

CHAPTER 4 – RESULTS AND DISCUSSIONS

This chapter explains the results of the stages Data Collection, Data Analysis, Solution, Improve, Verification, and Standardization.

4.1 Data Collection

In this sub-chapter, it is explained in detail regarding the performance data of dump truck Komatsu HD785-7 PT. XYZ consists of Physical Availability (PA), unscheduled downtime, Vehicle Health Monitoring System (VHMS), Periodic Inspection (PI), and lubricant analysis program.

4.1.1. Physical Availability (PA) Data

The Physical Availability (PA) data of Komatsu Dump Truck HD785-7 is taken at PT. XYZ during January – July 2023 as shown in Table 4.1 Summary of Physical Availability HD785-7 PT. XYZ.

Table 4.1 Summary of Physical Availability HD785-7 PT. XYZ

NO	MACHINE MODEL	MACHINE CODE	MACHINE S/N	PHYSICAL AVAILABILITY 2023						
				Jan	Feb	Mar	Apr	May	Jun	Jul
1	HD785-7	HD1114	8076	89.71%	88.89%	88.15%	75.13%	87.00%	89.72%	88.26%
2	HD785-7	HD1117	8079	74.85%	78.91%	80.13%	82.94%	86.60%	74.91%	87.96%
3	HD785-7	HD1118	8206	77.69%	75.13%	74.85%	76.89%	82.94%	83.84%	86.17%
4	HD785-7	HD1119	8208	86.17%	87.07%	87.69%	86.17%	87.07%	86.17%	87.69%
5	HD785-7	HD1120	8212	83.84%	87.68%	86.35%	83.84%	87.68%	83.84%	86.35%
6	HD785-7	HD1121	8213	89.78%	88.26%	88.21%	79.78%	87.07%	79.78%	88.21%
7	HD785-7	HD1122	8437	86.72%	86.78%	82.94%	86.34%	87.51%	85.78%	87.07%
8	HD785-7	HD1123	8438	75.82%	87.96%	86.72%	86.72%	87.96%	75.82%	86.72%
9	HD785-7	HD1124	8439	76.82%	86.86%	86.04%	86.04%	86.86%	76.82%	86.04%
10	HD785-7	HD1125	8440	74.91%	71.26%	86.60%	86.78%	86.17%	74.91%	86.60%
AVERAGE				81.63%	83.88%	84.77%	83.06%	86.69%	81.16%	87.11%
TARGET				88.00%	88.00%	88.00%	88.00%	88.00%	88.00%	88.00%

From Table 4.1 Summary of Physical Availability HD785-7 PT. XYZ above we can draw the conclusion that the PA HD785-7 is not achieved according to the monthly target of PA.

4.1.2. Downtime Summary Data

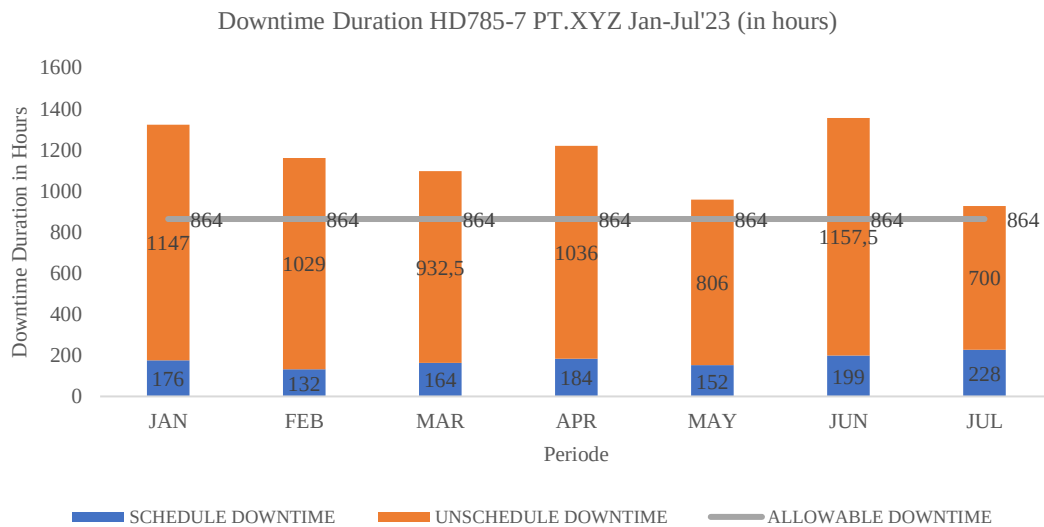


Figure 4.1 Downtime Summary HD785-7 PT. XYZ Jan-Jul'23.

As we can see from the Figure 4.1 Downtime Summary HD785-7 PT. XYZ Jan-Jul'23 that total duration both scheduled downtime and unscheduled downtime duration is higher than allowable downtime duration 864 hours in every month.

