

ENGINEERING APPLICATIONS

UDC 658.7

Barsbold B., Gerelmaa G. Feasibility study for optimizing spare parts supply

Barsbold. B., Gerelmaa G.

School of Management, University of Science and Technology
Global Leadership University

Abstract. This research work aims to identify opportunities and ways to optimize the management of spare parts supply resources on the example of “Energy Resources” LLC. The study used quantitative analysis methods based on ABC/XYZ classification, economic order quantity (EOQ), and historical data. The object of the study is the company’s spare parts orders, consumption, and delivery time data for 2016–2024. The analysis revealed that the stock level deviated from the optimal level by 15–20%, and a solution was developed to introduce an automated planning system. Optimization of spare parts supply proves the real possibility of reducing technical downtime and saving warehouse costs.

Keywords: Spare parts inventory management, ABC analysis, EOQ model, Supply chain

Рецензент: Торопцев Василий Владимирович - кандидат технических наук, доцент.
ФГБОУ ВО «РГАУ-МСХА им. К.А. Тимирязева»

The continuous operation of the mining industry directly depends on the availability of equipment. Optimizing the spare parts supply chain is a key factor in reducing operating costs and increasing productivity. [1]. However, the unstable demand for spare parts and long supply times make it difficult to implement an optimal resource management policy. For “Energy Resources” LLC, spare parts inventory accounts for a significant part of the operating costs. A shortage of spare parts causes technical downtime, while an excess of resources leads to the freezing of working capital [2]. Therefore, this study analyzed the current state of the company's spare parts supply and sought opportunities to optimize resources using mathematical modeling. Mining spare parts research focuses on three major solutions in practice: warehouse optimization (ABC, SLP, EOQ, (S,s)), mathematical optimization/stochastic modeling (multi-echelon, robust optimization), and criticality-based classification + MCDM. [3]. The purpose of this study is to analyze the current state of spare parts supply in the mining transportation sector, identify the challenges, and suggest possible ways to optimize the supply process.

The normal operation of mining equipment directly depends on the availability of spare parts. The study analyzed the relationship between spare parts turnover, delivery time, stock level, and cost using supply chain theory, logistics optimization, and resource planning methodologies. By combining quantitative and qualitative data, it was possible to

identify internal and external factors affecting the spare parts supply system.

The results of the study revealed the following main problems: poorly developed spare parts resource planning, non-optimal rotation classification, and high variability in supply time. In order to solve these problems, it was determined that it is necessary to implement measures such as refining supply planning, automating resource management, and establishing performance monitoring.

I. THEORETICAL OVERVIEW

In mining companies, spare parts supply is a strategic decision-making factor for ensuring production continuity, and failures in this system affect not only the efficiency of logistics, but also the productivity and cost structure of the entire organization. According to the main results of the conducted studies, the following basic system failures dominate the spare parts supply chain. [4].

First, the loss of resource estimation and uncertainty in demand-supply lead to a surplus or shortage of spare parts, which slows down the turnover of financial investments. When the demand forecasting model is poor, optimization based on reliability indicators such as MTBF and MTTR cannot be performed, and the planning efficiency is lost.

- *Second*, the long international supply cycle, combined with the size, weight, and transportation characteristics of mining equipment, further complicates the chain and increases the variability of supply time. As a result, the safety stock level is set higher than required, and the cost of warehousing tends to increase.

- *Third*, weak supplier reliability assessment poses a risk to the stability of supply, causing problems such as substandard parts, quality defects, and time discrepancies. Studies have shown that weak KPI systems that regularly evaluate supplier performance are a major cause of quality defects.

- *Fourth*, poor integration of warehouse management and information systems creates discrepancies between actual parts stocks and order information, creating conditions for making decisions based on outdated information. Research repeatedly shows that data errors increase when ERP, EAM, and CMMS systems are not fully integrated.

- *Fifth*, due to the characteristics of the mining industry, the backward procurement process and the complexity of coordination slow down the order coordination and increase the risk of production downtime.

The large number of procurement steps is the cause of the system to reduce the supply cycle. Finally, these problems together create high-cost risks such as reduced spare parts supply efficiency, reduced mining equipment service life, and increased unplanned downtime. According to the research level, it is necessary to integrate scientific methods

such as mathematical modeling in demand forecasting, supplier risk management, system integration, and process innovation to optimize the mining spare parts supply system.

The METRIC model developed by Sherbrooke was the first to scientifically demonstrate the ability to determine the stock level of repairable parts in accordance with the system availability requirements. The peculiarity of this model is that it introduces a mathematical method for solving the relationship between the randomness of demand, the repair cycle, and the multi-level resource positions. The METRIC method is the basis of all advanced models in the industry today [5]. Researcher Muckstadt developed a scientific systematic theory of the relationship between the supply of parts and service level indicators.

