Considering investment risk in the mechanism for selecting mining-metallurgical waste refining investment projects

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Abstract

One of the most actual investment problems is the problem of ferrous and non-ferrous metallurgy waste refining. But existing investment attractiveness appraising methods have several vital drawbacks, not allowing to perform an effective selection of investment projects, considering specifics of mining-metallurgical waste refining. To overcome these drawbacks the developed approach includes modified criterions choice for projects estimation and created mechanism for investment projects selection.

The criterion set has included either quantitative or qualitative criterions and has been formed the way, allowing to consider non-systematic part of investment risk. Besides, the future investment projects competitiveness determination is fulfilled in the selection mechanism to allow considering market conjuncture changes during projects realization period as systematic part of investment risk. The assignment of preferences and user preferences structure construction, which finalize the selection mechanism, are based on the feasible goals theory to decrease the amount of information, required from a decision-maker, and to accelerate and ease the most effective projects distinguishing process on account of using criterions tradeoff curves graphic visualization.

The multicriteria investment projects estimation model, based on the selection mechanism created, has been realized in Microsoft Visual Studio 6 environment. This model allows to perform the optimal investment projects selection for financing and to decrease considerably the subjectivity of a projects assessment process. Due to this the investment risk is considered in the conditions of uncertainty of a decision making by mining-metallurgical waste refining investment projects.
1 Introduction

The problem of mining-metallurgical enterprises waste’ refining is one of the most actual investment problems by a number of reasons, main of which are:

- reducing a raw price on account of decreasing a first cost of its obtaining in comparison with mineral raw production and transport expenses;
- natural resources economy on account of maximum involvement of waste into the economic turnover;
- environment sanitation.

The object program “Waste” of Russian Federation government has been being realized since 1996 for stimulating of waste refining. This federal program envisages selecting investment projects of enterprises, domesticating waste refinery technologies, giving loans under low rates to these projects and managing selected investment projects.

For effective projects’ selection and management two things are needed. First, a criterion set, considering individual preferences of all program “Waste” investors and maximally formalizing main uncertainties of waste refining investment process. Second, a projects selection mechanism, taking into account the environment specific. However, existing investment attractiveness appraising methods have a number of vital drawbacks (using the restrained array of significant criterions at an estimation, incorrect working with qualitative criterions, the absence of future conjuncture possible changes considering, etc.), which do not allow to perform an effective selection of mining-metallurgical complex waste refining investment projects.

The new mechanism of investment projects estimation and selection has been developed at MSMU, which eliminates the drawbacks of existing methods and includes the following steps:

1) criterions values non-inconsistency verification;
2) precursory estimation of investment projects’ acceptability;
3) digitalization of qualitative criterions values;
4) criterions values normalization and generalization into aspects;
5) forecasting a future competitiveness of investment projects;
6) filtration of investment projects (IP);
7) assignment of preferences and user preferences structure construction.

2 Forming the criterion set for a projects estimation

Criterion arrays of main existing methods had been taken as the basis at forming the set of criterions. Further, the criterion set had been supplemented by new criterions, determined by the specifics of investing to the program “Waste”. The received set consists of 77 qualitative and quantitative criterions.

It follows up from the accomplished analysis of an uncertainty, inherent to the decision making process at waste refining investment, that investment risk is the most significant component of an uncertainty as the most probable factor of an initial capital investment loss.
The analysis of different risk appraising techniques had shown that risk includes most non-formalized components, like political, natural (so-called unforeseen circumstances), etc. Similar factors practically do not yield to assessment and forecast, with the exception of probability techniques (e.g. Monte-Carlo technique) recruiting a number of experts. However, a usage of expert appraisals makes this means of risk estimation very subjective, inaccurate and irrational. Therefore, at estimating and selecting IP it is suggested to limit by considering only financial parts of investment risk by dint of criterions, used for a waste refining projects estimation.

For this purpose the investment risk classification, suggested in [1], has been used. According to this classification risk is divided into two groups: systematic and non-systematic risk.

![Diagram: Investment risks]

- **Non-systematic risks**
  - (financial risk, relation of own and loan resources, risk of financial liabilities non-compliance)

- **Systematic risks**
  - (peculiar for all IP and defined by possible changes of market situation)

Figure 1: Financial components of investment risk.

