

# Application of the "lean thinking" concept to the analysis of coal mining region's sustainable development objective

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**Abstract.** The article is devoted to the application of resource saving technologies as an important tool to achieve sustainable development at coal mining regions of the Russian Federation. The negative impact of coal-mining enterprises on the water and air basins of the regions, on withdrawal of fertile land continues to be unacceptably high. As a result the objective to preserve natural environment in these regions has gained high priority. Its solution requires development and implementation of fundamentally new, cost-effective and environment friendly underground and open pit coal mining technologies. It is shown that an effective solution of the problem, a radical contraction of resource consumption requires radical rethinking of the whole coal mining management and production system. The basic principles of "Lean thinking" methodology have been applied to structure the issue and to develop guidelines for coal-mining systems reengineering.

## 1 Introduction

Ensuring sustainable development in the process of economic activities aimed at meeting the needs and ensuring the high quality of human life, the world community has recognized a very acute and pressing problem of our time. At the end of the UN Conference (Rio de Janeiro, 1992), the heads of state and government of the world recognized that the development of modern society cannot be considered in isolation from the preservation of the environment, destroyed by man-made activities. According to the decision adopted at the conference, the Concept of Sustainable Development is raised to the rank of state and interstate policy. All governments of the world are recommended to ensure the fulfillment of the conditions of sustainable development in the implementation of national development programs.

On the eve of this conference, in one of the largest industrial centers of the Russian Federation - the Kuznetsk coal basin, a large-scale study was carried out on the ecological and economic assessment of the functioning of coal mining and processing technologies [1, 2]. A system analysis of the previous twenty-year period of economic activity of 78 mines, 25 cuts and 16 processing plants and the consequences of this activity in terms of its impact on humans, water and air basins, on land resources and the region's mineral resources, revealed an extremely high

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level of destructive impact all listed areas of the environment. It was shown that further intensive development of the coal-mining complex will lead to an increase in environmental problems in the region and to change the current situation, greening of mining production is necessary, development and introduction of fundamentally new, not only economically more efficient, but also environmentally friendly coal mining technologies is needed.

The years passed, the socioeconomic transformations and the restructuring of the coal mining industry of the Russian Federation, which took place in the 90s of the 20th century, significantly changed the characteristics of the external business environment, the criteria and indicators of economic efficiency of enterprises in relation to the planned economy. The closure of unprofitable mines, the commissioning of new capacities in favorable geological conditions, an increase in the share of open coal mining, the introduction of modern powerful mining and transport equipment, increased concentration and intensification of mining operations brought the industry to a competitive level of efficiency and contributed to its integration into the global economic space.

However, these transformations almost did not affect the historical technological paradigm of the production systems of coal-mining enterprises. As a result, the environmental problems of a large mining region not only did not lose their acuteness, but became even worse.

In addition, the market principles of economic activity fundamentally changed the working conditions of business entities. Coal-mining enterprises, basically formed in stable and fairly well-predicted conditions of a planned economy, faced fundamentally new realities. New economic conditions are characterized by a high degree of variability and uncertainty of the market environment, which limits the ability of coal mining enterprises, which are characterized by high resource intensity and inertia of the production system, to fully realize the potential of their economic efficiency. As a result, the coal mining industry, despite the above transformations, continues to give up its position in the competition with alternative energy sources. Its share in the domestic market of hydrocarbons is reduced due to the expansion of the use of cheaper and more technologically advanced fuels. If at the beginning of the 90s the ratio “coal: oil: gas” in the fuel and energy balance of Russia was 26:33:41, then by this time the share of coal here has been almost halved [3].

It should be added that the modern period is characterized by an intensive search for solutions to create efficient power plants based on alternative energy sources to hydrocarbons. A number of forecast estimates indicate the closure of the “era of fossil hydrocarbons” [4, 5]. In accordance with the forecast of the famous futurologist Ray Kurzweil, technical director of Google, by 2028 alternative energy will be one of the key technologies for the development of all others. It will be approved as the dominant concept. Solar panels will become so efficient that they are enough to cover most of the energy costs of humanity [4].