His work includes multi-level system optimization, risk analysis, and low-demand spare parts classification methods. His research has been of practical significance by integrating the theory of service level control with resource policies and developing decision trees and algorithms that are suitable for the characteristics of low-demand and high-value spare parts [6]. The spare parts supply system in the mining industry is an important component that directly ensures the reliability of equipment, machinery, and production operations, and poor organization of the resource, order, and supply processes is the main cause of technical downtime, maintenance delays, and inefficient costs. In this context, the study of supply theory, resource management, and logistics optimization methodologies is the basis of research. A supply chain is a system that efficiently manages the flow of goods and services from source to consumer, including planning, warehouse organization, and transportation management. This theory suggests a methodology for optimizing inventory levels, order frequency, delivery time, and risk management. Based on this, the study identified weaknesses in the parts supply chain structure and identified opportunities for performance improvement.

The theory of stock classification allows for the optimal determination of stock levels by classifying them according to turnover, price, and frequency of demand. ABC classification is a widely used method that provides guidance for management by dividing spare parts into high, medium, and low turnover categories. Also, mathematical models such as Economic Order Quantity (EOQ) allow for the optimal calculation of order volume, lead time, and cost. The study used these methods to analyze spare parts turnover, stock levels, and order frequency. Demand forecasting is essential for ensuring efficient supply operations, and taking into account historical consumption, demand variability, and seasonality can reduce lead times and reduce the risk of surpluses and shortages.

This study used a combination of methods such as system analysis, quantitative data analysis, and qualitative analysis to analyze warehouse records, delivery time statistics, and work process reports to identify the main factors affecting spare parts performance. The

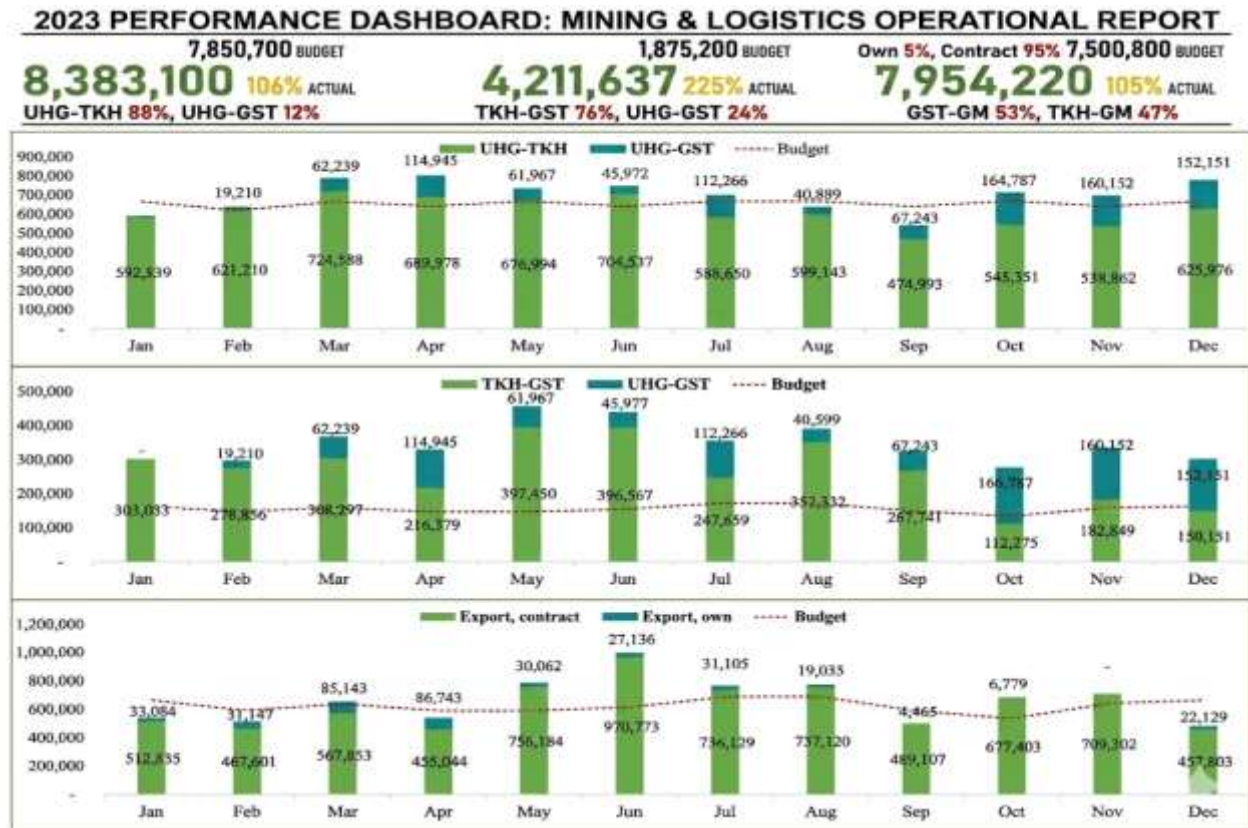
optimization methods proposed in the study were practical, aimed at reducing delivery time, reducing excess inventory, and reducing cost risks, which is the novelty of the study, and it is believed that they can make a real contribution to improving the spare parts supply system in mining organizations, ensuring equipment continuity, and increasing production productivity. When managing spare parts resources, it is effective to adopt a differentiated policy based on demand frequency and value. The theoretical basis of the study focuses on determining the strategic importance of spare parts by combining ABC and XYZ classification methods. In this study, the Economic Order Quantity (EOQ) and safety stock models were used to minimize resource costs in accordance with the characteristics of Mongolian mining logistics. The EOQ model was used to calculate the optimal order quantity.

