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Borya Orkhontuul

Tsend-Ayush Battsetseg

Tserenbaljir Serchmaa

Ulziibayar Oyunkhuu

Natsagdorj Zulaa

See next page for additional authors

Authors

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OPEN-PIT MINING AUTO TRANSPORT DATA PROCESSING

Borya Orkhontuul[1], Tsend-Ayush Battsetseg[2], Tserenbaljir Serchmaa[3], Ulziibayar Oyunkhuu[4], Natsagdorj Zulaa[5], Udanbor Batsanaa[6]

ABSTRACT: Increasing the efficiency of mining dump trucks is impossible without a scientific assessment of the level of organization of quarry technological processes, operating conditions and quality indicators. To evaluate the operational parameters of dump trucks for the open-pit mining of Erdenet Mining Corporation of Mongolia, the statistics derived from the cycling of six selected machines with different technical conditions, transporting to the processing plant and low-grade waste dump in summer and winter, were processed. The operating parameters of the six trucks which were measured and studied along the direction selected to fully represent the entire route of the mine, vary widely. The initial data of the PITRAM were unordered and according to the first data, the start and end times of a full cycle were calculated using the corresponding values of subsequent data, the amount of fuel consumed in one complete cycle and the cycle time duration of one complete route. Factors are taken into account and a new large dataset is created to evaluate the operating parameters of dump trucks.

INTRODUCTION

Data processing is based on the analysis of raw data in the database, the selection of the necessary data for research purposes, the creation of grouped data and then pre-processing, the organization of the transmitted data and their compaction as well as the creation of a large database.

The administration of Erdenet Mining Corporation came to the conclusion that the Russian VIST system which has been used for more than 10 years, since 2006, in the open-pit mining of Erdenet ore mining and has given the mine real advantages. This system is used to directly view the location of equipment, count the cycles of mining trucks and generate related reports. Further, the company needs a new programme that will have many positive results, among which the following main benefits will be directly related to production activities (Purevtogtokh, 2018). It includes:

- The ability to obtain information in relation to the use and technical condition of mining machines, equipment and mining dump trucks in real-time and with high accuracy allowing for the development of scientific and technological solutions around the reduction of unit costs and increasing the productivity and production of mining equipment, machines and equipment, especially technological machines, working under difficult mining and technical conditions;
- Since the grade of ore fed from the pit to the concentrator fluctuates, it affects the economic efficiency, so during the shift there is a need to control the grade with high accuracy;
- It is necessary to improve the classification of excavators loading ore. This will improve the control of the grade of ore fed to the concentrator;
- The introducing of an automatic monitoring system reduces the number of human interventions such as foundation drilling and marking, thereby increasing the level of safety.

[1] *Associate Professor in Mining Mechanical Engineering, School of Geology and Mining, Mongolian University of Science and Technology. Email: orkhontuulbo@gmail.com Tel: +976 9918 78666*
[2] *Researcher in Information Technology, School of Information and Communication Technology, Mongolian University of Science and Technology. Email: battsetseg_ts@must.edu.mn Tel: +976 9191 7405*
[3] *Researcher in Information Technology, Department of Academic Program and Quality, Mongolian University of Science and Technology. Email: serchmaa@must.edu.mn Tel: +976 9909 2993*
[4] *Researcher in Mining Safety, Energy Resource LLC. Email: oyukaaoojig@yahoo.com Tel: +976 9111 8426*
[5] *Researcher in Mining Management, School of Civil Engineering and Architecture, Mongolian University of Science and Technology. Email: n.zulaa@must.edu.mn Tel: +976 9902 2939*
[6] *Researcher in Mining Management, School of Geology and Mining, Mongolian University of Science and Technology. Email: agar_togs@yahoo.com Tel: +976 9904 0899*

Since 2017, MICROMINE's PITRAM system has been used in Erdenet mining operations to solve the above problems as part of the introduction of modern complex intelligent technologies. A computer installed in a mining dump truck provides basic information such as the cycle performed by the machine, the direction, rotation of the load, and the distribution of the excavator, the type of material being transported, the location of stacks and unloading points as well as the real payload. If the unloading location changes, a warning signal will be given in advance indicating the correct direction required and a warning signal will be given if the truck approaches any equipment. The cycle time of each truck is recorded and reported for each loading, waiting, loaded and empty trip.

