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Assignment 1: Maintenance Strategy Effectiveness

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4. Introduction

This report evaluates the maintenance practices for a Bucket-Wheel Reclaimer (BWR) at Port Talbot steelworks, focusing on enhancing operational reliability and efficiency. It’s aim is to assess the effectiveness and cost-efficiency of current maintenance strategies, comparing them against industry benchmarks to pinpoint improvement opportunities and recommend practical solutions.

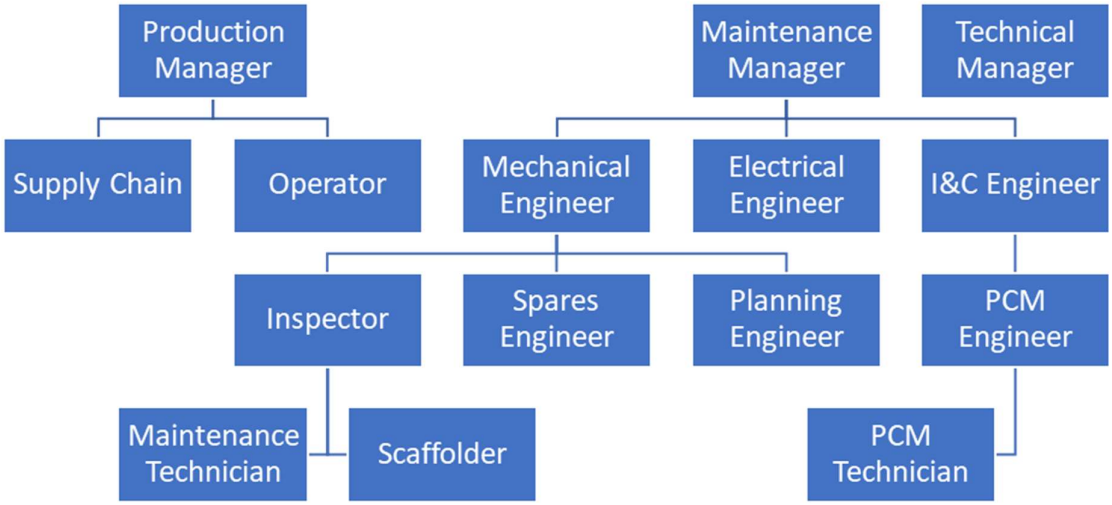
Port Talbot steelworks, a major UK steel producer, outputs over 5 million tonnes annually, contributing significantly to the global steel market with a variety of products for sectors like construction, automotive, and aerospace. (Tata Steel Europe, 2022)

The BWR at Port Talbot is integral to the steel production process, handling the primary bulk raw materials (iron and coal) required for ironmaking. operating under harsh conditions characterized by heavy loads, abrasive materials, and continuous usage, the BWR's performance is critical to maintaining the efficiency and output of the entire operation. Key performance indicators (KPI) for the BWR include Asset Availability, Reclaim Rate, Energy usage, and maintenance cost-effectiveness.

The BWR, crucial for managing key raw materials under demanding conditions, impacts the plant's overall productivity. Its performance metrics include Asset Availability, Reclaim Rate, Energy Usage, and Maintenance Cost-Effectiveness.

The maintenance team as shown in Figure 1 is organized to ensure thorough task execution. This structure, alongside coordination with operations, scaffolding, tribologists, and supply chain departments, ensures maintenance aligns with production needs and resource availability.

Figure 1 - Organisation Chart



4.1. Aims and Objectives

1. Map the current maintenance practices for the BWR at Port Talbot steelworks.
2. Analyse current maintenance and operating data and effectiveness.
3. Suggest improvements based on the latest trends and technologies.
4. Evaluate the feasibility and potential impacts of the proposed improvements.

