio can be taken into account as the objective function and its goal will be to maximize it. Finally, they can implement an optimization with objective function aimed at maximizing the success of the project portfolio.

Results

The resulting mathematical model of bivalent programming to optimize the project portfolio will have, due to its above-mentioned characteristics, the following shape:

Variants of the objective function:

$$Max \rightarrow NPV = NPV_1x_1 + NPV_2x_2 + \cdots + NPV_nx_n$$

$$Max \rightarrow ASB_1x_1 + ASB_2x_2 + \cdots + ASB_nx_n = total\ strategic\ importance$$

$$Max \rightarrow U_1x_1 + U_2x_2 + \cdots + U_nx_n = total\ success\ of\ the\ project\ portfolio$$

For restrictive criteria:

$$R_1x_1 + R_2x_2 + \cdots + R_nx_n \leq available\ budget$$

$$Z_1x_1 + Z_2x_2 + \cdots + Z_nx_n \leq available\ human\ resources$$

$$x_j - x_i = 0 \rightarrow mutually\ supportive\ project\ intentions$$

$$x_j + x_i <= 1 \rightarrow mutually\ exclusive\ project\ intentions$$

$$x_j \geq x_i \rightarrow independent\ project\ intentions$$

$$x_j = 0\ or\ 1;\ j = 1, 2, \ldots, n.$$

Where:
x_j − project intentions,
NPV_j − net present value of project intentions,
ASB_j − absolute strategic importance of project intentions,
R_j − budget of project intentions,
Z_j − the need for human resources for project intentions,
U_j − success of project intentions.

In order to demonstrate the functionality and applicability of the mathematical model of bivalent programming designed by us to optimize the project portfolio, it is necessary to propose the possibility of solving the mathematical model.

Since we wanted to create an innovative method to optimize a project portfolio and the integer programming method with binary variables has already used for such problems, we tried to include in the optimization the criteria that are not considered in common practice and theory. These criteria are the strategic importance and success of project intentions. We have designed a mathematical model of bivalent programming and possibility to solve it by creating a modelling language in the software LINGO 17.0.

We decided to apply the proposed modelling language to a model example of project portfolio optimization. For the purpose of the model example, the modelling language will be modified accordingly. The same would apply to the use of a modelling language in the conditions of a particular company where the modelling language would also require adjustments to the actual starting point of the company. In the model example, we will consider twenty project intentions whose characteristics are shown in Table 3. The data in Table 3 does not represent real data, but it is just an example to present the behaviour of the model. We will progressively optimize the project portfolio always with a different objective function. First, we will optimize the project portfolio with the NPV optimality criterion, and the aim of the objective function will be to maximize it. The second criterion of optimality will be the strategic importance, and the aim of objective function will be to maximize it. The third criterion of optimality will be success, and the aim of the objective function will be to maximize it. In all three cases, we will consider restrictive criteria based on the limited availability of human resources to 312 workers and a limited budget of 500 000 €. We will also take into account the interrelationships between projects. The condition for optimization will be that project intentions 5 and 6 have the same purpose and are mutually exclusive, and the implementation of project intent 10 is a precondition for the implementation of project intent 11, i.e. these two project intentions are mutually supportive. Optimization results are shown in Table 4. The aim of the model example implementation is to critically evaluate the proposed modelling language and evaluate the significance of the individual optimality criteria in the optimization process.

In the case of the first optimization with a purposeful function to maximize net present value, the project intentions P1, P2, P4, P5, P7 – P11, P13, P15 – P18 and P20 will be included. Project intentions P3, P6, P12, P14 and P19 did not get into the portfolio. The resulting NPV value of the created project portfolio is 187 500 €, the strategic importance of the project portfolio is 2.214 and the total success rate is 694. Nearly all available human resources will be used for such a project portfolio structure, leaving only three free workers who can provide a reserve in case of unexpected situations in the implementation of the project portfolio. As for the final budget, 46 000 € would remain unused and could also be a reserve.

The results of the second optimization with the objective function of maximizing the strategic importance of the project portfolio show that the project portfolio includes project intentions P1, 3, PZ5, P7, P9 – P18 and P20. Project intentions P2, P4, P6, P8 and P19 were not included in the project portfolio. The resulting value of the strategic importance of the project portfolio is 2 712, which is an increase of 498 points compared to its value in the previous case. Maximizing strategic importance has resulted in a reduction in the NPV value, but on the other hand, the success of the project portfolio has increased by 98 points. Respecting ASB maximization will require 308 workers (four will be unused or will be a reserve) and a budget of 460 000 € (in this case, 40 000 € will remain free from the total budget available).

