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IMPLEMENTATION MECHANISM FOR A SET OF SOCIAL PROJECTS IN A MINING REGION WITH REGARD TO RISK FACTORS: A CASE-STUDY OF THE TIKSI–NAIBA AGGLOMERATION

Introduction

In the first quarter of the 21st century, mineral mining advanced from the developed regions to the Arctic since new deposits of hydrocarbons are discovered and being operated ashore and on the shelf in this region (for example, coal—Syradasay deposit; oil and gas reservoirs—Paiyak and Vankor fields (Suzun, Tagul, Lodochnoe) in the Taimyr Dolgano–Nenets District, Vaneivis and Layavozh, Kumzha and Korovinskoe gas condensate reservoirs, reservoirs in the Bolshaya Kheta depression, and other; rare earth metals—Lovozero and Tomtor deposits in the Murmansk Region and in the Republic of Sakha (Yakutia)) [1].

On the whole, commercial-scale development in the Arctic enhances the regional budget revenues [2] and improves the life quality of the local population [3]. At the same time, geological exploration, development and operation of mineral deposits, construction of the required infrastructure and transportation system (oil and gas pipelines, railroad tracks for mineral shipping, new freight terminals at mouths of rivers or along the Arctic coastlines) affect the land where indigenous peoples carry out their traditional activities [4].

Such heavy impact strongly changes the customary mode of life and husbandry of indigenous peoples engaged in deer breeding, hunting and fishery for ages. In this connection, it is advisable to consider these changes in the context of harmonization of the relationship between subsoil users and local people in the course of development of natural resources in the Arctic Region [5, 6]. Alongside with that, there is a point on the assessment of contribution of implemented mineral mining projects in the socio-economic development of the Arctic areas, and on the social support of the local population.

Methods

Currently a certain amount of experience gained in the social support of the Arctic population has been accumulated in the form of environment- and people-targeted projects [7]. In this regard, it is required to ensure selection of the projects that are really essential for the indigenous peoples, and to perform evaluation of the relevance (priority ranking) of the projects, to schedule their implementation with respect to investment possibilities of mining and transportation companies, as well as to identify and prevent the negative effects which can impede the projects.

Figure 1 describes the sequence of project-related operations and prediction of negative effects on their implementation.

The first and the second stages involve the participatory methods based on the involvement of the local population [8, 9]. At these stages, a set of social projects, which the local communities demand and are interested in, is shaped. This will promote restoration of people's confidence in mining and transportation companies, and will ensure harmony in the development of the Arctic Region. The scope of the algorithm also

The article discusses the issue connected with the harmonization of concerns of the subsoil users and local people in the course of mineral mining in the Arctic. The Russian mining, processing and transportation companies engage themselves in dynamic development of the previously commercially unaddressed Arctic regions where new deposits of hydrocarbons and rare earth metals are discovered. Economic activity in underpopulated regions in the Arctic requires that the interests of the parties concerned are coordinated through implementation of socially-oriented projects for the indigenous peoples.

As a case-study of the Tiksi–Naiba agglomeration being developed as a logistics hub for transportation of minerals along the Northern Sea Route in the Arctic zone of Yakutia, an optimization model and an algorithm are proposed for compiling a set of social projects for the local population. The model includes the project scheduling with regard to their priorities, costs and implementation periods. The estimation mechanism is developed for the negative factors that affect the size of investment and the efficiency of projects.

It is proposed to recalculate the sequence of projects and to perform their integrated outcome evaluation using the index of the lost benefit of population. This index is meant for the ranking of negative factors in the risk rating matrix for the further efficient management of the project implementation. The proposed algorithms and procedures are aimed at the materialization of terms and conditions declared in the Concept of Sustainable Development for the Indigenous Small-Numbered Peoples of the North, Siberia and the Far East of the Russian Federation over the period to 2036, approved in 2025.

Keywords: Arctic regions, mineral mining, indigenous peoples, social projects, territorial development, risk factors, lost benefit of population, risk rating matrix

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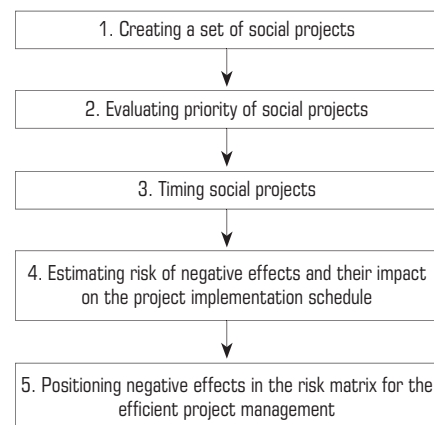


Fig. 1. Arrangement of project planning, evaluation and scheduling and risk analysis

includes a graded evaluation of priorities of compensatory projects for various population groups during commercial-scale development in the Arctic [10].