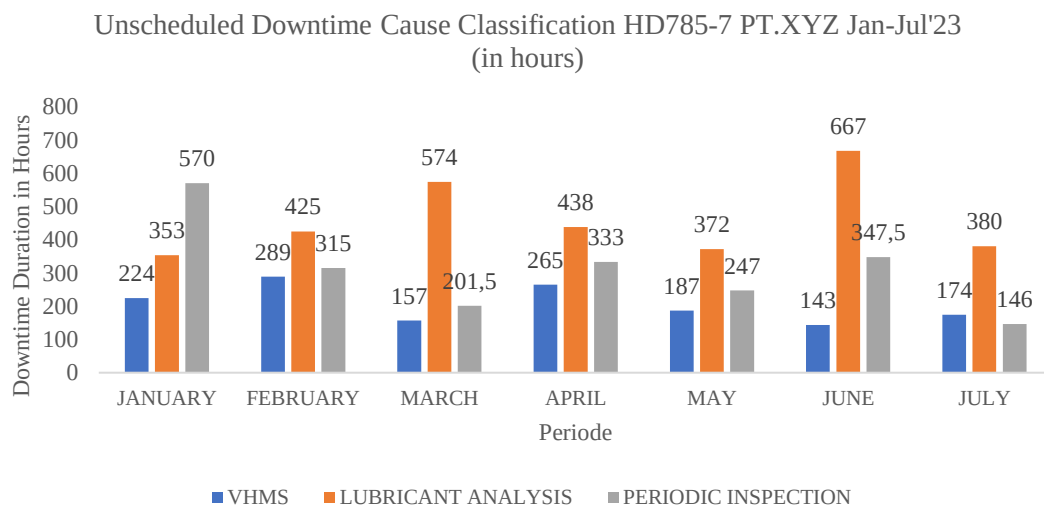


Figure 4.2 Unscheduled Downtime Cause Classification HD785-7 PT.XYZ Jan-Jul'23.

Figure 4.2 Unscheduled Downtime Cause Classification HD785-7 PT.XYZ Jan-Jul'23, shows downtime classification based on the main root problem, namely lack of optimization of VHMS monitoring, Lubricant Analysis Monitoring, and Periodic Inspection (PI) execution.

Table 4.2 Pareto Problem by Duration HD785-7 PT. XYZ January – July 2023

NO	COMPONENT FAILURE	JAN-JULY'23 (Hours)
1	Hydraulic	1436
2	Engine	1209
3	Electric	1075
4	Tyre	831
5	Air Conditioning	772
6	Instrument Panel	608
7	Brake	372
8	Dump Body	318
9	Accessories	105
10	Auto Lubrication	82
TOTAL		6808

From the Table 4.2 Pareto Problem by Duration HD785-7 PT. XYZ January – July 2023 we can see that The Top 3 Pareto Problem by duration sequentially, hydraulic, engine, and electric component failure.

4.1.3. Vehicle Health Monitoring System (VHMS) Data

The summary of HD785-7 Vehicle Health Monitoring System (VHMS) is taken at PT. XYZ during January – July 2023 as shown in Table 4.3 Summary VHMS Download Data January - July 2023. From the table below, the total caution value and critical value for each parameter is still very high. This is the impact of a lack of optimization of VHMS monitoring which causes high levels of unscheduled downtime. This can be prevented by monitoring the VHMS on a scheduled basis, so that if a trend in increasing numbers for one of the parameters is detected, preventive action can be taken immediately so that the machine is not damaged.

Table 4.3 Summary VHMS Download Data January - July 2023

MACHINE CODE	SERIAL NUMBER	Blowby Press Max		LF Exh.Temp. Max		LR Exh.Temp. Max		RF Exh.Temp. Max		RR Exh.Temp. Max		Engine Oil Press. Low Min		Coolant Temp. Max.		Transmission Oil Temp.Max		Boost Press. Max	
		CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI
HD1114	8076	35	13	27	7	14	3	20	8	9	2	8	1	27	8	12	1	7	0
HD1117	8079	45	20	15	6	9	3	17	5	14	3	6	2	35	6	11	1	5	0
HD1118	8206	38	12	18	9	21	5	13	3	12	2	9	2	21	5	9	1	9	0
HD1119	8208	29	8	11	4	15	4	9	2	16	3	4	1	18	3	7	1	11	1
HD1120	8212	49	13	23	11	13	3	7	1	10	2	7	2	14	3	14	1	7	0
HD1121	8213	37	15	16	10	8	6	19	7	8	3	2	0	38	5	17	2	8	0
HD1122	8437	32	14	12	6	7	1	21	6	7	2	4	1	25	4	5	0	15	1
HD1123	8438	40	18	13	3	14	7	6	2	5	2	5	2	21	3	10	1	10	1
HD1124	8439	21	9	7	2	18	9	8	1	10	3	7	2	11	2	8	1	7	0
HD1125	8440	16	7	5	3	9	3	10	4	5	1	8	2	17	2	9	1	5	0
TOTAL EVENTS		342	129	147	61	128	44	130	39	96	23	60	15	227	41	102	10	84	3

Note:

CAU: Caution

CRI: Critical

Exh.: Exhaust

Temp.: Temperature

Press.: Pressure

LF: Left Front

LR: Left Rear

RF: Right Front

RR: Right Rear

4.1.4. Periodic Daily Inspection Data

Periodic inspections are carried out every day by mechanics appointed by management as inspectors. Inspectors are required to record the results of their daily inspections in the inspection check sheet that has been prepared, take pictures if abnormal conditions are found and are required to request validation of their inspection results from the supervisor. The summary of HD785-7 Periodic Daily Inspection data is taken at PT. XYZ during January – July 2023 as shown in Table 4.3 Summary Periodic Daily Inspection HD785-7 January – July 2023.