In this research paper, the number of dump trucks in the fleet transporting on the selected route in the summer and winter months of 2021 along with the number of excavators that will be loaded into the trucks along with the sea level height at which mine work will take place were selected as the main columns, the primary raw data of the PITRAM system was also processed according to the cycle preformation including rotation, payload, and location.

METHODODLGY

For the purpose of processing and statistical analysis of data on fuel consumption for one full cycle of operation of the Erdenet mining trucks from January 01 to January 12, 2021, from the total of 212.3 million pieces of data for 2017-2021, the total information of the full cycle (42.4 million) completed in the 1st of January to the end of the 31st December in 2021 was grouped by the PITRAM system (**Figure 1**).

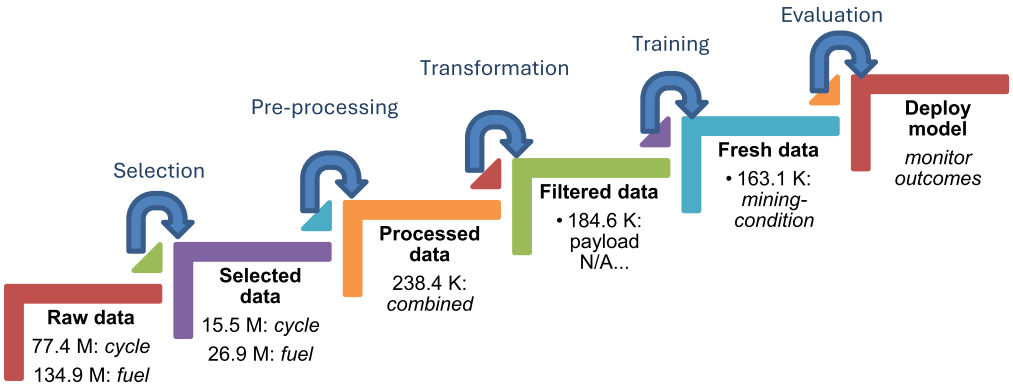


Figure 1: Diagram of generate a new big data

The Stockpile was named KKD (KSI) and the Waste dump 9 (WD 9, 9a, 9b) with the mining trucks selected depending on their technical condition, fleet numbers 65, 66 (old), 80, 81 (normal), 150, 151 (new) grouped data, data on the transportation cycles carried out in the direction, were extracted.

The initial data in the PITRAM system were unordered and from the first data, the start and end times of the full cycle were calculated using the corresponding values of the subsequent data, and the amount of fuel consumed in one complete cycle and duration of a full cycle. As a result, 18 336 rows and 13 columns of data were generated which aggregated information related to the full cycle of dump trucks selected for the study.

During data sorting in the PITRAM system database, the following issues were identified. It includes:

- In the detailed fuel consumption time data, most of the information at the point in time in the direction of the stockpile KKD (KSI) deviated from the specific time indication (hour: minute: second) of the data containing full cycle information;
- The actual payload value of the dump truck, corresponding to some full cycles, is missing;
- Loaded or empty transportation routes do not matter;
- The start time of full cycle`s is unknown;
- Some full cycle times are vastly different from other values transported in the same direction;

- Some fuel consumption values differed for the same route depending on the distance and direction of delivery.

Therefore, the following principle was used for data compression. It includes:

- In case of discrepancies at certain points in time, the duration of the full cycle is compensated by the approximation method;
- In the full cycle data, the data excludes the actual truck capacity, the value of the loaded and empty transport direction, the data of the beginning of the full cycle without information as well as risky and unfinished cases;
- Duration of a complete cycle over 60 minutes differs from neighbouring values transported in the same direction, negative and extreme values of fuel consumption (200 gram per ton kilometre-g/tkm) are not included in further processing;
- Removed some duplicate full lap data and tire load readings that were recorded as non-numeric values.

