Features of Methodological Approaches to the Study of Problems of Open Pit Transport

A V Glebov

1Federal state budget establishment the Institute of Mining Ural branch Russian Academy of sciences (IM UB RAS), Mamin-Sibiryak st., 58, Yekaterinburg, 620075, Russia

E-mail: glebov@igduran.ru

Abstract. Research has been carried out on the development of research methods on the problem of open-pit transport in the 20th century and in the beginning of the 21st century, which made it possible to establish the nature of the change in the research methodology. It is established that the development of science has a cumulative nature. At each new stage of development there is a concentration, rethinking and refinement of the results obtained in the past. The alternation of stages of intensive and extensive development indicates a cyclical sequence of the process of accumulation of knowledge. The obtained results include the following: a brief description of the parameters of development and open-pit transport, the main directions, goals and objectives of research, a general methodological approach and methods for solving problems, in chronological order with the identification of stages corresponding to the stages of extensive and intensive development. A new methodological approach to the study of open-pit transport problems has been shown, based on the study of transients using the principles of systemic, integrated, interdisciplinary and innovative trend. This approach can and should be used in the formation of open-pit transport systems in conjunction with the development of an open-pit space and its working area in order to introduce new types of transport means and transportation schemes for the reconstruction of the existing open-pit mines and the construction of new open-pit mines.

1. Introduction
The development of research methods for the problem of open-pit transport in the 20th century has been considered in the paper [1]. The authors have investigated the issue on the basis of a retrospective review of research methods used by various authors in defending doctoral dissertations on the problem of open-pit transport. The research results of the following leading scientists have been considered: E. F. Sheshko, M. V. Vasiliev (1961), B. V. Faddeev (1967), M. G. Potapov, A. N. Shilin (1972), V. L. Yakovlev (1978), A. A. Kuleshov (1982), V. A. Galkin (1988), V. P. Smirnov (1990), S. L. Fesenko (1991), S. Zh. Galiev (1997), Yu. I. Lel (1999), A. S. Dovzhenok (2002), L. I. Andreeva (2004) [2-15].

2. Methodology study
Studies have made it possible to establish the nature of the change in the methodology of research during the period 1930-2000. It is established that the development of science has a cumulative nature. At each new stage of development there is a concentration, rethinking and refinement of the results...
obtained in the past. The alternation of stages of intensive and extensive development indicates a cyclical sequence of the process of accumulation of knowledge. At the stage of intensive development, a qualitative leap takes place that changes the structure of cognitive activity and the style of thinking itself. The mechanism of intensive development is associated with the accumulation of facts and experimental data that can not be explained with the help of existing concepts. The contradiction is resolved by the creation of new ideas that allow us to explain these facts and experimental data. Upon approval of the new structure of cognitive activity, its extensive development and distribution to new subject areas begins. The alternation of the stages of intensive and extensive development is characteristic both for individual scientific disciplines and for their complex as a whole.

Over the past 15 years, several doctoral dissertations in the sphere of open-pit transport have been defended.

As a result of the research, I. V. Zyryanov (2006) has solved a major scientific problem of providing stable, efficient operation of open-pit transport systems under extreme climatic and complex mining and technical conditions of diamond mining enterprises [16]. He has developed scientific approaches to managing the dump truck resource under extreme conditions, which representing a qualitatively new level of the use of expensive mining transport equipment and being a development of the theory of the functioning of complex, dynamic systems of technological vehicles.

In his dissertation, K. Yu. Anistratov (2013) has developed a scientific method for the formation of the structure of complex mechanization of mining operations in open-pit mines, taking into account the features of the functioning of each unit of equipment of mining equipment parks in the changing natural and technological conditions of open-pit mining [17].

3. Research result

Guided by the knowledge of the general laws of the development of science, we have presented the obtained results, including: a brief description of the parameters of development and open-pit transport, the main directions, goals and objectives of research, a general methodological approach and methods for solving problems, in chronological order with the identification of stages corresponding to the stages of extensive and intensive development (Table).

A new qualitative leap in the development of research methods for the problem of open-pit transport (stage IV) is characterized by a concentration of knowledge, a rethinking and refinement of the results obtained at previous stages of development. The decisive importance here, as in the stage II of development, is attributed to a theoretical form of research, for which there are the necessary prerequisites associated with the transition from modern complex-mechanized production to complex-automated production.