In addition, following the results of the 2016 Paris Climate Conference, the protocol of which prescribes the next reduction of CO<sup>2</sup> emissions, the idea of creating in Siberia, where the main coal deposits of the Russian Federation, carbon-free zone are concentrated, is being actively discussed. This makes the coal industry of Russia even more acute the task of transformation in the light of new environmental requirements.

Thus, the above, speaks of the incredibly high competitive pressure faced by the coal mining industry in the global energy market, and in the coming years, taking into account the noted tendencies and the growth of environmental restrictions, will experience it to an even greater degree.

In the light of the above, it becomes quite obvious that the problem of sustainable development and improving the efficiency of coal mining production continues to be highly relevant and needs to be addressed.

## 2 Materials and methods

Successful solution of the problem under consideration requires a clear understanding of what principles, what concept should be used as the basis for building production systems for coal mining in modern conditions.

The world economy considers the problem of sustainable development in close connection with the problem of resource conservation, for the solution of which it is necessary to increase the efficiency of resource use based on the principle: spend less - produce more [6]. This approach is the dominant direction in the development of modern production systems in various sectors of the world economy.

It is believed that the basis of modern economical, resource-saving production systems and methods of organizing and managing production was made up by the achievements of Japanese manufacturers and, above all, the automotive giant Toyota [7, 8, 9].

Having become a pioneer in the development of new methods and technologies based on the concept of continuous improvement of processes and systems (quality concept) and their introduction into the structure of their enterprise, Toyota built the Toyota Production System (TPS) production system, achieved outstanding economic results and became of the leading leaders of the world economy.

The main idea of the “Toyota Production System” is a new way of thinking that provides a movement towards efficient resource-saving production, based on the ubiquitous and continuous elimination of any activity that consumes resources, but does not create consumer value. This system has become the object of careful study throughout the world in many industries. J. Womack and D. Jones summarized the results of these studies and formulated the main methodological approaches that ensure the use of TPS ideas in various industries and in all kinds of organizations in their work «Lean thinking: banish waste and create wealth in your corporation» [7].

In accordance with the recommendations of this study, the construction of resource-saving production systems is a process consisting of the following five steps:

1. Definition of use value;
2. Designing a value stream;
3. Organization of flow movement;
4. "Pulling" the product;
5. Continuous improvement.

At the same time, the technological scheme of mining enterprises is fundamentally different from the technological schemes of industrial production, where the idea of “Lean thinking” is being developed. It is a combination of basic and auxiliary production processes in combination with the workings necessary for their execution, mechanization and automation tools, which, with the rational organization of work, ensure safe and efficient development of the field. The technology of mining production assumes the continuous dynamics of the working zone of a coal-mining enterprise, when technological systems move along a complex constantly changing three-dimensional surface of the coal-bearing strata. In the process of implementing technological processes, significant amounts of mineral and host rocks are extracted and transferred (mass transfer), which requires the involvement of a huge amount of material resources (in the cost structure of mining products, material costs (past work) reach 50% or more total production costs). Moreover, these resources, from the point of view of creating consumer value, are used extremely inefficiently, and the intervention of mining production in the biosphere, both at the stage of past labor and living, and its active destruction, predetermine a high level of environmental pressures on the environment.

Thus, when considering the problem of sustainable development of a coal-mining region, success, to a decisive extent, will depend on the results of finding solutions that minimize the volume of mass transfer and resource consumption, and also increase the efficiency of their use,

which, as a result, will create prerequisites for reducing the level of negative impact of mining on the biosphere.

The following are the basic principles for building production systems that implement the concept of “Lean thinking” in the aspect of their implementation in coal mining enterprises.