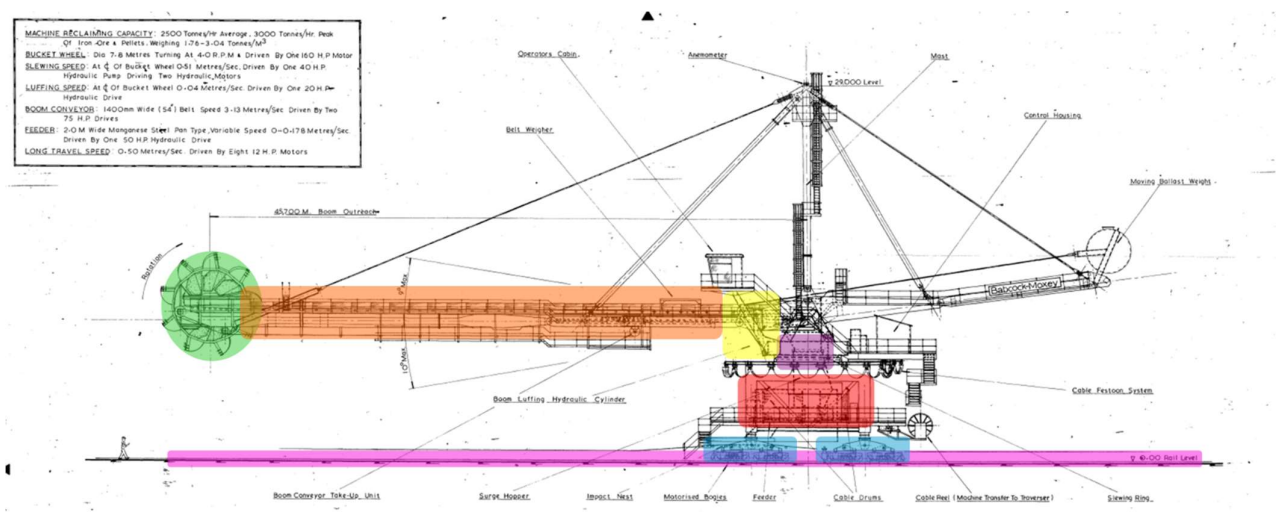
5. Critical Review of Current Maintenance Practices

5.1. Equipment information

The Bucket-Wheel Reclaimer (BWR) is essential for handling bulk materials in industries like mining and ports, designed to reclaim materials from stockpiles for consistent mix delivery direct to furnaces. This 2,000-tonne-per-hour reclaimer, commissioned in 1973 by Babcock Moxey, was initially designed with a 35-year lifespan. However, through various upgrades including structural component replacements, hydraulic systems enhancements, bucket wheel assembly modifications, slew bearing updates, and improvements to the long travel drives, its operational life has been significantly extended.

The BWR is comprised of seven main components, each integrating complex mechanical, electrical, and control systems.

Figure 2 – BWR Schematic



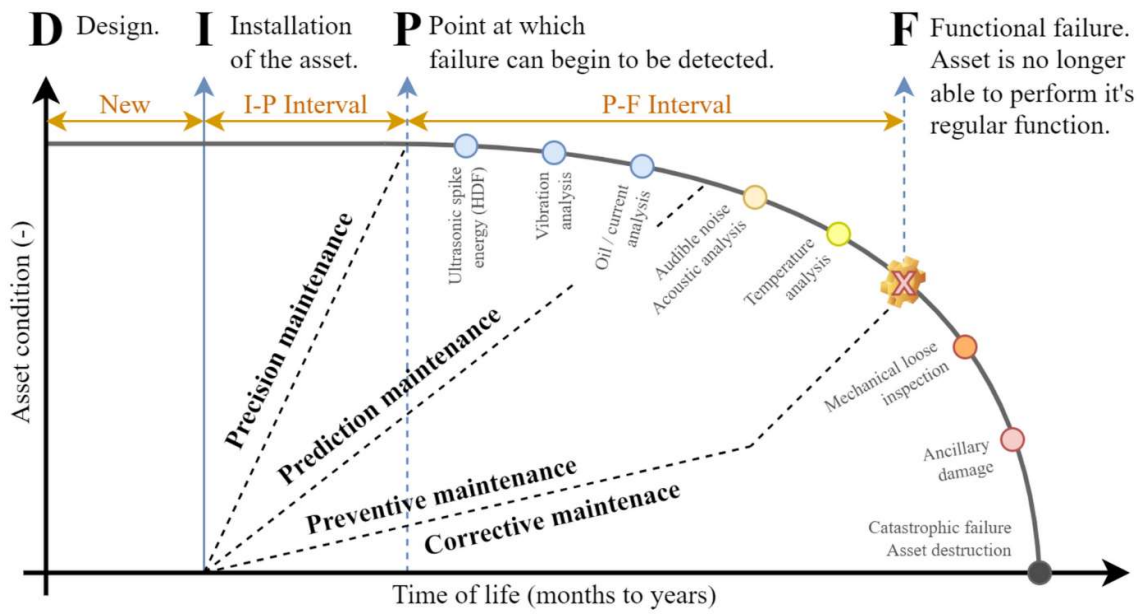
1. Bucket Wheel
2. Boom Conveyor
3. Hopper and Feeder
4. Slewing System
5. Luffing System
6. Long Travel System
7. Yard Conveyor

