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Preventive and Predictive Maintenance

for Heavy-duty Machinery

Bachelor Thesis

by

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Ulaanbatar/Nalaikh, 05/16/2022

Statutory Declaration

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Preventive and Predictive maintenance for Heavy-duty Machinery

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

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Abstract

Research into the maintenance management of the mining industry and equipment maintenance is scant, despite the increased mining operation and productivity in recent years. In this paper the appropriate maintenance method for the subsystems of tracked dump truck and overall equipment is accomplished, by combining several maintenance analysis tools is. The maintenance data were processed using Pareto analysis technique, which assumes that 80% of a project's benefit may be realized by completing 20% of the work—or, conversely, that 80% of issues can be traced back to 20% of the causes. Pareto analysis is a used as a useful technique for evaluating quality and making decisions in this thesis. The target truck is decomposed into subsystems and historical data is collected and analyzed using failure analysis tools to evaluate the right maintenance plan. Since the data is very broad, the more accurate results can be achieved by breaking down the subsystem into smaller components level and analyzed. The results obtained from subsystem analysis proved that the proposed method is applicable to the truck maintenance in component level.

Acknowledgement

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List of abbreviations

PdM	Predictive Maintenance
PM	Preventive Maintenance
MTTF	Mean time to failure
MTBF	Mean time between failure
TPM	Total Productive Maintenance
RCM	Reliability Centered Maintenance
CBM	Condition Based Maintenance
MTTR	Mean time to repair
FMEA	Failure modes and effects analysis
DOM	Design out maintenance
DMG	Decision making grid
SLU	Skills level upgrade

1 Introduction

1.1 Background

1.1.1 Significance of maintenance in mining operations

The primary objective of any business is to generate profit, since without profit the company would cease to exist (Robbins, 1994). Regardless of the subdivisions within the industry, companies function by earning a profit from the sale of goods produced, materials extracted (coal, stone, mineral, etc.). Therefore, the company's structure is designed to effectively produce and sell these goods. So the most essential thing in producing goods effectively is choosing the right maintenance strategy.

Mongolia's mining industry contributes a significant amount of the country's annual GDP, thus all mining organizations and businesses must maintain their operations at optimum level to ensure high productivity and revenues. Regular maintenance checks and inspections on mining equipment are one beneficial technique for all mining businesses to improve their mining operations.

The mining equipment is built to survive the most extreme conditions, yet even the most powerful mining equipment needs regular maintenance. Mining equipment that is not properly maintained and serviced on a regular basis will not work as expected and will also pose a risk to everyone on the mining site.

Because various mining equipment is utilized on different mining sites, each mining site should have its own unique maintenance plan. This unique maintenance schedule will ensure that every piece of equipment will be properly maintained depending on the working environment, capacity and type of equipment. Regular maintenance has several advantages on the working site, including enhanced mining equipment lifetime, increased mineworker safety, fulfilling cost targets by limiting mining equipment downtime, and many other advantages.

1.1.2 Case study

The company mentioned on this paper is an open pit gold mining company. The company has over 500 pieces of machinery including dump trucks, excavators, loaders and graders. The company conducts a preventive maintenance schedule every 350 motor hours. Yet, the proactive maintenance culture does not occupy a huge role in maintenance management of the company.

The data used in this research was collected from the Komatsu Dump truck section. Historical maintenance data of two different types of komatsu dump trucks with different capacity were analyzed for the procedure. The first dump truck that was selected was a Komatsu HD1500-7 with a 1406-horsepower engine, a 7-speed automatic transmission and a capacity of 150 tons. The second dump truck is Komatsu HD785 with a 1042-horsepower engine, a 7-speed automatic transmission, and a capacity of 91 tons. The both dump trucks have same preventive maintenance intervals and in other cases maintenance management is noticed to be run-to-failure management.

From my observation, it seems that the waiting time for the parts to arrive is one of the biggest problems. Due to the company having a lot of equipment, they rely on equipment in stock and neglect the tasks related to the waiting for parts. Decreasing the number of equipment and improving maintainability seems possible. Also, the company conducts almost the same maintenance strategy to all equipment regardless of types is quite disadvantageous.

This paper outlines a simple, but powerful way of analyzing data in order to address these issues.

1.2 Objective of the study

1.2.1 General objective

Any company's principal goal is to make money, since without it, it would go out of business. Companies operate by profiting from the sale of commodities produced or materials mined, regardless of the industry subdivisions. As a result, the company's structure is set up to create and sell these commodities efficiently. So, the most essential thing in producing goods effectively is choosing the right maintenance strategy. As mentioned before predictive maintenance optimizes whole plant performance by utilizing the actual operational condition of plant equipment and systems. Analyzing the maintenance status that is previously made may help which subsystem of truck is having the most failures and downtime. So, the company can focus on these subsystems more to increase availability and decrease downtime.

Rather than analyzing each dump truck one by one, taking all dump trucks as a whole will be easier to generate the general condition of the certain type of truck. In this thesis, defining the methodology to determine maintenance techniques, more specifically PM and PdM techniques, for system failures and keeping balance between these maintenance techniques was the goal.

1.2.2 Specific objectives

- Research on the combination of the PM and PdM service
- Analyze historical data on tracked Komatsu dump truck's failure
- Evaluate the maintenance plan and make recommendation using analysis results
- Improve data collecting methods

1.2.3 Expected outcomes

This study focuses on analyzing the historical data on equipment (Komatsu dump truck) failure to determine the possible maintenance methods for candidates. The case study's findings are being utilized to look at the cost reductions that may be realized by using different types of maintenance methods in mining.

2 Literature review

2.1 Maintenance management methods

There are 2 main types of maintenance approach including reactive and proactive maintenance. Reactive maintenance is unplanned maintenance and takes action after a problem has occurred, costing company hundreds or thousands of dollars in repair. On the other hand, proactive maintenance or planned methods (Preventive, Predictive) are maintenance strategies that correct the source of underlying equipment conditions. The goal of proactive maintenance is to reduce unplanned downtime, equipment failure, and risks associated with operating faulty equipment.

2.1.1 Run-to-Failure Management

The logic of run-to-failure management is simply reactive maintenance method, it repairs equipment after failure occurred. Since the first manufacturing plant was built, The run-to-failure method of maintenance was the major maintenance method. It is also the most expensive maintenance method. High spare parts inventory costs, high overtime labor costs, high machine downtime, and low production availability are the principal costs associated with this form of maintenance management.

This reactive management style compels the maintenance department to have large spare parts inventories, which include spare machines or at the very least all significant components for all of the plant's important equipment. The other option is to rely on equipment providers that can deliver all essential spare parts right away. Even if the latter alternative is feasible, the price of repair components and the downtime necessary to fix machine breakdowns are significantly increased by charges for faster delivery. To reduce the impact of unexpected machine breakdown on production, maintenance workers must be able to respond quickly to any machine malfunctions. The end result of this reactive maintenance management is increased maintenance costs and poorer process equipment availability. According to an analysis of maintenance expenses, a reactive or run-to-failure repair will cost around three times as much as a planned or preventative repair. Scheduling the maintenance minimizes repair time and personnel costs.

2.1.1.1 Preventive Maintenance

Preventive maintenance (PM) is the routine repair of equipment and assets to keep them functioning and avoid unplanned downtime due to unexpected equipment breakdown. Preventive maintenance has different meanings, but all preventive maintenance management plans are time-based. In other words, maintenance tasks are dependent on the amount of time that has operated. Figure-1 depicts an example of a machine's statistical life. The bathtub curve, or mean-time-to-failure, shows that a new machine has a high risk of failure due to installation issues during the first few weeks of operation. For a long time after this first stage, the chances of failure are minimal. After this normal machine life term, the likelihood of failure grows dramatically as time passes. Machine repairs or rebuilds are planned based on the MTTF statistic in preventative maintenance management.

Preventive maintenance is implemented in a variety of ways. Some programs are quite basic, consisting mainly of lubrication and small changes. For all important plant machinery, comprehensive preventative maintenance plans schedule repairs, lubrication, adjustments, and machine rebuilds.

All preventative maintenance management strategies presume that machines will deteriorate over time in accordance with their classification. A single-stage horizontal split-case centrifugal pump, for example, will typically last 18 months before needing to be replaced. After 17 months of operation, the pump would be taken from service and rebuilt using preventative management approaches. The difficulty with this Impact of Maintenance is that the mode of operation and system or plant-specific factors have a direct impact on the machinery's normal working life. A pump that handles water and one that handles abrasive slurries have different mean-time-between-failures (MTBF). Using MTBF statistics to plan maintenance usually results in either unnecessary fixes or catastrophic failure. After 17 months, the pump in the example may not need to be rebuilt. As a result, the time and materials spent on the repair were wasted.

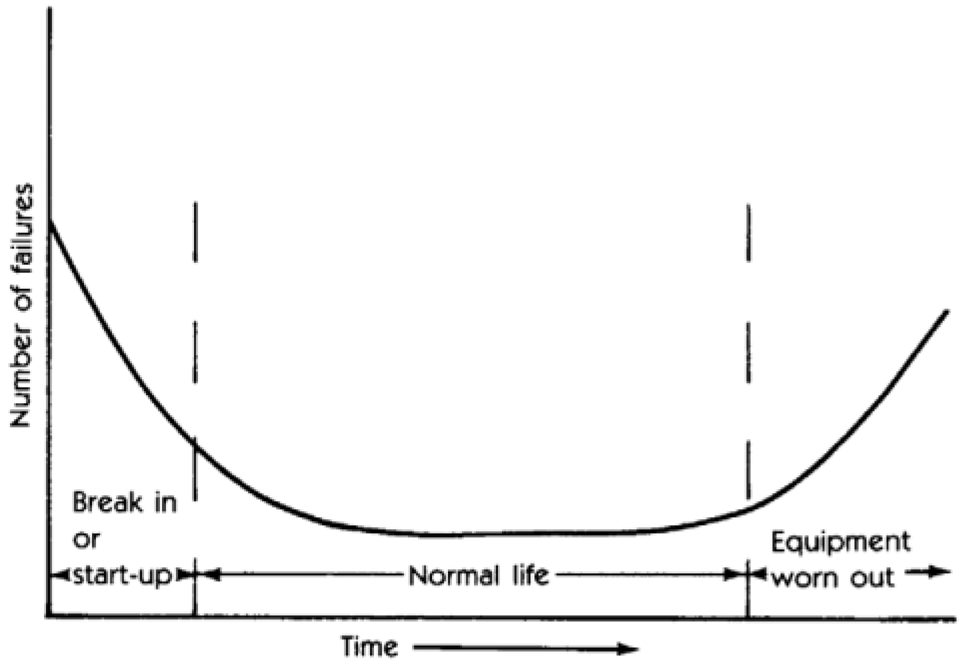


Figure 1. Bathtub curve

The second alternative, which involves preventative maintenance, is much more expensive. If the pump breaks before the 17-month period, a run-to-failure method must be used to fix it. Repairs conducted in a reactive approach are typically three times more expensive than repairs made on a planned basis. (3)

2.1.2 Predictive Maintenance

Predictive maintenance method is designed to analyze the condition of the equipment and help to predict when the maintenance should be performed. The PdM method is the most effective maintenance method among other methods. Predictive maintenance, like preventive maintenance, is defined in a variety of ways. PdM involves monitoring the vibration of spinning machinery in order to detect potential issues and avoid catastrophic failure. Otherwise, it's looking at the infrared picture of electrical switchgear, motors, and other electrical equipment to see if any issues are developing. Predictive maintenance is based on the idea that regular monitoring of the actual mechanical condition, operating efficiency, and other indicators of the operating condition of equipment and process systems will provide the data needed to ensure the longest possible interval between repairs and reduce the number and cost of unscheduled outages caused by equipment failures.

Predictive maintenance is a philosophy or attitude that, simply put, optimizes whole plant performance by utilizing the actual operational condition of plant equipment and systems. A comprehensive predictive maintenance management program obtains the real operational status of essential plant systems using the most cost-effective techniques and schedules all maintenance actions on an as-needed basis based on this actual data. Predictive maintenance, when included in a comprehensive maintenance management program, maximizes the availability of equipment while drastically lowering maintenance costs. It improves the quality, productivity and profitability of production facilities.

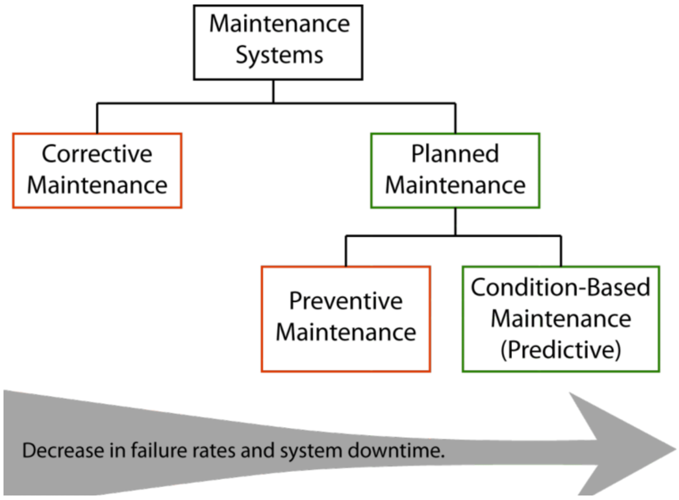


Figure 2. The two basic types of maintenance

Predictive maintenance is a condition-driven preventive maintenance program. Predictive maintenance, rather than relying on average-life statistical data (i.e., mean-time-to-failure) to schedule maintenance activities, uses direct monitoring of mechanical condition, system efficiency, and other indicators to determine the actual mean-time-to-failure or loss of efficiency for each equipment and system in the industry. The maintenance manager's intuition and personal experience must be used to make the final choice on repair or rebuild schedules in preventive or run-to-failure methods. As shown on the Figure-3 predictive maintenance strategy has the lowest cost and number of failures compared to the other maintenance methods.

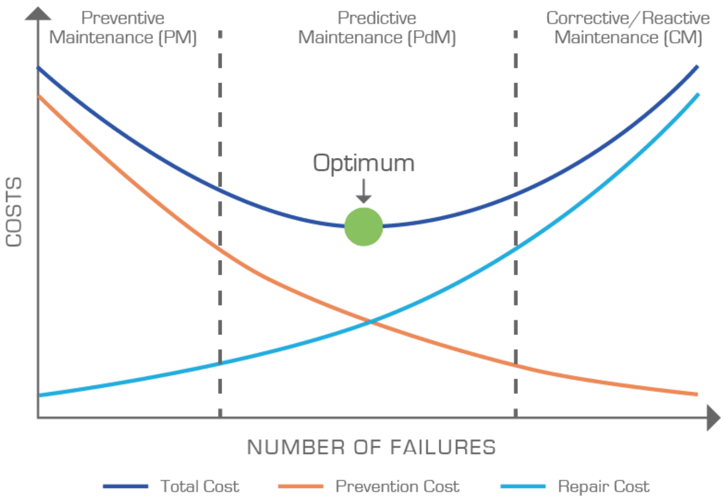


Figure 3. The correlation between the maintenance costs and failures for three different maintenance strategies

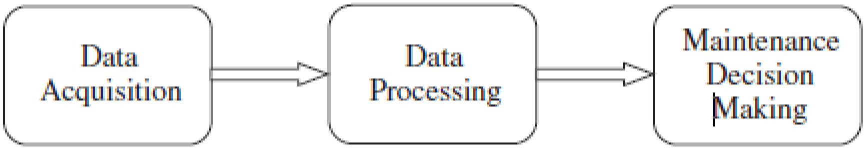


Figure 4. Three steps in CBM or PdM method

Predictive maintenance techniques

Vibration analysis

As part of a complete predictive maintenance program, a range of technologies may and should be utilized. Vibration monitoring is usually a core component of most predictive maintenance programs since mechanical systems or machines account for the majority of plant equipment. On the other hand, vibration monitoring cannot give all of the information needed for a good predictive maintenance program. This technique uses the noise or vibration created by machinery or equipment to determine their actual condition.