II. RESEARCH SECTION

“Energy Resources” LLC is a nationally invested mining company established in 2005 and is one of the leading enterprises in the mining sector of Mongolia.

As part of the research, a detailed analysis of the planning, execution, stocking and shortages of spare parts supply in the planning section of the transport and logistics department of “Energy Resources” LLC was conducted. The study was based on the actual conditions of the company’s internal operations, documentary information, observations and interviews with relevant employees. The current state of spare parts supply at “Energy Resources” LLC is characterized by the lack of an automated system and the loss of planning management due to many manual processes:

- Order delays
- Technical downtime
- Cost increases
- Loss of income, etc. This leads to direct economic risks.



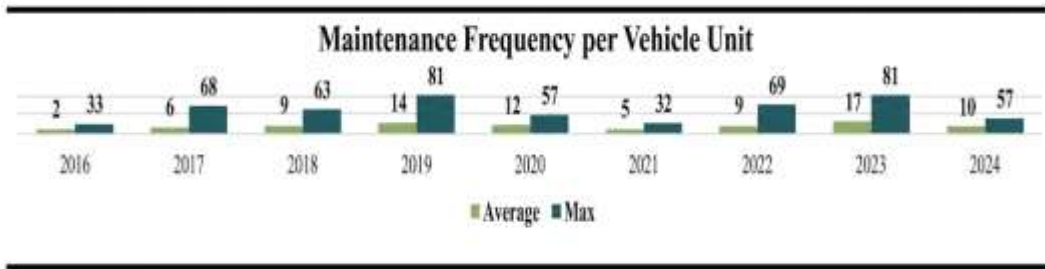
Source: Researcher's elaboration

Figure 1: Transportation of "Energy Resources" LLC, 2024

"Energy Resources" LLC's shipments in the UHG-TKH and UHG-GSCT routes in 2024 amounted to 8,383.1 thousand tons, exceeding the plan by 106%. Of this, the UHG-TKH route accounted for 88% and the UHG-GST route for 12%, indicating that the main flow of the company's coal exports is concentrated in the "Ukhaa Khudag – Tsagaankhad" route.

The supply of the Tsagaankhad-Gashuun Sukhait (TKH-GST) and Ukhaa Khudag-Gashuun Sukhait (UHG-GST) routes was compared. The total supply volume in these routes was 4,211.6 thousand tons, exceeding the plan by 225%, indicating an increase in export activity and improved border conditions. Overall, the company's coal supply was 7,954.2 thousand tons, exceeding the plan by 105%. It can be concluded that the fluctuation in supply between seasons increases sharply in March-May and September-October, which is directly related to market demand, border entry factors, and transportation conditions at that time.

The maintenance section completed 289,020 hours of maintenance work in 2024, with a staff of 254 people.



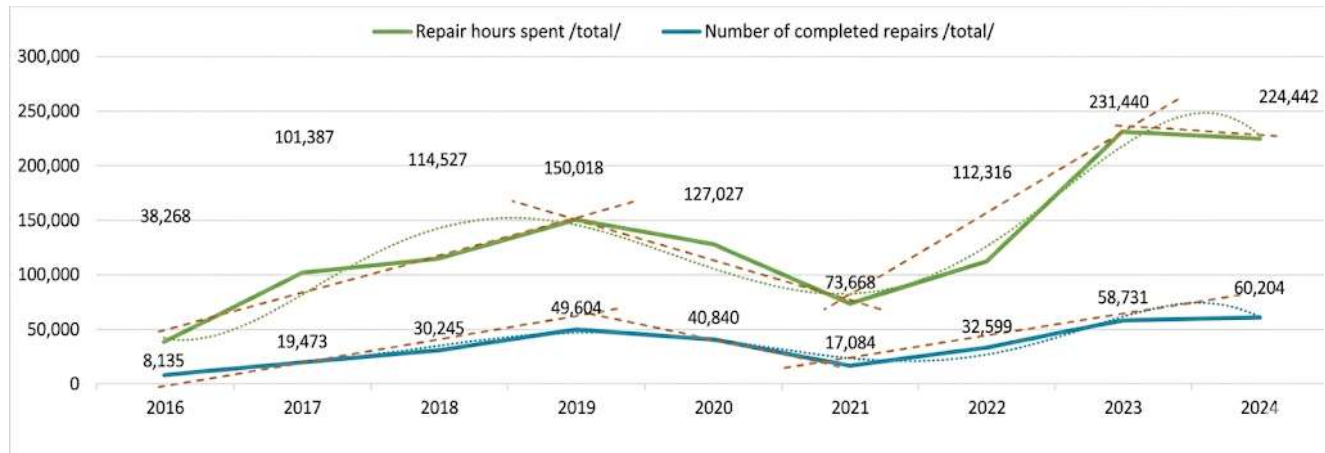
Source: Researcher’s elaboration

Figure 2: Vehicle repair frequency

The annual maintenance frequency of a unit of “Energy Resources” LLC from 2016 to 2024 shows the change in the frequency of maintenance of vehicles. Between 2016 and 2019, the maintenance frequency increased steadily, reaching its highest level in 2019, at 81 times. However, in 2020, the frequency decreased to 57 times due to the restrictions on operations and the decrease in transport volume during the COVID-19 pandemic.