### **3 Results and discussion**

Principle 1. Definition of use value. Consumer value is a key moment in the construction of production systems on the principles of “Lean thinking”, this is the purpose and meaning of their existence in modern economic conditions. Creating maximum use value, i.e. the fullest satisfaction of the interests of the consumer is what serves as the main criterion for the optimization of all processes in the organization. The enterprise discards everything that is unimportant or secondary, and concentrates on the main factor causing its survival - the consumer. It is the consumer who satisfies his needs, pays them, and thereby finances your business [10].

This approach is radically different from the traditional vision of the organization. Only relatively recently, in the conditions of an unsaturated consumer goods market, the situation when demand exceeded supply was characteristic. For the specified state of the market, rather homogeneous products of a very limited range were produced - “mass production”. In this case, the consumer was not a limiting factor: everything that was produced was consumed, and, as a result, the manufacturer dominated the market, and the production systems of the inception and flourishing of the industrial era were built on the principles of “PUSH” - pushing production. The main task facing the production systems of this period is to ensure maximum production volumes with minimum costs.

In the second half of the 20th century, the situation in the global economy changed dramatically. By this period, the problem of raising the standard of living was solved, markets were saturated with consumer goods with an acceptable standard level of quality, supply exceeded demand, competition between manufacturers in various market segments sharply intensified. The consumer has become a key market player, its limiting factor. New conditions transfer the attention of the manufacturer to the question: how and what do you produce? - the question of what and how you produce. This means that the consumer needs to offer not what your company can produce, but what it would like to receive. If he is not interested in what he is offered, then you lose the source of the working capital.

With regard to the products of coal-mining enterprises, the overall goal of production can be defined as the satisfaction of the consumer's need for additional energy to ensure the vital needs of a person (heat, light) and its production activities.

The main place in the set of indicators affecting the use value of coal is occupied by the heat of combustion, ash, moisture, volatile content, that is, components that characterize the ability of coal to concentrate and provide movement to any distances in the smallest possible amount of energy, as well as features of ignition and heat emission dynamics. At the present stage of development, these traditional indicators of coal quality retain their value, however, this group of characteristics is considered to be performed unconditionally, but the focus and attention of the consumer are also the volumes and reliability of supply, and the supplier's ability to predictably and with high accuracy ensure an agreed delivery schedule and product price at the point of delivery, and environmental performance of mining production, etc.

Thus, in order to achieve the highest production results, it is necessary to build production systems and manage the entire distribution chain, focusing not on one's abilities, but on the criterion of consumer value, to the fullest possible satisfaction of the needs and requirements of the end user.

At the same time, the consumer is absolutely not interested in the mining and geological conditions in which your enterprise carries out work, or the level of technical and techno-

logical perfection of your enterprise, nor indicators of equipment use efficiency, nor the geographical location of your enterprise, nor your level of costs. In modern economic conditions, the manufacturer must know exactly what should be done in order to fully meet the needs and expectations of the consumer. This requires him to continuously work with consumers and implement specific technical, technological, organizational and managerial decisions aimed at meeting the identified requests and expectations of the latter.

Principle 2. Designing a value stream. The value stream is a set of all actions that must be performed to bring a product with an established use value from the idea to the release of the finished product. In the process of implementing this stage of value creation, it is necessary, firstly, to know exactly what you are creating exactly what the consumer needs, and secondly, you do it as efficiently as possible from the standpoint of creating use value. At this stage, it is necessary to exclude from the process or minimize all operations that consume resources but do not create use value, i.e. it is necessary to ensure that the ratio of resources spent in a useful way (to create use value) to the total amount of resources used is as high as possible.

From this point of view, it is very important to understand - what type of production systems currently constitute the main potential of the coal mining industry, to what extent they meet modern economic conditions and efficiency requirements from the standpoint of "resource-saving production", and if not, what needs to be done to radically change the situation .