Thermography

Thermography is a predictive maintenance technique that uses instrumentation designed to monitor the emission of infrared energy or temperature in other words, to monitor the condition of equipment or plant machinery structures and systems. The idea is to detect the thermal abnormalities of the areas which are being colder or hotter than they should be. In this technique special instrumentations are used to detect the infrared emissions. However, this technique is quite complicated, due to the 3 sources of thermal energy which are emitted from the object itself, energy reflected from the object and energy transmitted by the object. We cannot tell if the source itself is producing the thermal energy.

Tribology

Tribology is the general term that refers to the design and operating dynamics of the bearing lubrication rotor support structure of machinery. There are several tribology techniques used for predictive maintenance including lubricating oil analysis, spectrographic analysis, ferrography and wear particle analysis.

Lubricating oil analysis is an analysis technique that determines the condition of lubricating oils used by equipment or machinery. Oil analysis has turned into a valuable tool for preventative maintenance. Samples of equipment lubricant should be obtained at regular intervals to determine the condition of the lubricating layer, which is crucial to machine-train functioning, according to the laboratory's recommendation. Typically, 10 tests are conducted on lubrication oil samples including viscosity, contamination, fuel dilution, solids content, fuel soot, oxidation, nitration, total acid and base number and particle count.

Spectrographic analysis determines many elements present in lubricating oil in an accurate and faster way compared to standard lubricating oil analyses. These elements are worn metals, contaminates or additives. Standard lubricating oil analyses do not attempt to determine the specific failure modes of developing machinery or equipment problems.

Wear particle analysis offers real-time data on the machine train's wearing state, while lubricating oil analysis establishes the real condition of the oil sample. Particles in an equipment's lubricant can provide important information about the equipment's condition. And the data related to this analysis can be a particle shape, composition, size, and quantity. According to particle categorization, there are five primary forms of wear: rubbing wear, cutting wear, rolling fatigue wear, combined rolling and sliding wear, and severe sliding wear (Table 1.) (7)

Ferrography technique is similar to spectrography, but there are two major differences. First, ferrography uses a magnetic field to separate particle contaminants while spectrographic analysis burns a sample. Due to the pollutants being separated using a magnetic field, this approach is limited to ferrous or magnetic particles. The second distinction is the ability to isolate and analyze particle pollution should be greater than 10 micrometers. Normal ferrography examination will catch particles up to 100 micrometers in diameter and offer a more accurate picture of the overall oil contamination than spectrographic approaches.

Type	Description
Rubbing wear	Result of normal wear in machine
Cutting wear	Caused by one surface penetrating another machine surface
Rolling fatigue	Primary result of rolling contact within bearings
Combined rolling and sliding wear	Results from moving of contact surfaces within a gear system
Severe sliding wear	Caused by excessive loads or heat in a gear system

Table 1. Five types of wear

2.1.3 Other Maintenance Improvement Methods

Over the past years, a variety of maintenance management methods has developed including Total productive maintenance (TPM) and Reliability centered maintenance (RCM). To figure out when to apply RCM and TPM, the decision-making grid acts as a map (DMG). The concept of the DMG enables the user to determine when to apply TPM or RCM approaches shown in Figure 4. Each of the DMG's nine divisions is represented by one of five distinct maintenance techniques. The optimal maintenance plan is determined by the asset's position on the grid.

The DMG is divided into nine components, each of which is represented by one of five maintenance techniques. Assets are plotted on two dimensions in the DMG: downtime and failure frequency. The goal is to take activities that will shift the asset's performance to the upper left area, which is represented as low failure frequency and low downtime shown in

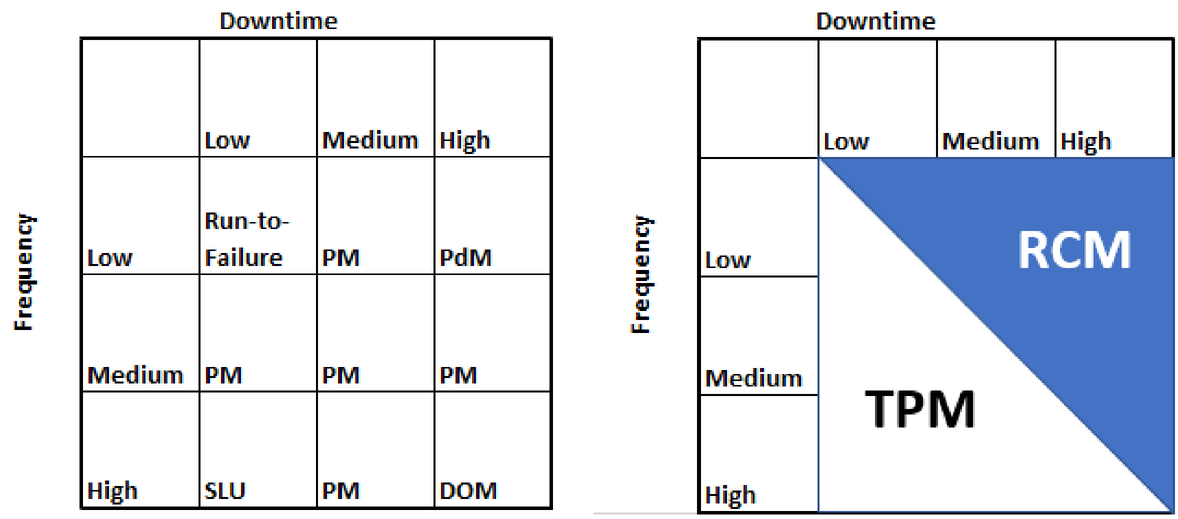


Figure 5. When to apply RCM and TPM
in decision making grid

The new abbreviations are included in Figure 5. Design Out Maintenance (DOM) represents the worst performing assets in both criteria. For any equipment in this division, major design out tasks must be considered. This section indicates that an asset is not suitable for its purpose and should be scheduled for shutdown, overhaul, or turnaround. The skills level upgrade (SLU) method should be employed when faults occur often and result in low downtime but are readily repaired. The transmission of certain fundamental maintenance skills from maintenance experts to front-line production operators is one of the foundational pillars of TPM. (8)

2.1.3.1 Total productive maintenance

Total productive maintenance (TPM) is the practice of increasing equipment effectiveness by involving all supporting departments in the process. TPM aims to boost overall productivity by maximizing the availability of equipment. TPM's quantitative advantages are expressed in terms of capacity, product quality, and overall production cost. The major causes of equipment

Figure 6. The eight Pillars of Total productive maintenance (TPM) (12)

losses are failure, set up adjustments, idling and minor stoppage, reduced speed, process defects and reduced yield, and the TPM aimed at improving or eliminating those losses. In the Japanese model for TPM, there are eight pillars (Figure 6) that help define how people work together in this partnership. TPM is based on cooperation between manufacturing or production workers, maintenance, engineering, and technical services to increase overall equipment effectiveness (OEE). (7)

2.1.3.2 Reliability-Centered Maintenance

The idea that all machines must fail and have a finite useful life is a fundamental premise of RCM, although none of these assumptions is true. Machinery and plant systems that are correctly planned, built, operated, and maintained will not fail and will have a nearly unlimited usable life. Reliability-centered maintenance analyzes the company's most vital tasks and then works to improve maintenance procedures to reduce system failures and boost equipment reliability and availability.

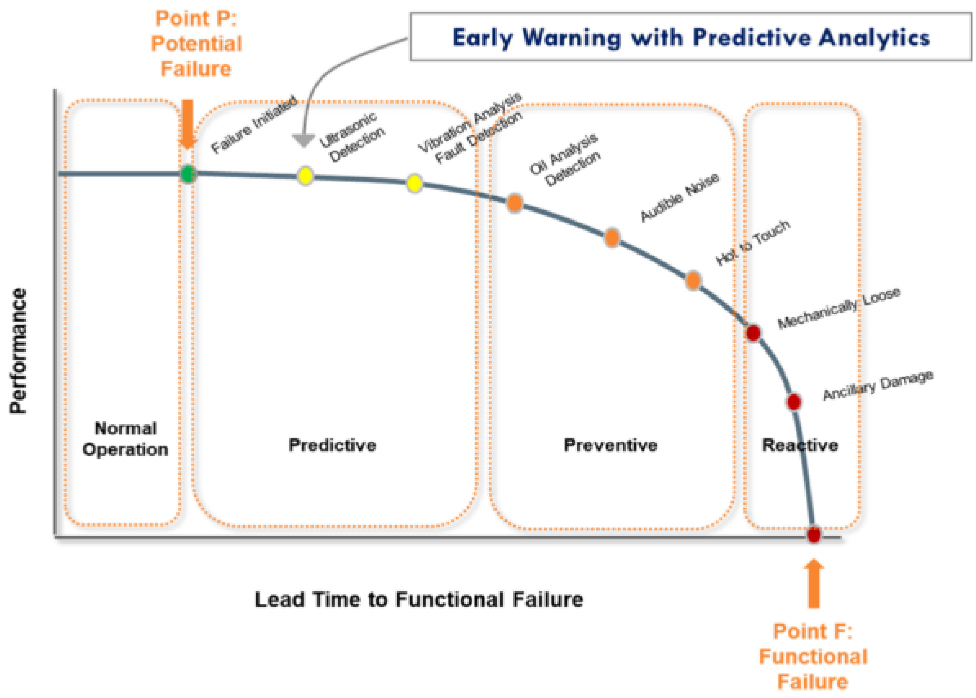


Figure 7. P-F curve

RCM is based on the assumption that all machines will degrade and break shown in Figure 7. Most tasks, such as failure modes and effects analysis (FMEA) and Weibull distribution analysis, are used to predict when these failures will occur. Both theoretical techniques rely on probability tables that assume adequate plant machinery design, installation, operation, and maintenance. (7)

2.1.4 Failure analysis methods

2.1.4.1 Pareto Analysis

Pareto analysis is based on the assumption that 80% of a project's benefit may be realized by completing 20% of the work. Conversely, that 80% of issues can be traced back to 20% of the causes. Pareto analysis is a useful technique for evaluating quality and making decisions. Generally, this technique is used for getting necessary information needed for setting priorities. In maintenance it is commonly used for identifying failure types responsible for the majority of equipment maintenance downtime. Based on the failure types, the maintenance plan can be elaborated to lower maintenance costs or improved equipment availability.

Recent studies on pareto analysis in maintenance, shows Pareto analysis of failure data is useful for identifying problems within the maintenance process. Some studies showed that the pareto analysis indicates failure downtime was independent of equipment type and component

Description	Hours	Cumulative	Cum%	Failures	Cumulative	Cum%	Average repair time, h
Hydraulics	5154	5154	26.9	1233	1233	30.4	4.2
Engines	4699	9852.5	51.5	980	2213	54.6	4.8
Drivetrain	2494	12346	64.6	411	2624	64.7	6.1
Miscellaneous	2178	14524	75.9	104	2728	67.3	20.9
Electrical	1789	16312.5	85.3	679	3407	84.0	2.6
Brakes	1149	17461.5	91.3	187	3594	88.7	6.1
Structure	847	18308.5	95.7	196	3790	93.5	4.3
Wheels and tyres	816	19124.5	100	264	4054	100	3.1
Total fleet	19124			4054			4.7

type. (4)

Table 2. Pareto analysis calculation results for underground mining scoop

Description	Hours	Cumulative	Cum%	Failures	Cumulative	Cum%	Average repair time, h
Engines	2399.5	2399.5	23.5	485	485	21.0	4.9
Hydraulics	2375.5	4775	46.8	548	1033	44.8	4.3
Wheels and tyres	1723	6498	63.7	421	1454	63.0	4.1
Drivetrain	1523.5	8021.5	78.7	222	1676	72.6	6.9
Electrical	961	8982.5	88.1	387	2063	89.4	2.5
Misc.	477.5	9460	92.8	81	2144	92.9	5.9
Structure	382.5	9842.5	96.6	111	2255	97.7	3.4
Brakes	351.5	10194	100.0	52	2307	100.0	6.8
Fleet total	10194			2307			4.4

Table 3. Pareto analysis calculation for underground mining truck

As we can see from table 2 and 3 that the critical subsystems are set at different priorities due to their working condition and equipment features. This distinction shows that every single equipment needs a unique maintenance plan regardless of their equipment type.

Code	Description	Quantity	Duration (min)	% Time	% Cum.
1	Electrical inspections	30	1015	13.0	13.0
2	Damaged feeder cable	15	785	10.1	23.1
11	Motor over temperature	36	745	9.6	32.6
3	Change of substation or shovel move	27	690	8.8	41.5
10	Overload relay	23	685	8.8	50.3
7	Auxiliary motors	13	600	7.7	58.0
12	Earth faults	7	575	7.4	65.3
8	Main motors	12	555	7.1	72.5
5	Power cuts to substations	21	395	5.1	77.5
15	Air compressor	8	355	4.6	82.1
6	Rope limit protection	10	277	3.6	85.6
9	Lighting system	26	240	3.1	88.7
4	Coupling repairs or checks	15	225	2.9	91.6
17	Over current faults	6	220	2.8	94.4
14	Control system	7	165	2.1	96.5
16	Operator controls	5	155	2.0	98.5
13	Miscellaneous	9	115	1.5	100
	TOTAL	**270**	**7797**	**100**	

Table 4. Unplanned shovel downtime data (15)

Some related studies show an alternative method for analyzing equipment downtime using logarithmic (log) scatterplots to address some shortcomings of pareto histogram.

The ranking structure of Pareto histograms is preserved in log scatterplots, but new information content about failure frequencies and Mean time to repair (MTTR) is included. Log scatterplots are split into four quadrants using limit values as shown in figure 8, allowing failures to be categorized by acute or chronic features and helping root cause investigation.

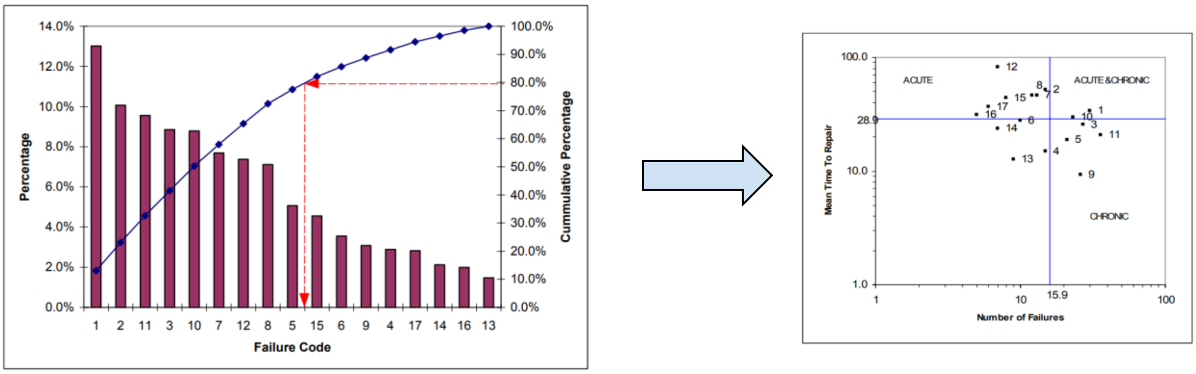


Figure 8. Conversion of Pareto chart to Logarithmic Scatter plot with limit values (15)

Subsystems included in the acute condition have a meaning of low frequency of failure and results in high down time. On the other hand, chronic condition means that the frequency of failure is high but the repair time is low. Acute and chronic condition is the worst one which indicates that the both criteria is high. Using the limits, the reliability, availability and maintainability problems can be determined as shown in the Figure 9. By identifying the downtime priorities, it is helpful to improve the business performance. (15)

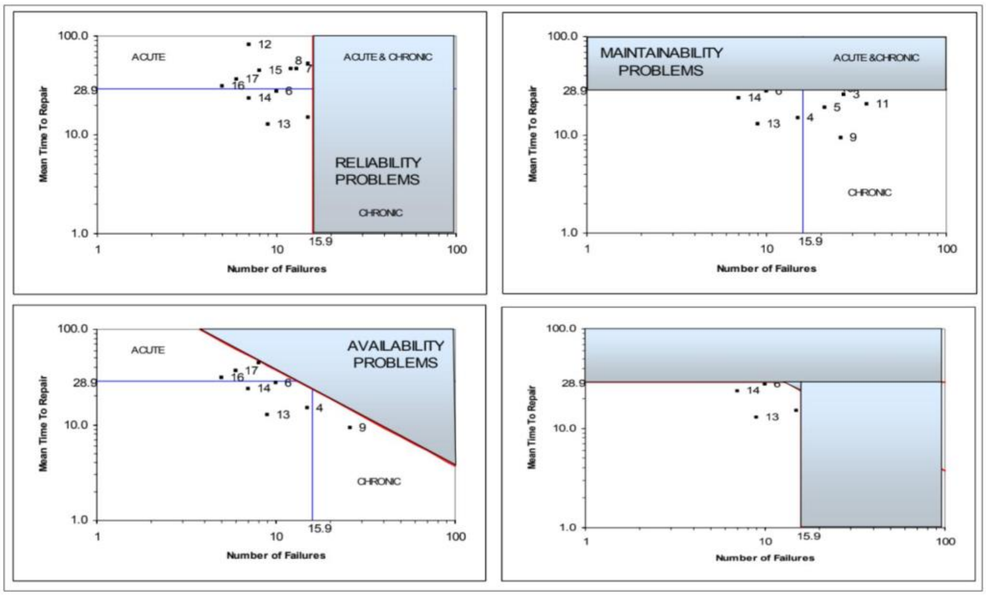


Figure 9.