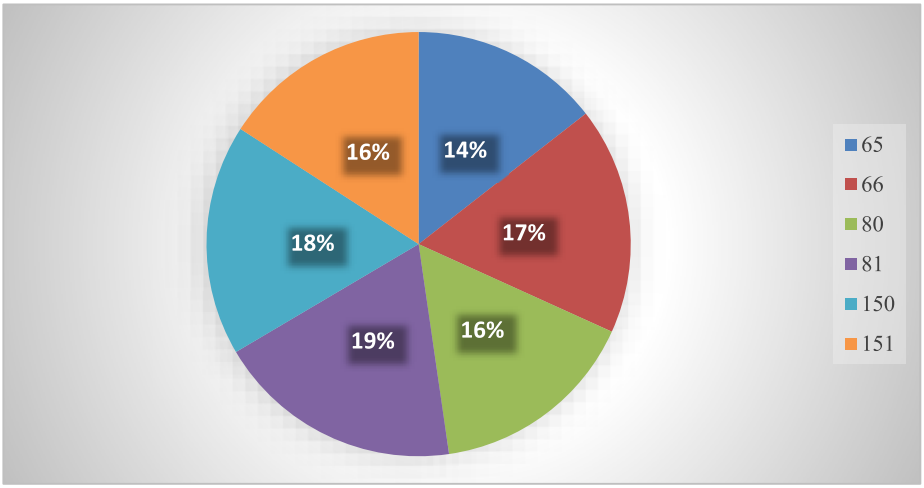
RESULTS AND DISCUSSION

After processing the primary data according to the specified methodology, 14 201 rows and 13 columns of data were included in further statistical analysis and are shown in **Table 1** for each dump truck.

Table 1: Full cycles data distribution of the surveyed dump trucks

Fleet number of trucks	Old		Normal		New		Total
	65	66	80	81	150	151	
July 2021	1137	1249	1193	1364	1301	1074	7318
December 2021	915	1211	1070	1306	1202	1179	6883
Total	**2052**	**2460**	**2263**	**2670**	**2503**	**2253**	**14201**

From the above table, 14% of the total data falls on dump trucks with fleet number 65 and dump trucks with numbers 66, 80, 81, 150 and 151 accounts for 17%, 16%, 19%, 18% and 16% of the total turnover (**Figure 2**). The data of the two trucks selected as the representatives of the old truck is 31% of the total data, 35% of the normal class and 34% of the new class which means that it is appropriate



to select the representatives of the open-pit ore mining truck class.

Figure 2: Data distribution of the surveyed dump trucks in Erdenet mining

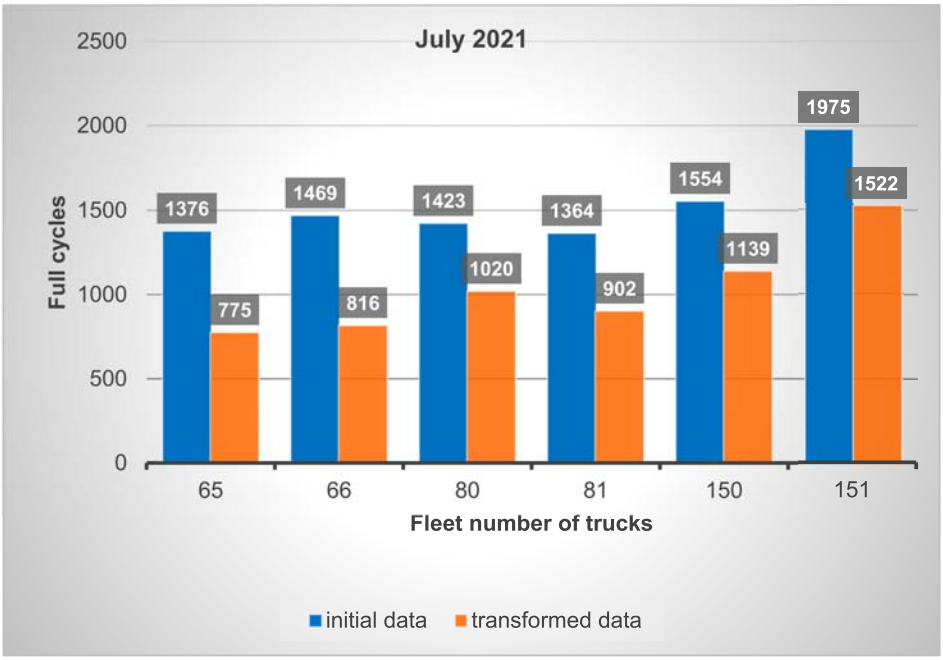


Figure 3: Number full cycles per trucks during July of 2021

Looking at the number of full dump truck cycles by season: 6 549 in July and 7 068 in December, there is a total of 13 617 filtered data after the first compaction. After pre-processing the data, the distance between loaded and empty routes differs by 1.5-3 times and after deleting the full cycle data for each vehicle in July and December, only 12 547 remained as shown in **Figures 3** and **4**.