Technological processes implemented in real coal-mining production systems, from the point of view of participation in the creation of consumer value, can be attributed to one of three types [8]:

1. Operations or processes that can be defined as unconditionally involved in creating the use value of a product: for example, destruction of a seam, separation of coal from an array of rocks, its excavation, enrichment or sorting, and storage

2. Operations or processes that are not involved in creating use value, but they are inevitable due to the characteristics of currently used technologies and types of equipment. With regard to the mining industry, for example, all processes associated with the preparation, excavation, movement and storage of overburden can be attributed to this category of losses.

3. Operations or processes that do not create use value and are not technologically based. In the mining industry, such situations may arise as a result of, for example, erroneous technological solutions.

Analysis of efficiency indicators for the use of resources such as metal, electrical energy, diesel fuel, oils, and explosives showed that, for example, in open-cast coal, most of the resources are consumed by technological processes not involved in creating use value. As a result, the consumption efficiency of the above resources is 17%, 15%, 6%, 10% and 25% respectively.

In accordance with the classification given above, in the case under consideration there are losses of the second kind, that is, losses whose presence is predetermined by a constructive imperfection of the technological cycle. An example of a solution to a problem considered may be the reengineering of a production system. The abandonment of the currently widely used, in-depth longitudinal development system, when the entire volume of overburden moves beyond the boundaries of the quarry field and is placed on external dumps, in favor of development systems with internal dumping, for example, longitudinal longitudinal blocks transverse, will allow to increase the indicator of efficiency of use of resources, respectively, for these systems by 1.2; 1.3; 1.4 times.

It should be noted that this result was obtained solely by creating conditions for internal dumping with a corresponding change in the direction of cargo overburden, reducing the range of movement of quarry cargo and, consequently, reducing the amount of resources consumed by the technological chain, but maintaining the traditional structure of the latter.

Significantly higher efficiency (several times) can be achieved by implementing transformations of the traditional structure of the technological chain and building a new one,

with a large number of operations involved in creating use value. An example of such a solution is the transition to open-pit coal mining [11]. In this case, there are options when underground mining is carried out mechanohydraulic method. In this case, the technological chain is built up, when most of the processes — opening and preparatory workings from the quarry space along the mineral reservoir, cleaning works, coal transport in the form of coal-water mixture and dehydration — are involved in creating use value. In this case, the coefficient of efficiency of resource use increases several times and reaches a value of 0.5, i.e., it increases 4.1 times.

Thus, the review allows us to conclude that a qualitative increase in the efficiency of resource use requires a transition to new principles for the formation of coal production systems. In particular, in the structure of the technological chain, the number of processes involved in creating consumer value should tend to the maximum and the absolute amount of resources consumed in the technological cycle to a minimum. The implementation of this principle will contribute to a significant increase in the efficiency of resource consumption, which, as a result, will ensure an increase in the competitiveness of coal-mining enterprises in the current economic conditions, as well as the fulfillment of sustainable development conditions.

Principle 3. Organization of flow movement. Most modern coal mining production systems are organized in such a way that they have no direct connection with their end user and the interaction is carried out through a chain of intermediate suppliers and consumers. Obviously, the effective functioning of such a production and logistics chain is possible only if each “internal” supplier within the framework of this system would satisfy the requirements of its “internal” consumer, but at the same time, they would ensure the needs and requirements of the end user. If this condition is not fulfilled at least in a single link, then the entire production and logistics chain of creation of consumer value may collapse. This, in turn, requires the joint and coordinated action of all components of the production and logistics chain. It makes no sense to improve the quality and cost indicators of the components of the system separately, if the entire gain is lost due to inconsistency of interaction at the joints. An attempt of this kind will be an example of sub-optimization, i.e. local (imaginary) optimization, which does not benefit from the point of view of the system as a whole. The considered approach to the management and optimization of the production and logistics chain of creating consumer value as a single system is a fundamental moment of “resource-saving production” based on the principles of “Lean thinking”.