Determining problems affecting system availability, reliability and maintainability by using logarithmic scatter plot (15)

2.1.4.2 Root cause analysis (RCA)

The root cause analysis technique is used to investigate an issue or series of events in order to determine what occurred, why it occurred, and what can be done to avoid it from occurring again. The three basic types of root causes are physical causes, human causes and organizational causes. Human causes occur when one person or several team members conduct maintenance incorrectly. On the other hand, organizational causes happen when a system or process that a company uses to do their job. Root Cause Analysis (RCA) is a step-by-step process for determining the root cause of failures and issues down to their root cause. The steps are defining the problem, collecting data, identifying possible causal factors, identifying the root causes and recommending and implementing solutions. The problem definition and data gathering can be obtained by questioning questions shown in Table 5. (11)

Category	Questions
What	• What happened? • What are the symptoms? • What is the complaint? • What went wrong? • What is the undesirable event or behavior?
When	• When did it occur: what date and what time? • During what phase of the production process?
Where	• What plant? • Where did it happen? • What process? • What production stream? • What equipment?
How	• How was the situation before the incident? • What happened during the incident? • How is the situation after the incident? • What is the normal operating condition? • Is there any injury, shutdown, trip, or damage? • How frequent is the problem? • How many other processes, equipment or items were affected by this incident?

Table 5. Questions that aid in defining the situation and gathering information (11)

The next important steps are identification of problem, event and causal factor charting and conducting corrective actions. Event and causal factor charting is a type of analysis in which events, circumstances, changes, barriers, and causal factors are represented on a timeline using symbols similar to those illustrated in Table 6.

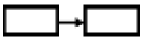
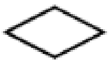
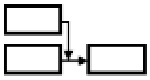
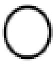
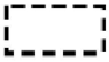
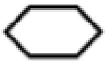
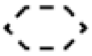
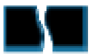
Item	Symbols	Explanation
Event		An action that occurs during some activity
Primary event		The action directly leading up to or following the primary effect
Undesirable event		An undesirable event (failure, conditions deviation, malfunction, or inappropriate action) that was critical for the situation
Secondary event		An action that impacts the primary event but is not directly involved in the situation
Terminal event		The end point of the analysis
Condition		Circumstances pertinent that may have influenced and/or changed the course of events, or caused the undesirable event
Presumptive event		An action that is assumed because it appears logical in the sequence but cannot be proven
Causal factor		A factor that shaped the outcome of the situation, the root cause of the problem
Presumptive Causal factor		A factor that is assumed as it appears to logically affect the outcome
Change		A change in the condition of the situation after an event have occurred
Barrier		Physical or administrative barrier to prevent an unwanted situation
Failed barrier		Physical or administrative barrier that failed to prevent an unwanted situation

Table 6. Standard symbols for factor charting (11)

The team begins root cause analysis after identifying all causal elements. There will certainly be several causes for each given incident.

There will probably be several root causes for each causal element. The final process is generation of suggestions for remedial action based on the following questions:

1. What can be done to avoid a recurrence of the problem?
2. How will the solution be put into action?

3. Who will be responsible for it?
4. What are the risks and consequences of putting the solution in place?

Also, it is important to make a report including a discussion of corrective actions, management and personnel. The report should also include information that might be useful to other departments. The report should include:

1. Definition of the problem
2. Event and causal factors chart
3. Cause and effect analysis
4. Root causes of the problem
5. Solution of the problem
6. Implementation plan with clear responsibilities and follow-up (11)

3 3 Proposed methodology for Maintenance

3.1 Overview of methodology

The methodology proposed in this study is to analyze historical data on Komatsu dump trucks to find an appropriate maintenance method for the candidates. Different types of dump trucks with different capacities need to be maintained differently. In order to analyze historical data and prioritize subsystem pareto analysis methods were used. The Pareto chart is only capable of determining the priorities of defects. Due to some shortcomings of the pareto chart, logarithmic scatter plots are used to determine the limits, acute and chronic conditions of the failure. After that, using a decision-making grid the determination of the maintenance method can be suggested by combining logarithmic scatter plot and DMG. After setting the priority of subsystem failures, the company or organization can focus more on these subsystems and apply more appropriate maintenance methods depending on the conditions.

The general methodology was illustrated by the case study of Komatsu HT-1500 and HD-785 dump trucks operating in the open pit gold mining site. The two dump trucks mentioned above have different loading capacities and are from the same manufacturer.

Description	Manufacturer	Model	Year	Capacity	Quantity
Truck	Komatsu	HT1500-5	2011-2012	150 tn	20
Truck	Komatsu	HD785-5	2004-2005	91 tn	9

Table 7. General equipment specification

3.2 Decomposition of truck systems into subsystems

Predictive maintenance or condition-based maintenance requires knowledge of the condition of equipment so that maintenance can be scheduled. In order to analyze the condition of the truck, the dump truck's system was divided into subsystems shown in Figure 10. The Pareto analysis approach was conducted to assess which subsystems are having significant failure.

If necessary, the decomposing process can be reused in subsystems. By breaking down subsystems, we can perform a more in-depth analysis at the component or part level using the same pareto analysis to find the root cause of a significant problem.

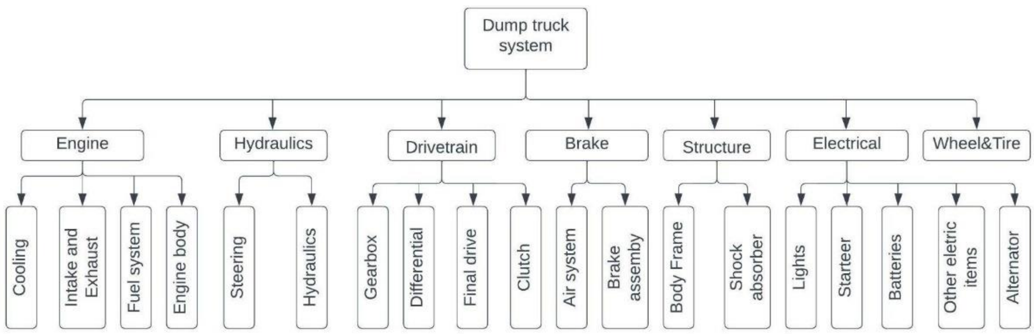


Figure 10. Decomposition of truck system into subsystems (13)

3.3 Construction of Pareto chart

The data was collected from the company's work order log. The work order log included the information about downtime period, backlogs, technicians who conducted the maintenance, labor description, reason of delay, used parts and machine hour meter.

The analysis was presented using a Pareto diagram (or chart), which is a useful technique for evaluating quality and making decisions. Unplanned downtime due to failure of relevant parts of the subsystem was noted to the excel sheet. The collected failure data and repair time in each subsystem were then used to represent cumulative percentage of downtime (Pareto histogram) to find which system contributes the most downtime to the dump trucks.

A Pareto Chart is a combination of a bar graph and a line graph as shown in Figure 11. The inputs are charted using a line graph along the horizontal y axis in descending order of output frequency (using the cumulative percentage of the outputs). The vertical x axis calculates the frequency of each input's output and plots it using a bar graph.

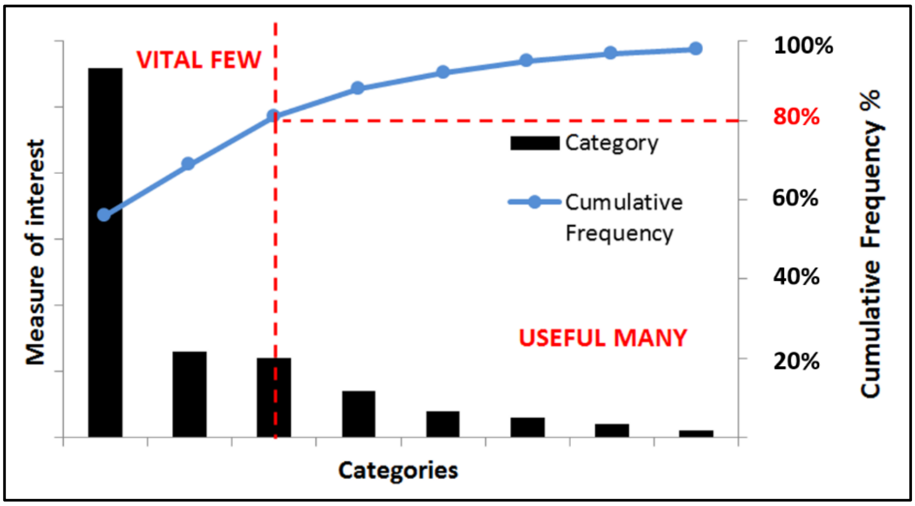


Figure 11. Typical pareto histogram (14)

3.4 Limit determination and failure categorization

In order to categorize failures using logarithmic scatter plot of MTTR and Failure frequency, threshold limits should be determined to categorize failures into acute, chronic and acute & chronic. Threshold limits can either be absolute or relative values. But in this thesis work average values were used as relative values. To determine the values, the following equations were used.

Total downtime, D, caused by unplanned failures is calculated as:

$$D = \sum_i Downtime_i \qquad (1)$$

The total number of failures, N, is:

$$N = \sum_i n_i \qquad (2)$$

The threshold limit for acute failures can be calculated as:

$$Limit_{MTTR} = \frac{D}{N} \qquad (3)$$

And threshold limit for chronic failure can be defined as:

$$Limit_{n} = \frac{N}{Q} \qquad (4)$$

where Q is the number of distinct failure codes used to categorize the downtime data.

3.5 Determining appropriate maintenance methods for system failures.

To determine appropriate maintenance plans for the main system failures, the logarithmic scatter plot of MTTR vs Failure frequency with threshold limits and decision-making grid (DMG) were used. As both of them consider the same factors, downtime and failure frequency, the 9 components of DMG, each of which is represented by one of 5 maintenance techniques, could be used in a logarithmic scatter plot to determine which maintenance plans could be appropriate for which system failure, since, the logarithmic scatter plot categorizes failures according to the failure characteristics DMG considers (see Fig 12). Downtime and MTTR for this case are indicating the same thing for this case and could be interchangeably used.

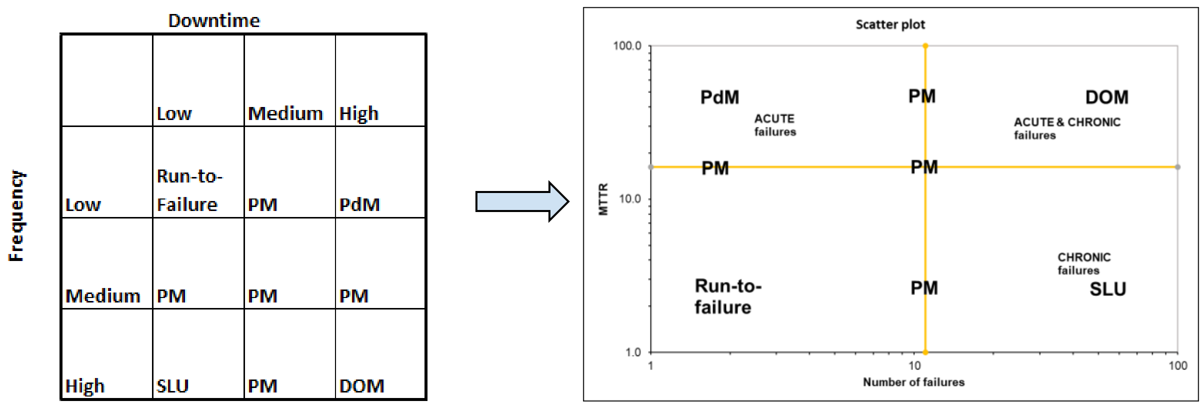


Figure 12. Adapting DMG in Logarithmic scatter plot of MTTR vs Failure frequency

4 Results and discussion

4.1 Results

The Pareto analysis findings for each fleet of equipment are graphically represented in Figures 13 and 14 for trucks, respectively. Calculated results are represented on tables 8 and 9. From the graph we can see a nearly linear relationship between the cumulative percent of failures and downtime which means that there were no critical systems that possessed significant amounts of downtime for certain subsystem. The linear relationship proves that the time to repair a piece of equipment is roughly the same regardless of what fails.