The conclusion can be made from the shown classification, that non-systematic risks are considered completely enough by financial criterions of an organization, realizing an IP (coefficients of workability, business activity, financial stability and liquidity) and also by a number of other criterions, included into the set formed, such as budget guarantee of investment risks to project participants and criterions of IP financial condition.

For considering the systematic part of investment risk it is necessary to add the new criterion to the criterion set for the method being developed – future competitiveness of IP, which depends directly upon possible fluctuations of the market conjuncture.

Market conjuncture of a raw, which can be substituted by an IP product, is one of the factors, influencing on a competitiveness of waste refining IP, but not depending on IP itself. This indicator influences directly on a projects effectiveness, having the property to change it suddenly and substantially. Existing investment attractiveness appraising methods take into account only a current situation in a branch, not fulfilling a precise forecast of a future situation and trends at the corresponding production market. Notwithstanding, if a market
conjuncture worsen in the perspective, it will be able to worsen considerably
future competitiveness of IP, for instance, on account of decreasing in future a
realization price of a product, production of which is envisaged by an IP. In this
case a project, estimated as perspective earlier, further loses it’s attractiveness.

The analysis of the program “Waste” specifics brings out that a price of a
corresponding resource, substitutes by a project product, influences on a future
income from an IP most of all. It takes place because enterprises, realizing
projects, utilize its products as their own raw in the most IP of the program
“Waste”. Thus, it is suggested in the method being developed to use a relative
average world price variation for an appropriate resource, calculated by eqn (1),
as the criterion “future competitiveness of IP”:

\[
\Delta P = \frac{P_2 - P_1}{P_2} \times 100,
\]

where \( \Delta P \) – relative variation of resource average world price;

\( P_1 \) – resource average world price for beginning of IP realization;

\( P_2 \) – resource average world price for end of IP realization.

The average world price is used at calculation of future competitiveness of
waste refining IP by two reasons:
• prices of the Russian raw market have been aligned with prices of the world
  raw market;
• any changes at the world market are reflected immediately on indexes of the
  Russian market.

So, after forming the criterion set it is necessary to solve the task of waste
refining projects selection taking into account all properties and restrictions of
the program “Waste”.

3 General setting of the selection task

Let us study the finite array of IP \( X = x_1, x_2, \ldots, x_N \). Each project \( x_i \) is
characterized by the set of criteria appraisals \( F_i = f_1, f_2, \ldots, f_C \), and besides, a part
of appraisals from the array \( F_i \) are qualitative. Let the initial projects array \( X \)
be provided for the estimation to a number of investors, each of them—is
characterized by the typical set of preferences \( R_i \), where \( i = 1, T, T - \) the number
of investors. \( V \) – the overall amount of investment resources, intended for
financing projects from the array \( X \).

The selection task consists in an array \( X \) dividing by 4 sub-arrays. The sub-
array \( X_1^* \) must include the most effective and, appropriately, the least risky
projects alternatives, besides, an amount of a loan capital for its realization
should not exceed \( V \), the sub-array \( X_2^* \) – average projects, \( X_3^* \) – projects on the
effectiveness margin, \( X_4^* \) – unacceptable projects.

Formally, the task, being solved by the developed selection mechanism, can
be represented as:

\[
<X, F, R, V> \rightarrow X_1^*, X_2^*, X_3^*, X_4^* \subseteq X, \sum_{x \in X_1^*} f_V(x_i) \leq V,
\]
where $f_i(x_i)$ – required amount of loan investment resources for financing projects $x_i \in X_1$.

As far as direct solving of this task is not effective considering its properties, further decomposition of the developed approach by 7 stages is fulfilled.

4 Stages of mechanism of estimating and selecting projects

4.1 Criterions values non-inconsistency verification

The analysis of the practice of investment projects calculating shows, that in some cases appraisals by either criterions can be artificially raised or, on the contrary, lowered. Existing methods, such as UNIDO, environmental method and etc., do not recommend any measures to bring out suchlike discrepancies. The exception is the method RPOI, in which many steps of criteria values check by experts is envisaged during projects estimation. That is why the selection mechanism performs the criterions values non-inconsistency verification, which consists in signifying some criterions through the others and substituting criterions values, provided by project developers, to received expressions.