At the same time, to ensure the coordinated activities of all participants in the production and logistics system, the choice of management criteria is of fundamental importance. Until recently, as a criterion in the production systems of the coal-mining complex, the concept of costs is widely used - the cost of production.

However, in recent years, the concept of cost has been criticized [12]. To date, a sufficient number of examples of the negative consequences of its use have been accumulated associated with the local suboptimization of individual parts of business systems to the detriment of their effectiveness as a whole.

Significant progress towards the development of a set of indicators to ensure system optimization has been achieved in Goldrath’s work [12]. As Goldrath has shown, the main problem of the cost-based management system is the impossibility of adequately accounting for the interaction of various elements of the system. This is due to the fact that its model is based on the assumption of the independent nature of the costs arising in various elements of the system. However, in fact, the level of costs, as a rule, is the result of the interaction of elements of the system and is determined by the circumstances of this interaction at the previous and subsequent stages of the technological cycle. According to Goldrath, in modern conditions, the achievement of system optimization requires the abandonment of the concept of costs and the transition to using the system of “global operational criteria”. In accordance with [12], this system includes:

- the rate of revenue generation by the system;
- operating expenses;
- the average for the period level of equity capital.

The use of this system of indicators focuses the management's attention on organizing the optimal interaction of the processes of the managed system in order to identify and eliminate the bottleneck, that is, the resource that limits the rate of revenue generation by the system as a whole. Management of the limiting resource is aimed at both the growth of the system's performance indicators as a whole, and the reduction of operating expenses and the amount of capital linked in the system.

The Constraints Authority aims performers to focus on those factors that are most critical to overall success, that is, on the constraints of the system.

Thus, the secret of sustainable development is to create such a set of systemic factors that would provide the opportunity for system-wide optimization both within the enterprise and in the chain of intermediate partners of the logistics chain - in the interests of the end user.

Principle 4. "Pulling" the product. Depending on the mode of operation, production systems can be divided into "push" (PUSH) and "retractor" (PULL) type systems.

Until recently, the majority of production and logistics chains traditionally implemented in the coal mining industry belong to push-type systems. The logic of the functioning of systems of this type is determined by the requirement of the most complete use of expensive fixed assets. "The equipment should not be idle!" This is the meaning of the control system and organization of production of the "pushing" type. The reason for this decision was a seemingly completely "obvious" fact - the transfer of capital invested in fixed assets is possible only when these funds are working. In accordance with the above system of organization and production management, including methods of current and operational planning, the system of organizational policies of the enterprise (including wage systems) direct managers and employees to the fullest possible load of funds.

At the same time, coal mining production systems operate in conditions of a significant level of seasonal and conjunctive variability of demand and the said organization of work leads to the fact that the appearance of products at the output of the production and technological system is inconsistent with the volumes of its sales. As a result, in the production system, the level of work in progress and stocks of finished products in the warehouse increases periodically. This leads to the binding of significant amounts of working capital and the emergence of significant economic risks.

The general negative consequence of the "pushing" type of production is predetermined by the fact that the optimization of the system is carried out not by the system-wide criterion of economic efficiency, but by the totality of local efficiency criteria. Figuratively speaking, instead of optimizing the ability of the production system as a whole to make money (to ensure maximum efficiency of the rate of generation of cash flow with the minimum level of resources used and the capital linked in the system), the system is set up to "minimize costs", "evenness" or "continuity of production", "Permanent employment", i.e., local optimization.

The negative effects that the "pushing" production system has on enterprises have stimulated the development of "pull-in" type systems. The main feature of this type of system is the synchronization of production, i.e., the release of products demanded by the market in a mode consistent with the dynamics of market demand.