Table 4.4 Summary Periodic Daily Inspection HD785-7 January – July 2023

MACHINE CODE	SERIAL NUMBER	ZONE 1 FRONT & UPPER AREA				ZONE 2 LEFT AREA				ZONE 3 RIGHT AREA					Overall Score
		Front Side of Machine	Upper Side of Machine	Cabin	Access.	Left Side of Engine	Left Side of Machine	Left Side of Lub.	Dump Body	Right Side of Engine	Right Side of Machine	Right Side of Lub.	Dump Body	Rear Axle and Rear Lamp	
HD1114	8076	75%	71%	90%	88%	87%	78%	98%	75%	85%	80%	78%	50%	85%	80%
HD1117	8079	83%	68%	88%	96%	80%	88%	90%	75%	97%	75%	68%	100%	90%	84%
HD1118	8206	90%	93%	89%	85%	85%	81%	85%	75%	81%	68%	70%	100%	75%	83%
HD1119	8208	65%	86%	91%	95%	82%	77%	100%	75%	88%	71%	83%	100%	88%	85%
HD1120	8212	78%	87%	87%	81%	89%	87%	95%	100%	98%	82%	81%	50%	78%	84%
HD1121	8213	87%	90%	83%	80%	78%	68%	100%	50%	91%	78%	75%	50%	80%	78%
HD1122	8437	78%	86%	82%	88%	91%	75%	79%	50%	78%	64%	89%	50%	79%	76%
HD1123	8438	92%	87%	81%	89%	71%	95%	81%	75%	95%	90%	85%	50%	68%	81%
HD1124	8439	88%	79%	84%	85%	88%	93%	91%	50%	75%	87%	76%	100%	71%	82%
HD1125	8440	87%	80%	85%	90%	78%	96%	95%	100%	86%	75%	89%	100%	82%	88%
AVERAGE SCORE		82%	83%	86%	88%	83%	84%	91%	73%	87%	77%	79%	75%	80%	82%

Note:

Access.: Accessories

Lub.: Lubrication

4.1.5. Lubricant Analysis Program Data

Lubricating oil sampling is carried out every time a machine is undergoing periodic service by referring to the correct oil sampling procedure. Carelessness in taking oil sampling will cause the oil sampling readings from the laboratory to be inaccurate. The summary of HD785-7 lubricant analysis program data is taken at PT. XYZ during January – July 2023 as shown in Table 4.5 Summary Lubricant Analysis Program January – July 2023.

Table 4.5 Summary Lubricant Analysis Program January – July 2023

MACHINE CODE	SERIAL NUMBER	ENGINE Na		ENGINE Cu		ENGINE Si		ENGINE Fuel		ENGINE Soot		TM. Si		TM. Fe		DIFF. Si		DIFF. Fe	
		CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI	CAU	CRI
HD1114	8076	15	2	9	1	11	2	3	0	2	0	5	0	2	0	3	0	2	0
HD1117	8079	17	3	8	1	10	2	1	0	4	1	7	1	1	0	5	0	3	0
HD1118	8206	13	5	4	0	15	3	0	0	1	0	3	0	3	0	7	1	1	1
HD1119	8208	11	2	8	1	9	1	0	0	1	0	1	0	2	0	2	0	1	0
HD1120	8212	21	3	5	1	8	1	0	0	0	0	0	1	1	0	2	0	2	0
HD1121	8213	23	2	7	1	7	1	0	0	3	0	0	1	4	0	1	1	1	1
HD1122	8437	16	1	6	1	3	1	0	0	2	0	0	0	6	1	4	1	2	0
HD1123	8438	19	2	10	1	14	1	0	0	5	1	3	1	0	0	3	0	2	0
HD1124	8439	14	4	5	1	3	0	2	0	1	0	4	0	0	0	2	0	2	0
HD1125	8440	12	3	8	1	5	1	1	0	0	0	0	0	0	0	2	0	3	1
TOTAL		161	27	70	9	85	13	7	0	19	2	23	4	19	1	31	3	19	3

Note:

CAU: Caution

CRI: Critical

Na: Natrium

Cu: Cuprum

Si: Silicon

Fe: Ferrum

TM: Transmission

DIFF: Differential

4.2 Data Analysis

From the data shown in previous section, analysis can be carried out by outlining the causes of unscheduled downtime of dump truck using some tools, namely Root Cause Analysis (RCA) and 5-Why Analysis.

4.2.1. Root Cause Analysis (RCA)

At this stage, the researcher uses Ishikawa Diagrams to identify the possible problems that occur in the problem of Physical Availability of Dump Truck HD785-7 only 84,04% which is not achieve the target of 88%. This Ishikawa Diagram shows how causes and effects are linked and helps analyse what is going wrong with the maintenance process of Dump Truck HD785-7. Researcher uses the 4M critical factors to find the main problem: Man, Machine, Method, and Measurement as shown in Figure 4.3 Ishikawa Diagram.