5.2. Current Performance

Understanding current performance is crucial for identifying areas of inefficiency and potential improvement within the maintenance practices of a bucket wheel reclaimer. By examining key performance indicators (KPIs) such as OEE, Operation and Maintenance costs; organizations can gain a comprehensive view of their equipment's productivity, reliability, and cost-effectiveness. (Moubray, 2001)

The Deterioration-Initiation-Propagation-Failure (DIPF) curve as shown in Figure 3 is a critical tool in understanding and improving reliability, as it visually represents the lifecycle of a component's degradation over time. This curve allows maintenance professionals to identify key stages in the lifecycle of equipment: from initial deterioration, through the initiation of a detectable defect, its propagation, and ultimately to failure. By analysing the DIPF curve, organizations can strategically plan maintenance activities to intervene at the most effective points, potentially during the initiation phase before a defect begins to propagate significantly. (Jardine & Tsang, 2021) suggests a proactive approach to maintenance, supported by predictive analytics and condition monitoring, can significantly enhance the reliability of equipment by preventing failures before they occur, thus minimizing downtime and associated costs.

Figure 3 - DIPF Curve (Lara de Leon, et al., 2024)



5.2.1. Current OEE

The current OEE of the bucket wheel reclaimer is an essential metric, combining availability, performance efficiency, and quality rates to gauge overall equipment productivity (Nakajima, 1988).

Table 1 reveals that the BWR's poor availability in 2021 and 2023 led to decreased performance and quality. To maintain production during downtime, mobile reclamation plant was hired, and material was reclaimed manually from stockpile bases. This resulted in lower reclaim rates and reduced material quality, the latter due to increased water content at the stockpile bases.

Table 1 - OEE Data

	2020	2021	2022	2023
Performance	82%	54%	80%	55%
Availability	80%	50%	79%	51%
Quality	87%	55%	88%	54%
OEE	*57%*	*15%*	*56%*	*15%*

5.2.2. Current Operation Costs

Operation costs encompass energy costs, manpower, machinery hire, and other day-to-day expenses required to keep the BWR operating. (Mobley, 2002) suggests these costs can be high due to inefficiencies in operation and maintenance strategies. Analysing OEE data from Table 1 alongside operation costs from Table 2 reveals a clear correlation: lower OEE values are associated with higher unplanned operating costs, primarily due to the added expense of hiring mobile reclamation plants during BWR downtime.

Table 2 - Operation Cost Data

	2020	2021	2022	2023
Planned	£2.5m	£2.7m	£2.7m	£2.7m
Unplanned	£0.5m	£1.6m	£0.8m	£1.7m
Total	*£3.0m*	*£4.3m*	*£3.3m*	*£4.4m*

5.2.3. Current Maintenance Costs

Maintenance costs include routine and corrective maintenance expenses. (Mobley, 2002) suggests high maintenance costs often indicate frequent breakdowns or inefficient maintenance practices. Table 3, displaying maintenance costs over the past four years, indicates a direct correlation: decreased availability leads to increased unplanned maintenance costs.

Table 3 - Maintenance Cost Data

	2020	2021	2022	2023
Planned	£1.0m	£1.2m	£1.2m	£1.2m
Unplanned	£0.1m	£0.5m	£0.1m	£0.4m
Total	*£1.1m*	*£1.7m*	*£1.3m*	*£1.6m*

5.3. Review of current maintenance practices

The maintenance framework for the BWR is comprehensive, encompassing some frequency-based preventive, condition based preventative, and reactive unplanned strategies. Table 4 outlines the maintenance activities categorized by their nature and frequency, allowing for a clear understanding of the current maintenance regime.