The initial set of social projects must be shaped at the level of interaction between the local authorities and mining companies and, then, it should be presented to the local people for discussion and adjustment of the list of projects.

At the second stage, it is necessary to evaluate priorities α_i of the selected social projects $i = 1, 2, \dots, n$. This stage involves survey of the population and further processing of the survey data using the methods of multicriteria ranking, for instance, the paired-comparison method or the hierarchy analysis method [11, 12]. The priorities range as $0 \leq \alpha_i \leq 1$ and are scored in points. Stages 3–5 in Fig. 1 required a comprehensive research, special model and algorithms of action, as well as a new estimated figure.

At the third stage, timing of implementation of social projects is carried out, which includes optimization economical–mathematical modeling to determine the project timelines with respect to the granted volume of investment by the criterion of minimization of total execution time of all projects. The formal criterion of optimality is written as:

$$\max_{i=1,2,\dots,n} \{T_i^e\} \rightarrow \min, \tag{1}$$

where T_i^e is the finish time of an i -th project ($i = 1, 2, \dots, n$).

The start and finish dates of projects obey a strict dependence:

$$T_i^e = T_i^b + t_i, \quad i = 1, 2, \dots, n, \tag{2}$$

where T_i^b is the intended start date of an i -th project; t_i is the preset implementation time of the i -th project, months.

The project implementation is possible subject to the condition that aggregate expenses connected with the project implementation at each time moment are never higher than the available investment amount B :

$$\sum_{i \in J_\tau} z_i \leq B, \quad \tau = 1, 2, \dots, \max_{i=1,2,\dots,n} \{T_i^o\}, \tag{3}$$

where J_τ is the set of projects implemented at the time moment τ , i.e. $J_\tau = \{i: T_i^b \leq \tau \leq T_i^e\}$; z_i is the preset value of expenses connected with the project implementation, MRub/month.

Model 1–3 belongs in the class of scheduling theory problems which are commonly solved using the heuristic methods, including the step-by-step method. This method has an important advantage over the other methods as it involves step selection of projects for scheduling by a preset criterion or a system of criteria. In the problem being solved, it is logical to use the project priority estimates α_i ($i = 1, 2, \dots, n$) and to select the projects which have the highest priorities for the scheduling. This will ensure implementation of the most demandable projects.

Results

The algorithm of the step-by-step project scheduling in the required project timing involves the following steps.

Step 1. Setting the current time moment $\tau = 1$.

Step 2. Selecting a project i^* with the highest priority among the projects remained out of scheduling and consideration.

Step 3. If the project is unpicked, transition to Step 5.

Step 4. If scheduling of the project i^* at the time τ never violates constraint 3, the project is incorporated in the schedule: $T_{i^*}^b = \tau$ and $T_{i^*}^e = T_{i^*}^b + t_{i^*}$; otherwise, the project i^* is entered in the list of the projects addressed.

Step 5. Check-up: are all projects included in the schedule? Yes—finish the calculations; no—transition to Step 6.

Step 6. Transition to a new time $\tau = \tau + 1$; adjustment of the list; transition to Step 2.

The resultant schedule and timelines of the projects are carried into effect in case of enlistment of highly skilled specialists, prompt moving of the required equipment and materials, favorable weather, preset amount of investment, as well as correct techno–economic assessment. Depending on negative events, the project implementation conditions may change, which violates the project scheduling.

At the presumptive investment size, as well as costs and timelines of project implementation, the project times found using model (1–3) are denoted as a reference variant: $T_i^{b(f)}$ and $T_i^{e(f)}$.

The fourth stage includes assessment of negative effects and their impact on the social project implementation, which assumes detection and analysis of factors that can have influence on the parameters of social projects and on the amount of investment. If we decrease the amount of investment, increase the project timelines, increase the project implementation cost, then the finish dates of the projects from optimization model (1–3) get rescheduled and the whole set of the selected social projects is implemented later than in the reference variant.