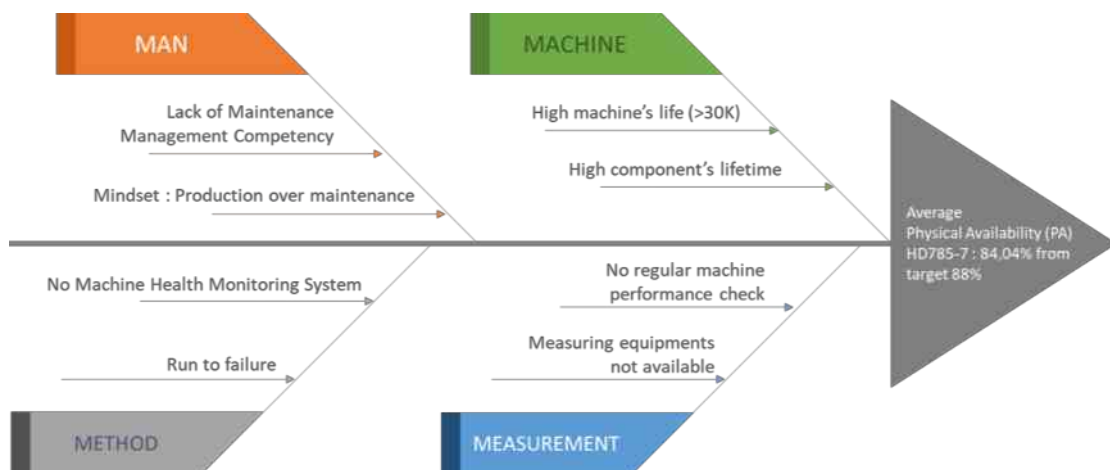


Figure 4.3 Ishikawa Diagram

4.2.2. 5-Why Analysis

After using Ishikawa Diagram to identify the main problem, researcher complete the analysis using 5-Why analysis to answers all the basic elements within a problem which are what, who, when, where, why, and how as shown in the Table 4.6 5-Why Analysis below.

Table 4.6 5-Why Analysis

No	Problems	Why 1	Why 2	Why 3	Why 4	Why 5	Solution
1	Frequent machine breakdowns	Mechanical & Electrical failures occur	Pre-failure condition not detected	Inconsistent Periodic Inspection execution	No Periodic Inspection schedule (plan)	No monitoring tools for Periodic Inspection execution yet	Develop machine health monitoring dashboard
2	Frequent machine breakdowns	Error appears on the operator panel monitor	VHMS trend parameters in Caution & Critical range	Inconsistent VHMS data download	No monitoring tools for VHMS data download	No Predictive Maintenance (PdM) strategy yet	Develop machine health monitoring dashboard
3	High unscheduled breakdown duration	Failure major component: engine, transmission, etc.	High major component's lifetime causes poor performance	No follow up Lubricant Analysis result yet	No condition based-maintenance schedule yet	No monitoring tools for lubricant analysis program yet	Develop machine health monitoring dashboard
4	High unscheduled breakdown duration	Failure major component: engine, transmission, etc.	High major component's lifetime causes poor performance	Inconsistent machine performance check	Run-to-failure (RTF) mindset	Lack of maintenance management competency	Conduct Maintenance Management Training
5	High unscheduled breakdown duration	Parts availability is poor	Parts ordered when machine already broke	Cost efficiency	Run-to-failure (RTF) mindset	Lack of maintenance management competency	Conduct Maintenance Management Training

From the table above, researcher concludes that there are 2 main problems that cause the PA HD785-7 to be unattainable:

1. Frequent machine breakdowns.
2. High unscheduled breakdown duration.

And researcher obtained at least 2 alternative solutions:

1. Develop machine health monitoring dashboard.
2. Conduct maintenance management training.

These 2 solutions will be used as a reference in making improvements to increase engine performance, especially in achieving PA targets of 88%.

4.3 Improvement

4.3.1. Weighted Scoring

The researchers using weighted scoring to evaluate and rank items or options based on predefined criteria, where certain criteria are assigned different levels of importance or priority, represented by weights. This approach allows decision-makers to give more significance to specific factors that are deemed more crucial in the decision-making process. The data used to assign a score is taken from VHMS download data, lubricant analysis program, and Periodic Inspection as shown in Table 4.7 Machine Health Parameter Weighted Scoring.

This weighted scoring is determined based on the results of a Focus Group Discussion (FGD) conducted by Subject Matter Expert (SME) of PT. XYZ and distributors who have competence in the field of maintenance management and machine technical competence as shown in Figure 4.4 Focus Group Discussion (FGD).



Figure 4.4 Focus Group Discussion (FGD)

The members of Subject Matter Expert (SME) from PT. XYZ are Engineer, Planner, and Data Analyst. While the members of SME from distributor are Site Technical Engineer, Plant Production Control, and Data Analyst.