Table 4 – BWR Planned Maintenance Activities

COMPONENT	VISUAL INSPECTION	PHYSICAL MAINTENANCE	SUPPLEMENTARY MAINTENANCE	TRIBOLOGY	VIBRATION ANALYSIS	TEMPERATURE MONITORING
BUCKET WHEEL	DAILY (NO DOWNTIME)	24 WEEKLY (6 HOURS DOWNTIME & SCAFFOLDING REQUIRED)	N/A	MONTHLY (2HRS DOWNTIME & SCAFFOLDING REQUIRED)	N/A	N/A
BOOM CONVEYOR	DAILY (NO DOWNTIME)	24 WEEKLY (2HRS DOWNTIME)	N/A	MONTHLY (10 MINUTES DOWNTIME)	MONTHLY (NO DOWNTIME)	WEEKLY (NO DOWNTIME)
HOPPER AND FEEDER	DAILY (NO DOWNTIME)	24 WEEKLY (2HRS DOWNTIME)	N/A	MONTHLY (10 MINUTES DOWNTIME)	MONTHLY (NO DOWNTIME)	WEEKLY (NO DOWNTIME)
SLEW SYSTEM	DAILY (NO DOWNTIME)	24 WEEKLY (2HRS DOWNTIME)	N/A	MONTHLY (10 MINUTES DOWNTIME)	N/A	DAILY (NO DOWNTIME)
LUFF SYSTEM	DAILY (NO DOWNTIME)	24 WEEKLY (SCAFFOLDING REQUIRED)	N/A	MONTHLY (2HRS DOWNTIME & SCAFFOLDING REQUIRED)	N/A	DAILY (NO DOWNTIME)
LONG TRAVELS	DAILY (NO DOWNTIME)	24 WEEKLY (8 HOURS DOWNTIME)	MONTHLY (6 HOURS DOWNTIME)	MONTHLY (30 MINUTES DOWNTIME)	N/A	WEEKLY (NO DOWNTIME)
YARD CONVEYOR	DAILY (NO DOWNTIME)	24 WEEKLY (3HRS DOWNTIME)	N/A	MONTHLY (10 MINUTES DOWNTIME)	MONTHLY (NO DOWNTIME)	WEEKLY (NO DOWNTIME)

5.3.1. Preventive Maintenance

Preventive maintenance aims to conduct regular maintenance and inspections to avert equipment failures proactively. As noted by (Palmer, 2019) , such maintenance significantly reduces unplanned downtime.

5.3.2. Visual Inspections

Daily visual inspections of the BWR components by the area inspector, conducted while the machine is operational, form a key part of preventive maintenance. This approach ensures prompt detection of new or worsening issues, (Moubray, 2001) talks about this activity as confirming the machine's safety for operation.

5.3.3. Physical Maintenance

Physical maintenance of the BWR's major components is scheduled every 24 weeks, performed by maintenance technicians, and requires scaffolding for component access, requiring the machine to be temporarily out of service. Additionally, monthly supplementary maintenance targets long travel assemblies and common wear items. These practices are in line with preventive maintenance objectives to service and maintain equipment proactively to prevent failures, a concept supported by (Jardine & Tsang, 2021) Following a strict maintenance schedule enables systematic management of wear and tear, extending the machinery's lifespan. Figure 4 shows a snapshot of some of the maintenance tasks that are completed during the monthly maintenance task inspection (MTI). Figure 5 shows a snapshot of some of the maintenance tasks that are completed during the 24 weekly MTI.

Figure 4 - Monthly MTI Pro-forma

TATA	**No.2 BUCKET WHEEL RECLAIMER MECHANICAL PHYSICAL INSPECTION**
Functional Location	**3001-320-2108-0013**
TATA Department	**Blending Plant**
Plant	**No.2 Bucket Wheel Reclaimer**
Discipline	**4 x Mechanical Personnel**

Physical Inspection

Adhere to all plant safety procedures and works rules.
Review SAP notifications and tasks carried out on No.2 Bucket Wheel Reclaimer since last inspection.Check SCADA for alarm history since last inspection.
Ensure all defects detected are fed back via a notification in SAP.
Ensure good housekeeping standards in all areas are maintained.