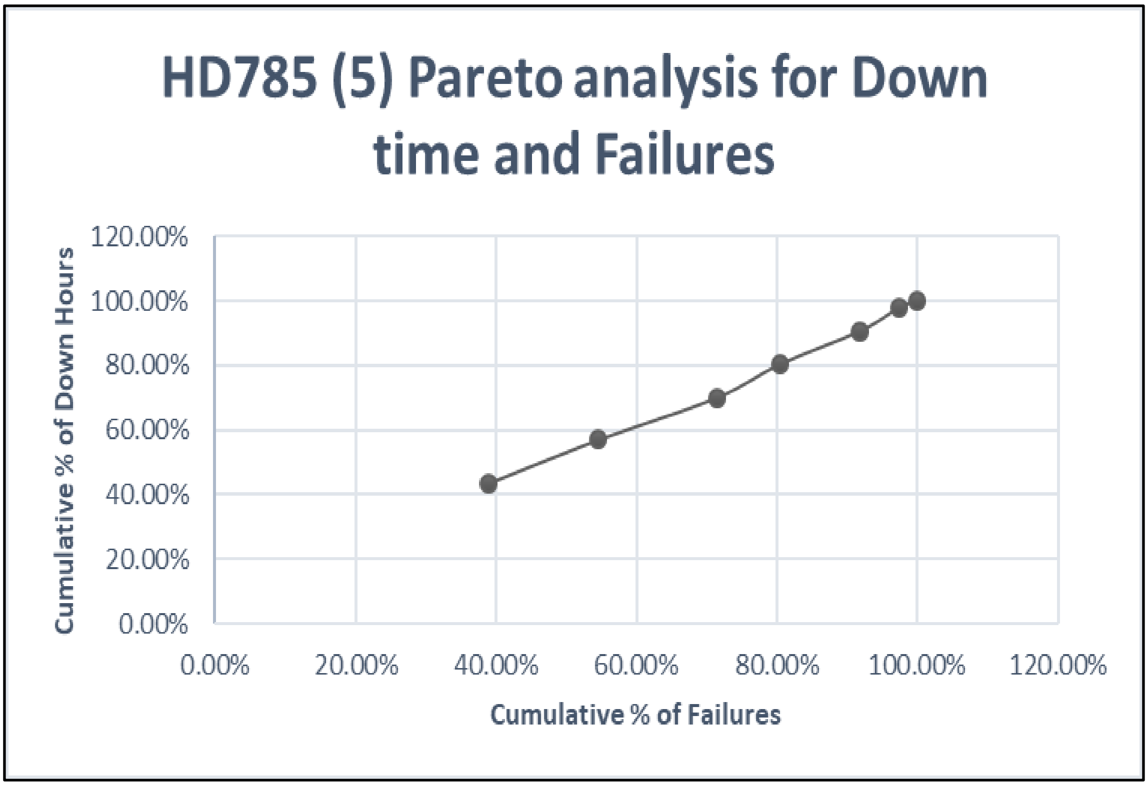


Figure 13. Pareto analysis for downtime and failures for HD785(5) trucks

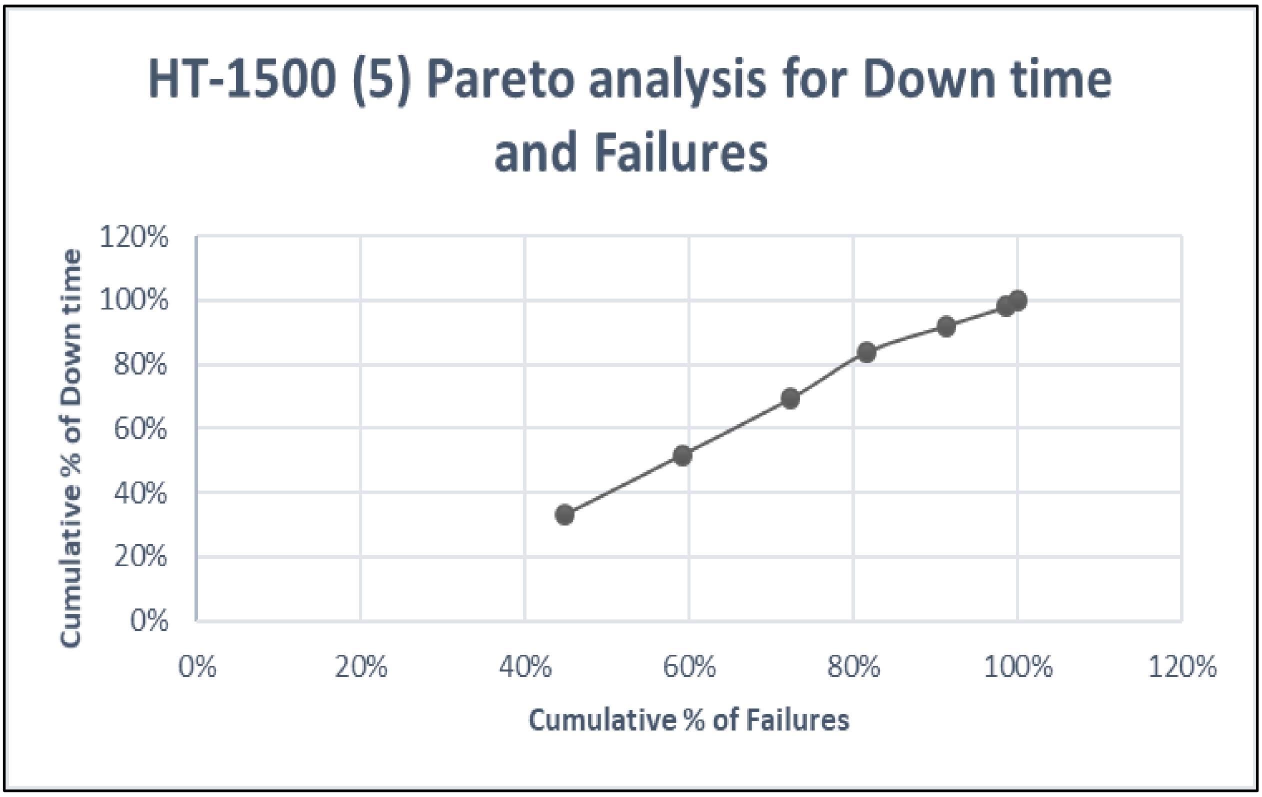


Figure 14.Pareto analysis for downtime and failures for HT-1500(5) trucks

Failure Code	HT1500 (5)	Failures	Cumulative % failure	MTTR (hrs)	Down time (hrs)	Down time percentage	Cumulative% Down time
1	**Hydraulics**	361	45%	2.85	1027.6	33%	33%
2	**Structure**	116	59%	5.04	585.15	19%	52%
3	**Engines**	107	72%	5.14	550.2	18%	69%
4	**Drivetrain**	74	82%	6.04	447	14%	84%
5	**Brakes**	78	91%	3.27	255	8%	92%
6	**Electrical**	59	99%	3.14	185.5	6%	98%
7	**Wheels and**	12	100%	5.42	65	2%	100%

	tyres						
8	**Fleet total**	**807**		**3.9**	**3115.45**	100%	

Table 8. Komatsu HT1500-5 Dump truck unplanned failure and down time.

Failure code	HD785 (5)	Failures	Cumulative % failure	MTTR (hrs)	Down time (hrs)	Down time percentage	Cumulative% Down time
1	**Engines**	185	39%	6.03	1115.13	44%	33%
2	**Brakes**	74	55%	4.61	341.47	13%	52%
3	**Electrical**	80	71%	4.15	332.17	13%	69%
4	**Drivetrain**	43	80%	6.14	264	10%	84%
5	**Hydraulics**	54	92%	4.85	262	10%	92%
6	**Structure**	27	97%	6.95	187.73	7%	98%
7	**Wheels and tyres**	12	100%	4.275	51.30	2%	100%
	Fleet total	**475**		**5.4**	**2553.81**	100%	

Table 9. Komatsu HD785-5 Dump truck unplanned failure and down time

4.1.1 Detailed breakdown of failures for HD785-5 truck

The total down hours were analyzed by subsystems and equipment. Figure 15 and 16 present failure downtime by equipment as well as the major failure categories by capacity. As we can see, the major faults categories are different depending on the capacity and series of the truck.

For the HD785-5 series truck major failures are caused by engines, brakes, electrical and drivetrain. During data collection, it was observed that most of all engine system failures are caused by fuel systems, especially fuel hardline tubing leak. The occurrence of fuel system failure seemed unusual. For the brake subsystem, air compressor and air hose failures are the most common causes of failure and downtime. In addition, during the winter, this type of dump truck has problems related to the starting up. The fuel system usually freezes and requires more labor to start the truck than the HT1500-5 truck. The total machine days lost through was estimated to be 127.65 machine days. According to the data, 89.4 machine days, or 71 percent of the total time, were spent repairing engine, brake, and electrical systems for the truck.

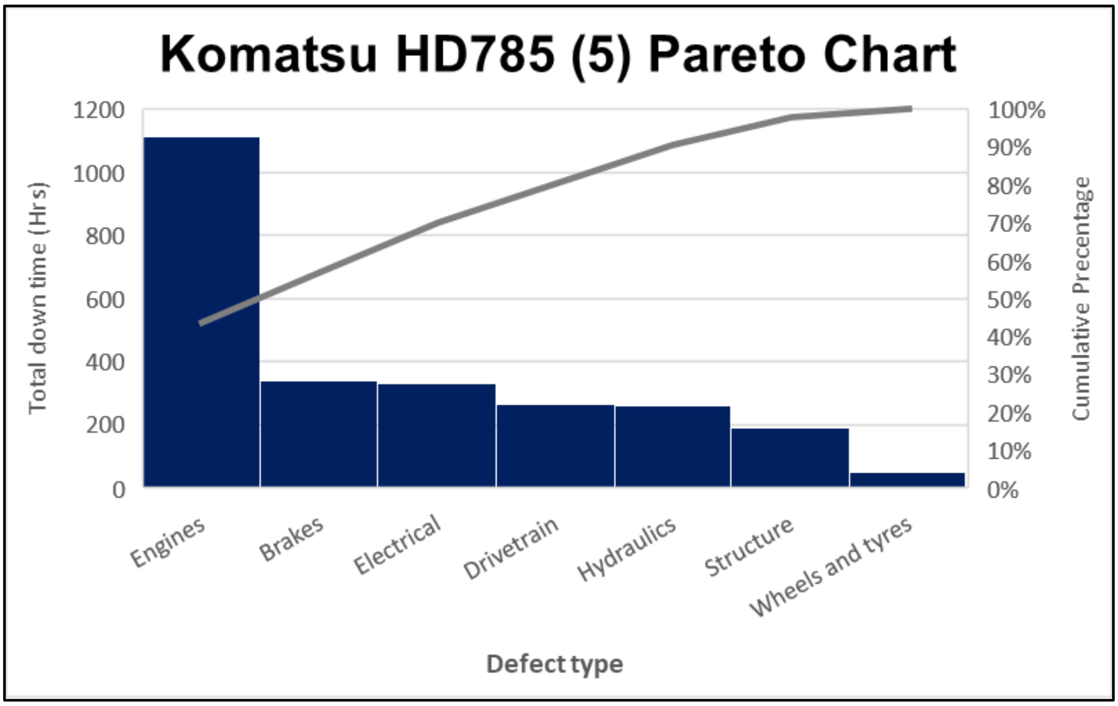


Figure 15. Pareto chart for Komatsu HD785(5) truck

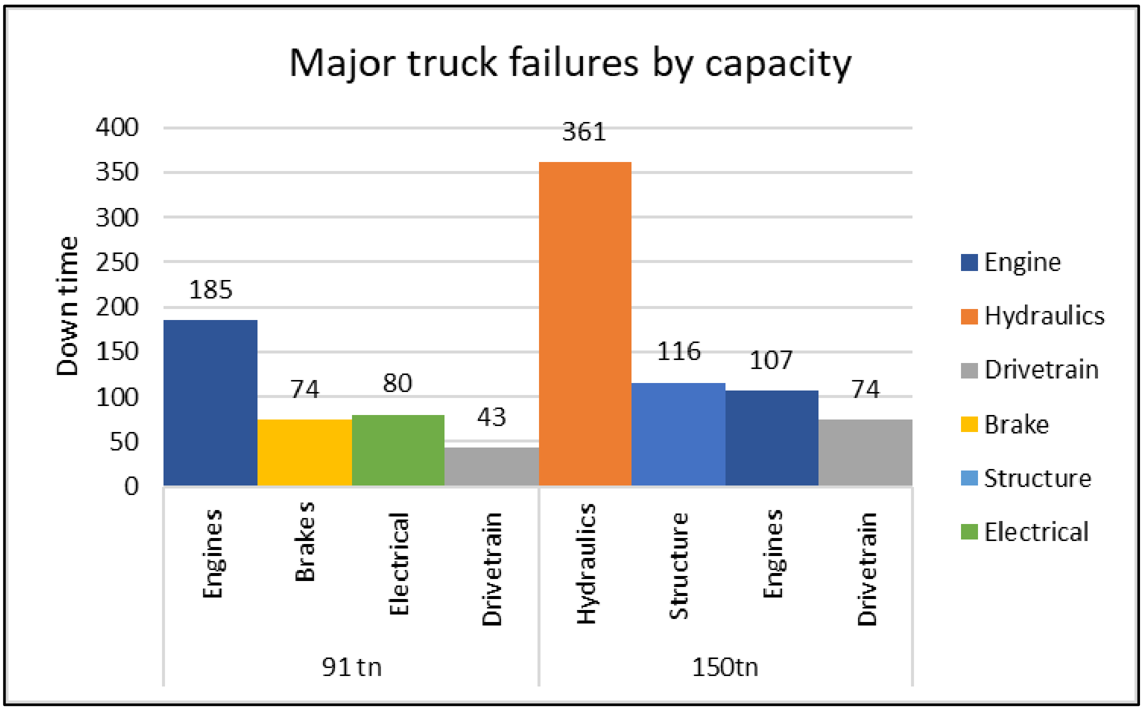


Figure 16. Major truck failures by capacity

4.1.2 Detailed breakdown of failures for HT1500-5 truck

Compared to the HD785 truck, HT1500-5 truck has major failures on hydraulics, structure, engine and drivetrain subsystems. The total machine days lost through was estimated to be 155.75 machine days. According to the data, 108 machine days, or 72 percent of the total time, were spent repairing hydraulics, structure, and engine systems for the truck. From my observation, in the hydraulic subsystem, the damage to the pressure hoses and cylinders is very high, leading to a large amount of hydraulic fluid leakage. Structure subsystem related failures were mostly shock absorbers, buckets and structure related failures requiring high maintenance time. In my opinion, the breakdown of these trucks is due to its capacity. The HT-1500 truck has a capacity of 150 tons and can handle much more loads than the HD785, resulting in higher structural and hydraulic failures.

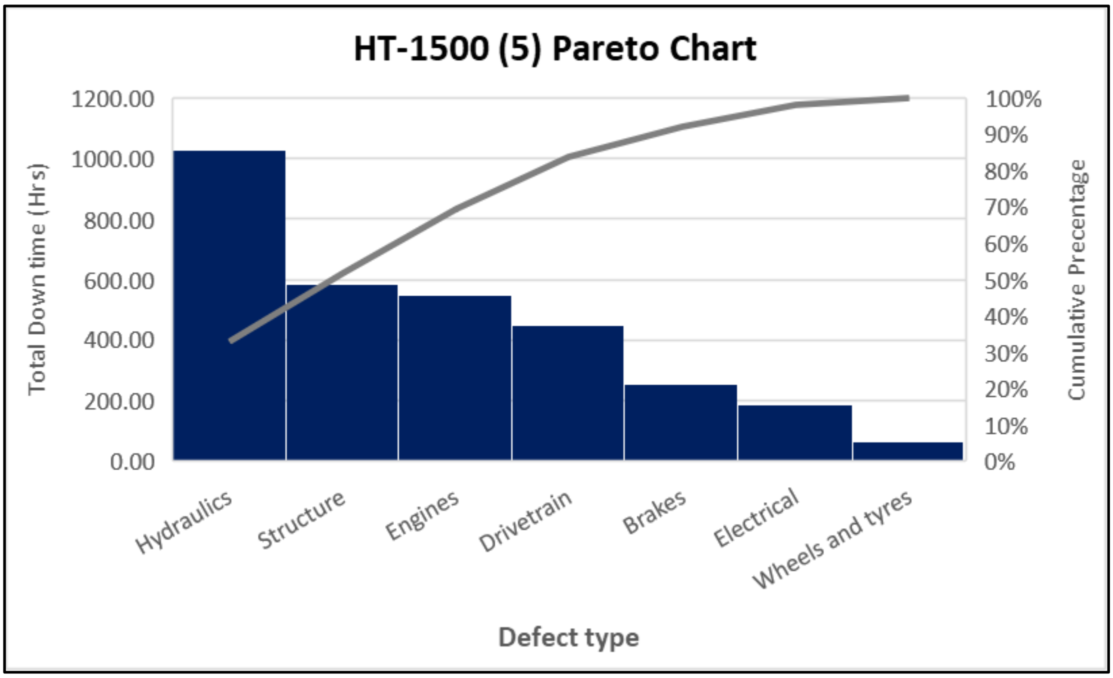


Figure 17. Pareto chart for Komatsu HT-1500

4.1.3 Logarithmic scatter plot limit determination and failure categorization

Using the equations 1-4, threshold limits were determined using total downtime, D, total failure frequency, N, number of distinct failures, Q for trucks HD785-5 and HT1500-5. The results of determining threshold limits were shown in the tables 10 and 11.

Limits for HT1500-5	X	Y
Limit 1 for number of failures	1	3.9
Limit 2 for number of failures	1000	3.9
Limit 1 for MTTR	115.3	1
Limit 2 for MTTR	115.3	100

Table 10. Threshold limits for failure categorization determined for HT1500-5

Using the values from table 10, Figure 18 was constructed to categorize the system failures. As logarithmic scatter plot indicates, the hydraulic system failure was determined as chronic failure, meaning that it occurs frequently but does not take much time to fix compared to other system failures. Failures of engine, structure and wheels and tire were determined as acute failures which occur infrequently and require much time to repair.

Limits for HD785-5	**X**	**Y**
Limit 1 for number of failures	1	5.4
Limit 2 for number of failures	1000	5.4
Limit 1 for MTTR	67.9	1
Limit 2 for MTTR	67.9	100

Table 11. Threshold limits for failure categorization determined for HD785-5

The same method was used to categorize system failures (see Figure 19). Unlike HT1500-5 truck, Braking and Electrical systems were categorized as chronic failures and as Figure 19 indicates, there is both acute and chronic failure, Engine system failure, exists for HD785-5. Same system failures were categorized differently for these 2 trucks as figures indicate.

