Methodological support for the formation of socio-cultural projects in the area of responsibility of ferrous metallurgy companies

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Iron and steel enterprises are currently making great efforts to reduce the negative impact on the environment and implement important social projects in their areas of responsibility. To create an effective set of social and cultural projects, it is necessary to consider the priorities of different population groups and the availability of financial resources from the enterprise. The article presents an enlarged scheme of information and logical connections between the stages of forming socio-cultural projects developed by the authors, a mechanism for forming such projects based on assessing the priority of projects based on public opinion surveys and the authors' algorithm for processing them, a mathematical model for forming an optimal set of projects, and an iterative algorithm for determining the optimal amount of funding to assess public satisfaction with the selected projects. The scientific novelty is the multi-criteria model of forming an optimal set of projects, which ensures the same degree of satisfaction of the interests of all population groups. The approbation of the developed mechanism of forming projects using a specially developed software package demonstrates the efficiency of the proposed methodological support and allows us to reveal in detail all steps of forming socio-cultural projects on a numerical example.
Key words: project, population, algorithm, fuzzy assessments, optimality criteria, multi-criteria optimization, methodological support, optimization model.
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Introduction. Goal setting for the formation of socio-cultural projects

Iron and steel works play an important and key role in restoration and development of the other Russian industries – such as building, machine-building, hydrocarbon extraction etc. The feature of the overwhelming majority of such works is that they are monotown enterprises [1, 2]. For example, Cherepovets Steel Mill is located in Cherepovets, Oskol Electrometallurgical Plant in Stary Oskol, Novolipetsk Steel – in Lipetsk etc. Essential parts of inhabitants of these cities are employees of these works; working dynasties were formed there, because many of these plants were established during the first five-year industrial plans, i.e. in the beginning of 1930-ies. These metallurgical works not only provided different RF industries with their products, but also executed essential social functions for supporting urban residents (building and maintenance of health camps and resorts, stadiums, social centers, circles for children and youth etc.). At present time, this work is gradually restored: metallurgical works return to the practice of a social support of employees and their families, as well of all urban residents where a plant is located [3]. Such work is realized at present time by metallurgical works with use of the specially developed projects within the range of corporate social responsibility. Such social and cultural projects provide sustainable development of cities and regions in the areas of their responsibility both in Russia and other countries [4–6].

For example, social investments of "Severstal" corporation were 7.5 bln rub. in 2024, and there are plans to increase them by 25 % in 2025. Self projects were implemented within this program, as well as the corporation participated in co-financing of federal and regional projects in the educational area, as well in the fields of culture, sport, aimed support of selected groups of population etc. Together with the fund "Kindness of the North", it also realizes the projects for Cherepovets city development as well as more than 20 cultural projects. Only in 2023, more than 1.5 bln rub. were addressed for the projects on restoration of the historical buildings, the prospect and the city park. Many projects were initiated by local population within the ranges of the grant competition, what allowed selecting 16 projects for realization of financial support from "Severstal" corporation. 11 museums were also selected within the competition "Museums of the Russian North", they have got support for restoration, development of museum expositions and growth of attractiveness for tourists.

The company also participates in single events in the city, e.g. in annual action "Night in museum" was carried out with support of the fund "Kindness of the North" and "Severstal" corporation. It joined to the action of the People's front "Flame of the memory – 2025" and provided several large

events devoted to 80th anniversary of the Victory in the Great Patriotic war. VIII International competition "The northern rhapsody" of musicians with wind and percussion instruments in Cherepovets in April 2025 took place under sponsorship of "Severstal" corporation; more than two thousand musicians from five countries (including Belorussia, China, Kazakhstan etc.) participated in this event. Realization of the educational project named art laboratory "Ves", which examines Cherepovets urban medium, its culture, mentality, mythology, legends and natural medium of Vologda region, provided principally knowledge about regional history and love to the small motherland. Financial support of "Severstal" corporation ensures lectures, practical seminars, tours and researches within the range of this project.