Table 4.7 Machine Health Parameter Weighted Scoring

DATA	ITEM/PARAMETER	WEIGHTED SCORING
Vehicle Health Monitoring System	Cool Temperature Max	15%
	Blowby Pressure Max	12%
	Transmission Oil Temperature Max	10%
	Engine Oil Pressure Low Min	5%
	Left-Front Exhaust Temperature Max	3%
	Left-Rear Exhaust Temperature Max	3%
	Right-Front Exhaust Temperature Max	3%
	Right-Rear Exhaust Temperature Max	3%
Lubricant Analysis Program (wear metal)	Engine – Natrium (Na)	8%
	Engine – Cuprum (Cu)	4%
	Engine – Silicon (Si)	2%
	Engine - Fuel	3%
	Engine - Soot	3%
	Transmission – Silicon (Si)	6%
	Transmission – Ferrum (Fe)	4%
	Differential – Silicon (Si)	6%
	Differential – Ferrum (Fe)	4%
Periodic Inspection	Zone 1 - Front & Upper Area	2%
	Zone 2 - Left Area	2%
	Zone 3 - Right Area	2%
TOTAL		100%

4.3.2. Building Machine Health Monitoring Dashboard

This machine health monitoring dashboard was developed using the Google Looker Studio platform. The machine health monitoring dashboard itself consists of 2 pages:

a. Summary Page

In this summary page as shown in Figure 4.5 Machine Health Monitoring Dashboard – Summary, users can get summary information on engine health which includes VHMS score highlights, Lubricant Analysis, Daily Inspection displayed on the gauge. Besides that, users will also get information about downtime performance, PA performance, Health Score, and Health Status which is displayed next to the gauges. Meanwhile, at the bottom, users will get summary information on the machine health of each machine which is presented in table form.

b. Single Machine Monitoring Page

In this single machine monitoring page as shown in Figure 4.6 Machine Health Monitoring Dashboard – Single Machine Monitoring, Users will get detailed health information for each machine which can be selected based on the machine code. Machine serial number and service meter reading (SMR) information is displayed below the machine code option, this is so that users can find out the machine serial number and the actual number of machine operating hours. Next to machine code and SMR information, there are 3 displayed gauges, each representing the VHMS, Lubricant Analysis, and Daily Inspection scores of each selected machine. These three gauges will make it easier for users to see the scores for each health parameter from VHMS, Lubricant Analysis, and Daily Inspection.