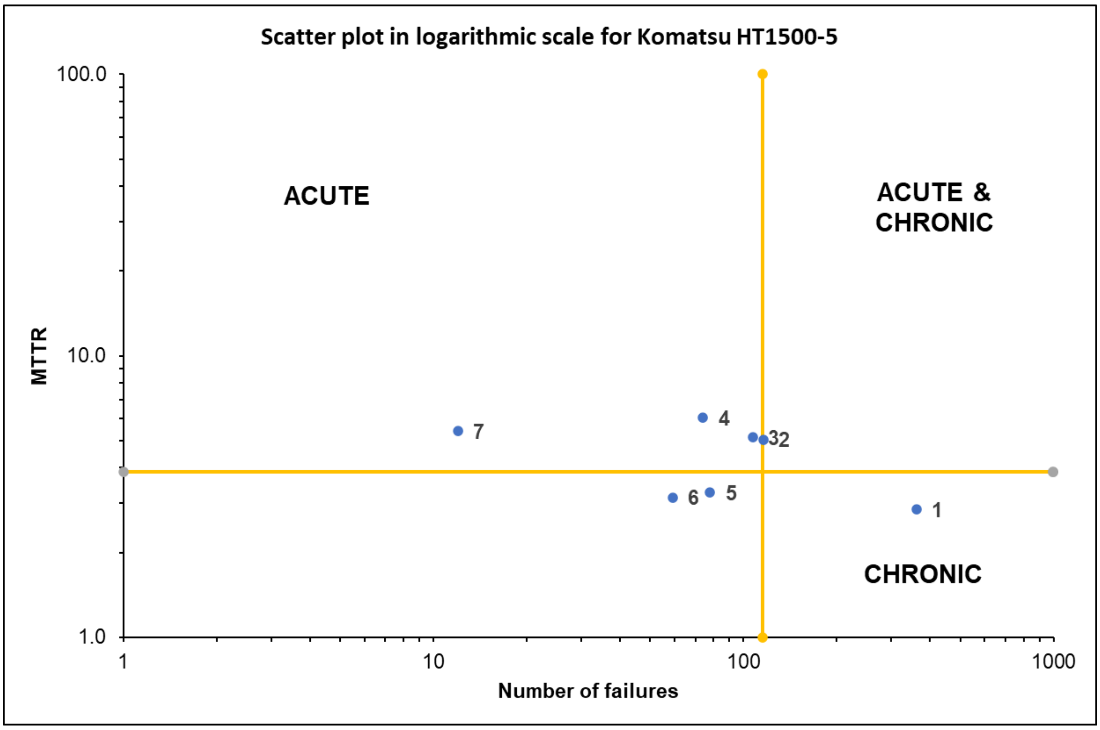


Figure 18. Log scatter plot of MTTR vs Number of Failures for HT1500-5 truck

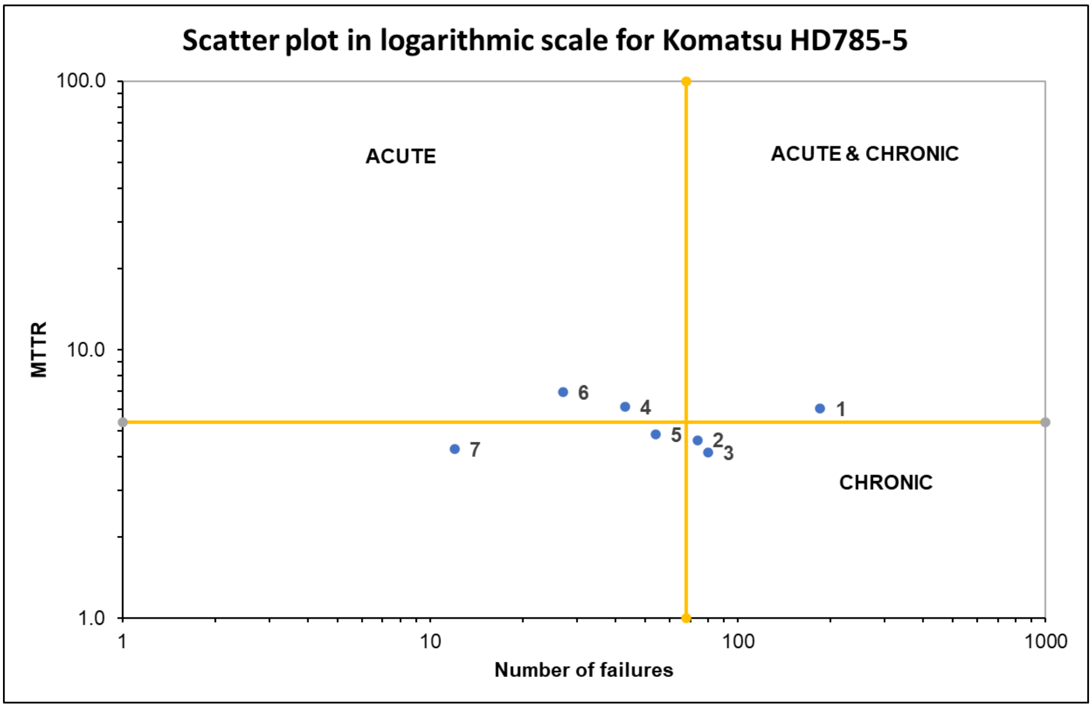


Figure 19. Log scatter plot of MTTR vs Number of Failures for HD785-5

4.1.4 Results of determining appropriate maintenance method for system failures

Not only identifying the subsystems that have the most failures and downtimes, by combing DMG with Logarithmic scatter plot of MTTR vs Number of failures, the recommended maintenance methods were determined for these unplanned system failures (see Table 12 and 13). Since some subsystems were plotted near to the limits, it proves that these systems can be maintained by preventive maintenance methods using Figure 12 in the Methodology section. At the same time, the results seemed relatively reasonable and feasible.

Methods	Engine (3)	Hydraulics (1)	Structure (2)	Drivetrain (4)	Electrical (6)	Brakes (5)	Tires (7)
PdM	+	-	-	+	-	-	+
PM	+	+	+	+	-	-	+
SLU	-	+	-	-	-	-	-
DOM	-	-	-	-	-	-	-
Reactive	-	-	-	-	+	+	-

Table 12. Selection of maintenance method for HT1500-5 truck subsystems

Methods	Engine (1)	Hydraulics (5)	Structure (6)	Drivetrain (4)	Electrical (3)	Brakes (2)	Tires (7)
PdM	-	-	+	+	-	-	-
PM	+	+	+	+	+	+	+
SLU	-	-	-	-	+	+	-
DOM	+	-	-	-	-	-	-

Reactive	-	+	-	-	-	-	+

Table 13. Selection of maintenance method for HD785-5 truck subsystems

From the tables it can be seen that, these 2 trucks require different maintenance techniques for its main system. For example, for the HT1500-5 truck, it is more recommendable to practice PdM more than PM, and for other truck it could be more recommendable to employ PM more than PdM.

5 Conclusion and recommendation for future research

5.1 Conclusion

In this thesis, the methodology to determine maintenance techniques, more specifically PM and PdM techniques, for system failures and keep balance between these maintenance techniques was considered.

5.1.1 Pareto analysis

Pareto analysis of failure data is effective in identifying significant problems in maintenance process. The Pareto analysis revealed that downtime was independent of equipment type and component type. The pareto itself has number of deficiencies. A Pareto histogram based on downtime alone can't determine which factor (or factors) are the most critical in causing the downtime associated with specific failure codes. As well as, Pareto analysis of machinery downtime could exclude individual incidents with a significant related downtime or often occurring failures with a low associated downtime but frequent operational disruptions. Because of Pareto graphs are only created for the major contributors to system downtime, failures related with minor components or functional failures will not be investigated. It's likely that we'll miss a component or failure mode that has a ton of potential in forming reliability issue. It is observed that pareto analysis is more efficient when used with additional tools, logarithmic scatter plots etc. By using additional tools, the chronic and acute condition of the equipment is considered and now we can conclude the right maintenance methods for the candidates.

5.1.2 Detailed breakdown of failures for the trucks

Two different trucks had different load capacities and the analysis results were different. The dump truck with higher loading capacity which is HT1500-5 has more failures related to hydraulic system and structure subsystems. Especially broken hoses were dominant failure in the subsystem which was unusually high. Further investigation or RCA method may suggest why the failure is occurring more often. As suggested on table 12, The SLU and PM methods are more suitable in the hydraulic section. Chronic breakdown conditions or short average maintenance time are the main reasons for the proposed skill level upgrade approach. For the HT1500-5 truck, the proposed reactive method of maintenance seemed reasonable, as no chronic or acute conditions were observed in the electrical and brakes subsystems.

For the HD785-5 series truck major failures are caused by engines, brakes, electrical and drivetrain. It was observed that most of all engine system failures are caused by fuel systems, especially fuel hardline tubing leak. During the winter, the fuel system's freezing and other fuel system failures increase, as I see it from the company's job order records. As well as, it was the only subsystem which is included to the chronic and acute failure condition resulting in suggesting design out maintenance (DOM) approach. DOM indicates the system or equipment is not suitable for the process or work. For the HD785-5 truck, the proposed reactive method of maintenance seemed reasonable, as no chronic or acute conditions were observed in the hydraulic and wheel subsystems.

5.1.3 Failure categorization

Logarithmic scatter plot of MTTR vs Number of failures categorized system failures into acute, chronic failures and acute & chronic failures, showing all of them in the same figure. From the plots, system failures of the trucks, even if they had the same system with the same working principle, categorized into different kinds of failures compared to one another.

From this, it can be concluded that as they have different characteristics of failure it could be not recommendable to plan the same course of actions for these 2 kinds of trucks.

5.1.4 Determining appropriate maintenance methods for system failures

Using the DMG model, the maintenance techniques were determined for system failures distinctly. After determining maintenance techniques for the systems of 2 different kinds of trucks, it was clear that distinct kinds of trucks required different maintenance techniques for the same systems.

In conclusion, it could be wrong to assume they require the same maintenance technique based on the assumption that they have systems which have the same working principle. It can be better to keep balance between PdM and PM

5.1.5 Final remarks

In this paper the goal to find appropriate maintenance method for the subsystems and overall equipment, by combining several maintenance analyzing tools is accomplished. Since the data is very broad, the more accurate results can be achieved by breaking down the subsystem into smaller components level and analyzed.

5.2 Recommendation for future work

In the thesis, not only major system failures were considered but other minor system failures are included and their suitable maintenance methods are suggested. However, in order to achieve more accurate results, it is recommended to break down the basic subsystem into components and analyze the breakdown of the components. Because major systems are so broad that some critical component failures might be left without any consideration.

It can be better to perform analysis at the component level and compare them with the result of the analysis at a broad system level. In order to perform analysis at component level, it is recommended to use Failure mode and effects analysis (FMEA) to determine maintenance techniques and to keep the balance between them more effectively.

Determining the cause of the downtime requires recording more detailed information, such as the actual repair time, waiting for parts, manpower, and waiting for spare parts. Training the employees to record the data fully and appropriate will be important as well.

Tribology, thermography, and vibration testing are also recommended to determine the major failures. Since the company is overrunning the machinery and conducting PM service in every 350 hours which is 100 more hours than the recommended value, the oil sampling techniques should do the prevention job.

For the HT1500-5 truck the pressure hose, suspension system and bucket failures were unusually high. So, the root cause analysis (RCA) is strongly recommended to assess more deep knowledge on these certain types of failures and we can get a clue that whether it is caused by inappropriate service or environmental factors are causing these issues. After determining the causal factors, we can put barriers to the issue and prevent it from happening often. Since the company is conducting PM service in 350 hours interval, there should be planned down time and the pressure hose, suspension system and bucket conditions should be inspected diligently during the PM downtime.

For the HD785-5 truck the fuel system has significant failures in engine subsystem. After applying the pareto analysis and related tools on historical data it is considered to be maintained in DOM. The failure was occurring too often and requiring much time to repair which was pretty reasonable to choose DOM method. Since PM or PdM are considered ineffective in solving the problem, designing an RCA or fuel system independently may be a more appropriate solution to the problem.