In 2021, the maintenance frequency was the lowest at 32 times, due to weak technical operation, but increased again in 2022–2023, reaching 81 times, due to the resumption of mining operations. In 2024, it decreased again to 57 times, indicating that technical modernization, improved spare parts supply, and the effective implementation of the planned maintenance system were underway.

Category	2016	2017	2018	2019	2020	2021	2022	2023	2024
Repair Statistics Report (2016–2024)									
Welding	1,666	4,398	7,151	11,327	9,766	3,821	6,609	12,058	11,319
Tires	2,095	4,160	7,625	12,875	7,770	2,587	5,759	12,813	15,212
Electrical	118	456	2,408	5,811	4,469	2,052	3,653	8,954	8,931
Service Calls	1,777	4,534	4,611	6,380	7,105	3,080	5,816	9,248	8,942
Aggregates	1,838	4,994	6,928	11,039	10,052	4,862	9,831	13,026	12,588
Planned Maint.	604	730	1,356	1,903	1,453	592	807	2,274	2,876
Engine	37	201	166	269	225	90	124	358	376
Total	8,135	19,473	30,245	49,604	40,840	17,084	32,599	58,731	60,204
Total Repair Hours Spent (2016–2024)									
Welding	4,753	13,989	17,653	25,431	21,467	15,993	15,905	31,781	36,324
Tires	5,690	12,038	17,303	25,972	15,914	5,314	11,726	28,241	36,131
Electrical	414	2,308	5,779	10,932	8,562	4,709	8,325	18,542	15,586
Service Calls	6,925	18,326	19,001	21,276	19,882	8,381	13,824	30,328	26,932
Aggregates	16,388	42,087	43,974	50,016	47,457	31,224	51,903	87,524	77,902
Planned Maint.	3,063	2,657	5,093	8,223	7,262	4,809	5,603	16,781	14,941
Engine	1,035	9,983	5,724	8,169	6,483	3,240	5,030	18,244	16,626
Total	38,268	101,387	114,527	150,018	127,027	73,668	112,316	231,440	224,442



Source: Researcher's elaboration

Figure 3: Growth and decline graph

Energy Resources LLC's vehicle repair activities have fluctuated with a steady increase and decrease over the past nine years. In 2016, a total of 8,135 repairs were performed, spending 38,268 hours on them, while in 2019, the highest figure was reached, with 15,430 repairs and 150,018 hours of labor. This is due to the increase in the mine's transportation load and a sharp increase in equipment utilization during those years.

The number of repairs and hours spent in 2020 sharply decreased (12,093 repairs and 127,027 hours) due to the closure of borders and the slowdown in transportation activities due to the COVID-19 pandemic. This was followed by a decrease in the lowest level in 2021, with 7,368 repairs and 73,668 hours, due to operational restrictions, disruptions in the supply of spare parts, and a decrease in transportation. However, starting in 2022, due to the economic recovery and increased exports, the number of repairs and hours spent increased sharply, reaching 23,599 repairs and 231,440 hours in 2023, and 60,204 repairs and 224,442 hours in 2024. This indicates that the mine has started operating at full capacity, the intensity of technical utilization has increased, and the planned and preventive maintenance policy is being actively implemented. By subcategory:

- Welding, tire, and unit repair types account for about 70 percent of total time spent.
- Although the share of planned and engine repairs is small, they are characterized by long time spent per unit of work and require complex operations.

Overall, the total number of vehicle repairs increased by 7.4 times between 2016 and 2024, while the time spent increased by 5.8 times, which is related to the efficiency of technical operation, load, spare parts supply conditions, and internal repair planning. Spare parts supply activities are affected by many factors, including the company's internal organization, technical planning, system solutions, as well as foreign markets, supplier conditions, and

transportation environment. These are classified into internal and external factors and analyzed as follows.