Realization of many cultural projects allows not only to provide high cultural level of Cherepovets inhabitants and to ensure their leisure, but also to arise the interest in young generation for working in the iron and steel industry. For this purpose, the corporation leadership develops industrial tourism and within its framework it provides acquaintance with metallurgical history development in Vologda region and with technological stages directly in the metallurgical work's shops. Additionally, the corporation organizes the annual competition of creative projects "Steel style" for school pupils, where the youth develops own projects in the area of metallurgical production development. The new programs for students' training in the Advanced engineering school "Low-temperature solutions", as well as actualization of preparation programs for conventional directions "Technological machines and equipment", "Metallurgy" etc., were developed within the framework of joint work of "Severstal" and Cherepovets State University. It also allowed opening the new specialties, which are required for metallurgy [7].

As for environment protection, "Severstal" also realizes ecologically important projects and programs; this direction strengthens every year and the volume of investments made 3 bln rub. in 2024, what is larger by 51 % comparing with 2023. The brief review of the social and ecological activity of "Severstal" corporation displays importance of participation of metallurgical companies in the regions of their location.

To form social and cultural projects in the regions of location of metallurgical works, methodical guidelines are suggested, taking into account the following aspects:

- the interest to these projects from city inhabitants, based on their regular needs and prospective requirements;
- differentiation of projects priority for various population groups;
- forming the set of projects within the framework of investments addressed for realization of these projects;
- the same satisfaction degree for the requirements of various population groups with the formed set of projects.

Let's consider the stages of realizing the mechanism of forming social and cultural projects, taking into account the above-mentioned features.

The methods of forming social and cultural projects in the responsibility area of metallurgical companies

Forming of social and cultural projects is implemented by a regional administration with local population taking part in these projects, i.e the "participation" principle is realized. Regional administration establishes the center of regional social and cultural development (in the same way as it was created in Pereslavsky municipal district) in order to extract active population groups, discussing project variants, questionnaire surveying and finalizing of the results. The obtained projects, taking into account their priority, are financed by the companies operating in the examined region. Assessment of this priority on the base of questionnaire surveying of various population groups can be realized via well-known methods, such as hierarchy analytical method [8], method of pairwise comparison [9] etc. A verbal scale in these methods, which is used by the experts, is transformed in strictly quantitative assessments.

A. I. Posadky, T. V. Sivakova and V. A. Sudakov [10] noted that it is incorrect to consider the obtained answers as definite quantitative values for further processing within the framework of a verbal assessment; it is recommended to use fuzzy logic assessments, e.g. fuzzy triangular numbers. Comparison of transformation methods for the expert answers using preset balls and fuzzy figures was carried out by M. Freselam, A. M. Ainul and M. Masdi. Use of fuzzy quantitative values in transformation of verbal assessments is applied actively at present time; the algorithms for processing of the obtained information are developed on the base of hierarchy analytical method (HAM), more simple method of pairwise comparison and other known approaches. The algorithms suggested by I. Z. Mukhametzyanov [11], Huan Liu [12], V. S. Artamonov, A. Yu. Labinsky and O. V. Utkin [13] were built on the way of replacing HAM in matrixes by triangular figures; they use fuzzy values based on the Gauss curve. At the same time, Serkan Akbaş and Türkan Erbay Dalkılıç used fuzzy trapezoid figures for priority assessing and selection of projects.

Thereby the authors used transition of expert verbal assessments ikn fuzzy quantitative values in solving practical tasks of projects priority; in this case, HAM, method of pairwise comparison [14, 15] or simple averaging of the respondents' results were used depending on situation. In the concrete case, when choosing social and cultural projects for realization in the next year, the population groups should be placed at the first hierarchy place and the projects themselves at the second place. However, various population groups are identified a priori with the same weights, so building the hierarchy structure is inexpedient. That's why it will be correct in the examined situation to use the method of pairwise comparison or simple calculation of mean arithmetic values for the obtained fuzzy priority assessments.