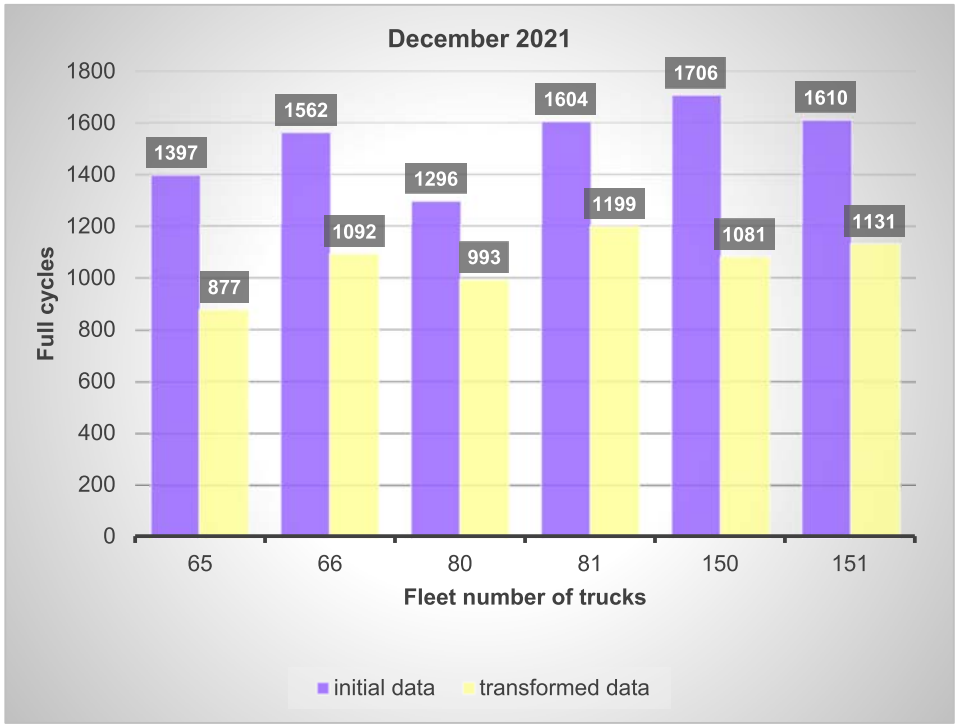


Figure 4: Number full cycles per trucks during December of 2021

After summarizing the primary data for each surveyed truck, 22.9-44.4% of the total primary data for July (for each dump truck) and 23.4-37.2% of the total primary data for December were removed (**Figure 3** and **4**). This indicates that, on average, 31.5% of the total amount of data accumulated in the PITRAM system database is erroneous. On the one hand, this indicates incorrect operation of the GPS system and sensors due to unforeseen factors when collecting data related to the operation and operation of the open-pit transportation system during operation. On the other hand, indicates that the data collected in the system is insufficient for conducting direct computational studies. Thus, 31.5% of the primary data associated with the use of six trucks included in the study were excluded as not meeting the requirements for further analysis and the remaining 68.5% or 12 547 data were processed.

DATA PROCESSING ON THE MAIN PARAMETERS OF THE DUMP TRUCK

To determine the dependence of dump truck fuel consumption on mining and technical conditions, it is necessary to carry out measurements in industrial conditions. During production testing the following were considered.:

- Directions and road conditions of the dump truck route;
- Specific production conditions;
- High accuracy results are obtained by making multiple measurements to high probability values reflecting different occurrences in time and space.

All factors affecting fuel consumption are random variables so fuel consumption can be determined by experimental probability depending on the above factors under certain conditions (Ryijov, 1973).