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7 Appendix

Table 14. HT-1500 Dump truck work order log example

Ажлын дугаар	Парк дугаа	Start	Төлөвлөгч	Ажлын тайлбар	ЭХЭЛСЭН ЦАГ			Хийгдсэн ажлын тайлан
ECO200130-006	DT-1082	2020.1-р сар.30	А. ТҮВШИН	Шланг бакуулах	1:30	15:30	14:00	Шлан базуулан Улаанбаатар хот болон Зааын үүд рүү явуулсан
ECO200130-007	DT-1081	2020.1-р сар.30	А. ТҮВШИН	Шланг бакуулах	1:30	15:30	14:00	Шлан базуулан Улаанбаатар хот болон Зааын үүд рүү явуулсан
ECO200130-008	DT-1216	2020.1-р сар.30	А. ТҮВШИН	Шланг бакуулах	1:30	15:30	14:00	Шлан базуулан Улаанбаатар хот болон Замын үүд рүү явуулсан
ECO200130-009	DT-1045	2020.1-р сар.30	А. ТҮВШИН	Шланг бакуулах	1:30	15:30	14:00	Шлан базуулан Улаанбаатар хот болон Замын үүд рүү явуулсан
ECO200130-010	DT-1241	2020.1-р сар.30	А. ТҮВШИН	Шланг бакуулах	1:30	15:30	14:00	Шлан базуулан Улаанбаатар хот болон Замын үүд рүү явуулсан
ECO200204-020	DT-1231	2020.2-р сар.04	Н.МАГСАРЖАВ	Шланг базуулах	1:00	15:00	14:00	Шлан базуулан Улаанбаатар хот болон Замын үүд рүү явуулсан
ECO200204-021	DT-1241	2020.2-р сар.04	Н.МАГСАРЖАВ	Шланг базуулах	1:00	15:00	14:00	Шлан базуулан Улаанбаатар хот болон Замын үүд рүү явуулсан
ECO200209-030	DT1097	2020.2-р сар.09	Н.МАГСАРЖАВ	HOSE Гидро хувиарлагчийн шланг солих	15:00	17:00	2:00	Замын Үүд явуулсан. Зөвшөөрлийн дагуу
ECO200213-034	DT-1081	2020.2-р сар.13	Н.МАГСАРЖАВ	Тормосны хөргүүрийн шланг базуулж Замын Үүд явуулах	14:00	15:00	1:00	Базуулан Улаанбаатар явуулсан
ECO200228-U143	DT-1216	2020.2-р сар.25	А.ТҮВШИН	Үзлэг засвар	15:00	18:00	3:00	Ухрахын гэрлийн утас масстай байсныг холболт хийн хэвийн болгож, лампыг сольсон
ECO200228-050	DT-1228	2020.2-р сар.25	А. ТҮВШИН	Тормасны шланг базуулах	16:00	17:30	1:30	Хуучин шланг язарч муудсан байсныг толгой бөгжийг тайлан 1м шинэ шланганд хуучин толгой бөгжийг хийн бэлдсэн
ECO200229-U146	DT-1217	2020.2-р сар.26	А.ТҮВШИН	Дугуй засвар	8:00	13:00	5:00	3.4-р дугуй цөмөрсөн байсныг авч, задлан засварлаж буцаан угсарч шпилкаг чангалсан.
ECO200229-U147	DT-1231	2020.2-р сар.27	А.ТҮВШИН	Дугуй засвар	15:00	19:00	4:00	3.4-р дугуйг авч задлан цэвэрлэж засварлан буцаан угсарч гагнуур хийн шпилкаг чангалсан.
ECO200229-U148	DT-1216	2020.2-р сар.27	А.ТҮВШИН	Дугуй засвар	15:00	19:00	4:00	3-р дугуйг авч задлан цэвэрлэж засварлан буцаан угсарч гагнуур хийн шпилкаг чангалсан.
ECO200229-U149	DT-1217	2020.2-р сар.27	А.ТҮВШИН	Хөдөлгүүрийн анхааруулга ассан	14:00	16:00	2:00	Хөдөлгүүрийн тос болон күлэнтийн төвшинг шалгасан. Түлш дууссан байсныг түлш хийн техникийг асааж шалгасан.
ECO200229-U153	DT-1231	2020.2-р сар.28	А.ТҮВШИН	Шим шахах	14:00	19:00	5:00	Подьёмны пальц холхио орсон байсныг гагнуураар шим бэлдүүлэн, тэвшийг краннаар өргүүрэн, пальцыг сугалж, бэлдсэн шимээ хийн шахаж, пальцаа
ECO200229-053	DT-1216	2020.2-р сар.28	А. ТҮВШИН	Цахилгаан засвар			0:00	
ECO200303-056	DT-1231	2020.2-р сар.29	А. ТҮВШИН	Гидрийн шланг солих	14:30	15:00	0:30	Трансмиссын пампнаас гарсан шланг холгогдож цоорсон байсныг шлангыг тайлж шинээр базуулан тавьсан.
ECO200303-U155	DT-1217	2020.2-р сар.29	А.ТҮВШИН	Шим шахах	15:00	17:00	2:00	Тэвшний пальц хольхоотой байсныг тэвшийг краннаар өргүүлэн пальцыг сугалан шимийг шахаж буцаан пальцыг хийсэн.
ECO200303-U156	DT-1216	2020.2-р сар.29	А.ТҮВШИН	Шим шахах	17:00	19:00	2:00	Тэвшний пальц хольхоотой байсныг тэвшийг краннаар өргүүлэн пальцыг сугалан шимийг шахаж буцаан пальцыг хийсэн. Мөн үйлчилгээнд 205литр
ECO200303-058	DT-1217	2020.3-р сар.01	А. ТҮВШИН	Шланг солих	18:00	18:30	0:30	Хойд тормасны шланг гоожилттой байсныг шлангийг шинээр базуулж тавьсан.
ECO200303-061	DT-1217	2020.3-р сар.02	А. ТҮВШИН	Шланг солих	15:30	19:00	3:30	Гидрийн шланг гоожилттой байсныг шлангийг тайлан авч шинээр 2.8м шланг базуулан тавьсан
ECO200303-U157	DT-1245	2020.3-р сар.01	А.ТҮВШИН	Шим шахах	13:00	18:40	5:40	Тэвшний пальц хольхоотой байсныг тэвшийг краннаар өргүүлэн пальцыг сугалан шимийг шахаж буцаан пальцыг хийсэн. Мөн үйлчилгээнд 205литр
ECO200303-U159	DT-1217	2020.3-р сар.01	А.ТҮВШИН	Засвар	8:00	19:00	11:00	ЗасварЗогсоолын тормасны тохиргоо хийсэн. Товуд насосны үзлэг оношилгоо хийсэн. Хөдөлгүүр болон гидро системийн ажиллагааг шалгасан.
ECO200305-U161	DT-1217	2020.3-р сар.02	А.ТҮВШИН	Засвар	10:00	17:00	7:00	Гидрийн тосыг тосон авсан. Тосны хөргүүрийн шлангыг сольсон. Гидрийн тосыг дүүргэсэн.аккумляторыг холбосон. Ажлын байрыг цэвэрлэсэн.
ECO200305-U164	DT-1217	2020.3-р сар.02	А.ТҮВШИН	Засвар	14:00	17:00	3:00	Техникийг асаах бэлтгэл ажил хийсэн. Батерэйны холболчыг сольж тавьсан. Тормасны хөргүүрийн шлангны орингийг сольсон. Гидро нэмж банкыг
ECO200305-U166	DT-1231	2020.3-р сар.04	А.ТҮВШИН	Цахилгаан засвар	17:00	19:00	2:00	Алдааг шалгасан. Хянах самбараас рулийн даралтын switch-г шалгасан.
ECO200305-U167	DT-1245	2020.3-р сар.04	А.ТҮВШИН	Цахилгаан засвар	16:00	19:00	3:00	Рулийн системийн цахилгаан системийг шалгасан. Рулийн насосны даралтыг шалгасан. Рулийн шүүрийг шалгасан. Рулийн насосныг солих
ECO200305-U168	DT-1217	2020.3-р сар.04	А.ТҮВШИН	Цахилгаан засвар	10:00	12:00	2:00	Гоожилтыг шалгасан. Тормасны хөрөгөлтийн холбогчийг чангалсан. Ажиллагааг шалгасан.
ECO200305-065	DT-1097	2020.3-р сар.05	А. ТҮВШИН	Шланг солих	9:00	17:30	8:30	1097-ын гидрийн банкнаас гаран пампруу орсон гоожилттой байсан тул шланг тогтоогчийг тайлан аван банк нь дээрх 19-ын боолтыг, памп нь дээрх 4
ECO200306-U173	DT-1216	2020.3-р сар.06	А. ТҮВШИН	Гоожилт зогсоох	15:00	15:30	0:30	Гидро гоожилтыг галнан үзэхэд гидро шүүр болон торкоор гоожилттой байсан тул засварлан ажилд гаргасан
ECO200306-U174	DT-1217	2020.3-р сар.06	А. ТҮВШИН	Гоожилт зогсоох	15:00	15:30	0:30	Гидро гоожилтыг шалгаж гидро акк-ын хувиарлагчны боолтоор буюу планг хийсэн боолтоор гоожилттой байсан тул гагнаж ажилд гаргасан
ECO200306-U170	HT-1216	2020.3-р сар.06	А.ТҮВШИН	Уулын дуудлага	22:00	20:40	#############	HT-1216 1-р подвеск суусан нэсэн дуудлагаар паркын талбай дээр дуудан үзлэг хийж ажилд гаргасан.
ECO200306-069	DT-1245	2020.3-р сар.06	А. ТҮВШИН	STEERING PUMP TRANSMISSION PUMP солих	8:00	18:30	10:30	Трансмисс памп задалж гол сольсон. Хуучин сэлбэгээс steering памп сольсон. Пампуудыг шалгаж 500л гидро, трансмисс 160л хийж асааж
ECO200307-070	DT-1092	2020.3-р сар.06	Н.МАГСАРЖАВ	ШЛАНГ БАЗУУЛАХ	15:00	18:00	3:00	DT-1092-ЫН гидрийн шланг задарсан байсан тул базуулан тавьсан
ECO200307-U176	DT-1216	2020.3-р сар.07	Н.МАГСАРЖАВ	Уулын дуудлага	15:00	15:30	0:30	Хазайсан гэсэн дуудлагийн дагуу шалган үзэхэд 4 дүгээх подвескноос азот гарган ажилд гаргасан.
ECO200308-073	DT-1241	2020.3-р сар.08	Н.МАГСАРЖАВ	Дугуй засварт	7:00	18:00	11:00	DT-1241-ын 5 6 дугуйны хязгаарлагч тасарч унасан байсан ба шопын дугуй засварлуу парклан дамокрадан хөндийрүүлж 5 6-р дугуйг тайлж аван гагнаж
ECO200308-076	DT-1097	2020.3-р сар.08	Н.МАГСАРЖАВ	ПОДЁМ ШИМ СОЛИХ	7:00	19:00	12:00	Подёмны шим байхгүй байсан тул кранаар өргүүлэн шим хийн подёмны завсарлагчийг боон тольны сүүрыг тааруулан хийж боосон. Глушитель
ECO200309-079	DT-1241	2020.3-р сар.09	Н.МАГСАРЖАВ	Гагнуурбн ажил	7:00	18:30	11:30	DT-1241-ын гидрийг тосож аван шинээр 600л гидро хийв.Кранаар өргөж хойд пальцны шимийг хийв. Мөн диффиренциалын тосыг тосон авч 480л sea50
ECO200309-080	DT-1097	2020.3-р сар.09	Н.МАГСАРЖАВ	Подвеск цэнэглэх	8:00	9:00	1:00	Дампны 4ш подвеск суулт өгсөн байсан тул азотоор цэнэглэсэн.Урд хойд подьескны тохиргоог хийсэн...
ECO200310-U183	DT-1216	2020.3-р сар.10	Н.МАГСАРЖАВ	дуудлага засвар	12:00	13:00	1:00	Сгналь ажиллахгүй байсан тул үзлэг шалгалт хийн цахилгаан асуудалыг шийдвэрлэн ажилд гаргасан.
ECO200310-082	DT-1245	2020.3-р сар.10	Н.МАГСАРЖАВ	ШИМ ХИЙХ	7:00	18:30	11:30	DT-1245 Хойд бөгсний тос болон 2 захын дамжуулагчийн тос шинээр сольсон. Шопын суурин тосолгооноос 480л тос авч сольсон. Мөн тэвшний
ECO200310-083	DT-1241	2020.3-р сар.10	Н.МАГСАРЖАВ	Анхны урьдчилэн сэргийлэх засвар	7:00	17:00	10:00	Хөдөлгүүрийн үзүүлэлтийг шалгасан. Трансмиссын үзүүлэлтийг шалгасан. Тормосны үзүүлэлтийг шалгасан.Техникийн цахилгааныг шалгасан. Үндсэн
ECO200310-084	DT-1097	2020.3-р сар.10	Н.МАГСАРЖАВ	Трансмиссийн засвар	17:00	19:00	2:00	Трансмисс алдааг шалгасан. Идэвхтэй алдааг дахин тохируулсан. Подвескны даралтыг сулласан хавхлагыг сольсон. Азотыг тохируулсан.
ECO200310-085	DT-1216	2020.3-р сар.10	Н.МАГСАРЖАВ	Трансмиссийн засвар, сигналь	14:00	17:00	3:00	Трансмисс цахилгаан шалгасан. Трансмисийн араа солих хөдөлгүүрийг сольсон.Сигналь цахилгааныг шалгасан
ECO200311-088	DT-1245	2020.3-р сар.11	Н.МАГСАРЖАВ	ШЛАНГ БАЗУУЛАХ	17:00	18:00	1:00	Тосолгооний пампны шланг гоожилттой байсан тул задалж шинээр шланг базуулан тавьж бэлэн болгосон
ECO200311-089	DT-1245	2020.3-р сар.11	Н.МАГСАРЖАВ	Хэрэгцээт засвар	18:00	18:30	0:30	Күүлент маш бага байсан тул үзлэг хийн 80л күүлент нэмэлт хийн ажилд бэлдсэн.
ECO200312-093	DT-1097	2020.3-р сар.12	Н.МАГСАРЖАВ	ҮЗЛЭГ ОНОШЛОГОО	7:30	8:00	0:30	Өглөөний үзлэгэййр гидро бага байсан тул гидро нэмж үзлэг хийн ажилд бэлэн болгосон.
ECO200312-094	DT-1216	2020.3-р сар.12	Н.МАГСАРЖАВ	ҮЗЛЭГ ОНОШЛОГОО	7:00	7:30	0:30	Өглөөний үзлэгээр тэвшний шим мултарч унасан байсан тул засварлан буцаан боосон ажилд бэлэн болгов
ECO200312-U190	DT-1217	2020.3-р сар.12	Н.МАГСАРЖАВ	дуудлага засвар	18:00	20:40	#############	DT-1217 Ойрыэ нэг гэрэл шатсанбайсанг задалж 1 ширхэг шинэ гэрлийн ламп сольж хийсэн.Утас нь тасарсан байсаныг холбож ажилд гаргасан
ECO200312-U192	DT-1097	2020.3-р сар.12	Н.МАГСАРЖАВ	дуудлага засвар	1:00	4:22	3:22	DT-1097-ын хойд талын нэг ширхэг ухрахын гэрэл асахгүй байсан. Гэрлийг тайлан авч лампыг шалган үзэхэд шатаагүй басан ба 1 дүгээр ээлжинд
ECO200313-096	DT-1092	2020.3-р сар.12	Н.МАГСАРЖАВ	ЗАСВАР	7:00	19:00	12:00	Тоормосны хөргүүрийн шланг сольсон. Динам суурьлуулсан. Стмтерын утсыг засварласан. ATC RTE удирдлага суурьлуулсан. Хөдөлгүүрийн ажиллуулж
ECO200313-097	HT-1245	2020.3-р сар.13	Н.МАГСАРЖАВ	Дугуй засвар	14:30	15:30	1:00	6-р дугуйны хошуугаар хий алдаж байсаныг үопын дугуйн засвар дээр байрлуулан зогсоож 6 дугуйг аван хийг гаргаж хошууг сольж , хийн хий тавьж
ECO200313-100	DT-1097	2020.3-р сар.13	Н.МАГСАРЖАВ	BRAKE ЗАСВАР	8:00	9:00	1:00	Өглөөний үзлэгээр BRAKE -ны анхааруулга асан үзлэг хийн засварлаж алдааг устган ажилд бэлэн болгосон.
ECO200314-105	DT-1245	2020.3-р сар.14	Н.МАГСАРЖАВ	ШЛАНГ БАЗУУЛАХ	9:00	15:00	6:00	Гидрийн шланг маш их гоожилттой байсан тул тайлж аван шланг базуулан угсарч ажилд гаргасан.
ECO200315-108	DT-1092	2020.3-р сар.15	Н.МАГСАРЖАВ	ШИМ ШАШАХ	8:00	19:00	11:00	Подём шим боосон. Караанаар тэвшийг өргүүлэн тэвшний шимийг шахаж авсан. Бүх тосны түвшин , бүх шланг даруулгүүдыг шалгасан. Тэвшний
ECO200315-U197	DT-1216	2020.3-р сар.15	Н.МАГСАРЖАВ	Дуудлага засвар	17:20	17:50	0:30	Дуудлагын дагуу үзлэг шалгалт хийхэд grease pump таг суларсан байсаныг авч цэвэрлэн буцаан боож ажилд гаргасан.
ECO200317-U199	DT-1097 DT-127	2020.3-р сар.16	Н.МАГСАРЖАВ	Дуудлага засвар	8:00	16:00	8:00	Үзлэг хийн явцад кардан хамгаалтандаа хүрч элэгдсэн байдалтай байссн мул тайлж авч засваран хэвийн ажил горимд оруулсан
ECO200317-113	DT-1092	2020.3-р сар.17	Н.МАГСАРЖАВ	ЗАСВАРЫН АЖИЛ	7:30	19:00	11:30	DT-1092-ын 3 дугаар подвеск буулгаж өмчийн хашаанаас хуучин подвеск авч асгыг сольж тавьж подвескыг сэрээт ачигч ашиглан суурвлуулж масшлянк
ECO200318-116	DT-1241	2020.3-р сар.18	Н.МАГСАРЖАВ	ШЛАНГ БАЗУУЛАХ	8:00	12:00	4:00	Өглөө үзлэг хийх явцад гидро шланг гоожилт ихтэй байсан учих шинээр шланг базуулан таьсан.Гидро нэмж ажилд гаргасан.
ECO200320-121	DT-1097	2020.3-р сар.20	Н.МАГСАРЖАВ	ШЛАНГ БАЗУУЛАХ	12:30	15:30	3:00	Дуудлагын дагуу үздэг хийхэд гидрийн шланг гоожилттой байсан Гоожилтыг шланг базуулан тавьж солин ажилд гаргасан
ECO200320-123	DT-1092	2020.3-р сар.20	Н.МАГСАРЖАВ	Подвеск угсралт	7:30	19:00	11:30	DT-1092 4дүгээр подвеск буулган авч, Өмчийн хашаанаас авч хууин подвескинд аягыг тайлан авч үгсран буцаан суурьлуулахад бэлэн
ECO200321-125	DT-1216	2020.3-р сар.20	Н.МАГСАРЖАВ	ЧИЧИРГЭЭН БУУРУУЛАГЧ АСУУДАЛТАЙ	7:00	18:30	11:30	Чичиргээ бууруулагчийн хаалтыг цэвэрлэсэн, Товуд дүүргэсэн. Товуд банкыг цэвэрлэсэн. Автомат тосолгооны системыг зассан.
ECO200321-U206	DT-1097	2020.3-р сар.20	Н.МАГСАРЖАВ	Дуудлага засвар	14:00	15:00	1:00	Дуудлагын дагуу үзлэг хийхэд гидрийг хувиарлагч шлангаар гоожилттой байсан тул засварлан шинэ оринг авж тавин ажилд гаргасан.