Internal factors

1. Unsystematic planning

- Planning staff orders spare parts based on their experience and previous year's needs
- No statistical analysis-based planning methods or software
- Limited ability to monitor the quality of spare parts supply

2. No stocking policy

- Excess and shortages coexist

External factors

1. Foreign supplier terms and conditions

- Many types of spare parts are sourced from China and European countries
- Fluctuations in global supply, factory production schedules, and export restrictions

directly affect

- The average foreign order lead time is 30–45 days, and it is not possible to deliver quickly when needed

2. Road, transportation, and border customs conditions

- When supplying spare parts via international routes, they are subject to customs and border delays

- Some spare parts require special permits and laboratory tests, so they take time at customs

3. Exchange rates and transportation tariffs

- Since most spare parts are denominated in US dollars and yuan, exchange rate fluctuations will affect supply costs

- A sharp increase in foreign exchange rates causes a difference between the preliminary budget and the confirmed order

- International transportation tariffs and fuel prices increase the cost of supply

4. Supplier responsibilities and contracts

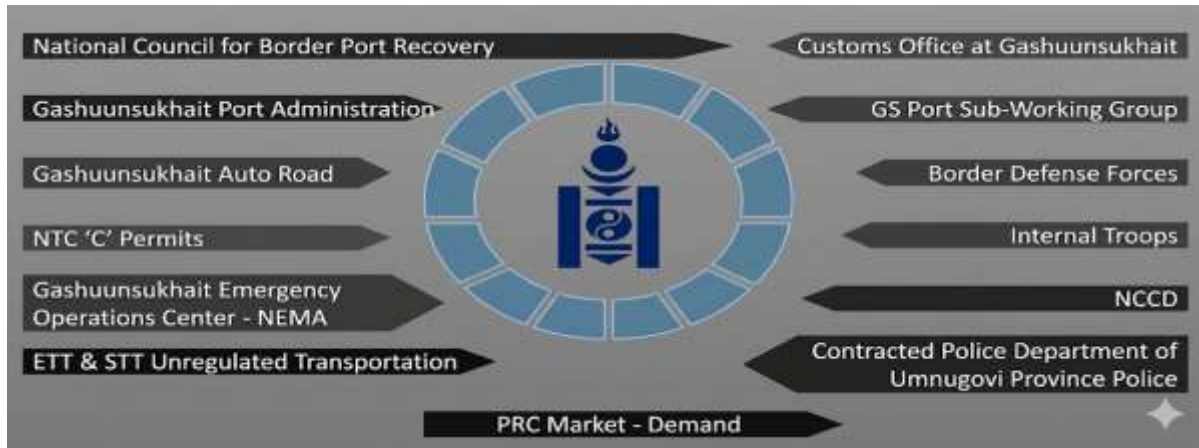
- In some cases, the contracted supplier:

- Delivering the wrong quantity

- Taking too long to transport to do

- Problems arise due to incorrect packaging and numbering of spare parts, etc.

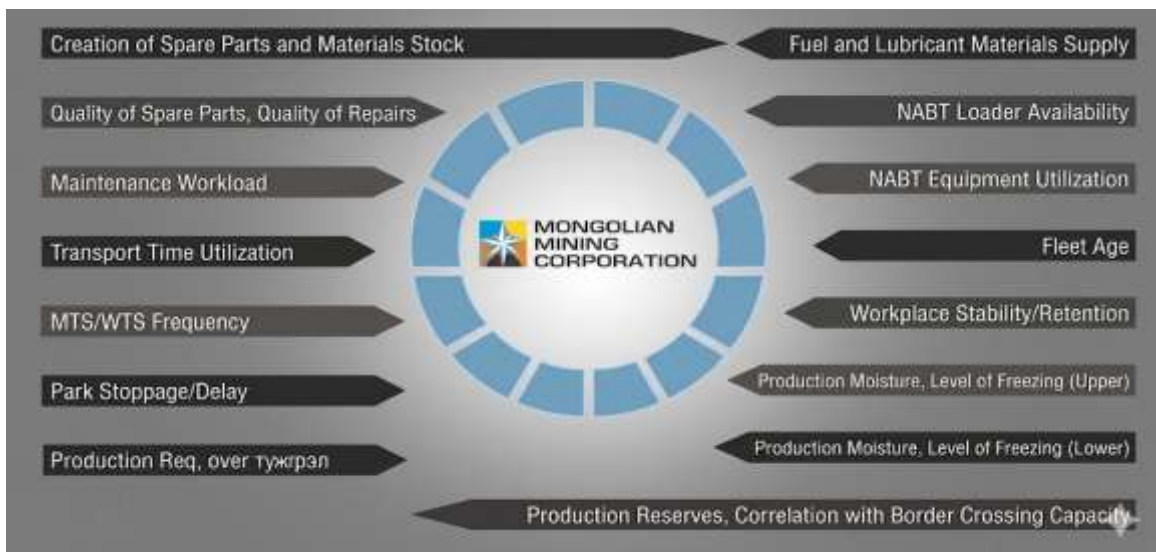
These create the risk of incorrect registration in the warehouse and technical downtime.



Source: Researcher's elaboration

Figure 4: Strategically important coal deposits

The following summarizes the external environmental institutions and policy factors that directly and indirectly determine the coal transportation performance of “Energy Resources” LLC. Transportation operations are not only related to the company’s internal planning and technical operation, but also depend to a large extent on the decisions and regulations of state and border control agencies, infrastructure capacity, and border crossing conditions.



