Advancement in modern approaches to mineral production quality control

EV Freidina[1,2], AA Botvinnik[1] and AN Dvornikova[1]

[1]Chinakal Institute of Mining, Siberian Branch, Russian Academy of Sciences, Novosibirsk, Russia
[2]Novosibirsk State University of Economics and Management, Novosibirsk, Russia

E-mail: [1]albyna@misd.ru

Abstract. The natural resource potential of mineral deposits is represented by three categories: upside, attainable and investment. A modern methodology is proposed in this paper for production quality control, and its tools aimed at ensuring agreement between the product quality and the market requirements are described. The definitions of the costs of the product quality compliance and incompliance with the consumer requirements are introduced; the latter is suggested to use in evaluating resource potential of mineral deposits at a certain degree of probability.

A mineral deposit as a raw material object has a definite resource potential. The resource potential is understood as the cumulative natural reserves that are or can be used in economic life given the actual technical capabilities and social and economic reality. Capabilities of a society is a variable that defines stages of progressive development in technology of mineral mining and processing. From that standpoint, the authors put forward an approach to evaluation of a resource potential classified into upside, attainable and investment potentials [1–3].

Upside potential is defined as the maximum value of mineral reserves consummated using technologies that ensure complete extraction a mineral and preservation of its natural quality.

Attainable potential is a value of mineral consummated given the key mineral mining and processing technologies now in use, i.e. this is a strategic resource of the industry.

Investment potential is an ability of a mine to produce and supply the market with a merchantable product ensuring acceptable profit under efficient use of all required natural and technological reserves.

The resource capacity of the upside, attainable and investment potentials is a frozen in time value. The size of the upside potential is a forecast of mining capabilities of a mineral deposit and always entails a certain risk associated with confirmation of proven reserves. The attainable potential is even more variable in time as the current and new technologies of mineral mining and processing undergo continuous improvement and development. The attainable potential grows with the diversification of different quality mineral products. For instance, coal products are marketable in fuel engineering (energy sector, coke chemistry) and in other industries (chemistry, pharmaceutics, agriculture, food industry, road construction, etc.).

Variation of the upside and attainable potentials changes the investment potential of a mineral deposit. The investment potential is a conversion of an attainable potential into a marketable product under prevailing conditions and considering quality requirements imposed by a consumer, market

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd

situation and prices. Adaptational capacity of a mineral producer should be flexible and efficient. Such adaptability has a few grounds.

First, the detailed and operational exploration of a mineral deposit under mining, as a rule, introduces modification in the estimates of ground conditions, mineral reserves and quality. It becomes necessary to have a selection of options for expansion or reduction in the range of different quality products with a view to deciding on an optimal alternative under prevailing conditions, considering mineral reserves and market demand.

Second, it is not impossible that demand of actual and potential consumers for a certain composition and quality product will change. Moreover, demands of consumers are unevenly distributed in time. Based on high variability and uncertainty of consumer behavior, it is required that the investment potential of a mineral deposit can be promptly re-evaluated so that to optimize interaction between a producer and a consumer under prevailing conditions.

Third, the investment potential is attackable by unpredictable and mine-independent fluctuations in the sphere of economics and finance.

Reduction in the uncertainty of investment potential of a mineral deposit is possible with the state-of-the-art procedure of product quality planning such as Quality Function Deployment (QFD) [4]. QFD method is an ordered way of transforming demands or requests of a consumer into quality standards for an anticipated product. QFD is applicable to planning any production, processes and operations aimed to improve product quality and competitive recovery.

Regarding mineral product quality planning, the basic procedures and instruments of QFD are listed below.

1. Determination of wants and detailed requirements of a consumer per key indexes of marketable product quality, rating of criticality of each requirement and allowable range of indexes.
2. Assessment of consistency between the key indexes of mineral quality with the product quality standards imposed by a consumer, setting of mineral quality targets and evaluation of quality indexes to be improved in order to satisfy the demand for a marketable product.
3. Determination of best capabilities (technologies) of a producer to achieve product quality standards to extremely satisfy consumer demands. Evaluation of technical difficulties of achievement of mineral quality targets.
4. Valuation of meeting consumer demands for mineral quality.
5. Estimate of competitors in satisfaction of consumer demands.
6. Evaluation of quality control methods that ensure efficiency of production and commercial activities in mineral mining.
7. Formulation of objectives and development of strategy of mineral quality control.

A worthy technique of QFD is the method of Product Planning Matrix capable to integrate an information field composed of (Figure 1):

—natural quality of a mineral;

—quality indexes to be improved to meet quality standards set by a consumer;

—info about competitors: whether they better or worse fulfill consumer demands;

—capability of a mine to outrun competitors;

—investment required to reach an agreement between marketable product quality and quality standards of a consumer.