Table 15. HD785 dump truck work order log example

Ажлын дугаар	Парк дугаа	Start	Төлөвлөгч	Ажлын тайлбар	ЭХЭЛСЭН ЦАГ			Хийгдсэн ажлын тайлан
ECO190611-005	HT-02	2019.6-р сар.11	Ч. МӨНХМАНЛАЙ	ЛАМП ЗАСВАР			0	
ECO190611-006	HT-03	2019.6-р сар.11	Ч. МӨНХМАНЛАЙ	ЛАМП ЗАСВАР			0	
ECO190611-007	HT-07	2019.6-р сар.11	Ч. МӨНХМАНЛАЙ	ЛАМП ЗАСВАР			0	
ECO190611-008	HT-03	2019.6-р сар.11	Ч. МӨНХМАНЛАЙ	ШЛАНГ БАЗУУЛЖ СУУРЬЛИУЛАХ			0	
ECO190612-010	HT-07	2019.6-р сар.12	Ч. МӨНХМАНЛАЙ	ЦАХИЛГААН ЗАСВАР - ГАЛ ХАМГААЛАГЧ			0	
ECO190612-014	HT-17	2019.6-р сар.12	Ч. МӨНХМАНЛАЙ	2800PM ҮЙЛЧИЛГЭЭ	14:00	20:00	6:00	Хөдөлгүүрийн тос тосож авсан. Маслын шүүр 6ш шинээр сольсон. Хөдөлгүүрийн тос шинээр солив. Трансмиссын тос шинээр сольсон. Маслын
ECO190613-015	HT-17	2019.6-р сар.13	Ч. МӨНХМАНЛАЙ	2800PM ҮЙЛЧИЛГЭЭ	7:30	15:10	7:40	2800PM үргэлжилж байгаа. Дифференциалын амьсгалагч (REAR AXLE BREATHER,07030-00252,HD1500) 1ш авсан,
ECO190613-016	HT-02	2019.6-р сар.13	Ч. МӨНХМАНЛАЙ	ШЛАНГ БАЗУУЛЖ СУУРЬЛИУЛАХ /ХИЙН ШЛАНГ/	7:00	10:00	3:00	Хийн шланг цоорсон, хийн тургигч нь тохиргоо алдагдаж эвдэрсэн байсан хийн шлангыг базуулан хийн тургигчын шинээр солин угсран завсарын ажил
ECO190614-017	HT-03	2019.6-р сар.14	Ч. МӨНХМАНЛАЙ	ХИЙН СИСТЕМ ЗАСВАР			0:00	
ECO190614-020	HT-17	2019.6-р сар.14	Ч. МӨНХМАНЛАЙ	ХИЙН СИСТЕМ ЗАСВАР ШЛАНГ БАЗУУЛАХ	13:50	15:30	1:40	3,4,5,6-р дугуйны хий сул гэсэн дуудлагын дагуу үзлэг хийн, 6-р дугуйны шпилка суларсан байсныг чангалан, хийн даралтын шлангыг базуулан сольж
ECO190616-023	HT-03	2019.6-р сар.16	Ч. МӨНХМАНЛАЙ	ХИЙН ШЛАНГ БАЗУУЛЖ СУУРЬЛИУЛАХ	7:30	19:00	11:30	Компрессорыг хийн шланг 2ш базуулж суурьлиулсан хойд хийн хувиарлагчаас компрессор хүртэл 5м орчимын хийн шланг мууdаж хатсан
ECO190616-025	HT-03	2019.6-р сар.16	Ч. МӨНХМАНЛАЙ	ХИЙН ШЛАНГ БАЗУУЛЖ СУУРЬЛИУЛАХ			0:00	Компрессорыг хийн шланг 2ш базуулж суурьлиулсан хойд хийн хувиарлагчаас компрессор хүртэл 5м орчимын хийн шланг муудаж хатсан
ECO190617-026	HT-19	2019.6-р сар.17	Ч. МӨНХМАНЛАЙ	ДУГУЙ ЗАСВАР	7:00	19:00	12:00	Дугуй засварын ажил хийх / Сэрээт ачигч болон дугуйн компрессор ажиллахгүй байгаа/
ECO190617-028	HT-03	2019.6-р сар.17	Ч. МӨНХМАНЛАЙ	ТРАНСМИСС ЗАСВАР			0:00	
ECO190619-029	HT-17	2019.6-р сар.19	Ч. МӨНХМАНЛАЙ	ТУРБИН ЗАСВАР	7:30	19:00	11:30	Күлэнтийг тосч аван, агаарын хоолойнууд болон, турбины холболтуудыг салгаж, сальникаараа масло цацсан байсныг турбиныг шинээр сольсон.
ECO190620-031	HT-19	2019.6-р сар.19	Ч. МӨНХМАНЛАЙ	ХИЙН СИСТЕМ ЗАСВАР	7:00	19:00	12:00	1-2-6-р дугуйг сольсон 6-р дугуйны шпилка сольсон 0114MJ0660.922212112271,92201212231
ECO190621-032	HT-07	2019.6-р сар.21	Ч. МӨНХМАНЛАЙ	ДУГУЙГ ШИНЭЭР СОЛЬЖ ТАВИХ			0:00	
ECO190623-035	HT-04	2019.6-р сар.19	А.Түвшин	Гидрийн шланг солих	7:00	19:00	12:00	
ECO190625-038	HT-07	2019.6-р сар.19	А.Түвшин	Маслын шүүрний хоолой солих	14:30	16:00	1:30	Маслын шүүрний хоолой сольсон
ECO190626-040	HT-16	2019.6-р сар.19	А.Түвшин	Стартер болон гидрийн шланг, мөн динамны ремень солих			0:00	
ECO190626-042	HT-06	2019.6-р сар.19	А.Түвшин	Гидрийн шланг солих	16:30	18:30	2:00	гидрийн шланг задарсан байсныг шинээр базуулж тавьсан.
ECO190627-043	HT-04	2019.6-р сар.19	А.Түвшин	Кондейшны ремень солих			0:00	Кондейшны ремень тасарсан байсныг шинээр сольж ажилд гаргасан.
ECO190628-045	HT-03	2019.6-р сар.19	А.Түвшин	Подвейск солих			0:00	2-р подвеск тос хаяж тосон цэнэг хийгээд авахгүй байсныг сольсон.
ECO190702-049	HT-02	2019.7-р сар.02	А.Түвшин	Аккумулятор солих			0:00	Аккумлятор муудсан байсныг сольж ажилд гаргасан.
ECO190704-052	HT-06	2019.7-р сар.04	А.Түвшин	СТАТЕР СОЛИХ	8:30	18:30	10:00	Хуучин стартерийг тайлж аван хуучин сэлбэгт тушаан шинэ сэлбэгээс шинэ стартер авч тавьсан.ЦАХИЛГААН ЗАСВАР ХИЙХ.
ECO190704-053	HT-07	2019.7-р сар.04	А.Түвшин	АЗОТООР ЦЭНЭГЛЭХ	14:00		1.00	АЗОТООР ЦЭНЭГЛЭсэн
ECO190707-060	HT-03	2019.7-р сар.07	Н.Магсаржав	ПОДВЕСК, ПЛАНЗ СОЛИХ	14:00		################	Подвеск планз сольж тавин шалгаж үйлчилгээ хийлгэн ажилд оржхлахаар болов
ECO190708-063	HT-03	2019.7-р сар.08	Н.Магсаржав	ПОДВЕСКА ЦЭНЭГЛЭХ, ДУГУЙ УГСАРАХ	19:00		################	Подвеск планз сольж дугуй угсаран тавин шалгаж үйлчилгээ хийлгэн ажилд оруулахаар болов
ECO190709-064	HT-03	2019.7-р сар.09	Н.Магсаржав	350PM ҮЙЛЧИЛГЭЭ	19:00		################	350 м/цаг ТҮ хийн, хөдөлгүүрийн тосыг тосон авч, маслын шүүр 6ш, түлшний шүүр 2ш тус тус шинээр сольж тавин, 140 литр хөдөлгүүрийн тос шинээр
ECO190712-067	HT-19	2019.7-р сар.12	Н.Магсаржав	Дугуйн ОРИНГ солих	7:00		щ2	3, 4-р дугуйны оринг сольж хий нэмж шпилк чангалан ажилд гаргасан
ECO190715-072	HT-06	2019.7-р сар.15	Н.Магсаржав	1 ширхэг дугуй агуулахаас авж тавих	13:00		################	1 ширхэг дугуй агуулахаас авж тавьсан
ECO190716-073	HT-16	2019.7-р сар.16	Н.Магсаржав	Гидрийн шүүр солих	13:00		о1.5	Гидрийн шүүр сольж урсгал засвар хийсэн
ECO190716-074	HT-19	2019.7-р сар.18	Н.Магсаржав	Гидрийн банкны амьсгалагч солих	13:00		################	Гидрийн банкны амьсгалагч сольж ажилд гаргасан
ECO190721-078	HT-03	2019.7-р сар.21	А.Түвшин	Гэрэл дохио засварлах	16:00		################	
ECO190722-080	HT-06	2019.7-р сар.22	А.Түвшин	Турбин солих	18:00		################	
ECO190722-081	HT-06	2019.7-р сар.22	А.Түвшин	Дугуйн оринг солих	19:00		д2	Дугуйн Оринг сольсон
ECO190724-082	HT-06	2019.7-р сар.24	А.Түвшин	350 мот/цаг ТҮ	20:00		################	350мот/цаг ТҮ хийн маслын шүүр 4ш, буцахын шүүр 2ш, түлшний шүүр 2ш тус тус сольж хөдөлгүүрийн тосыг шинээр сольсон.
ECO190724-084	HT-06	2019.7-р сар.24	А.Түвшин	Дугуй солих	22:00		i7.3	1-р дугуй илэгдэж муудсан байсныг 93281Z213531 сериал дугаартай шинэ дугуйгаар сольж 1-р дугуйг 3-р дугуйнд тавьсан.
ECO190725-085	HT-06	2019.7-р сар.25	А.Түвшин	дугуйн завсарлагч солих	23:00		################	Дугуйнд завсарлагч шинээр тавьсан.
ECO190725-086	HT-07	2019.7-р сар.25	А.Түвшин	трансмисс шүүр солих	0:00	2:00	2:00	Транмисс 4 ш шүүрийг задлаж шалгахад бохирдсон байсан. Трансмиссын банкинд хог тунасан байх магадлалтай байсан тул трансмиссын тосыг тосож
ECO190726-087	HT-17	2019.7-р сар.26	А.Түвшин	hoist pump солих	1:00	3:00	0:00	Захиалгын Pump засвараас ирсэн тул pump -г угсарч хоолойнуудыг бүрэн холбож гидрийн шингэнийг буцаан хийсэн.
ECO190727-089	HT-17	2019.7-р сар.27	А.Түвшин	Хийн систем засвар	3:00	5:00	################	Хий алдаж подем өргөхгүй байсныг хийн шланг сольж хий алдалтыг зогсоон подемны рычакны тохиргоо хийсэн.
ECO190730-094	HT-17	2019.7-р сар.30	А.Түвшин	Трансмиссын Шүүр солих	8:00	10:00	################	Тэвш өргөгдөөгүй. Хөшүүргийн холбогч суулгаж тохируулсан. Бүрхүүл суулгасан. 15 литр трансмиссын шингэн нэмсэн. Хурдний болон хөшүүргийн
ECO190731-095	HT-07	2019.7-р сар.31	А.Түвшин	Түлшний түб засвар	9:00	11:00	################	Үзлэг хийхэд түлшний буцах түб буюу эмзэг 12-оор түлш гоожиж байсан тул тайлан авч шалгаж үзэхэд R талын 1 цилиндрийн дээд тагны хэсгийн блок
ECO190802-097	HT-19	2019.8-р сар.02	А.Түвшин	Динам солих	11:00	3:00	################	Аккумляторын анхааруулга асаад байсныг үзлэг хийхэд динам шатсан байсан тул динамыг шинээр сольж ажилд гаргасан.
ECO190803-098	HT-07	2019.8-р сар.03	А.Түвшин	BRAKE CHAMBER СОЛИХ	12:00	2:00	################	Аккумляторын анхааруулга асаад байсныг үзлэг хийхэд динам шатсан байсан тул динамыг шинээр сольж ажилд гаргасан.
ECO190804-100	HT-17	2019.8-р сар.04	А.Түвшин	Турбин солих	8:00	10:00	2:00	Аккумляторын анхааруулга асаад байсныг үзлэг хийхэд динам шатсан байсан тул динамыг шинээр сольж ажилд гаргасан.
ECO190806-104	HT-19	2019.8-р сар.06	А.Түвшин	Түлшний шүүр солих	7:00	09::00	#VALUE!	Түлшний шүүр сольсон. Үзлэг хийхэд гидрийн памп резва алагдаж гидро алдсан байсан. Гидро пампны гадна гэрийг хуучин сэлбэгээс авч сольж
ECO190807-105	HT-07	2019.8-р сар.07	Н.Магсаржав	Агаар шүүгч солих	7:00	2:00	################	АГААР ШҮҮГЧИЙН ГАДНА ТАГИЙГ АВЖ 3Ш АГААР ШҮҮГЧ СОЛИИВ
ECO190808-106	HT-19	2019.8-р сар.08	Н.Магсаржав	Зэс шайв бусад засварын ажил хийгдэх	7:00	1:00	################	Түлш аппартурт ирэхгүй хий сорж асахгүй байсныг аппартураас түлшний түб шлангуудыг хөөж шалгасан. Түлшний орохын түб 2ш стувцний шайв
ECO190811-107	HT-04	2019.8-р сар.11	Н.Магсаржав	350pM ҮЙЛЧИЛГЭЭ	8:00	2:00	################	350 м/цаг ТҮ хийн, хөдөлгүүрийн тосыг тосон авч маслын шүүр 3ш сольж, түлшний шүүр 3ш шүүр шинээр солин тавьж 80 литр хөдөлгүүрийн тос
ECO190818-114	HT-16	2019.8-р сар.18	Н.Магсаржав	ТОРМАСНЫ ШЛАНГ СОЛИХ	8:00	4:00	################	Тормосны шланкыг сольсон
ECO190818-117	HT-19	2019.8-р сар.19	Н.Магсаржав	RING СОЛИХ ЗАСВАРЫН АЖИЛ	19:00	2:40	################	5-р дугуйны нуух сольж 6-р дугуйг задалж угсран буцаан хийсэн.
ECO190820-119	HT-19	2019.8-р сар.20	Н.Магсаржав	Захын дамжуулагчийн шпилк солих	19:00	2:40	################	3,4-р дугуйны захын дамжуулагч руу орсон трансмиссын 14 шланг базагчаараа кадарсан байсныг HT16-аас авч HT19-д тавьж гидро нэмэн
ECO190821-120	HT-19	2019.8-р сар.21	Н.Магсаржав	1400 мот/цаг ТҮ	12:00	3:00	################	1400 PM үйлчилгээ хийн хөдөлгүүрийн маслын шүүр 2 ширхэг, хөдөлгүүрийн маслын буцахын шүүр 4 ширхэг, Агаар шүүгч /гадна/ 3 ширхэг, Агаар шүүгч
ECO190821-121	HT-06	2019.8-р сар.21	Н.Магсаржав	Ба труба солих гидрийн	13:00		j2.5	гидрийн ба труба сольж тавиэ бэлэн болгосон
ECO190822-125	HT-19	2019.8-р сар.22	Н.Магсаржав	Түлшний труп солих	17:00		j9	Зөв талын 6-р труп хугарч гоожилттой байсныг тайлан авч гагнуулаад эргүүлж боон ажилд гаргасан. 6 цилинд түлш труб хугарсан гоожсон байсанг
ECO190823-126	HT-02	2019.8-р сар.23	2020.March.29	күлэнтийн мэдрэгч солих	17:00		################	Күлэнтийн мэндрэгч сольсон.
ECO190823-127	HT-07	2019.8-р сар.23	А. Түвшин	Кондейшны мотор солих	17:00		j5.5	Кондейшн ажиллахгүй байхгүй байсныг шинэ сэлбэг дээрээс шинэ кондейшн авч HT-07 ийн кабины суудлын ард талд нь суурь тааруулж гагнуулан шон
ECO190824-128	HT-06	2019.8-р сар.24	Ч. МӨНХМАНЛАЙ	СИГНАЛЬ СОЛЬЖ ТАВИХ			0:00	
ECO190825-130	HT-06	2019.8-р сар.25	А. Түвшин	Температур мэдрэгч8 трансмисс шүүр солих			0:00	Хийн температур мэдрэгч эвдэрснийг сольж тавьсан шинэ сэлбэгээс авч сольсон. \ Засвартай\
ECO190825-132	HT-06	2019.8-р сар.25	А. Түвшин	хомут солих			0:00	Күлэнтийн хомут задарсан байсныг сольсон
ECO190825-133	HT-04	2019.8-р сар.25	А. Түвшин	Түлшний труп солих			p9	Хийн болон түлшний асуудал тулгарсан. Оношлоход түлшний труп хугарч түлш гоожилттой байсныг өөр трупээр сольж тавьсан.
ECO190826-135	HT-05	2019.8-р сар.26	А. Түвшин	Трансмисс тавих			0:00	L талын аппаратурыг салгаж кабин дотор хийсэн байсныг мотор угсарч түлшний труп, шлангуудыг аппаратурыг цэвэрлэж угсарч бэлэн болгосон.