Source: Researcher's elaboration

Figure 5: Internal factors influencing transport production

The main internal factors determining the coal transportation performance of “Energy Resources” LLC are summarized. These factors directly affect the level of transportation performance in conjunction with the company’s technical readiness, material supply, labor

organization, human resource stability, and effective management. Spare parts supply is a system that is not only dependent on unit planning, but also on all levels of operations and is very sensitive to the impact of the external environment. “For Energy Resources” LLC, internal factors such as internal structure, lack of integrated systems, and human resource burden are causing the main supply failures, while factors such as instability of external supply, border and customs, and currency risks are making it even more difficult.

Table 1

Factor correlation and impact on supply

Factors	Impact
Unsystematic planning	Duplicate orders, delays, incorrect registration
Unstandardized warehousing	Excess inventory, registration discrepancies, worn out and rusty spare parts due to non-compliance with operational requirements
Human resource experience and skills	Planning, registration errors, lack of control
Currency appreciation	Increased order costs, over-planning of the package
Customs, border, logistics	Delayed deliveries, increased transportation time
Supplier misconduct	Defective spare parts arriving, technical commissioning delays

Source: Developed by the researcher

Parts Classification and ABC Analysis

ABC analysis is used to classify the total consumption of parts by cost and to plan for the most costly and high-risk categories

Table 2

ABC Classification of Company Parts

Category	Share of total spare parts assortment	Share of cost	Analysis value
Group A	15%	70–75%	Very expensive, if interrupted, the equipment will be stopped
Group B	25%	20–25%	Average cost, constant use
Group C	60%	5–10%	Low cost, some are hardly used

Source: Developed by the researcher

The spare parts consumption of “Energy Resources” LLC was taken from the report for January–December 2024 and ABC classification was performed as follows. It includes:

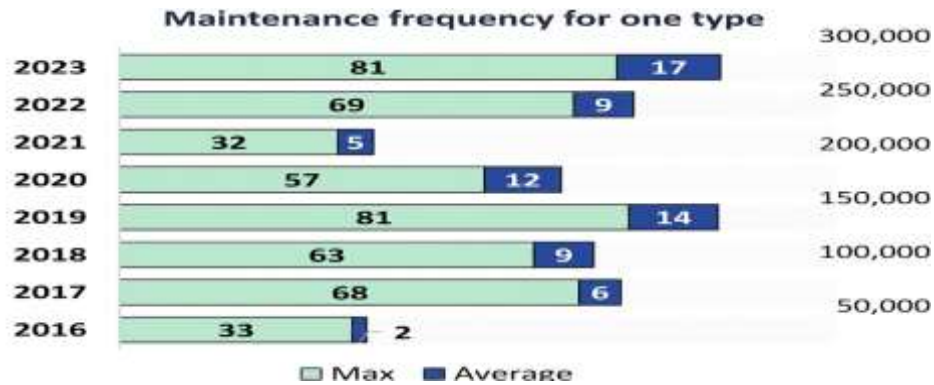
- Spare parts included in category A: engine block, hydraulic pump, turbine, differential
- Category B: filters, gasket sets, gas system spare parts
- Category C: small parts, rubber, seals, leak-proof fluids, labels, etc.

Importance of ABC analysis:

- More detailed planning and special stocking policies are required for spare parts in category A

- For categories B and C, it is necessary to use warehouse space optimally and improve stock turnover

Demand forecasting and supply chain analysis. Spare parts demand is often driven by technical failures, planned repairs, and replacements, and this demand is not constant and fluctuates seasonally.



Source: Developed by the researcher

Figure 6: Maintenance information

The efficiency of spare parts supply has a significant impact on ensuring technical reliability in the mining industry, reducing planned and unplanned downtime, and ensuring production continuity. For Energy Resources LLC, the spare parts reservation, ordering, and supply process is currently fragmented and unsystematic, and the information transfer is based on manual operations, which leads to disruptions, redundancy, and increased costs.



Source: Developed by the researcher

Figure 7: Comparison of maintenance activities

The current state of spare parts supply and research show that the company's spare parts planning, inventory, control, and supply processes lack an integrated and intelligent information system, which leads to various failures and losses.



Source: Researcher's elaboration

Figure 8: Information on substandard spare parts

Therefore, within the framework of this research, the requirements, direction and content of the development of the spare parts supply system were determined, taking into account the following grounds.

System development requirements. The company's spare parts flow includes the following main processes. These include:

1. Technical breakdowns and planned repairs
2. The emergence of spare parts needs
3. Sending orders
4. Checking the balance in the warehouse
5. Communication with external and internal suppliers
6. Receiving and recording
7. Operation and reporting

In the current situation, the above processes are carried out separately, predominantly manually, and based on Excel, email, and telephone communication, which leads to:

- Planning errors
- Resource surpluses and shortages
- Uncoordinated supply
- Weakened performance control.

Therefore, it is necessary to develop an integrated spare parts management system to solve these problems and streamline information flow.