Social and cultural projects are short-term ones, they are implemented during a year. Thus, when choosing these projects from a total list, it is inexpedient to present them in the form of a net graph and fix separate operations within such projects to a time scale. Economical and mathematical

models of optimal choices for these projects are rather various: they differ with restrictions for financing from different sources, with used optimum criteria with links between parts of projects [16, 17] and with other conditions. All these models unite the required variables, which are Boolean ones: they are equal to "one" when a project is planned for implementation and equal to "zero" in the opposite case. So, all these models are related to tasks of mathematical programming with Boolean variables.

The stages of forming social and cultural projects in the responsibility area of metallurgical companies

To form an optimal set of social and cultural projects, it is necessary to envisage expert procedures, algorithmic selection of projects and to leave the right of final decision to representatives of the interested participants (urban inhabitants and municipal administration etc.). The process of forming an optimal set of projects can be presented as six stages which are mutually connected in logical and information mode.

Stage 1. Assessment of projects priority. When forming social and cultural projects, it is extremely important to provide their joint expertise by the active part of urban inhabitants with participation of city administration, specialists in the field of history and architecture, representatives of education and outreach organizations. This stage is characterized by use of accumulated set of the projects which are not realized yet, as well as by development of the new prospective projects. An expert assessment provides complex evaluation of their priority. To calculate priority of the projects, the respondents of each group (youth, people of average age, retired persons etc.) assess verbally each project according to the five-point scale. Five variants of verbal assessments are presented in the first column of the **Table 1**. If the respondent doubts among two assessments, he can choose two adjacent variants, e.g. "Low attractiveness" or "Average attractiveness". For further processing, verbal assessments are transformed into quantitative ones within the range from $s^{\min}$ to $s^{\max}$, with intermediate value s^{av}. Transition of not only five verbal assessments, but also intermediate assessments (which are used in the case of doubt of a respondent) into quantitative ones is presented in the Table 1.

Table 1. The scale for transition of verbal expert assessments into quantitative assessments of projects attractiveness

Variants of assessment of projects attractiveness	Quantitative assessment in the form of fuzzy triangular figures		
	$s^{\min}$	s^{av}	$s^{\max}$
1. Very low attractiveness	0.000	0.100	0.200
Intermediate assessment	0.100	0.200	0.285
2. Low attractiveness	0.200	0.285	0.370
Intermediate assessment	0.285	0.370	0.505
3. Average attractiveness	0.370	0.505	0.640
Intermediate assessment	0.505	0.640	0.720
4. High attractiveness	0.640	0.720	0.800
Intermediate assessment	0.720	0.800	0.900
5. Very high attractiveness	0.800	0.900	1.000

The quantitative assessment is given in the form of fuzzy triangular figures with boundaries ($s^{\min}$ and $s^{\max}$) corresponding to a membership degree or confidence degree M (s) equal to "zero", while the intermediate value is equal to "one" [18]. All quantitative assessments from the Table 1 are also reflected in the **Fig. 1**. The number in the circle for fuzzy triangular figures is shown by full line and corresponds to the variant of attractiveness assessment from the Table 1; the dotted lines display fuzzy triangular figures corresponding to the intermediate variants of attractiveness assessment.

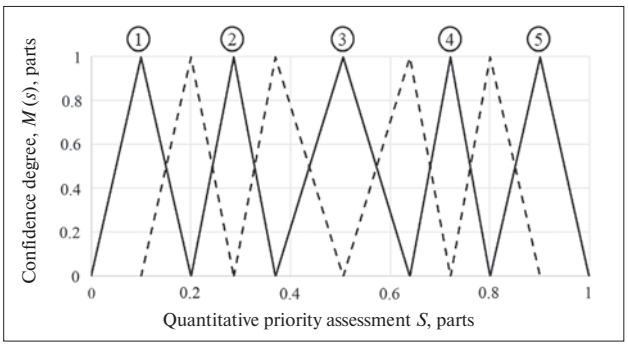

Fig. 1. Graphic reflection of fuzzy triangular figures, used in quantification of verbal assessments of respondents