Each step of the Product Planning Matrix is a sub-result of research aimed at the adequately supported representation of local matrices:

—matrix of relationship between consumer demands and producer capabilities;

—correlation matrix of links between adjustable quality indexes;

—matrix of evaluation of competitor supremacy (consumer benchmarking);

—matrix of evaluation of technological supremacy of competitors in reaching product quality targets (technical benchmarking);

—matrix of assessment of technical difficulties of reaching product quality targets;

—matrix of value of mineral mining at reached product quality targets.

An illustration of the matrix of meeting consumer demands for coal product quality is shown in Figure 2.

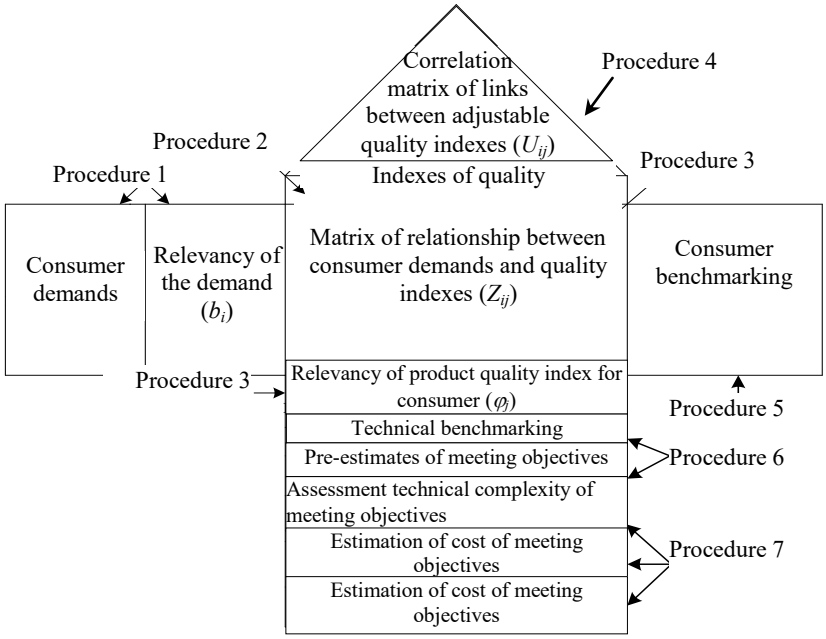


Figure 1. Product Planning Matrix.

Quality index	Priorities	Expert evaluation of quality consistency, grades: Low → High				
		1	2	3	4	5
Ash content, %	1	□	Δ ●			
Plastic layer thickness, mm	2		□		●Δ	
Moisture content, %	3		●	□	Δ	
Calorific heat, kcal/kg	4			●	□	Δ
Volatile content, %	5			Δ	● □	
Sulfur content, %	6		□		Δ	●
●— Test object		**Upside potential of product quality**				
□— Competitor 1						
Δ— Competitor 2						

Figure 2. Matrix of evaluation of competitors.

Development of QFD in short-range and long-range planning of mineral quality will require that mines prepare a package of documents on systemic management of product quality control. The framework of the QFD package software systems, procedures, methods, quality maps and some other intelligent products [4] mostly represented by trial specimens that successively pass approval finalization of which needs investment from operating mines.

Influence of mineral quality on efficiency of mining investment potential shows on supply of mineral products to consumers. Relationship between a mine–producer and an energy object–consumer of coal products has a feature: there is an estimated value of violation of quality standard set in a contract (price correction factor for fuel). For this reason, the issues of cost of coal quality conformity/nonconformity with consumer standards are to be handled at the stage of mining.

The nonconformity cost is exemplified in terms of the Novosibirsk Heat Power Plan. The price correction factors for violation of standards set for basic adjustable indexes of fuel quality are assumed as

—ash content: 1.95% discount per each percent of increment in mass fraction of ash content of ROM coal;

—moisture content: 1.69% discount per each percent of increment in mass fraction of moisture content of ROM graded coal.

In this connection, it is suggested to consider two measures of evaluation for each λ-th degree of quality (coal grade): conformance of an *i*-th quality index with consumer standards ($\varphi_{\lambda i}$) and cost accordance CA_λ [5].

Quality conformance of a mineral product is achieved when an average value of an *i*-th quality index ($\bar{X}_{\lambda i}$) is within the allowable range ($\Delta_{\lambda i}$) of a consumer-set standard $X^{н}_{\lambda i}$

$$X^{н}_{\lambda i} - \Delta_{\lambda i} \le \bar{X}_{\lambda i} \le X^{н}_{\lambda i} + \Delta_{\lambda i}. \quad (1)$$

When quality indexes that worsen final product quality, e.g. contents of ash, moisture, sulfur and volatiles for coal, exceed the allowable range, the nonconformity is given by

$$X_{\lambda i} - (X^{н}_{\lambda i} + \Delta_{\lambda i}) = \Delta X_{\lambda i}, \quad (2)$$

and the degree of nonconformity is

$$\omega_{\lambda i} = [\bar{X}_{\lambda i} - (X^{н}_{\lambda i} + \Delta_{\lambda i})] / (X^{н}_{\lambda i} + \Delta_{\lambda i}). \quad (3)$$