In 2007 V. L. Yakovlev had proposed a new methodological approach based on the combined use of the principles of systemic, integrated, interdisciplinary and innovative trend [18, 19]. Further studies had led to the creation in 2014 of a universal methodology based on the study of transient processes used in the design of the development of deep-seated deposits, planning, organizing and managing the extraction and ore preparation of mineral resources at operating mining enterprises, taking into account the growth of geological information, the introduction of developed innovative measures, the change of parameters and indicators of the mining engineering system of a mining enterprise as mining progresses.
Table 1. Development of research methods for the problem of open-pit transport in the twentieth century.

| Development parameters | 1930-1950 | 1960-1970 | 1980-2000 | 2000-2020 |
|-------------------------|-----------|-----------|-----------|-----------|
| Years, stages, nature of development | extensive | intensive | extensive | intensive |
| 1 Open pit depth: down to 100 m. | | | | |
| Range of transportation up to: 1.5 km - by road, 5 km - by rail | | | | |
| Loading capacity: 3-5 m³ | | | | |
| 2 Open pit depth: 150-250 m. | | | | |
| Range of transportation up to: 2.5 km - by road, 7 km - by rail | | | | |
| Loading capacity: 5-8 m³ | | | | |
| 3 Open pit depth: 300 m and more. | | | | |
| Range of transportation: up to 8.0 km - by road, 11 km - by rail | | | | |
| Loading capacity: 8-32 m³ | | | | |
| 4 Open pit depth: down to 500 m and more. | | | | |
| Range of transportation: up to 10.0 km - by road, 15 km - by rail | | | | |
| Loading capacity: 10-40 m³ | | | | |
| Development parameters | | | | |
| Rail: - steam locos (coupling weight 53 t); - electric locos (coupling weight 100 t, i = 40 %o); - dumpcars (Q = 50-172 t). Road (Q = 5-25 t, i = 8-10 %, W = 110-300 kW). Conveyor (Lp = 500 m, B = 1200 mm, Q = 100-450 t/h, Β = 15-18°, N = 3 x 85 kW). | | | | |
| Hydrotransport. | | | | |
| Rail: - electric locos (coupling weight 360 t, i = 40-60 %o); - dumpcars (Q = 100-200 t). Road (Q = 32-200 t, i = 10-12 %, W = 1850 kW). Conveyor (Lp = 500 m, B = 2000 mm, Q = 6000 t/h, Β = 16-18°, N = 3 x 1250 kW). Combined: - road and rail; - road and conveyor; - rail and conveyor; - road and conveyor and rail; Hydrotransport. | | | | |
| Rail: - electric locos (coupling weight 360 t, i = 40-60 %o); - dumpcars (Q = 100-200 t). Road (Q = 55-360 t, i = 10-22 %, W = 2610 kW). Conveyor (Lp = 500 m, B = 2000 mm, Q = 6000 t/h, Β = 16-18°, N = 3 x 1250 kW). Combined: - road and rail; - road and conveyor; - rail and conveyor; - road and conveyor and rail; Hydrotransport. | | | | |
| Special and specialized. | | | | |
| Line of research                                                                 | Goal of research                                                                 | Research objectives                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Complex mechanization of open-pit mines.                                        | Study of the relationship between loading and transport equipment parameters.  | Substantiation of technological parameters of existing types of open-pit transport and technical characteristics of transport means. Creation of new types of open-pit transport. Development of transport means.                     |
| Development of scientific bases for the design of open-pit transport.            | Creation of the theory for the formation of deep pit transport systems.          | Explanation of the main terms. Development of the principles of the formation of transport systems. Establishment of regularities in the strategy for the formation of transport systems. Development of methods for selecting types of open-pit transport, optimization of technological parameters and technical characteristics. |
| Determination of the rational use of various types of open-pit transport.        | Adapting the characteristics of technical means to changing the external environment: geological conditions of deposits, geomechanical properties of rock masses and rocks, basic and auxiliary production processes, ecology, economics, etc. | Deepening of research on individual types of transport, their interconnections, operating limits and ranges. Substantiation of a standard range of high-performance equipment. Search for new efficiency criteria, methods of selecting the transport types, optimizing the technological parameters and technical characteristics. Study of the processes of organization, management and maintenance of transport, ensuring the effective use of material, labor and financial resources. |
| Ensuring the efficiency of functioning of open-pit transport systems.            |                                                                                   | Research of transient processes of formation and development of transport systems in mining operations. Development of the theory for the formation of open-pit transport systems and the forecast of scientific and technological development in the sphere of open-pit transport until 2030. Search for new efficiency criteria, methods of selecting the transport types, optimizing the technological parameters and technical characteristics. Development of innovative machinery and technologies for transportation of rock mass in the dynamics of development of mining systems in the development of mineral deposits. |
| Approach | Functional System | Functional System |
|----------|-------------------|-------------------|
| Methods for solving problems | Full-time and timing observations, analytical and statistical methods, pilot-industrial experiment, technical and economic analysis, graphical and graph-analytical methods, method of options. | Ascent from the abstract to the concrete, idealization, abstraction, elementary-theoretical analysis and synthesis, induction and deduction, computer simulation, formalization. | Theoretical provisions of classical mechanics, optimization, probability, reliability, aging of machines and mechanisms, mass service, experiment planning, decision making, technical systems, the formation of open pit transport systems. Methods of statistical analysis of random functions, mathematical statistics, economic and mathematical modeling, computer simulation logic-statistical modeling, logistic approach, geoinformation modeling. | Program-objective methods based on the principles of systemic, integrated, interdisciplinary and innovative orientation. Methods of statistical analysis of random functions, mathematical statistics, economic and mathematical modeling, computer simulation logic-statistical modeling, logistic approach, geoinformation modeling. |
4. Conclusions
The main indicator characterizing the high degree of novelty of research is the further development of the program-objective methodological approach to the study of mining problems based on the principles of systemic, integrated, interdisciplinary and innovative trend, by introducing a fundamentally new concept of "transient processes" and taking into account the regularities of their execution under development of innovative mining technologies and ore preparation of mineral resources [20]. The essence of the novelty of the study of transient processes in the design and development of deep-seated deposits is that if the need arises to change the parameters of the technology or the technology of mining and processing production when estimating the dynamics of the mining system and its performance, it is necessary to determine the need, combination and sequence of a number of actions (measures) in order to adopt and implement the accepted technological innovation solutions.