Priority assessments of the project in the form of a fuzzy triangular figure $\left(a_{ig}^{\min}, a_{ig}^{av}, a_{ig}^{\max}\right)$ within the range $i = 1, 2, \ldots n$, according to the each group of respondents g ($g = 1, 2, \ldots G$) was determined via the formula:

$$a_{ig}^{\min} = \frac{\sum_{j=1}^{V_g} s_{ijg}^{\min}}{V_g},\ a_{ig}^{av} = \frac{\sum_{j=1}^{V_g} s_{ijg}^{av}}{V_g},\ a_{ig}^{\max} = \frac{\sum_{j=1}^{V_g} s_{ijg}^{\max}}{V_g},\ i = 1, 2, \ldots n \quad (1)$$

where Vg – is a number of respondents in the group g.

Stage 2. Assessment of expenses for realization of projects. The technical and economical substantiation was carried out for each of the analyzed projects; it allows determining the expenses for their realization z_i, features of this process, required scope of the works and their duration as well as the required resources.

Stage 3. Forming the model for optimal selection of projects. The expenses for selected projects should not exceed the volume of investments addressed by a city-forming enterprise (individually of together with a regional budget). This model uses the desired variables x_i which are indicators of selecting the projects. These variables can be equal to two values: "one" when a project i is planned for implementation and equal to "zero" in the opposite case. To provide more suitable model building and consequent calculations, it is expedient to replace priorities of the projects, which were obtained during the stage 1 and which are assessed via fuzzy triangular figures $\left(a_{ig}^{\min}, a_{ig}^{av}, a_{ig}^{\max}\right)$, by the values P_{ig} using the formula

$$P_{ig} = 0.25\left(a_{ig}^{\min} + 2a_{ig}^{av} + a_{ig}^{\max}\right) \quad (2)$$

Then the sum of priorities for the selected projects of the group g of city population will be equal to $\sum_{i=1}^{n} P_{ig} x_i$.

In order to find maximal possible satisfaction of the interests of the group g of city population, it is necessary to conduct local optimization – selection of the projects with maximizing of satisfaction of the interests for the considered population group $g = 1, 2, \ldots G$.

$$f_g(x) = \sum_{i=1}^{n} P_{ig} x_i \to \max \quad (3)$$

The ultimate volume of investment B for these projects should be taken into account as a restriction factor:

$$\sum_{i=1}^{n} z_i x_i \le B \quad (4)$$

The restriction in the area of varying the desired variables can be formulated as follows:

$$x_i = 1 \vee 0, \quad i = 1, 2, \ldots n \quad (5)$$

The obtained model is classified as the linear programming model with Boolean variables [19]. The wide spectrum of algorithms was developed to solve this model, including the method of fall-down vector. Lemke and Spilberg method, annealing method, random search method etc. As a result of solving the tasks according to the equations (3)–(5), the set of the projects will be found for the each population group, with the maximal satisfaction degree of its interest $f_g^{\max}$, $g = 1, 2, \ldots G$ achieved. These variants of selected projects meet the requirements of city population group interests, because the optimum criterion is present for each group, while the interests of other groups are not taken into account in this case. Such variants are named as local optimization, because selection of the projects is realized on the base of interests of only one population group.

Stage 4. Search of the fair compromise during selection of projects. It is possible to determine deviation from the optimal value $f_g^{\max}$ during selection of the variants for the projects $f_g(x)$ for each population group $g = 1, 2, \ldots G$; this deviation was determined via local optimization according to the following expression

$$\Delta_g = \frac{f_g^{\max} - f_g(x)}{f_g^{\max}} \quad (6)$$

The fair compromise by Pareto was accepted in the form of such solution when achievement of equal deviations from the best local values Δ_g for at least two population groups g' and g'' $\Delta_{g'} = \Delta_{g''}$, i.e. will be provided as a result of minimizing of the values (6). All other population groups will correspond to the conditions $\Delta_{g'} \le \Delta_g$ for $g = 1, 2 \ldots G \wedge g \ne g' \wedge g \ne g''$. Selection of such set of social and cultural projects is recognized as a fair compromise for satisfaction of preference for each population group [20, 21]. When searching such set of projects, the model using minimax Chebyshev criterion of the fair compromise should be formed:

$$\max_{g=1,2,\ldots G} \left\{ \frac{f_g^{\max} - \sum_{i=1}^{n} P_{ig} x_i}{f_g^{\max}} \right\} \to \min \quad (7)$$