4.2 Precursory estimation of investment projects acceptability

Specifics of the program “Waste” leads to the large amount of the projects array, offered for an estimation, by the reason of good credit conditions of this program. A part of these projects can prove unacceptable by definite criterions values. For a rejection of void projects the mechanism created uses acceptability criterions, comparing which with corresponding criteria appraisals from the array $F IP$ are divided by effective and not effective projects. Besides, this mechanism envisages the possibility of setting acceptability criterions values, outreaching the margin of economic effectiveness. It permits to take into account flexibly interests of any investors.

4.3 Digitalization of qualitative criterions values

The criterion set formed consists of either quantitative or qualitative criterions. But it does not allow to apply any multicriteria technique. Besides, most techniques of multicriteria optimization require numerical format of input data. Therefore, the developed mechanism performs digitalization of qualitative criterions values.

The analysis of the main formalization means had shown that means of the fuzzy arrays theory are the most admissible. It is explained by the reason, that the information by qualitative criterions is fuzzy and does not lay into 4-5 standard gradations, reducible to ordinal point scales.

For digitalization of qualitative criterions they are transformed into linguistic variables, set on base quantitative scales. Base scales can be divided by any big amount of segments, but more frequently they represent scales from 0 till 1, divided by 10 segments [1].
The developed mechanism gets numerical appraisals by qualitative criterions by dint of suggested in the fuzzy arrays theory technique of preference functions calculating (eqn (3)). This allows to simplify the digitalization process, together with raising it's accuracy.

\[ f = \frac{f_{\text{crit}} - f_{\text{min}}}{f_{\text{max}} - f_{\text{min}}} + w, \]  

where:
- \( f \) – numerical value of qualitative criterion;
- \( f_{\text{crit}} \) – value of qualitative criterion on the base scale from 0 till 1;
- \( f_{\text{max}} \) – upper border of base scale segment, which includes qualitative criterion value;
- \( f_{\text{min}} \) – lower border of this segment;
- \( w \) – integral weight, assigned to this segment.

4.4 Criterions values normalization and generalization of criterions into aspects

After the stage of digitalization the array \( F \) includes only numerical information. However, the size of the formed criterion set is large, besides, this set has some excessiveness. Thus, the selection mechanism created decreases the criterion set used. This is performed by reducing the criterion set \( F \) to the array of generalized aspects \( A \), represented interests of program “Waste” projects main investors, viz.: state, commercial creditor and owner of an enterprise, realizing a project.

On the basis of the criterions properties analysis and their classification there had been developed the structure of generalized aspects for waste refining IP (figure 2), which allow to consider interests of all types program “Waste” investors, and also the specifics of waste refining branch itself.

![Figure 2: Aspects for investment projects estimating.](image-url)
Linear and nonlinear curtail are traditional means of criterions generalization into aspects. But using one of these generalization means while solving the current task is irrational and difficult to apply. The developed selection mechanism fulfils the criterions generalization into aspects by calculating its arithmetical mean:

\[ m_x^* = \frac{1}{n} \sum_{i=1}^{n} x_i, \]  

where \( m_x^* \) – aspect value; 
\( x_i \) – value of criterion \( i \), included in this aspect; 
\( n \) – the number of criterions, included in this aspect.

The given generalization technique do not require setting criterions weights from a decision-maker, notwithstanding, it is not rid from a compensation effect, inherent to the weighting approach [7]. For the compensation effect reduction the mechanism created performs normalization of criterions values before their generalization. The used criterions values analysis had shown that the most number of criteria appraisals lies in the range from 0 till 10. Therefore, criterions normalization in the selection mechanism is fulfilled in the range from 0 till 10. This permits to decrease time expenses for this stage and to increase the final result objectivity.

