Conceptual framework for effective management of mining operations and fuel-and-energy development in the Arctic

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Abstract. Boasting a vast raw material base, the Arctic zone of the Russian Federation is an environment which is extremely vulnerable to environmental pollution. To achieve a significant reduction in toxic emissions into the Arctic environment, it is necessary that the advanced technologies are in place to reduce material consumption, which, however, means higher capital investment. This prerequisite is in line with the national and regional policies, according to which the government is to stimulate the introduction of advanced technologies or to compensate, fully or in part, for overexpenditure (that some of the Russian regions may incur). In order to enhance the efficiency of managing the nation’s mineral and fuel-and-energy resources and, in the first place, the resources of the Arctic, the authors have developed the technology life cycle model. Technological innovations are what reduces businesses’ operating costs: the overall reduction of material consumption leads to lesser environmental load. A new type of economic analysis is suggested – investment-and-innovation analysis (retrospective and predictive analysis) – which ensures the analytical correlation between the targets of the industries’ performance and those of technological innovation performance.

1. Introduction
The Arctic zone of the Russian Federation represents an important raw material base, and, given the prospects of the vast, offshore fuel and energy resources of the Arctic Ocean, its importance will only be increasing. [1]. However, the Arctic is a special territory: on the one hand, operating in its severe climatic conditions mean high capital (investment) expenses and current (operational) costs [2,3], and on the other hand, the nature of the Arctic is extremely vulnerable, causing the industries to increase their expenditures on environmental protection measures to prevent impact from liquid, solid and gaseous emissions [4]. All things considered, these are only large industries with ample financial resources that can afford such expenditures [5,6].

Economically speaking, each player in the resource management pursues its own interests. The state, represented by federal authorities, seeks Arctic development not only because of the vast natural resources and the possibility to increase GDP, but also because of the geopolitical location of the Arctic. So, on the one hand, the state is obliged to help businesses develop natural resources and, on the other hand, by virtue of Article 69 of the Russian Constitution, it must ensure that pollution levels in the Arctic do not exceed a threshold critical to the well-being of the small peoples of the North. The Russian regions, including those in the Arctic area, represented by the regional authorities, have the duty ensure that the natural resources in their areas are managed effectively and for the purpose of increasing the gross regional product (GRP). At the same time, the regions, must work towards lower environmental pollution in the interests of their communities.
For operating businesses, including those developing the natural resources of the Arctic, the main economic interest consists in reducing costs and increasing profits, making the cost of their products high. Operating in the Arctic requires ample labour efficiency, a task that can be achieved primarily through the use of new equipment and technology with due level of automation and digitalization. That said, there are three points to be considered by the businesses in order to avoid discrepancy with national and regional economic policies.

Firstly, the state is free to offer incentives, and among them financial incentives, to large businesses operating in the Arctic areas and at the same time regulate their economic progress by introducing, for instance, various norms and standards.

Secondly, as businesses move to new operating areas, the previously developed ones tend to experience higher levels of unemployment, thereby increasing the regions’ social burden—a point to be coordinated through mutual agreements between businesses and regions. At the same time, the use of advanced technology in the newly developed territories is expected to reduce the regions’ expenditure on social sphere.

Thirdly, the task of preserving the environment for the indigenous communities of the Arctic requires tightening of the environmental regulations with regard to equipment and technologies, which, in turn, will only increase the operating costs. Since the environmental costs are being sustained mainly by the businesses operating in the Arctic and the Arctic industrial projects constitute a national priority, it is only natural that the government should compensate the Arctic subsoil users, fully or partially, for their environmental costs.

Thus, for the government, regions, and businesses to meet one another’s needs, it is essential that advanced technologies should be in place, with the government playing, if necessary, the coordinating role. The question then arises as to what exactly the advanced technology should be capable of ensuring in order to foster economic growth through Arctic development.

Our study aims to identify the possibility for improving the efficiency of Arctic development and at the same time reducing the environmental pollution in the Arctic the technology life cycle model.

2. Method

Sustainable resource consumption, or intensive economic growth, can only be achieved if the share in the end product cost of added value increases. This means that the share in the end product cost of intermediate product value, i.e. the value of the material resources used in manufacturing of the product, should be decreasing. In principle, the same applies to business performance: any increase in the added value as a difference between production expenses and end product cost represents the contribution businesses make towards nation’s intensive economic growth. However, it should be borne in mind that an increase in the unit cost of added value means also a decrease in the material content of the product. This can be beneficial to businesses, as, all other conditions being equal, any decrease in the material content allows for higher production profitability and hence sales profit (profitability of sales, if expressed as a percentage).