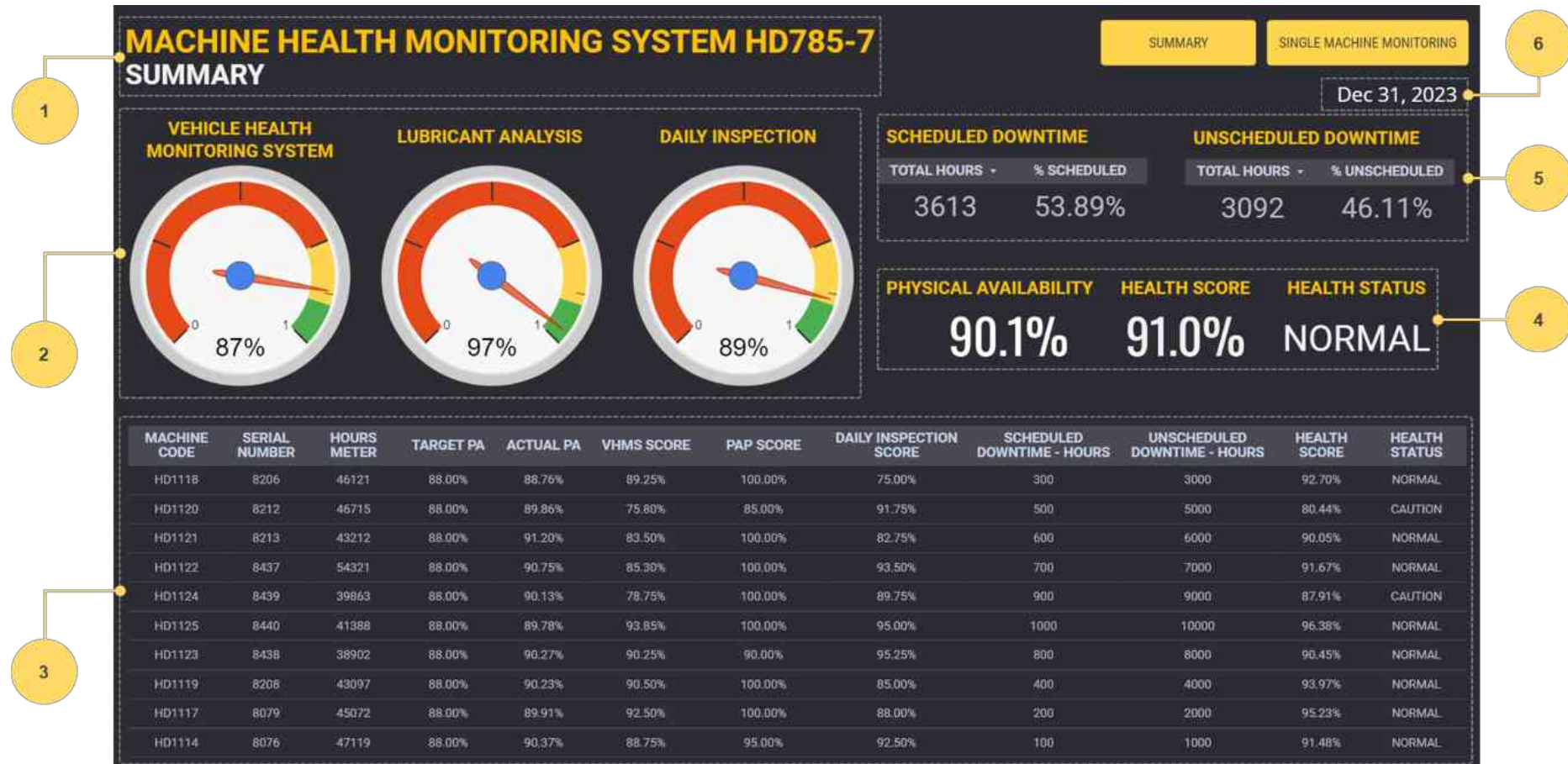


Figure 4.5 Machine Health Monitoring Dashboard – Summary

Table 4.8 Dashboard Information – Summary Page

No	Remarks
1	Shows the Page Title: Summary
2	Shows the Performance Gauges that informed average value of VHMS performance, Lubricant Analysis performance, and Daily Inspection performance
3	Shows the Summary Table of all machine health parameter
4	Shows the overall PA (by average), Machine Health Score, and Machine Health Status
5	Shows the Summary Downtime both Scheduled and Unscheduled
6	Shows the Date: Today