Model restrictions remain the same – see the expressions (4), (5). This model (4), (5), (7) is characterized by the minimax criterion, preventing use of the mathematical programming methods with Boolean variables. Thus, using Germeier transformation, we can replace the criterion (7) on the equivalent record – maximizing of α parameter (8) with the condition (9):

$$\alpha \to \min \quad (8)$$

$$\alpha \ge \frac{f_g^{\max} - \sum_{i=1}^{n} P_{ig} x_i}{f_g^{\max}} \quad (9)$$

The obtained model (4), (5), (8), (9) is a task of mathematical programming for multi-criteria optimization. To search the solution of this task, we can use the annealing method, the method of random search [22–24] etc.

Stage 5. Optimal selection of projects when varying investing volumes. As soon as we need to provide a balance between satisfaction of preferences of the population groups and financing volumes, it is expedient to implement several variants of selection of projects when varying investing volumes. These variants restrict selection of projects within the restriction framework (4), what will lead to different satisfaction degree of urban population. As soon as the task of multi-criteria optimization (8), (9), (4), (5) will be solved for various B values, all variants of solution will be found in the Pareto area and will satisfy to fair compromise of achieving the interests for different urban population groups.

Stage 6. Final selection of projects. The conducted calculations present the base for acceptance of the final variant of projects to be realized during the joint meeting, where experts and investors (including representatives of monotown enterprises) will participate.

The stages and presented calculation schemes are connected in logic and information ways. The stage 1 does not require any explanations with numeric examples because it is characterized by transparency and simplicity of the presented formulas. The stage 2 is the information one, it allows to accumulate the required data for execution of consequent calculations. The final stage 6 consists of conducting the meeting where calculations made at the previous stages as well as non-formalized criteria of selection of projects are taken into account. The most complicated stages 3–5 include solving the optimization problems of selection of projects on the base of local and multi-criteria optimization, it is expedient to consider them with numeric examples.

The example of forming the variants for selection of social and cultural projects based on the fair compromise principle

Let's consider forming of optimal set of social and cultural projects in Cherepovets with use of the developed model (8), (9), (4), (5) as the example. This model takes into account the interests of three population groups – youth, people of average age and retired persons.

Local optimization is carried out at the stage 3, i.e. solving of the task (3)–(5) via criterion of maximizing total priority for each population group:

- for the first group «Youth» via the criterion $f_1(x^{(1)}) \rightarrow \max$;
- for the second group «People of average age» via thecriterion $f_2(x^{(2)}) \rightarrow \max$;
- for the third group «Retired persons» via the criterion $f_3(x^{(3)}) \rightarrow \max$.

Calculations for this model for investing volumes 350, 450 and 550 mln. rubles are presented in the **Table 2**. It includes the values of criteria for the found optimal variant for selection of social and cultural projects, e.g. for selection of the projects based on the total priority maximizing criterion, taking into account youth interests (4.08). Other criteria are equal to 2.82 for people of average age and 4.10 for retired persons. Optimal values of total priority for each population group are underlined by bold font in the Table 2.

The adjacent column in this table includes deviation values from the best values according to the formula (6). These values $\Delta_g = \frac{4.08 - 4.08}{4.08} = 0.00$ made for youth and $\Delta_g = \frac{4.89 - 2.82}{4.89} = 0.42$ for people of average age.

It should be mentioned that increase of investing volumes for realization of social and cultural projects leads to rise of total priority values for all population groups. However, essential differences in achieving the best criteria values for urban population groups are seen in the presented calculations. For example, when financing at the level 350 mln. rubles, youth interests are realized at the maximal possible level (4.08), see the Table 2, and deviation from this value is equal to zero, while deviation from the maximal possible level makes 0.42 (42 %) and 0.22 (22 %) for people of average age and retired persons respectively.