In this case, an extremely important task for working in a market economy is being solved - the response time of the production system to a consumer request is reduced. In the conditions of unstable demand, the systems of "intrusive" type make it possible to abandon the practice of outstripping production of large volumes of products based on unreliable long-term forecasts and to produce products only to order. A direct consequence of this approach is a sharp reduction in the level of work in progress, the release of working capital, a reduction

in the need for storage space for finished products with a corresponding reduction in production costs and the entire set of production and economic risks.

Principle 5. Continuous improvement. "Resource-saving production" is a production system aimed at constant struggle with losses of various kinds. The solution of this problem requires constant monitoring of the state of the production system, control of variability (change) of the parameters of its processes, analysis of the collected statistics, development of improvement programs and their implementation.

The manufacturer focuses on the "causal factors" that limit the effectiveness of the system, and improving the processes, seeking to reduce the variability of parameters and characteristics of the latter, better use of working time (less breakdowns, setups, downtime), better use of materials (less scrap), reducing the cost of rework and control. This allows both to increase the degree of uniformity (quality) of products and to reduce its cost. It is on this basis that the efficiency of resource-saving production is formed.

At the same time, it is impossible to achieve this result without the creative participation in this action of those people who implement the entire set of production processes. This requires the development and implementation of appropriate organizational policies in the field of recruitment, training, motivation and personnel management, creating an environment of cooperation in the organization, maintaining a balance of interests of all participants in the process of creating use value.

Thus, it will be possible to achieve the goals of increasing the competitiveness of coal mining enterprises and the implementation of the conditions of sustainable development in the region only if all workers and employees of the coal mining complex are actively interested in this.

## Conclusion

The considered approaches to the construction of production systems on the principles of "resource-saving production", tested in world practice in various industries, despite the significant specificity of the structure of mining production compared to the structure of production systems in the processing and processing industries, of course, adapted to the conditions of the coal-mining industry, but will require a fundamental change in the fundamental principles of design and management of industrial coal mining systems.

The review allows us to conclude that a qualitative increase in the efficiency of resource use through the implementation of a new approach to the formation of production systems and their construction on the principles of "resource-saving production" will contribute not only to a significant increase in the competitiveness of coal mining enterprises in modern economic conditions, but also to solve sustainable development of a large coal mining region.

## References

1. V.V. Zhdamirov., V.I. Kuznetsov, V.V. Mikhalchenko, *Coal*, **11**, 3 (1991)
2. V.V. Mikhalchenko, R.M. Artyushkova, A.P. Kuzmin, *Coal*, **1**, 40 (1992)
3. Yu.N. Malyshev, V.E. Zaidenvarg, I.M. Zykov et al., *Restructuring of the coal industry (Theory. Experience. Programs. Forecast)* (Nedra, Moscow, 1996)
4. R. Kurzweil, *The Six Epochs. In The Singularity Is Near: When Humans Transcend Biology*. (Viking, New York, 2005)
5. D. Rifkin, *The Third Industrial Revolution: How horizontal interactions change energy, the economy and the world as a whole* (Alpina non-fiction, Moscow, 2014)
6. E. Weizsäcker, E. Lovins, L. Lovins, *Factor four: New report to the Rome Club* (Academia, Moscow, 2000)

7. J. Womack, D. Jones, *Lean manufacturing: how to get rid of losses and achieve prosperity of your company: Transl. from English* (Alpina Business Books, Moscow, 2004)
8. T. Ono, *The Toyota Production System. Departing from mass production: Transl. from English* - Institute of Integrated Strategic (Studies, Moscow, 2005)
9. I. Macmillan, *The Japanese Industrial System* (Progress, Moscow, 1988)
10. G. R. Niv, *Dr. Deming's Space: Principles for Building a Sustainable Business: Transl. from English* (Alpina Business Books, Moscow, 2005)
11. V.V. Mikhilchenko, A.A. Atrushkevich, Patent # 2143075 RF, Bulletin, **35** (1999)
12. E. Goldrath, *Purpose: a process of continuous improvement* (Popurri LLC, Minsk, 2004)