Table 16. HT – 1500 dump truck SMR data

KOMATSU HD1500-7 DUMP TRACK																																								
1	DT-1081	KOMATSU HD1500	вш гагнуурын аж		Дугуй засвар болон тэвш гагнуурын ажилтай /сэлбэг хүлээлт																					Захын дамжуулагч сольж байгаа SOLINIOD VALVE сэлбэг хүлээлт														
		80029																																						
2	DT-1082	KOMATSU HD1500	ӨДӨР АЖИЛД ГАРСАН. I											26844	26862		26896					26911	26927	26945	26962	26977	26995	27015	27031	27050	27070	27087	27112	27131			27172	27186	27196	27213
		80030									26810	26829			26871								26935	26952	26968	26985	27005	27022		27060	27077		27113							
3	DT-1083	KOMATSU HD1500					28384	Шинээр ирсэн гагнуурын ажилтай						28391																					28436	28446	28465		28481	
		80036																																	28436					
4	DT-1084	KOMATSU HD1500																																						
		80037																																						
5	DT-1085	KOMATSU HD1500																																						
		80038																																						
5	DT-1087	KOMATSU HD1500																																						
		80040																																						
6	DT-1088	KOMATSU HD1500																																						
		80043																																						
8	DT-1089	KOMATSU HD1500																																23346						
		KMTHD036P29080046															23342																							
7	DT-1090	KOMATSU HD1500															Ажиллах аргүй		25721			25742	25753		25777	25788	25806	25825	25843	25862	25880		25921	25939	25953		25968	25977	26001	26015
		80047																			25741	25750	25757															25986		
10	DT-1091	KOMATSU HD1500																																						
		80049																																						
8	DT-1092	KOMATSU HD1500	21886			21926					21984							22106		22132	22150				22169	22177	22191			22209	22220						22256		22271	
		80051		21902			21956	21975			21985			22038	22059	22077		22114								22185			22200											
9	DT-1093	KOMATSU HD1500					25867	Шинээр ирсэн гагнуурын ажилтай								25868	25896																							
		80052																																						
13	DT-1094	KOMATSU HD1500																																						
		80054																																						
14	DT-1095	KOMATSU HD1500																								1 3 дугаар подвескны SEAL тавьсан Сэлбэг хүлээлт														
		80056																																						
10	DT-1096	KOMATSU HD1500																																						
		80058																																						
16	DT-1097	KOMATSU HD1500			23300	23301																																		
		80060				23306	23335																																	
17	DT-1098	KOMATSU HD1500																													21794									
		80062																																						
11	DT-1099	KOMATSU HD1500																																						
		80064																																						
12	DT-1205	KOMATSU HD1500																																						
		80077																																						
12	DT-1215	KOMATSU HD1500																													25773						25796	25817	25826	25843
		80109																																					25835	25852
21	DT-1216	KOMATSU HD1500	23184	23200			23257	23270	23288			23298	23315	23333	23351	23369	23388		23422				23478			Хөдөлгүүрийн цлиндрийн Жийргээр тос хаясан 1243 руу Цахилгаан удирдлагын хавхлагыг шилжүүлж тавьсан Сэлбэг хүлээлтнгд байгаа гэхдээ 1241 ээс Шилжүүлэн гаргана														
		80110		23209	23229	23249	23267	23279				23306		23341	23360	23379									23511															
22	DT-1218	KOMATSU HD1500																																						
		80113																																						
13	DT-1219	KOMATSU HD1500																																						
		80114																																						
14	DT-1221	KOMATSU HD1500																																						
		80116																																						
15	DT-1222	KOMATSU HD1500																													23046									
		80117																																						
26	DT-1223	KOMATSU HD1500																													29576								29579	29587
		80118																																						
27	DT-1224	KOMATSU HD1500															30408							30458	30475	30493	30512	30531	30550		30583	30607		30645	30664		30703	30713		
		KMTHD036L29080119																					30449	30467	30484	30503	30522	30541	30558	30574								30723	30740	30758
28	DT-1225	KOMATSU HD1500																													27845									
		80119																																						
29	DT-1226	KOMATSU HD1500																																						
		80121																																						
30	DT-1227	KOMATSU HD1500															Ирсэн өдөр									Гагнуурын ажил дууссан Зүүн талын Hoist cylinder солих ажилтай														
		KMTHD036L29080122															27677																							
16	DT-1228	KOMATSU HD1500	SOLENOID /BRAKI							18048	18055	18060	18069													Трансмисс гоожилттой Сэлбэг Оринг хүлээлт														
		80123																																						
17	DT-1229	KOMATSU HD1500																																			26937	26944		
		80124															26901																				26939			
33	DT-1230	KOMATSU HD1500																																						
		80125																																						
18	DT-1231	KOMATSU HD1500		20028		20065	20084	20104	20122	20141	20160	20185	20193	20222		20249	20268	20287	20305	20324	20343					20434	20451	20470	20479	20506	20525	20541		20577	20593	20612	20632		20670	20680
		80126		20037		20075	20094				20170				20239			20296		20333	20352	20370	20388	20407	20425	20443			20488	20516	20532	20551			20603	20622	20640	20660		20687
35	DT-1232	KOMATSU HD1500																																						
		80127																													26576									
19	DT-1233	KOMATSU HD1500																													25792									
		80130																																						
20	DT-1234	KOMATSU HD1500															27926																				27971			
		80131																																						
22	DT-1235	KOMATSU HD1500															27582		27582	27587	2-дугаар Подвеск SEAL тавьсан Магадгүй Сэлбэг хүлээлт																			
		KMTHD036J29080132																																						
23	DT-1237	KOMATSU HD1500																																						
		80134																																						
24	DT-1238	KOMATSU HD1500																													23809									
		80135																																						
21	DT-1240	KOMATSU HD1500																																						
		80155																																						
42	DT-1241	KOMATSU HD1500	19139			19174	19192	19211		19240	19269							Хөдөлгүүр засварт явсан.																						
		80164								19259																														
26	DT-1242	KOMATSU HD1500																																						
		80169																																						
27	DT-1243	KOMATSU HD1500					18380																											18521	18530	18549	18564			18608
																																			18539		18573	18592	18602	18619
22	DT-1244	KOMATSU HD1500																																						
		80179																																						
29	DT-1245	KOMATSU HD1500																																						
		80184																																						
23	DT-1100	KOMATSU HD1500																																						
		80066																																						
24	DT-1201	KOMATSU HD1500																																						
		80073																																						
25	DT-1202	KOMATSU HD1500																																						
		80074																																						
26	DT-1212	KOMATSU HD1500																																						
		80098																																						
27	DT-1213	KOMATSU HD1500																																						
		80099																																						
28	DT-1214	KOMATSU HD1500																																						
		80108																																						
29	DT-1249	KOMATSU HD1500																																						
		80187																																						
30	DT-1253	KOMATSU HD1500																																						
		80197																																						
31	DT-1203	KOMATSU HD1500																																						
		80075																																						
32	DT-1204	KOMATSU HD1500																																						
		80076																																						
33	DT-1206	KOMATSU HD1500																																						
		80087																																						
34	DT-1250	KOMATSU HD1500																																						
		80191																																						
35	DT-1251	KOMATSU HD1500																																						
		80192																																						
36	DT-1252	KOMATSU HD1500																																						
		800196																																						
37	DT-1207	KOMATSU HD1500																																						
		80088																																						
38	DT-1208	KOMATSU HD1500																																						
		80092																																						
39	DT-1209	KOMATSU HD1500																																						
		80093																																						
40	DT-1211	KOMATSU HD1500																																						
		80097																																						
41	DT-1247	KOMATSU HD1500																																						
		80185																																						

Table 17. HD – 785 dump truck SM data

Парк №	Аралын дугаар	2019.06 сар																													
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
HT-02	KOMATSU HD785-5						засвар	23114	3123 1400pm хийсэн Цахилгаан засва					23131																	Засвар
																							23142								
HT-03	KOMATSU HD785-5	Цахилгаан засвар, 2-р подвескны засварын ажил хийгдэж байсан. Засварын ажилтай																													
HT-04	KOMATSU HD785-5	Трансмисс сэлбэг хүлээлт. /ИГЭ-рүү явсан/.Цахилгаан засварын ажил хийгдэж байгсан.																													
HT-05	KOMATSU HD785-5	Трансмисс сэлбэг хүлээлт. /ИГЭ-рүү явсан/																													
HT-06	KOMATSU HD785-5	Дугуй засварын ажил хийх / Сэрээт ачигч болон дугуйн компрессор ажиллахгүй байгаа/																													
HT-07	KOMATSU HD785-5	Тэвшний саравч гагнуурын ажил хийгдэж байсан.																	3-р дугуй хагарч зогссон засвар хийсэн.								21398	2-р подвеск тос хаясан.			
																									21394		21402				
HT-16	KOMATSU HD785-5	темийн засв[illegible]системийн засварын ажил хийж байгаа.																									Цахилгаан болон хийн сис		
HT-17	KOMATSU HD785-5								Засвар			50 1400PM үйлчил							лэнт цацаж зогссон засварын ажил хи												
																										19463				19467	
HT-19	KOMATSU HD785-5					Засвар		Дугуй засварын ажил хийх / Сэрээт ачигч болон дугуйн компрессор ажиллахгүй байсан/																				Засвар	24134		
																											24128	24131	Засвар		
HT-66	KOMATSU HD465	1, 6-р дугуй засварын ажил хийх / Сэрээт ачигч болон дугуйн компрессор ажиллахгүй байгаа/ Тормасны насос болон бусад сэлбэг хүлээлт																													
	KMTHD006E26007891																														
HT-67	KOMATSU HD465																			Хөдөлгүүрийн суурийг кран болон гагнуур дуудан авчирч кранаар өргүүлэн суурь бэлдэж лапыг тааруулан тавьж											
	KMTHD006L26007899																														
HT-126	KOMATSU HD465-5		18205	18216	18231	18246		18274	18289	18308	18338	18348	18364	18381	18398	18415	18425	18435	18449	18462	18481		18511	18516	18527	18540	18558		18583	18595	18611
	KTMHD034T29016215	18195	18212	18224	18238	18254	18266	18280	18299	18318		18355	18374	18391	18407	18424	18435	18440	18456	18472	18487	18494		18522	18534	18549	18565	18577	18587	18605	18619
HT-127	KOMATSU HD465-7R	17503	17521		17552	17568		17605		17643	17684		17696	17711	17728	17755	17757	17768	17778	17791	17811		17851	17856							
		17512	17534	17543	17561		17595						17704				17763		17786	17801	17821	17831				17889	17903	17914	17925		17943
HT-128	KOMATSU HD465-7R	кардан, динам, кондейшний мотор бусад сэлбэ					17069		17091	17106	17123	17134	Brake pump, дугуй сэлбэг хүлээлт																		
									17097	17123	17134																				
HT-129	KOMATSU HD465-7R						11486 Brake pump болон бусад сэлбэг хүлээлт																								
HT-130	KOMATSU HD465-7R												15558	15572	н сэлбэг сольж тавин, трансмиссийн амьсгалагчын шүүр тагыг шинээр соль								15576	15582	15589						
	KMTHD034PFD016347												15566												15597	15612	15621	15637	15648	15659	15676
HT-131	KOMATSU HD465-7R	12844	12863	12877	12894	12913	12928	12949	12969	12998		13027	13046	13074	13083	13093	13109	13118	13125				13161	13178	13191	13208	13224		13256	13267	13285
		12854	12872	12884	12904	12919	12938	12958	12978				13064			13107			13136		13154	13155	13171	13183	13201	13215		13247	13259	13276	13295
HT-132	KOMATSU HD465-7R	15403	15406	15417	15435	15454	15472	15492	15507	15527	15547	15567	15587	15606		15640	15652	15673	15682	15695			15734	15740	15752	15767	15783			15830	15847
	KMTHD034JFDO16349		15415	15426	15445	15462	15483	15497	15518	15538		15578	15596	15615			15662		15689	15705		15727		15745	15761	15775	15791	15809	15822	15839	15857
HT-133	KOMATSU HD465-5	15378	15387	15400	15414			15466	15484	15503	15521	15541	15570			15597	15610	15617	15636	15651	15671	15683	15703			15746					15832
	KMTHD034PFD016350															15606		15618	15644	1566	15681	15694	15713	15726	15738	15757	15773	15792	15805	15823	15840

2019.07 сар																														
01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		23149	**Цахилгаан засвар**																		**Цахилгаан засварын ажилтай**									
2-р подвейск солих засвартай																														
															25625															
																		Явах ангийн засвар					**Явах ангийн засвар**				**Явах ангийн засвар**			
Трансмисс сэлбэг хүлээлт. /ИГЭ-рүү явсан/																														
Цахилгаан болон хийн системийн засварын ажил хийж байгаа.											Цахилгаан болон хийн системийн засварын ажил хийгдэж байгаа										**Цахилгаан болон хийн системийн засварын ажил хийгдэж байгаа**									
				21405	21421		21431		21436	21454	21459	21464	21467								21502	21506	21513	21529	21533	21539		21550	21560	21573
								21439	21445																					21575
темийн засварын ажил хийж байгаа.								Цахилгаан болон хийн системийн засварын ажил хийж байгаа.								Цахилгаан болон хийн системийн засварын ажил хийж байгаа.								**Цахилгаан**			**Цахилгаан болон бусад засвар**			
																										19468	**Гидро халсан. Засвар**			
	24143	24140																					24186	24193	24197		24201			24201
			24157											24165																
								12016																12041	12051	12061	12066	12066	12072	12086
																									12058				12078	12089
Хөдөлгүүр болон цахилгаан засвартай								Хөдөлгүүр болон цахилгаан засвартай									Хөдөлгүүр болон цахилгаан засвартай													
18628	18651	18660	18673	18692	18710	18723	18739	18756	18773	18792	18815	18820	18846	18855	18873		18910	18921	18940		18965		18980	18995	19010	19015	19024		19041	
18628			18683	18701		18732	18747	18764	18783	18801		18829		18864	18883		18920							19002		19020	19030		19048	19064
	17978	17998	18008	18027	18046	18063	18081	18109		18138	18160	18173	18193	18203	18223		18261	18282		18329		18352	тормасны аппаратны seal тавьсан.				тормасны аппаратны seal тавьсан.			
17970			18018	18037			18090					18183		18213	18234		18272	18291	18311											
Brake pump, дугуй сэлбэг хүлээлт								Brake pump, дугуй сэлбэг хүлээлт									Brake pump, дугуй сэлбэг хүлээлт								Brake pump, дугуй сэлбэг хүлээлт					
11486 Brake pump болон бусад сэлбэг хүлээлт								11486 Brake pump болон бусад сэлбэг хүлээлт									11486 Brake pump болон бусад сэлбэг хүлээлт								11486 Brake pump болон бусад сэлбэг хүлээлт					
	.	15690	15707	15724	15735		15756	15760	15770	15788	15804	15820	brake pump зогссон				Тормасны насос засварын ажил хийх /							Brake pump эвдэрч зогссон засвар хийх						
15680			15716			15744			15780			15826																		
13303	13319	13337	13357	13374		13407	13423	13439	13459	13486		13510	13528	13537			13593	13622		13663	13672	13695	13701	утаа хаяж түлш их идсэн Brake pump з						13710
13310	13329		13367	13382	13398	13414	13433	13450	13467			13518		13547	13567		13603	13632	13643											
15865		15897	15915	15942	15933		15966	15991									16011			16027	16034	16045	16063	16077	16093	16109		16120	16127	
15874	15888		15924		15957	15975	15984	15996									16014					16055		16085	16103	16115	16119	16124		
	15867	15885	15904	15923	15938	15964	15973	15989	16008		16039	16054	16070	16087		сний ремень тасар			16142	16155	16157	16166		16199	16215	16230				
15858	15876		15914	15930	15948	15957		16000	16015			16064			16107			16132						16208	16224					