Key: OK = ✓ Not OK = x

1	**NORTH LONG TRAVEL DRIVES (x8)**		
	BOGIES (x8)	**Tick**	**Comments**
	PHYSICALLY CHECK CONDITION OF DRIVE BOGIE WHEELS, BEARINGS AND FLANGES/ RIMS FOR SIGNS OF WEAR.		
	PHYSICALLY CHECK CONDITION OF TRAILING BOGIE WHEELS, BEARINGS AND FLANGES/ RIMS LOOKING FOR SIGNS OF WEAR.		
	INSPECT THE VISIBLE SURFACE OF WHEELS FOR ANY CRACKS, PITTING OR OTHER SURFACE MARKS.		
	ENSURE DRIVE BOGIE WHEEL BEARING PEDESTAL BOLTS ARE IN PLACE AND SECURE. CHECK TIGHTNESS.		
	PHYSICALLY CHECK PRIMARY AND SECONDARY COMPENSATING BEAM PIVOT PINS FOR WEAR OR DAMAGE.		
	PHYSICALLY CHECK BOGIE AND BOGIE PIVOT PINS FOR WEAR.		
	PHYSICALLY CHECK TIGHTNESS AND SECURITY OF RAIL SCRAPER PLOUGH BOLTS.		

Figure 5 - 24 Weekly MTI Pro-forma

5	BUCKET WHEEL DRIVE ASSEMBLY		
	DRIVE MOTOR ***Scaffolding required for access*** **(Boom to be anchored down before scaffolding is erected)**	**Tick**	**Comments**
	REMOVE COUPLING GUARD.		
	REMOVE ANY DEBRIS/SPILLAGE FROM MOTOR AND ENSURE GOOD HOUSEKEEPING IS MAINTAINED IN AREA.		
	PHYSICALLY CHECK ALL HOLD DOWN BOLTS AFOR TIGHTNESS AND SECURITY.		
	CHECK MOTOR FEET FOR FRACTURES.		
	PHYSICALLY CHECK FOR LIFT IN BEARINGS.		
	ENSURE COWL IS FREE OF DAMAGE AND REMOVE ANY DEBRIS.		

5	BUCKET WHEEL DRIVE ASSEMBLY (Continued)		
	FLUID DRIVE COUPLING (Inc. Couplings)	**Tick**	**Comments**
	INSPECT CONDITION OF FLEXI PLATE/ SPIDER PLATE, CHECK FOR OVERALL CONDITION AND INTEGRITY. TIGHTEN AND SECURE ALL BOLTS.		
	INSPECT THE MULTI DISC FOR FRACTURES, WEAR OR DAMAGE INC.COLLARS AND HOLES CHECK FOR PLAY AND ELONGATION.		
	CHECK COUPLING BODY FOR DAMAGE, HOLES OR FRACTURES.		
	CHECK COUPLING KEYWAY IS NOT SHEARED.		
	CHECK ALIGNMENT OF FLUID COUPLING USING D.T.I. (RECORD READINGS). ANY OUT OF TOLERANCE / MISALIGNMENT TO BE RECTIFIED. ***Moble Crane required for this task***		**Top to Bottom = _____** **Side to Side = _____**
	INSPECT PLUGS IN THE RESERVOIR CASING FOR OIL LEAKS. IF LEAKS ARE EVIDENT REMOVE PLUGS AND RENEW SEALING WASHERS.		
	CHECK FOR ANY OIL LEAKS AROUND OUTPUT SHAFT. CHECK COUPLING IS NOT OVER FILLED.		
	PHYSICALLY INSPECT THE FLUID COUPLING THERMAL PLUG FOR CONDITION AND INTEGRITY.		
	CHECK CONDITION OF GUARD AND REFIT.		

5.3.4. Predictive Maintenance

Predictive maintenance utilizes data analysis to foresee equipment failures, facilitating pre-emptive interventions. (Mobley, 2002) champions this method, emphasizing condition monitoring's role in enhancing maintenance scheduling and resource optimization. Monthly tribological assessments are performed on the BWR to detect lubrication and wear issues in its moving components. (Bhushan, 2013) details how gearbox oil condition reflects the condition of internal gears and bearings, noting that component degradation alters oil properties through contaminants like water and ferrous material. Figure 6 shows an oil condition report for a department gearbox.