4.5 Forecasting future competitiveness of investment projects

It is known that the market conjuncture of a raw, which can be replaced by an IP product, directly influences on a projects effectiveness. Existing investment attractiveness appraising methods do not perform forecasting of a future situation and trends at the appropriate product market. Thus, the created mechanism fulfils the forecast of the world market conjuncture. For this purpose the optimum filter has been built by the Pugacheov’s theory of canonic decomposition taking into account the specifics and the number of chosen time row statistical values:

\[ s_f = \sum_{i=0}^{n} b_is^i, \]  

where \( s_f \) – forecast of statistical row; 
\( b_i \) – coefficients of canonic decomposition; 
\( s \) – values of forecasted statistical row; 
\( n \) – the number of optimum filter addendum.

In the general case, the number of used addendum \( n \) depends on a correlation function of a statistical row and a length of forecasting interval.

The forecasting error by this optimum filter does not exceed 5%, what is the good practical result for economic systems [4].

Future competitiveness of IP is calculated by forecasting results with eqn (1). This criterion directly influences on an IP profit, therefore, it relates to commercial effectiveness criterions. But if this criterion is generalized together with other criterions of commercial aspect, it’s influence is reduced excessively. To avoid this the criterion “future competitiveness of IP” is generalized with
already got commercial aspect value, decreasing or increasing it in dependence of a market conjuncture change.

4.6 Filtration of investment projects

After calculating values of all aspects some of them are unacceptable. It is explained by using only part of criterions for the precursory rejection stage. Thus, the mechanism developed performs IP filtration by aspects values. This is fulfilled by setting limits to aspects values, what allows to reject projects easy enough, which do not satisfy a decision-maker by definite aspects values.

Stages of precursory acceptability estimation and IP filtration perform selecting from the whole projects array the initial alternatives array (IAA), which is the input array for a user preferences structure construction. In the process of IAA forming it is solved the task \(<X, OP_F, OP_A>_\), i.e. selecting a sub-array of acceptable projects \(X_{pr} \subseteq X\) from the alternatives array \(X\) according with an optimum principle \(OP_F\), and then selecting a filtered sub-array of acceptable projects \(X_f \subseteq X_{pr}\) from the array \(X_{pr}\) according with an optimum principle \(OP_A\).

\(OP_F\) is determined by the choice function \(C_F\), which look like:

\[
C_F(X) = \{x_i | f_j(x_i) > p_j \land p_j \neq \text{const} \forall x_i \in X_{pr}\},
\]

where \(x_i\) – investment projects variant \(i\) from the array \(X\);

\(f_j(x_i)\) – appraisal of IP variant \(i\) by criterion \(j\);

\(p_j\) – acceptability threshold for criterion \(j\).

The choice function for determining \(OP_A\) has a structure, similar to eqn (6), but \(\sigma_j(x_i)\) (appraisals of IP variants \(i\) by aspects \(j\) from the array \(A\)) are compared with their threshold instead of \(f_j(x_i)\).

A project array, which has not been included into IAA, defines a sub-array \(X^*_d \subseteq X\).

4.7 Preferences assignment and user preferences structure construction

After a filtration the created mechanism forms user preferences and builds preferences structure on an array of IP from IAA. Traditional weighting approach to preferences setting, permitting to perform a linear alternatives regularization, has a number of drawbacks, which have been considered before. The mechanism developed has been built on the reasonable goals method (RGM) [6], which is based on the feasible arrays method (FAM) and Pareto theory. Applying RGM in the developed mechanism allows to fulfil:

- user preferences setting without pointing out weights of aspects used;
- visual graphic representation of aspects tradeoff curves and feedback to a decision-maker;
- transition from a layer regularization to a linear one and vice versa.

Before setting wishful aspects values, as the only user preference needed, by the FAM technique [3] in the \(n\)-dimensional space (where \(n\) – the number of aspects used) a Pareto hull is built by existing aspects values combinations for a studied projects alternatives array. This hull is not convex in most cases.
Therefore, then the created mechanism considers a minimal convex body, including the Pareto hull—convex Edgeworth-Pareto hull (CEPH) and performs a calculation of CEPH 2-dimensional cuts. This procedure is undertaking for a visualization of coordinate aspects tradeoff curves, which are built on a dialog decision map (DDM). From 2 till 5 aspects can be used at a visualization process.