Table 2: Average monthly specific fuel consumption in Erdenet mining (g/tkm)

Month/Year	2017	2018	2019	2020	2021	Average of month
Jan	77.6	80.5	81.3	79.2	75.4	**78.8**
Feb	75.3	81.7	79.3	76.4	79.7	**78.48**
Mar	77.6	83.3	81.6	81.1	79.6	**80.64**
Apr	80.6	85.2	82.1	80.5	82.3	**82.14**
May	84.1	83.6	82.5	79.4	83.6	**82.64**
Jun	79.2	82.9	82.5	80	84.3	**81.78**
Jul	81	85.7	84.4	81.6	84.5	**83.44**
Aug	85	86.9	84.1	79.4	83.7	**83.82**
Sep	83.8	86.4	80.9	82.2	85.1	**83.68**
Oct	82.4	88.5	80.5	81.1	83.4	**83.18**
Nov	80	81.3	78.6	77.7	81.5	**79.82**
Dec	84.2	84.9	77.5	82.8	81.4	**82.16**
Average of year	**80.9**	**84.2**	**81.4**	**80.2**	**81.4**	**81.7**

source: Autotransportation year report in EMC

Table 2 shows the specific value of fuel consumption of Erdenet open-pit mining trucks for 2017-2021 while **Table 3** shows fuel consumption descriptive statistics. Fuel consumption of trucks in 2017 amounted to 75.2-84.2 g/tkm for 29 trucks or an average of 80.9 g/tkm, in 2018 these figures increased to 80.5-88.5 g/tkm for 33 trucks, on average 84.2 g/tkm. But in 2019 it was 77.5-84.4 g/tkm for just 32 dump trucks and the average was 81.4 g/tkm, then in 2020 it dropped to 76.4-82.8 g/tkm and an average of 80.2 g/tkm for 35 trucks and 72.5-85.4 g/tkm for 33 dump trucks in 2021 and increased to an average of 81.4 g/tkm.

Looking at the size of the interval between the minimum and maximum values from the fuel consumption descriptive statistics, the minimum size was 5.1 in 2018 and the largest difference was

12.9 in 2021. This interval size represents the level of use of technological trucks used in the current year and if this size is large, then the old truck will increase and the cost of transportation will increase as well (**Table 3**).

Table 3: Descriptive statistics of fuel consumption for mining trucks in Erdenet mining (g/tkm)

Parameters	2017	2018	2019	2020	2021
Mean	80.9	84.2	81.4	80.2	81.4
Standard Error	0.3	0.3	0.3	0.3	0.5
Median	81.1	84.6	81.1	80.3	81.8
Mode	na	85.7	80.3	81.2	na
Standard Deviation	1.4	1.5	1.7	1.5	3.0
Sample Variance	1.9	2.2	2.9	2.2	9.0
Kurtosis	0.7	-1.2	-0.5	-1.1	3.6
Skewness	-0.3	-0.1	0.3	0.0	-1.9
Range	6.7	5.1	6.8	5.4	12.9
Minimum	77.5	81.8	78.5	77.8	72.5
Maximum	84.2	86.9	85.3	83.2	85.4
Sum	2347.0	2779.4	2603.4	2806.1	2685.1
Count	29	33	32	35	33

For a detailed assessment of the energy consumption of mining equipment in terms of specific fuel consumption, statistical processing of the values of specific fuel consumption, determined by transport and production measurements performed on representative routes of selected vehicles, was carried out. This will be the basis for modelling costs depending on the factors influencing them. Fuel consumption by open-pit mining equipment was taken into account in winter and summer, in different directions of ore flows. Figures for July and December 2021 are presented in **Figure 3** and mathematical statistical processing - in **Table 4**, respectively.

Table 4*:* Descriptive statistics of fuel consumption for mining trucks in Erdenet mining (g/tkm)