Figure 6 - Oil condition report

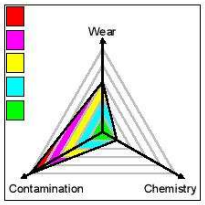
Database:	RJB	Equipment:	E16 - 802 Primary
Area:	C784 - Harbour	Point:	P1 - Gearbox

Ref Oil	Unknown - 320 - 320				
Lab Unit ID	71621/4				
Sample Date	22/02/2024	29/11/2023	07/08/2023	22/06/2023	22/02/2023
Sample #	833203	786728	721001	693613	626701
Lab #	833203	786728	721001	693613	626701
Analyst	Rhian	Megan	TE	Megan	Megan
Unit Usage - hrs					
Oil Usage - hrs					
Oil Added - gus			2		

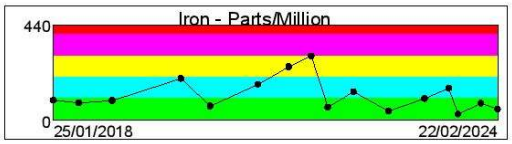
Wear	21	78	30	77	87
Iron - ppm	50.6	77.6	27.7	147.8	98.2
Chromium - ppm	.2	.1	.3	.7	.4
Copper - ppm	.4	1.1	1.1	.4	2.5
Tin - ppm	0.0	.2	.6	0.0	.1
Lead - ppm	.4	1.3	2.3	21.6	6.4
Nickel - ppm	.2	.2	.2	.7	.2
Silver - ppm	.3	.8	.1	0.0	.3
Cadmium - ppm	0.0	0.0	.1	0.0	0.0
Vanadium - ppm	0.0	.1	0.0	0.0	.1
FW Idx - Idx	30.1	156.1	38.1	138.9	297.2
Aluminum - ppm	1.9	2.7	2.3	1.6	2.4

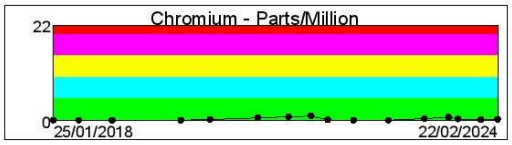
Contamination	73	36	10	0	0
Silicon - ppm	7.4	6.1	1.8	15.3	69.0
Sodium - ppm	2.7	3.4	5.1	5.6	7.9
Water K.Fish - ppm	16,898.000	6,371.000	2,588.000	0.000	0.000
% Water - %	1.690	.637	.259	0.000	0.000
PPM Water - %					
ISO >4 - n/a					
ISO >6 - n/a					
ISO >14 - n/a					
NAS 1638 - Idx					
Cnts >4 - pml					
Cnts >6 - pml					
Cnts >14 - pml					
Boron - ppm	1.0	2.7	6.4	1.5	2.3
Flash Point - DegC					

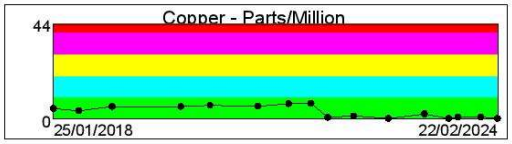
Chemistry	0	0	0	3	0
Manganese - ppm	.3	.3	.3	1.0	.6
Phosphorus - ppm	265.2	245.7	569.9	310.9	335.0
Calcium - ppm	5.8	8.9	52.8	13.0	9.9
Zinc - ppm	4.3	5.2	9.1	2.7	14.2
Magnesium - ppm	.4	.9	.9	2.5	2.3
Molybdenum - ppm	0.0	.1	.3	0.0	0.0
Barium - ppm	.2	0.0	.4	2.8	.1
Potassium - ppm	1.3	2.0	10.9	1.5	.4
Lithium - ppm	2.9	1.7	3.5	1.5	2.6
Visc 40C - cSt	309.5	317.3	310.7	321.0	291.7
Visc 100C - cSt					
Visc Idx - VI					
Total Acid - koh	.27	.34	.20	1.09	.20