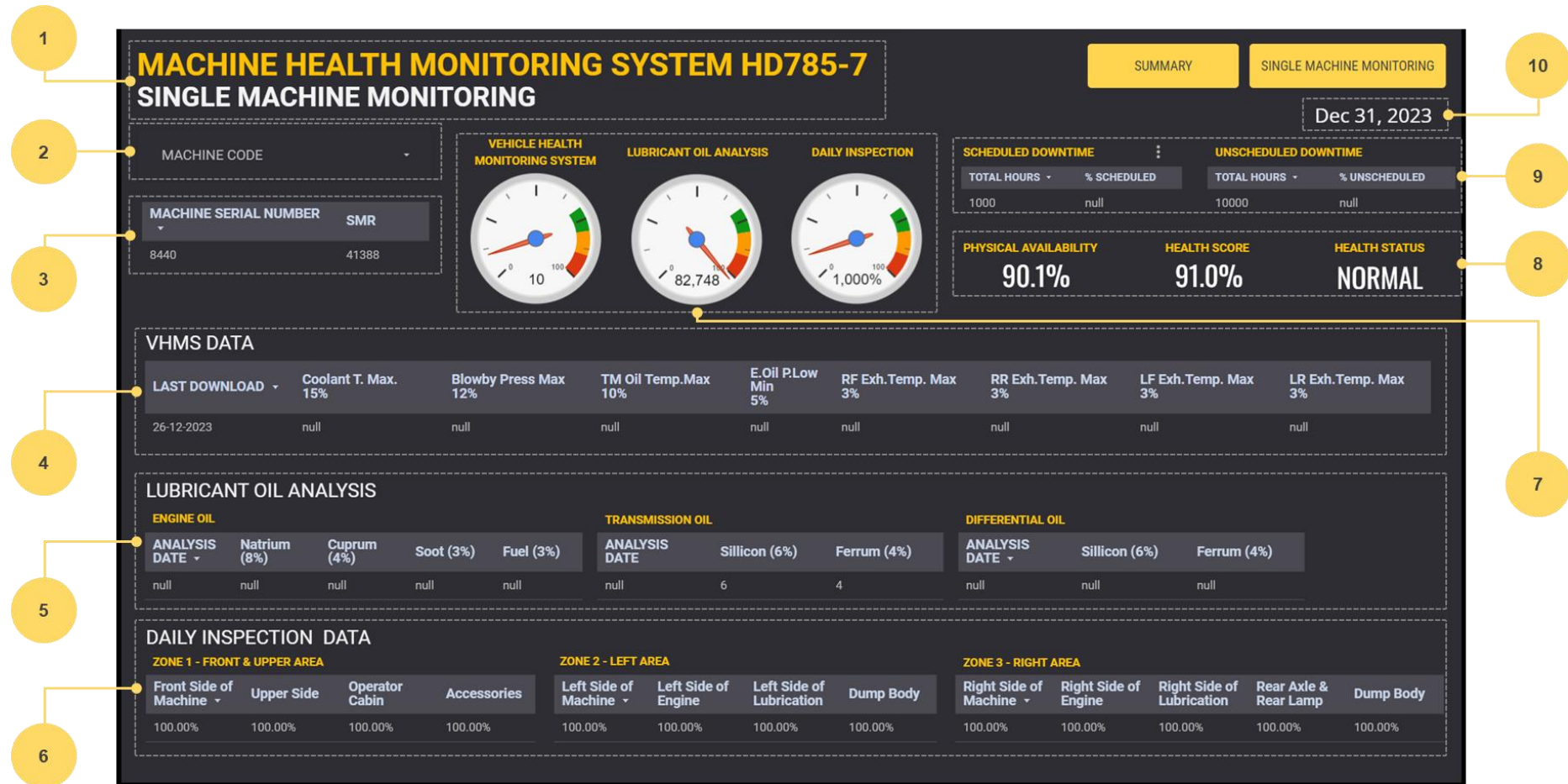


Figure 4.6 Machine Health Monitoring Dashboard – Single Machine Monitoring

Table 4.9 Dashboard Information – Single Machine Monitoring Page

No	Remarks
1	Shows the Page Title: Single Machine Monitoring
2	Shows the Komatsu Dump Truck HD785-7 based on Machine Code
3	Shows the Machine Serial Number and Service Meter Reading (SMR) of selected machine
4	Shows the Parameter of VHMS Data of selected machine
5	Shows the Parameter of Lubricant Analysis of selected machine
6	Shows the Parameter of Daily Inspection of selected machine
7	Shows the Performance Gauges: VHMS, Lubricant Analysis, and Daily Inspection
8	Shows the overall PA, Machine Health Score, and Machine Health Status of selected machine
9	Shows the Summary Downtime both Scheduled and Unscheduled of selected machine
10	Shows the Date: Today

4.3.3. Maintenance Management Training

As one way to fulfil competency regarding good heavy equipment maintenance management, PT. XYZ sent several of its plant employees to take part in maintenance management training. The hope is that after participating in this maintenance management training, PT. XYZ can implement maintenance management strategies to achieve KPI of dump truck HD785-7, especially in achieving PA targets. Figure 4.7 Maintenance Management Training shows the process of Maintenance Management training held by distributor and followed by 6 employees of PT. XYZ.



Figure 4.7 Maintenance Management Training

Some of the topics discussed in Maintenance Management training are as follows:

1. Maintenance System.
2. Maintenance Planning.
3. Condition Based-Maintenance.
4. Predictive Maintenance.
5. Machine Monitoring Program.
6. Maintenance Facility.
7. Manpower Planning.
8. Machine Replacement Analysis.

4.4 Control

4.4.1. Downtime Calculation

As shown in Figure 4.8 Downtime Summary HD785-7 PT. XYZ Jan-Dec'23, total downtime duration decreases in period after the project conducted August – December 2023. Reducing unscheduled downtime has a big impact on the reduction of the total downtime duration so that it can be below the allowable downtime duration 864 hours.

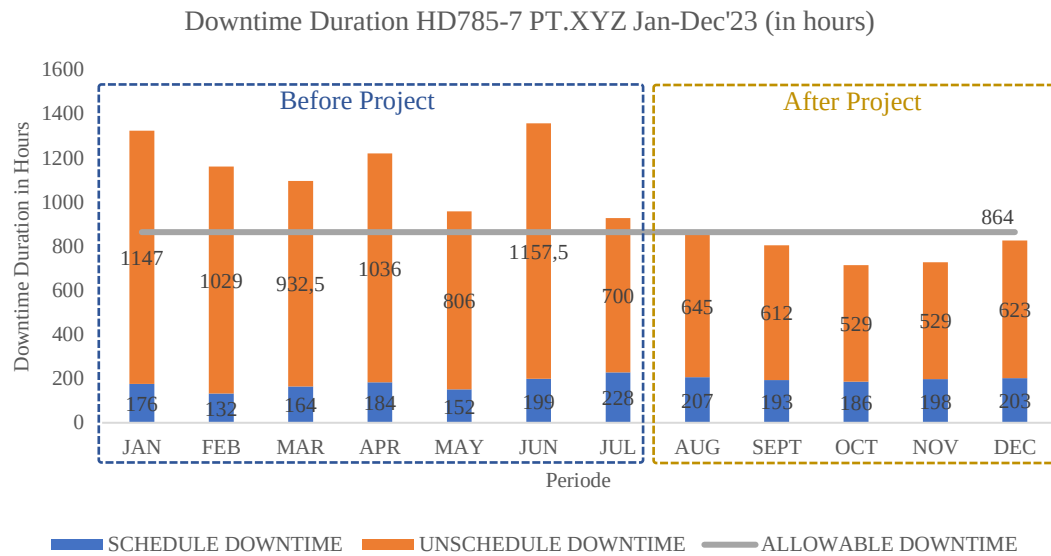


Figure 4.8 Downtime Summary HD785-7 PT. XYZ Jan-Dec'23

Figure 4.9 Unscheduled Downtime Cause Classification HD785-7 PT. XYZ Jan-Dec'23 shows the downtime classifications before and after the project has been conducted.