Parameters	KKD (KSI)		WD 9 (a,b)	
	Jul 21	Dec 21	Jul 21	Dec 21
Mean	81.19	87.01	78.31	85.65
Standard Error	0.18	0.16	0.19	0.22
Median	81.70	87.24	77.33	85.48
Mode	na	na	na	na
Standard Deviation	5.70	4.84	5.41	4.76
Sample Variance	32.44	23.45	29.26	22.62
Kurtosis	-1.07	-1.18	-0.95	-1.12
Skewness	-0.27	-0.14	0.36	0.18
Range	19.96	16.95	19.96	16.95
Minimum	70.02	78.03	70.01	78.01
Maximum	89.97	94.98	89.96	94.97
Sum	82652.21	78482.91	61162.19	41541.95
Count	1018	902	781	485
Largest (1)	89.97	94.98	89.97	94.97
Smallest (1)	70.02	78.03	70.01	78.01
Confidence Level (95.0%)	0.35	0.32	0.38	0.42

a) KKD (KSI): Jul 21 b) KKD (KSI): Dec 21

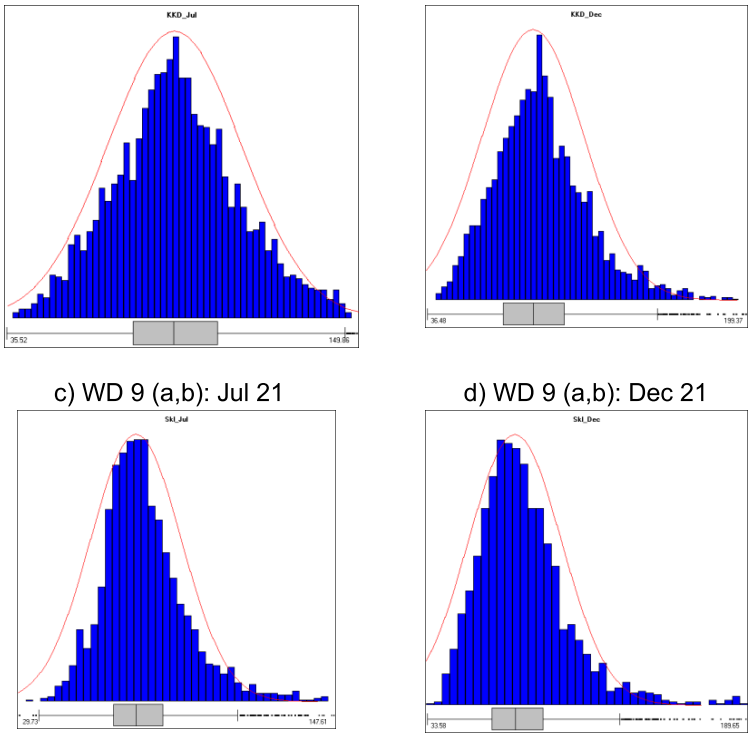


Figure 3: Fuel consumption data distribution of mining trucks depending on the direction (g/tkm)

The average fuel consumption of technological trucks in Erdenet mining in the summer season is D_{kkd} = 81.19 g/tkm, D_{skl} = 78.31 g/tkm, taking into account the direction of KKD (KSI) and WD 9 (a, b). The maximum value is max_{kkd}=89.97 g/tkm and max_{skl}=89.96 g/tkm as seen from the above table (**Table 4**). But in winter, this figure is 87.01 g/tkm and 85.65 g/tkm, taking into account the direction of the KKD (KSI) and WD 9 (a, b); the maximum values are 94.98 g/tkm and 94.97 g/tkm. In the winter season, the KKD (KSI) route was 1.07 times higher than the summer season and along the WD 9 (a, b) route - 1.09 times higher.

Expressing the variability of the original population by the sample variance (Kothari, 2004), the December value of WD 9 (a, b) of 22.62 is the lowest value, and the July value of the KKD (KSI) route is the highest at 32.44. 0.32-0.42 is a high value for determining the level of a different part of the data characteristic with a confidence limit of 95%.

CONCLUSIONS

In this research paper, there are 772236 rows and 20 columns of Erdenet open-pit mining truck productivity in 2021; 6 748 032 rows and 4 columns of aggregate fuel consumption data were extracted from the PITRAM system. The initial data received from the system were unordered and according to the first data, the start and end times of a full turn of the dump truck were calculated according to the corresponding values of the subsequent data, the amount of fuel consumed for a full turn. As a result, 18 336 rows and 13 columns of data were generated which aggregated information related to the full cycle of dump trucks selected for the study.

Based on these data, it is quite possible to further develop the operational and economic parameters of a mining truck, depending on factors such as the depth of the pit, the slope and length of the transport road, the type of road surface and the actual payload of the truck.

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