The main goals of system development are:

- Real-time monitoring of spare parts orders, supplies, income, and expenses
- Data-based support for planning and decision-making
- Enable recording and analysis of spare parts life cycles
- Reduce losses caused by duplicate orders, registration errors, and downtime

Table 3

Development directions

Direction	Content
ERP Solutions	Integrated order-supply-warehouse-usage-reporting platform
CMMS (Computerized Maintenance Management System)	Link technical breakdown and repair plans to spare parts orders
Data Modeling	Record each spare part code, usage frequency, cost, and time in the system
KPI Monitoring	Monitor performance indicators such as delivery time, order fulfillment, and warehouse turnover
Alerts and Reminders	Automatic warning when resource levels are low
Analytic Reporting	Planning based on demand modeling and ABC/XYZ analysis

Source: Developed by the researcher

The main modules of the development system. The proposed system consists of the following 5 main modules.

Table 4

The main modules of the development system

Modules	Responsibilities
Order and consumption accounting	Record and create history of spare parts needs
Resource control	Monitor warehouse balances and income and expenses for each batch
Supply management	Monitor order progress and supplier performance
Planning and forecasting	Automatically forecast based on demand, frequency, and necessary resources
Reporting and analysis	Generate KPI, cost, ABC, XYZ reports, provide decision support, and view visual reporting dashboards instantly

Source: Developed by the researcher

Table 5

Expectations for development outcomes

Results	Description
Reduced order lead times	Reduce manual work by 50-70%, and information flows in real time
Reduced technical downtime	More accurate resource planning management will increase the availability of equipment
Reduced revenue losses	Reduce the time spent on repairs and waiting, ensuring equipment availability
Reduced warehousing costs	Improve warehouse turnover by reducing excess inventory and increasing space utilization
Improved management decision-making	Reduce the time spent on decision-making based on data and analysis, and increase the level of optimization

Source: Developed by the researcher

To solve the problem of spare parts supply, it is necessary to update the basic structure of the organization's operations through system development, not only by changing the warehouse and supply department. According to the analysis and research results of the current situation of the spare parts supply system, "Energy Resources" LLC has system weaknesses in key indicators such as information, planning, execution coordination, and decision-making support within the logistics system. It is clearly observed that this directly affects the efficiency of the company's spare parts supply, leading to technical failures, operational delays, and loss of revenue. Based on this, the requirements for developing an integrated logistics subsystem to systematize and automate the spare parts supply management process and support data-based decision-making were determined within the framework of this research work, and the framework for system development was determined based on the following theoretical and practical foundations.

The need and reasons for system development. According to the study, the following main reasons create the urgent need to systematize the spare parts supply system. These include:

- The registration of spare parts classification, usage, and cost information is not standardized and duplicated
 - It is impossible to monitor the performance of orders, reserves, and supplies in real time
 - There is no model for predicting supply time
 - There is a lack of a contract and performance monitoring system with suppliers
 - It is impossible to systematically record the life cycle and usage history of spare parts

- The ability to make decisions based on information is weak, and reports are processed manually

In order to correct and improve the above problems, a combined solution of ERP and CMMS based on information that is consistent with the company's operations is proposed within the framework of system development.

Development structure and components

The proposed system consists of the following main sub-modules:

1. Technical breakdown and repair registration module (CMMS)

- Recording of breakdowns, repairs, and spare parts consumption for each machine

2. Spare parts order and reserve management module

- Monitoring the order stage and calculating delivery time
- Setting minimum resource levels and safety buffers
- Creating automatic alerts and shortage notifications

3. Supplier performance monitoring

- Monitoring the fulfillment of SLA or service level agreement
- Creating performance indicators for time, quality, and integrity

4. ABC–XYZ classification and demand forecasting analytical module

- Determining spare parts classification and optimizing planning
- Dynamic planning based on demand fluctuations

5. Reporting and decision support

- Comparative reports on usage, resources, and order performance
- Dashboards based on KPI (key performance indicator)

Development stages and implementation status It is considered optimal to perform the following stages when developing the system:

1. Identifying requirements and mapping user problems
2. Analyzing current processes and performing BPR
3. Developing data modeling and registration coding
4. Selecting and developing software solutions (ERP, CMMS)
5. Testing, training, and pilot use
6. Formal introduction and performance monitoring

Expected results. The following improvements will be achieved as a result of the system development. For example:

- Spare parts outages and technical downtime will be significantly reduced
- Order and supply management will be automated and speed will improve
- Warehouse turnover will increase and excess investment will be reduced
- Management decisions will be based on data and calculations

- Control and accountability in relations with suppliers will be improved

The development of a spare parts logistics system is not only a technical issue, but also an important strategic step to optimize the organization's business processes and support data-based management decisions. Therefore, the phased implementation of the system in the future and the creation of an integrated use of ERP and CMMS systems will be the main conclusion of this study and the basis for the next stage of development.