After construction of an initial DDM a user sets his preferences by means of entering limitations on non-coordinate aspects values. Then a user fixes values of coordinate aspects on DDM, i.e. formulates a reasonable goal, lying on an effective border of CEPH 2-dimensional cuts. Reasonable goal represents an acceptable aspects tradeoff value, which is close to feasible aspects values.

At the final step of the RGM selection procedure an in pairs comparing all variants with a goal set and selecting most effective from them by means of any sorting out techniques [2] is fulfilled.

By finishing this step a first level of a user preferences structure has been constructed, containing one or several IP variants. If this layer includes the non-acceptable number of projects, the mechanism created repeats calculation by RGM, having changed user preferences so as to get the needed number of projects in the first layer.

Because the task does not consist only in finding one or several effective IP variants, then a received array of first layer projects is subtracted from an initial projects array—an operation \( X_f = X_f \setminus X_1^* \) is performed. Further for a residuary projects array a new reasonable goal is fixed and a calculation is repeated. When all projects are shared by layers, we have \( X_1^* \supset X_2^* \supset X_3^* \supset X_4^*, X_1^*, X_2^*, X_3^*, X_4^* \subseteq X_f \). The choice function for layer \( j \) alternatives is as follows:

\[
C_{\eta}(X_j) = \{x| x_i \succ G_{\eta} \forall x_i \in X_j, X_j \subseteq X_f \}.
\]

Using RGM in the selection mechanism allows to make a projects estimation and selection process more simple and objective.

On the basis of the developed mechanism the projects selection algorithm has been created. By dint of this algorithm there has been performed the modeling by 9 real IP (projects concerning the refining of waste, which contain iron, copper and gold) for two types of program “Waste” investors (owner of an enterprise, realizing IP, and budget investor). The process of modeling shows the workability of the algorithm and permits to get results, represented in the table 1.

<table>
<thead>
<tr>
<th>Estimation steps</th>
<th>Step 1 Owner/Budget</th>
<th>Step 2 Owner/Budget</th>
<th>Step 3 Owner/Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ecological</td>
<td>7.00/8.31</td>
<td>6.84/8.09</td>
<td>6.76/8.09</td>
</tr>
<tr>
<td>Technological</td>
<td>7.74/7.74</td>
<td>7.61/7.75</td>
<td>7.26/7.24</td>
</tr>
<tr>
<td>Organization</td>
<td>4.17/4.17</td>
<td>3.44/2.92</td>
<td>1.66/2.08</td>
</tr>
<tr>
<td>Social</td>
<td>4.49/6.50</td>
<td>4.24/5.25</td>
<td>4.00/4.00</td>
</tr>
<tr>
<td>Financial</td>
<td>4.72/5.89</td>
<td>4.62/5.45</td>
<td>3.54/3.87</td>
</tr>
<tr>
<td>Commercial</td>
<td>4.89/4.89</td>
<td>4.53/4.53</td>
<td>3.59/3.59</td>
</tr>
<tr>
<td>Budget</td>
<td>3.98/6.02</td>
<td>3.97/6.02</td>
<td>3.92/3.57</td>
</tr>
<tr>
<td>Preferable IP number</td>
<td>2/2,3,4</td>
<td>1,3,4,5,7,1,5,7,9</td>
<td>6.8/9/6.8</td>
</tr>
</tbody>
</table>
It is clear from the considered example that the final result changes under user preferences changing. The transit from the layer regularization to the linear one is graphically illustrated by the result of the first estimation step in the table 1. Besides, it is understandable that first layer contains the least risky alternatives of waste refining IP.

5 Conclusion.

In this article stages of the created IP estimation and selection mechanism have been expounded. It has been proved, as well as by the provided imitation of different IP estimating situations, that the mechanism created allows to solve the task having been set completely and also most rationally and objectively without an experts. Besides, one of the main advantages of the developed mechanism is the maximally full considering of the financial component of the investment risk, what serves the additional stimulus of a capital investment to waste refining IP. This mechanism has been realized in Microsoft Visual Studio 6 and represents a compound part of developed in MSMU decision support system at investing to mining branch waste refining.

References

Section Three:

Emergency response