It stipulates expedience of searching a fair compromise between population groups. Such compromise variants, obtained via solution of the tasks (8), (9), (4), (5), are presented in the **Table 3** for various investing volumes. For example, when investing volume for social and cultural projects is equal to 350 mln. rubles, the compromise plan was obtained, where deviation of total priorities for revealed sets of projects from the best values were equal for youth and people of average age (0.09), while for retired persons they are principally smaller (0.06).

It is suggested to discuss the revealed compromised variants during the meeting with participation of administration, representatives of population groups and the enterprise in order to form the final set of the social and cultural projects, based on the agreed variant of their investing volume.

Table 2. The results of local optimization in selection of social and cultural projects for various investing volumes *B*

B, mln. rubles	Urban population group g	Calculation results according to the criteria					
		$f_1(x^{(1)}) \rightarrow \max$		$f_2(x^{(2)}) \rightarrow \max$		$f_3(x^{(3)}) \rightarrow \max$	
		$f_g(x^{(1)})$	$\Delta_g(x^{(1)})$	$f_g(x^{(2)})$	$\Delta_g(x^{(2)})$	$f_g(x^{(3)})$	$\Delta_g(x^{(3)})$
350	Youth $g = 1$	**4.08**	**0.00**	2.94	0.28	3.68	0.10
	People of average age $g = 2$	2.82	0.42	**4.89**	**0.00**	3.97	0.19
	Retired persons $g = 3$	4.10	0.22	4.29	0.19	**5.27**	**0.00**
450	Youth $g = 1$	**4.87**	**0.00**	3.58	0.27	4.16	0.15
	People of average age $g = 2$	3.85	0.35	**5.95**	**0.00**	5.19	0.13
	Retired persons $g = 3$	4.63	0.21	5.31	0.09	**5.85**	**0.00**
550	Youth $g = 1$	**5.79**	**0.00**	4.79	0.15	4.89	0.12
	People of average age $g = 2$	5.25	0.18	**6.95**	**0.00**	5.80	0.10
	Retired persons $g = 3$	5.91	0.04	5.98	0.02	**6.52**	**0.00**

Table 3. The result of multi-criteria optimization with different investing values for social and cultural projects

Calculation variants with investing volume *B*, mln. rubles	Indicators	Compromised calculation results		
		Youth $g = 1$	People of average age $g = 2$	Retired persons $g = 3$
350	$f_g(x)$	3.69	4.58	4.81
	$\Delta_g(x)$	0.09	0.06	0.09
450	$f_g(x)$	4.39	5.36	5.78
	$\Delta_g(x)$	0.1	0.1	0.02
550	$f_g(x)$	5.22	5.32	6.08
	$\Delta_g(x)$	0.08	0.08	0.07

Conclusion

Separate components of the described methodical provision were practically used for the procedure of assessing priority and forming methods of the optimal set of social and cultural projects (at the enterprises of "Anabar Diamonds", the placer mine on Malaya Konamka river in Olenek national Evenki district, Yakutia) and for analysis of the social and cultural projects in the region of responsibility of Tomtor rare metal deposit (developed by PJSC "Rosneft") etc. These economical and mathematical tools were based on the results of practical application and were improved permanently. Multi-criteria optimization, allowing to find the compromise solution by Pareto method and to provide equal satisfaction degree of preferences for all population groups, was the principal feature of the presented model for the set of social and cultural projects. Additionally, conduction of multi-variant optimizing calculations for various financing volumes is suggested, what makes it possible to analyze these calculation results and to find a suitable variant during a meeting with participation of administration, representatives of population groups and the enterprise. The described procedure of forming the social and cultural projects is recommended for practical use in all regions of responsibility of metallurgical works. Wide participation of representatives of population groups in the process of assessment and selection of social and cultural projects ensures a reliable assessment of relevant demand for these projects, while use of optimizing methods for selection of the projects of the base of fair compromise provides an adequate comprehension of obtained results by all urban population groups. To realize the described process of solution taking, the authorized software complex in VBA-Excel medium was developed.

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