III. CONCLUSION

This research work is aimed at optimizing the spare parts supply system and creating an efficient and reliable system. Based on the example of "Energy Resources" LLC, it successfully combines the theory and practical methods of logistics. The specifics of the mining industry and the high requirements for technical continuity require that the planning, stocking, and supply organization of spare parts be optimized at the strategic level.

When managing spare parts resources, it is effective to adopt a differentiated policy based on demand frequency and value. The theoretical basis of the research is aimed at determining the strategic importance of spare parts by combining ABC and XYZ classification methods. In this study, the Economic Order Quantity (EOQ) and safety stock models were used to minimize resource costs in accordance with the specifics of Mongolian mining logistics.

The optimal order quantity is calculated using the $EOQ = \sqrt{2DS/H}$ model. The study found that the following problems exist in spare parts supply. These include: overdependence on suppliers, late orders, duplication of resources, and planning uncertainty, which are the main factors that increase costs and cause technical downtime. During the study, theoretical methods such as EOQ, ABC analysis, safety stock calculation, demand forecasting, flow and cause-and-effect diagrams were used to evaluate the current supply performance and develop optimal solutions. In addition, the study found that the terms of contracts with suppliers should be based on key performance indicators, be more stringent, and be more controllable.

The risk of spare parts supply is related to over-dependence on a single supplier, weak contract protection, and poor data processing infrastructure. Therefore, in order to improve the efficiency and reliability of supply, it is necessary to update the contracts with suppliers based on performance criteria and accountability conditions, and on the other hand, it is necessary to abandon traditional tools such as Excel and introduce an automated system for integrated management of logistics and resource information. Therefore, the results of this study can serve as a basis for practical solutions, proposals, methods, and system improvements that can be implemented not only in the internal operations of the organization,

but also in other organizations in the mining and manufacturing sectors that operate in the same way. In the future, the stability, flexible organization, and automation of the supply chain will be the main drivers for increasing the competitiveness and productivity of the industry.

References

1. Zipkin, Foundations of Inventory Management, 2000
2. Jaakko Huiskonen, "Maintenance Spare Parts Logistics: Special Characteristics and Strategic Choices", Journal of Purchasing & Supply Management, 2001
3. Şenses, Sena, Gölbaşı, Onur, Bakal, İsmail Serdar. A spare parts inventory optimization study in mining, Pamukkale university journal of engineering sciences-pamukkale universitesi muhendislik bilimleri dergisi, 2022
4. Zhang et al, "A Comprehensive Review of Spare Parts Inventory Management: Classification, Trends, and Future Directions", International Journal of Production Research, 2021
5. Craig C. Sherbrooke, Optimal Inventory Modeling of Systems: Multi-Echelon Techniques (2nd Edition), 2004
6. John A. Muckstadt, Analysis and Algorithms for Service Parts Supply Chains, 2005
7. Guo, Y., Shi, Q., & Guo, C. (2022). Multi-Period Spare Parts Supply Chain Network Optimization under (T, s, S) Inventory Control Policy with Improved Dynamic Particle Swarm Optimization. Electronics, 11(21), 3454.
8. Wu, J., Liu, H., Zuo, H., Cheng, Z., Yang, Y., Ma, Y., & Kong, L. (2021). The Demand Supply Steady-State Process-Based Multi-Level Spare Parts Optimization. Sensors, 21(24), 8324.
9. Soltani, M. (2018). Joint Optimization of Opportunistic Predictive Maintenance and Multi-location Spare Part Inventories for a Deteriorating System Considering Imperfect Actions. ArXiv preprint.
10. Han, S., Noro, T., & Ho, K. (2024). Analysis and Design of Satellite Constellation Spare Strategy Using Markov Chain. ArXiv preprint.
11. Chen, Y.-k., Gao, Q., Su, X.-b., FLqang, S., & Guo, C.-m. (2018). Research on Optimization of Spare Parts Inventory Policy Considering Maintenance Priority. International Journal of System Assurance Engineering and Management, 9(6), 1336–1345.
12. Gao, J. D., Zhang, Y., Zhou, F. J., & Mao, H. L. (2014).
13. Research on Control Model for Spare Parts Inventory Based on the Optimal Replenishment Cycle, Applied Mechanics and Materials, 519–520, 1390–1394.
14. Şenses, S., Gölbaşı, O., & Bakal, İ. S. (2022). A spare parts inventory optimization study in mining. Pamukkale University Journal of Engineering Sciences.

15. Wang, Z., ... (2025). Research on the optimization method of inventory management of important spare parts of intercity railway. PLOS One.

16. Rahimi-Ghahroodi, S., Al Hanbali, A., Vliegen, I. M. H., & Cohen, M. A. (2019). Joint optimization of spare parts inventory and service engineers staffing with full backlogging. International Journal of Production Economics, 212, 39–50.

17. Pang, C. (2022). Management Optimization of Equipment Maintenance and Spare Parts for Automobile Intelligent Manufacturing Enterprises. International Journal of Frontiers in Engineering Technology.

18. АШИГТ МАЛТМАЛ, ГАЗРЫН ТОСНЫ ГАЗАР

19. <https://www.energyresources.mn/>