In this case, the degree of conformity

$$\varphi_{\lambda i} = 1 - \omega_{\lambda i}. \quad (4)$$

Inasmuch as violation of quality indexes of a delivered product as against the contractual product standards is estimated in the same units of measure (percentage) and the cost of nonconformity of a negative quality index is evaluated in units of money, it is possible to reduce the oval nonaccordance cost to a generalized index given by

$$CN_\lambda = \sum_{i=1}^{M} \Delta X_{\lambda i} r_{\lambda i}, \quad (5)$$

where *M*—number of quality indexes for the given subject of power engineering; r_i—rate for overrun of allowable value of a negative quality index.

The anticipated returns from sales or the cost of the final product meeting the consumer quality standards is determined as

$$C = \sum_{\lambda=1}^{N} V_\lambda \gamma_\lambda p_\lambda, \quad (6)$$

where N —number of degrees of quality of coal grades; V_λ , γ_λ , p_λ —production output, yield of concentrate of a λ-th quality degree or grade of coal and the concentrate price, respectively.

Let a power engineering plant is supplied with coal of the same quality or grade. Per each quality index, the degree ($\omega_{\lambda i}$) and the overall cost (CN_λ) of quality nonaccordance are determined. With a view to CN_λ, the accordance cost CA_λ will be evaluated as the difference between the anticipated returns and rate for unrated quality violations

$$CA_\lambda = V_\lambda \gamma_\lambda p_\lambda - CN_\lambda. \quad (7)$$

It follows from (7) that the actual returns of coal product sales will be

$$CA = \sum_{\lambda=1}^{N} (V_\lambda \gamma_\lambda p_\lambda - CN_\lambda). \quad (8)$$

The quality nonconformity shows to a high probability when a consumer is supplied with ROM coal. The economic efficiency of the investment potential is to be reduced by the value of nonaccordance cost of the supplied product quality and the consumer-set quality standards.

Evaluation of mineral quality based on positive indexes should take into account that the product value is higher when a positive quality index is higher. For example, for black coal, the positive quality indexes are, primarily, calorific heat and plastic layer thickness. From the standpoint of a consumer, the degree of conformity between the supplied product quality and the consumer demand is given by

$$\omega_{\lambda i} = [\bar{X}_{\lambda i} - (X^{\text{н}}_{\lambda i} - \Delta_{\lambda i})] / (X^{\text{н}}_{\lambda i} - \Delta_{\lambda i}). \quad (9)$$

So, a producer should control coal quality so that the coal quality indexes are always within the pre-set allowable ranges. Otherwise, coal price suffers considerable changes. The afore studies are based on an approach to enhancement of mining efficiency implemented in Neryungri Coal Field based on the recommendations made by the Eastern Research Institute for Coal Chemistry. It was advised to grade quality of local coking coal reserves based on plastic layer thickness and to set essentially different prices for each quality grade. In this case, the producer objective is to minimize quality divergence of a marketable product with respect to positive quality indexes, or the aggregate value of a coal product will drop and, accordingly, the economic efficiency of mining investment potential will decline.

Conclusion

Identification of categories of a mineral resource potential (upside, attainable and investment) enables elaboration of the perception of usability of mineral resources, their conversion into marketable product and efficient marketing of the latter.

The authors have proposed to add the value of an investment potential with the cost of nonconformity between the supplied coal product quality and the quality standards set by consumers—power engineering objects. It is found that when the supplied product is ROM coal, the quality nonaccordance is highly probable.

The investment potential sustainability is supported by the use of QFD method of product quality planning this method means a systemic transformation of the demands and wishes of a consumer into the measures of quality of the anticipated product. On the whole, the effectiveness of activities toward the development of the investment potential of mineral mining gets enhanced. Adherence to QFD method will allow a producer and a consumer to be sure that the planned quality of coal product will be attained and the producer will enjoy stable and successful position in the fuel market.

References

[1] Freidina EV, Botvinnik AA and Dvornikova AN 2005 Information technologies for resource potential control at a coal deposit *Surface and Undersea Mineral Mining: VIII International Conference Proceedings* Sofia

[2] Petrov OV (Ed) 2001 *Geological Dictionary* Saint-Petersburg: VSEGEI (in Russian)

[3] Fomin PA and Starovoitov MK *Features of Production Potential Evaluation* Available at: http://www.cfin.ru/management/manufact/manufact_potential.shtml

[4] Freidina EV, Botvinnik AA and Dvornikova AN 2008 Coal quality control in the context of international standards ISO 9000-2000 *Journal of Mining Science* Vol 44 No 6 pp 585–599

[5] Freidina EV, Botvinnik AA and Dvornikova AN 2009 Selection of a criterion of conformance between coal product quality and consumer requirements *Gorn. Inform.–Analit. Byull.* No 5 (Special Issue) pp 90–101 (in Russian)