For the population, these adjustments will be higher with the later fulfillment of the highest-priority projects, which can be considered as the Lost Benefit (LB). LB is determined as a sum of the products of the project priority weight factors and the length of the project fulfillment delay. For writing the calculation formula of the lost benefit, we denote the related social project dates as $T_i^{b(e)}$ and $T_i^{e(e)}$. With regard to the adopted denotations, the lost benefit because of delayed implementation of social projects is found from the formula:

$$LB = \sum_{i=1}^n \alpha_i (T_i^{e(e)} - T_i^{e(f)})$$

Since the addressed variants assume worsening of project implementation conditions, then the project times obey the inequality: $T_i^{e(e)} \geq T_i^{e(f)}$. So, the value of the lost benefit from formula (4) is always non-negative.

The risk of project schedule variance is wise to determine as a product of a negative effect probability and a value of the lost benefit [13]. The negative effect risk assessment can use an expert approach, with verbal assessment of probabilities and their rating from 1 to 5 (Table 1).

Since methodical guidelines and instruction manuals propose to use probability ratings and negative aftereffect estimates, the risk assessment should use the risk rating (RR) as a product of scores of probability and consequences of a negative event, PQ and MQ , respectively: $RR = PQ \times MQ$.

In the set problem, the consequences of a negative effect are calculated using model (1–3) and the index of lost benefit (4). In this case, it is sufficient to evaluate the left boundary of the upper limit of the lost benefit, LB_5^{left} , equal to the right boundary of the fourth range $LB_4^{right} = LB_5^{left}$, and to divide this range to five intervals in accordance with the algorithm:

Step 1. Calculation of the range division interval, $dLB = 0,25 \times LB_5^{left}$.

Step 2. Setting of the left boundary of the first range, $LB_1^{left} = 0$.

Step 3. Determination of the right boundary of the first range, $LB_1^{right} = LB_1^{left} + dLB$.

Step 4. Determination of the left boundary of the second range, $LB_2^{left} = LB_1^{right}$.

Table 1. Scales of single negative event probability assessment

Verbal assessment of negative event	Interpretation	Score	Options of values of P, %	
			Uniform scale	Nonuniform scale
Very high probability	The event is very likely to occur	5	$P > 80$	$90 < P \leq 100$
High probability	The event is more likely to happen than not	4	$60 < P \leq 80$	$60 < P \leq 90$
Average probability	There is a 50–50 chance of the event	3	$40 < P \leq 60$	$40 < P \leq 60$
Low probability	The event is more unlikely to happen	2	$20 < P \leq 40$	$10 < P \leq 40$
Very low probability	The chances of the event are slim	1	$P < 20$	$0 < P \leq 10$

Developed by the authors on the basis of Risk Management Guideline / Approved by the PARTAD Committee for Internal Control, Inner Audit and Risk Management, Protocol No. 4/2018 dated December 12, 2018

Table 2. Transition from ranging to scoring of lost benefit

LB ranges	LB score
$LB_3^{left} \leq LB$	5
$LB_4^{left} \leq LB < LB_4^{right}$	4
$LB_3^{left} \leq LB < LB_3^{right}$	3
$LB_2^{left} \leq LB < LB_2^{right}$	2
$LB_1^{left} \leq LB < LB_1^{right}$	1

Step 5. Determination of the right boundary of the second range, $LB_2^{right} = LB_2^{left} + dLB$.

Step 6. Determination of the left boundary of the third range, $LB_3^{left} = LB_2^{right}$.

Step 7, determination of the right boundary of the third range, $LB_3^{right} = LB_3^{left} + dLB$.

Step 8. Determination of the left boundary of the fourth range, $LB_4^{left} = LB_3^{right}$.

After that, it is possible to score the consequences of negative events in points (Table 2).

From the scoring of a negative effect and the lost benefit, it is possible to build a risk rating matrix (Table 3).

Three zones of risk weight are identified in the risk rating matrix on the basis of the obtained values:

- from 1 to 4—moderate risk weight;
- from 5 to 9—high risk weight;
- from 10 to 25—critical risk weight.

When forecasting implementation of a set of social projects in the Arctic region, three factors are specified: F_1 —reduction of the amount of investment; F_2 —increase in the cost of project implementation; F_3 —extended term of project implementation. The influence of the factors may vary. For instance, the variant $F_{1,1}$ —reduction of the amount of investment by 5%; the variant $F_{1,2}$ —reduction of the amount of investment by 10%, etc. Each variant has a numerical score of the probable occurrence of the factor and of the lost benefit. The risk rating matrix allows estimating the factors with regard to their influence on the implementation efficiency of social projects and on the value of the lost benefit with a view to abating and eliminating adverse consequences.