Undoubtedly, the effort to reduce material content requires introduction of advanced technologies, mainly process ones. Yet, not all of the advanced technologies lead to a reduced material content, no matter if they result from an efficient investment project. The fact is that such important performance indicators as material intensity (MI) and capital productivity (CP) are, as a rule, left beyond the scope of the methodologies, used in Russia [7,8] and abroad [9,10], for assessing the effectiveness of individual investment projects. Consequently, it appears that even the growth in CP does not always lead to a decrease in MI, as was shown by us in our work [11]: based on the production technology in use and in terms of cost-effectiveness of its fixed assets, i.e. physical capital, and material resources, a business follows a trajectory in its development which is either innovative-and-effective (with CP growing and MI decreasing), or innovative-and-ineffective (with MI and CP decreasing concurrently), or uninnovative-and-effective (with CP increasing in response to an increase in MI), or uninnovative-ineffective (with MI increasing and CP decreasing concurrently).
3. Results and discussion
In [12,13] we analyze two scientific concepts – “producibility level” and “technology life cycle”. The producibility coefficient (k) reflects proportional relationship between capital intensity (CI) and material intensity (MI). Numerically, it represents the value of fixed assets (FA) which a business needs to process the unit value of material resources. The proportional dependence between CI and MI was illustrated by us by example of several large enterprises operating in Northern Russia, and by example of performance, over the period of ten years (2005-2015), in three economic sectors of 12 northern Russian regions [11]. By tracking the dynamics of the said coefficient, we concluded that within two of the four trajectories defined above (the first and the fourth), two options are possible. It appears that any increase in the value of the producibility coefficient, in fact, leads to growth in CP and concurrent reduction in MI; and, oppositely, any decrease in the producibility coefficient leads to a decrease in CP and an increase in MI. A conclusion was therefore made that any increase in k-coefficient determines a certain level of corporate innovative technological development, which is consistent with the theory of endogenous economic growth [14,15]. The research into this issue was undertaken, in the 1980s, by famous Soviet scientists N.A. Trapeznikova [16], Yu.V. Yakovtsa [17], A.I. Anchishkina [18], S.Yu. Glazyeva [19].

The k-coefficient is very simple to calculate – at a corporate level, that of an economic sector, or entire country – using the statistical reporting data. Thus, the dynamics of the k-coefficient over identical periods of time can be used as a yardstick for identifying whether a technology in use is effective of not. That said, knowing the values of MI and CP it is possible to identify also the trajectory of technological development. The relation between these trajectories, and their crucial indicators that determine the transition from one trajectory to another, are shown in the matrix below (Figure 1) [12].

| MI | | CP |
|----|----|----|
| MI increase | CP decrease | K decrease | IV-1 | MI increase | CP increase | K decrease | III |
| MI increase | CP decrease | K increase | IV-2 |
| MI decrease | CP decrease | K increase | II |
| MI decrease | CP increase | K decrease | I-2 |
| MI decrease | CP increase | K increase | I-1 |

**Figure 1.** Matrix and indicators of technological development trajectories¹,
where MI is material intensity of products; CP is capital productivity of fixed assets; k is producibility coefficient; and I-IV are technological development trajectories and options within them.

In [13] we show that technological development of any business can, depending on the efficiency of its material, labor and physical capital (fixed assets), be presented in the form of a cycle consisting of six stages. Each stage and the transition between the stages are marked by a distinctive change in the values (increasing or decreasing) of the three indicators – MP, CP and k. Thus, the most beneficial of all stages is the second, where the values of all the three indicators increase in parallel.

We propose our technology life cycle model as a tool for the “investment-and-innovation analysis” of businesses, economic sectors, and national economies. This model enables user to determine the economic expediency for and the financial feasibility of a switch to new production technology, as
well as time needed to have this switch implemented, based on calculations of all essential economic and financial indicators. Further, the model allows for identifying the minimum required levels of MP, CP and k, which a business should meet in order to have a new technology introduced, and the required volume of fixed capital investment. Thus, it becomes possible to trace the analytical interdependence between the economic targets of business/sector performance and the targets of technological updates – something which is missing in the commonly used Kaplan-Norton balanced scorecard [20].

Together, the technology life cycle model and the investment-and-innovation analysis allow the national economy to switch towards digitalization of the mineral and fuel-and-energy resources management (MFER) and, above all, the management of the Arctic resources. Such switch implies a reduction in businesses’ operating costs, resulting from the reduced material intensity, and hence a reduction in environmental pollution. However, it should be borne in mind that over the previous decades of industrial operations in the Arctic have accumulated a significant amount of solid wastes that contain useful components (off-balance ores, tailings, metallurgical slags) and that their processing may become profitable, provided that the advanced technologies are introduced. It should be noted also that the use of these wastes is in line with the economic interests of both the state and the regions, as it does meet the goal of intensifying the use of mineral resources and decreasing the environment pollution. Provided that the state creates necessary conditions, it could become less expensive to businesses to store solid industrial wastes and the competition may arise between SMEs on secondary resources market. When it comes to the Arctic, it could be expedient and highly advisable to increase, significantly, the harmful emissions fee and the fee for storing solid industrial wastes longer than the prescribed term, for some of the waste components, including those hazardous to human health, penetrate the soil and water bodies. Accordingly, the SMEs that are using wastes could be offered tax incentives – through public-private partnerships. Additionally, SMEs could be suggested to perform the follow-up mining on the abandoned sites (mines, quarries, wells) in order to recover those off-specification remains and contribute to the effort of sustainable environmental management.

4. Summary
1. To achieve a significant reduction in toxic emissions in the Arctic, it is necessary that the advanced technologies that are capable of reducing the material intensity are in place, ultimately leading to increased fixed capital investment. Since this line of development is in line with national and regional policies, it is the duty of the government to either provide incentives or compensate, fully or in part, for the additional costs businesses are sustaining with regard to technological updates (compared to other regions of the country).

2. The extreme conditions of the Arctic force industrial enterprises to significantly increase their performance through the use of modern equipment and production technology. At the same time, the growth in labor productivity in the already developed Arctic areas (RF regions and municipalities) should be coordinated with the authorities in order to prevent consequences of sharp increase in unemployment and in social spending in single-industry towns.

3. To manage the process of technological modernization in Russia and in the Arctic areas, it is necessary to promote the investment and innovation analysis of corporate performance (retrospective and predictive), which is based on indicators other than the previous used – the productivity coefficient and the investment-and-innovation leverage.

5. Direction of further research
Our further research aims to provide a more in-depth analysis of the possibility of reducing the material intensity of products and the environmental pollution in the Arctic area.

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