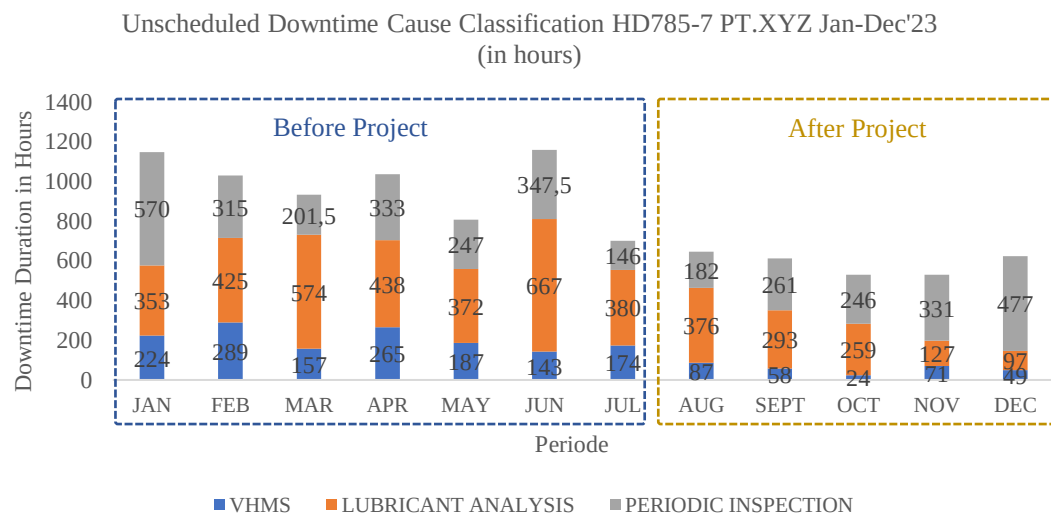


Figure 4.9 Unscheduled Downtime Cause Classification HD785-7 PT. XYZ Jan-Dec'23

From the Table 4.10 Pareto Problem Summary HD785-7 PT. XYZ January – December 2023 we can see that each component failure duration reduces significantly. By total, the reduction of downtime duration is 57% or 3870 hours.

Table 4.10 Pareto Problem Summary HD785-7 PT. XYZ January – December 2023

NO	COMPONENT FAILURE	JAN-JULY'23 (Hours)	AUG-DEC'23 (Hours)	REDUCTION
1	Hydraulic	1436	731	49%
2	Engine	1209	507	58%
3	Electric	1075	378	65%
4	Tyre	831	337	59%
5	Air Conditioning	772	281	64%
6	Instrument Panel	608	279	54%
7	Brake	372	164	56%
8	Dump Body	318	173	46%
9	Accessories	105	52	50%
10	Auto Lubrication	82	36	56%
TOTAL		6808	2938	57%

4.4.2. Physical Availability (PA) Calculation

As the duration of unscheduled downtime decreases, the Physical Availability of HD785-7 dump truck slowly begins to increase as shown in Figure 4.10 Summary PA HD785-7 PT. XYZ Before vs After Project. It can be seen that starting in August 2023 the PA value has exceeded the target, reaching 88.17%. And from September to December 2023 the PA value is maintained at an average of 89.33%.

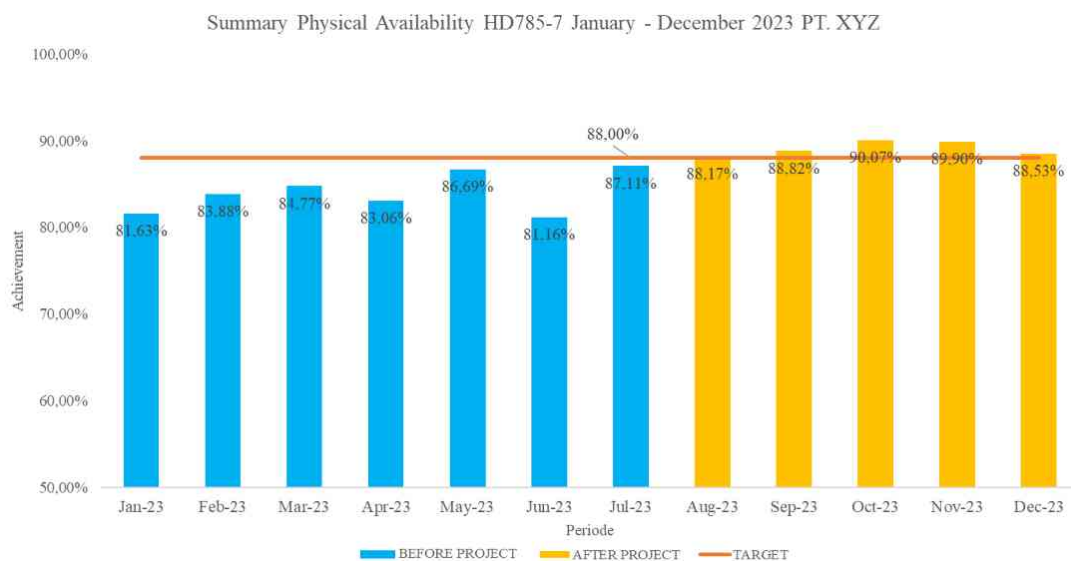


Figure 4.10 Summary PA HD785-7 PT. XYZ Before vs After Project.