The resulting project portfolio, in the case of maximizing the success of the project portfolio within the third optimization, is composed of project intentions P1 – P3, P7, P8, P10 – P12, P14, P15, P17 – P20. Project intentions P4–P6, P9, P13 and P16 are not part of the project portfolio. The resulting project portfolio success rate is 961. However, maximizing the success of the project portfolio has led to the lowest NPV among all the optimizations made. On the other hand, the project portfolio thus created requires the use of all available human resources as well as the highest budget need among all optimizations. However, in the case of the budget, there will still be free funds available to create a reserve.

All three resulting project portfolios include project intentions P1, P7, P10, P11, P15, P17, P18 and P20. Project intentions P10 and P11 are included in all project portfolios due to their mutual relationship, as they are mutually supportive project intentions, which must be implemented both, or none of them. The project intention P6 was not included in the project portfolio in any case, which again results from the condition of its relationship with the project intention P5. These project intentions are mutually exclusive and therefore only one of them can be implemented or neither of them is included in the portfolio. The reason for selecting the project intention P5 in the first optimization results from NPV maximization, as the NPV of the project intention P5 is higher than the NPV of the project intention P6 and is also less demanding on both human and financial resources. As part of the third optimization, none of the mutually exclusive project intentions was included in the project portfolio due to the low value of their success, which is understandable given the goal of maximizing the overall success of the project portfolio. The project intention P2 was not included in the project portfolio in the second optimization, because of its low ASB value due to the objective function of maximizing strategic importance. The P3 project intent was not part of the project portfolio of first optimization due to the low NPV value and the high level of needed financial and human resources involved in the case of maximizing NPV. In the second and third optimizations, the project intention P4 did not get into the project portfolio because of its low success rate in the third optimization, and while the second optimization had a relatively high ASB value, it is very demanding on both human and financial resources. Project intentions P8, P9, P12 – P14 and P16 were not always included in only one project portfolio and it was always due to the low value of the optimality criterion of the selected objective functions. Finally, the project intention P19 was not part of the project portfolio of first and second optimization, mainly due to high resource demands.

We considered three approaches in the model example (maximizing NPV, maximizing ASB and maximizing success). The results of the different approaches are different values of NPV, ASB and success of the project portfolio. We decided to determine which approach should be chosen based on the results of the model example. We used the TOPSIS multi-criteria decision method. We decided between the above three approaches based on three criteria, namely NPV, ASB and success. Based on the final ranking, we consider the most appropriate use of the approach number three, which is aimed at maximizing the success of the project portfolio. The results of the TOPSIS method are shown in Table 5.

Discussion

In view of the above-mentioned comprehensive interpretation of the results of the individual optimizations, we can conclude that performing the optimization as well as the subsequent selection of the final project portfolio (after executing corrections by managers based on their experience or intuition) is a truly demanding and responsible process that without the use of analytical tools would be extremely difficult. That is why we consider the modelling language we have created to be an important tool that will greatly simplify the entire optimization process with a number of restrictive criteria. The difference between our proposed mathematical model and the models of other authors who have applied bivalent programming to optimize the project portfolio lies in the criteria that have been taken into account and in the perception of the same criterion, which is risk. While Fotr *et al*. (2013, pp. 71–88), Doerner *et al.* (2006, pp. 830–841) and Tahri (2015, pp. 339–347) respected the risk of project intentions expressed by the use of Monte Carlo simulation, we in our article take into account the risk expressed from the point of view of the success of project intentions based on fuzzy logic.

Conclusions

In the paper, we focused on filling the gap in the solution of project portfolio optimization by Slovak authors. We have provided a literature review focused on the issue, which was the basis for creating a mathematical model. In order to reflect the practice of Slovak companies, we conducted a questionnaire survey to identify the criteria relevant to the assessment of project intentions from the perspective of Slovak companies. Subsequently, we reflected the findings into a mathematical model of integer programming with bivalent variables to optimize the project portfolio of Slovak companies. An important benefit of our proposal is the inclusion of criteria that have not been used in the mathematical model of other authors so far and so our proposal offers new possibilities for project portfolio optimization.