This approach can and should be used in the formation of open-pit transport systems in conjunction with the development of an open-pit space and its working area in order to introduce new types of transport means and transportation schemes for the reconstruction of the existing open-pit mines and the construction of new open-pit mines.

5. References
[1] Yakovlev V L, Stolyarov V F and Glebov A V 2006 Research methods for the problem of the kern transportation: from 20 to 21 century J. News of the Higher Institutions Mining Journal vol 1 115-123
[2] Sheshko E F 1950 Opening and systems of open development of mineral resources storage: auto Dr. then. science (Moscow: Institute of mining USSR Academy of Sciences) p 30
[3] Vasiliev M V 1961 The main issues of development of open development with road transport: cars Dr. then. them sciences (Moscow: IM AS USSR) p 37
[4] Fadeev B V 1967 Investigation of the application of the transport conveyor in open works GR to improve the economy of storage development: auto Dr. then. them sciences (Moscow: IM AS USSR) p 44
[5] Potapov M G 1971 Research of technological schemes and parameters of the equipment of transport on open pit developments: auto Dr. then. them sciences (Moscow: IM AS USSR) p 40
[6] Shilin A N 1972 Research open development scales rocks and ores with the use of conveyor transport: cars Dr. then. sciences (Moscow: Moscow Institute) p 44
[7] Yakovlev V L 1978 Theoretical basis of choice of transport ore quarries: auto Dr. then. sciences (Sverdlovsk: IM MISI USSR) p 36
[8] Kuleshov A A 1983 Theoretical foundations of high-performance exploitation high-end systems open pit mining vehicles: auto Dr. then. sciences (Leningrad: Mining Institute. G. V. Plekhanova) p 31
[9] Galavin V A 1988 Technological basis for the design and planning of cargo flows on the red car carrier with transport: auto Dr. then. them sciences (Moscow: IM AS USSR) p 30
[10] Smirnov V P 1990 Justification and optimization of parameters of technological road transport of ore quarries: Dis Dr. then. sciences (Yakutsk) p 359
[11] Fesenko S L 1991 Substantiation of parameters and development of technical means of railway transport systems with slopes 60% in deep pits: auto Dr. then. sciences (Moscow: Institute of problems of comprehensive exploitation of mineral resources) p 33
[12] Galiev S J 1997 Optimization of parameters of mining and transport systems of quarries on the basis of simulation: Auto Dr. then. sciences (Almaty: IM of the national center for complex processing of mineral raw materials of the Ministry of science-Academy of Sciences of the Republic of Kazakhstan) p 41
[13] Lel Y I 1999 Methods of calculation of parameters of steady work of motor transport of deep pits: auto Dr. then. sciences (Yekaterinburg: IM UB RAS and URSMA) p 35
[14] Dovzhenok A S 2002 Development of management theory and methods to transport by mining enterprise system: auto Dr. then. sciences (Chelyabinsk) p 47
[15] Andreeva L I 2004 *Formation of technical methodology of horn-service system of transport equipment at coal mining enterprise: auto Dr. then. sciences* (Yekaterinburg: URSMU) p 50

[16] Zyryanov I V 2006 *Improving the efficiency of quarry transport systems in extreme operating conditions: Dis. Dr. then. sciences* (St. Petersburg) p 378

[17] Anistratov K Yu 2013 *Development of a method of forming the structure of complex mechanization of mining operations in open pits: Dis. Dr. then. sciences* (Apatite) p 376

[18] Yakovlev V L, Kornilkov S V 2013 *Methodological features of subsoil development at the present stage* *J. Bulletin of UB RAS. Science. Society. Man* vol 4 43-49

[19] Kornilkov S V, Yakovlev V L 2015 *On the methodological approach to research in the field of subsoil development on the basis of consistency, complexity, interdisciplinary and innovation* *J. Mining journal* vol 1 4-5

[20] Yakovlev V L 2017 *Research of located processes - a new methodological approach to the development of innovative technologies of extraction and ore preparation of mineral raw materials in the development of deep-lying estrogen* *J. Problems of subsoil use* vol 2 5-14 (DOI: 10.18454/2313-1586.2017.01.112.)