Table 3. Risk rating matrix

Scoring of negative effect probability	Scoring of lost benefit				
	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Table 4. List of projects on the Tiksi–Naiba agglomeration within the 2030 Development Program of the Republic of Sakha (Yakutia) in the Arctic Zone

Project number and name	Priority, percentage	Base indicators	
		Implementation period, months	Implementation cost, MRub/month
1. Creation of broadband (internet) access for public and business	0.20	4	3
2. Construction of multifunctional public facilities	0.40	6	2
3. Health center construction and pharmacological support of population	0.10	5	1
4. Secondary vocational education and training of the regional youth	0.60	3	3
5. Construction of blocks of flats for early career professionals	0.70	6	1
6. Regular passenger transportation for local residents	0.30	5	2
7. Construction and reconstruction of central heating facilities	0.80	5	2
8. Introduction of online education for the youth in the region	0.90	3	3
9. Healthy life style in the Arctic	0.75	3	4
10. Short wave radio to cover the region	0.85	4	1
11. Artificial rehabilitation of water bioresources in the region	1.00	2	3

Surveys show that the Arctic population reckon among the acutest concerns such issues as insufficient medical service, slow internet connection, poor condition of available housing, high wear of engineering infrastructure, difficulties of shipment and public conveyance, lack of urban services, entangled procurement of traditional local trade products, etc. On the ground of information collected at the Planning Office for Sustainable Development in the Arctic Zone of the Republic of Sakha (Yakutia), and on the evidence of conversation with the local people, 11 socially-oriented projects were formulated and their priorities were

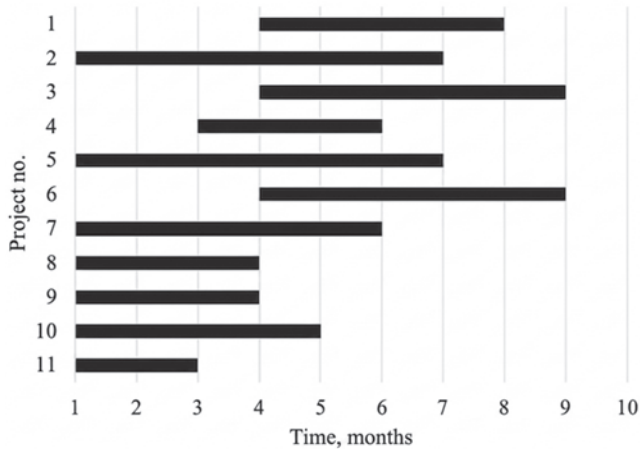


Fig. 2. Gantt chart of implementation of projects on the ground of base indicators

determined. These projects are connected with the development of the Tiksi–Naiba agglomeration as a sea port and a logistics hub to transport produced mineral resources along the Northern Sea Route (Table 4).

The base value of the monthly investment amount is 16 MRub. Using model 1–3, the proposed algorithm and calculations, the schedule of implementation of the projects was obtained in the form of the Gantt chart shown in Fig. 2.

Then, for each negative factor, the predictive analysis of the variants of the project schedules is carried out. Table 5 presents such analysis for the variant of a certain negative factor.

In the variant of the factor $F_{1,1}$, some projects shift along the timeline to the later terms as compared with the reference variant. As per Table 5, Project 2 is completed in the ninth month instead of the sixth month, and Project 3—in the ninth month instead of the eighth month. Projects 2 and 3 have the priorities of 0.4 and 0.1, respectively. Thus, the lost benefit can be found from formula (4): $0.4 \times (9 - 6) + 0.1 \times (9 - 8) = 1.3$ points. The experts estimated the limit lost benefit at the level of 20 points. Herefrom, we have the value of the interval $dLB = 0.25 \times 20 = 5$, which allows creating a scale for the transition of the calculated points to the rating of the lost benefit (Table 6).

The verbal expert estimates of the probability of negative factors to happen were converted to ratings (Table 7).