Although we have created a mathematical model that is geared to the conditions and requirements of Slovak businesses, we consider it to be generally applicable to businesses from other countries where it is necessary to adapt it to the specific requirements of a particular company. The issue of project portfolio, its management and optimization still offers space for future research. Our future research in this area would be to focus on applying the mathematical model we have designed to the conditions of particular businesses in order to identify its further benefits or limitations. Due to the literature review, where foreign authors Liu and Zhang (2019, pp. 282–293) and Xiao *et al*. (2018, pp. 1–17) propose to optimize project portfolio through a modern tool such as genetic algorithms, the subject of future research could be to create a genetic algorithm to optimize the project portfolio, respecting the same constraints and the optimality criteria as is the case with our mathematical model.

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Annex

Table 1. Criteria for assessing project intentions and their normalized weights

Criteria	f_1	f_2	f_3	f_4	f_5	f_6	Sum
Average rating	4.26	4.17	3.87	3.73	3.63	3.37	**23.03**
Normalized weights	**0.185**	**0.181**	**0.168**	**0.162**	**0.158**	**0.146**	**1**

Table 2. Hillerov scoring model

Strategies		Weights	Research projects		Organizational projects		...
			Project1	**Project2**	**Project1**	**Project2**	**...**
R & D	Strategy1	1	++*		--		...
	Strategy2	4		+		++	...
	Strategy n	5					...
IT	Strategy1	3	-				...
	Strategy2	5					...
	Strategy n	2	+		-		...
...	...	...					...
	ASB						...
	RSB						...

Note: * ++ is 3, + is 1, - is -1 and – is -3

Source: Hiller (2002).

Table 3. Input data to LINGO 17.0.

	OBJECTIVE FUNCTIONS			CONSTRAINTS	
PROJECT INTENTIONS	**NPV**	**Risk**	**Strategic importance**	**Human resources**	**Budget**
P1	148	49	193	22	41
P2	63	54	28	19	31
P3	77	60	129	33	36
P4	125	9	120	31	49
P5	159	26	286	24	10
P6	126	28	91	25	14
P7	77	57	175	22	27
P8	84	80	48	21	21
P9	184	10	62	18	25

Table 3. Continued

	OBJECTIVE FUNCTIONS			CONSTRAINTS	
PROJECT INTENTIONS	**NPV**	**Risk**	**Strategic importance**	**Human resources**	**Budget**
P10	73	98	74	10	26
P11	82	59	294	33	23
P12	57	100	289	10	33
P13	123	4	77	11	29
P14	53	81	276	27	38
P15	74	91	93	19	32
P16	171	14	166	17	23
P17	163	61	147	18	43
P18	193	30	224	31	49
P19	75	89	59	34	41
P20	156	52	227	13	25
			Constraints	**312**	**500**

Table 4. Output data of optimization

Project intentions	Optimization 1 NPV	Optimization 2 ASB	Optimization 3 Success	Frequency of inclusion
P1	1	1	1	3
P2	1	0	1	2
P3	0	1	1	2
P4	1	0	0	1
P5	1	1	0	2
P6	0	0	0	0
P7	1	1	1	3
P8	1	0	1	2
P9	1	1	0	2
P10	1	1	1	3
P11	1	1	1	3
P12	0	1	1	2
P13	1	1	0	2
P14	0	1	1	2
P15	1	1	1	3
P16	1	1	0	2

Table 4. Continued

Project intentions	Optimization 1 NPV	Optimization 2 ASB	Optimization 3 Success	Frequency of inclusion
P17	1	1	1	3
P18	1	1	1	3
P19	0	0	1	1
P20	1	1	1	3
Resulting NPV	1875	1790	1375	
Resulting ASB	2214	2712	2256	
Resulting success	694	792	961	
Human resources	309	308	312	
Budget	454	460	466	

Table 5. TOPSIS to select the resulting approach of the optimization

The decision matrix			
	NPV	ASB	Success
Approach 1	1875	2214	694
Approach 2	1790	2712	792
Approach 3	1375	2256	961
The transposed matrix			
	NPV	ASB	Success
Approach 1	0	498	267
Approach 2	85	0	169
Approach 3	500	456	0
The normalized decision matrix			
	NPV	ASB	Success
Approach 1	0	0,737522876	0,844962095
Approach 2	0,167595494	0	0,534826195
Approach 3	0,985855847	0,675322151	0
Weights	0,343	0,412	0,245
The weighted normalized decision matrix			
	NPV	ASB	Success
Approach 1	0	0,303859425	0,207015713
Approach 2	0,057485254	0	0,131032418
Approach 3	0,338148555	0,278232726	0

Table 5. Continued

Final ranking			
	d+	d-	c
Approach 1	0,338148555	0,49953028	0,596326729
Approach 2	0,420566166	0,440505839	0,511578401
Approach 3	0,208595861	0,347743703	0,625056576