Based on the ratings of negative factors and lost benefits, the risk rating matrix is compiled, where the factor F_1 falls in different zones of

Table 5. Project term in the reference variant and in the variant of the negative factor $F_{1,1}$

Project no.	Project terms in the reference variant		Project terms in the variant of the negative factor $F_{1,1}$	
	$T_i^{b(t)}$	$T_i^{e(t)}$	$T_i^{b(e)}$	$T_i^{e(e)}$
1	4	7	4	7
2	1	6	4	9
3	4	8	5	9
4	3	5	3	5
5	1	6	1	6
6	4	8	4	8
7	1	5	1	5
8	1	3	1	3
9	1	3	1	3
10	1	4	1	4
11	1	2	1	2

Table 6. Scale for transition from calculated to rating value of lost benefit

LB ranges	LB rating
$20 \leq LB$	5
$15 \leq LB < 20$	4
$10 \leq LB < 15$	3
$5 \leq LB < 10$	2
$0 \leq LB < 5$	1

risk (Table 8): $F_{1,1}$, $F_{1,2}$ and $F_{1,3}$ —in the zone of moderate risk; $F_{1,4}$ —in the zone of high risk.

For the practical application of the matrix, it is proposed to use a chart where the number of the fragments agrees with the number of variants of a negative factor, and the length of a fragment for each variant of a factor conforms with its risk rating (Fig. 3).

It follows from Fig. 3 that three variants of the first factor are in the zone of moderate risk, and the last variant ($F_{1,4}$) is in the zone of high risk. Two variants of the factor F_3 are in the zones of high risk ($F_{3,2}$) and extreme risk ($F_{3,3}$). Furthermore, the overall risk rating of the factor F_3 (extension of the project implementation period) is the highest: $2 + 8 + 10 = 20$, which calls for the measures to be undertaken to extenuate this risk factor in the course of implementation of social projects.

Table 7. Estimates of variants of negative factors and lost benefits

Description	Variant of the factor F_1 (influence on investment amount)				Variant of the factor F_2 (influence on project implementation cost)			Variant of the factor F_3 (influence on project implementation period)		
	$F_{1,1}$	$F_{1,2}$	$F_{1,3}$	$F_{1,4}$	$F_{2,1}$	$F_{2,2}$	$F_{2,3}$	$F_{3,1}$	$F_{3,2}$	$F_{3,3}$
Verbal estimate of probability of event	Average probability	Very low probability	Very low probability	Average probability	Very low probability	Very low probability	Low probability	Very low probability	Low probability	Low probability
Rating of probability of event	3	1	1	3	1	1	2	1	2	2
Lost benefit, points	1.3	4.9	8.4	11.15	5.4	11.15	16.05	7.8	15.6	23.4
Rating of lost benefit	1	1	2	3	2	3	4	2	4	5

Table 8. Matrix of risk rating for factors under analysis

Rating of negative factor probability	Rating of lost benefit				
	1	2	3	4	5
5					
4					
3	F _{1,1}		F _{1,4}		
2				F _{2,3} ; F _{3,2}	F _{3,3}
1	F _{1,2}	F _{1,3} ; F _{2,1} ; F _{3,1}	F _{2,2}		

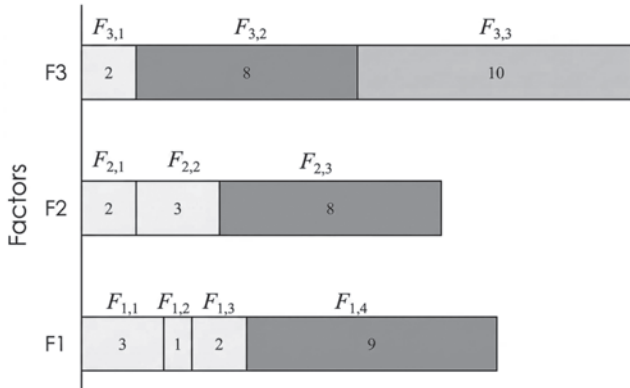


Fig. 3. Risk rating for variants of negative factors under analysis

Conclusions

The developed tool allows scheduling socially-oriented project with regard to their priorities and investment amounts, and also enables expert estimation of probabilities and risks of negative factors that can affect efficiency and cost of projects. For the integrated evaluation of the consequences of the changed project terms, it is proposed to use the authors' index of the population's lost benefit for the risk rating of each negative factor being analyzed.

The proposed model and algorithm of formulating and implementing a set of socially-projects during mineral mining in the Arctic offer a scientific tool for the harmonization of concerns of the subsoil users, authorities and local peoples. The calculation procedures described in the article are logically and informationally correlated; for their application, a software is designed in VBA in the Excel environment.

This approach can be used during implementation of the Concept of Sustainable Development for the Indigenous Small-Numbered Peoples of the North, Siberia and the Far East of the Russian Federation over the period to 2036, approved in 2025, including expansion of the Tiksi–Naiba agglomeration in the Russian Arctic.

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