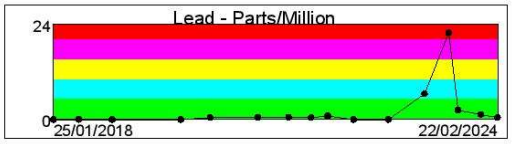


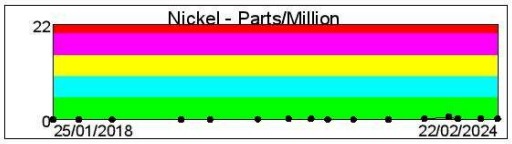
Sarma Volety
TATA Harbour

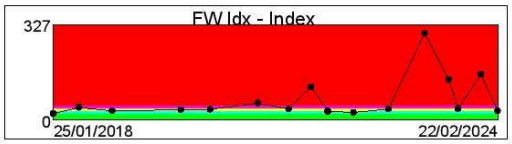


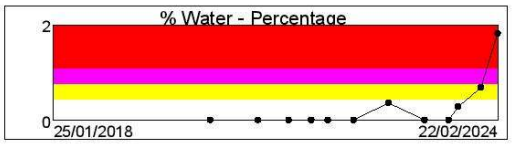












Note the levels of FW and water. Indications of component wear / debris disturbed on sampling and water contamination ingress.
Action - Source areas of contamination ingress, check breathers and seals. Drain, flush, change oil and resample at a reduced interval to monitor trends.

Weekly Vibration analysis is completed on most BWR components as a predictive maintenance tool. (Girdhar, 2004) identifies vibration analysis as crucial for detecting equipment behaviour anomalies that could indicate potential failures. They note an increase

in vibration due to mechanical looseness as components wear down, making it a reliable indicator of asset condition. Figure 7 shows a snippet of a vibration monitoring report for some department gearboxes.

Figure 7 - Vibration Report

801 Conveyor No.2 Drive	**Online**	Vibration amplitudes remain elevated across the motor, due to looseness (Vertical 8.2mm/s & Axially 18.9mm/s). Check all hold down bolts & base. Increase in imbalance at motor DE axial - recommend coupling inspection. **Note:** Iconet Connected - No Issues **Notification - 15907279**
802 Conveyor No.1 Drive	**4W**	As reported in October, vibration amplitudes continue to increase at the motor DE (7mm/s). Data showing imbalance & misalignment. O inspection found hold down bolts loose & shims missing (22/02). Tighten bolts & check coupling. Gearbox vibration is ok. **Notification - 15903918**

Weekly temperature monitoring is performed to detect overheating, a symptom of potential failure. This predictive maintenance strategy, as emphasized by (Sachs, 2019), is crucial for early detection and prevention of equipment issues. Figure 8 shows a snippet of a thermal report for some department gearboxes.

Figure 8 - Thermal report

Unloader 4 - Mechanical

Conveyor I.D	Condition	Comments
(A) Pan Feeder		Bearing Temperatures are within limits
(B) Cable Wheel		Bearing Temperatures are within limits
(C) Engine House - Rack		Bearing Temperatures are within limits
(C) Engine House - Hold		Bearing Temperatures are within limits
(C) Engine House - Close		Bearing Temperatures are within limits
(C) Engine House - Hoist	N/R	**Unit not in service**
(B) Shuttle Trolley - Rear		Bearing Temperatures are within limits
(C) Main Trolley - Front		Bearing Temperatures are within limits

Unloader 5 - Mechanical

Conveyor I.D	Condition	Comments
(A) Pan Feeder		Drives & Drum Bearings ok - **No access to some support Rollers**
(B) Cable Wheel		Bearing Temperatures are within limits
(C) Engine House - Rack		Bearing Temperatures are within limits
(C) Engine House - Hold		Bearing Temperatures are within limits
(C) Engine House - Close		Bearing Temperatures are within limits
(C) Engine House - Hoist	N/R	**Unit not in service**
(B) Shuttle Trolley - Rear		Bearing Temperatures are within limits
(C) Main Trolley - Front		Bearing Temperatures are within limits

Key	
	Temperatures within set limits
	Temperature breaching Alert levels
	Temperature breaching Fault levels
	No data taken (ND), Not Running (NR)
	No survey completed

In conclusion, the combination of these practices is in line with predictive maintenance strategies, enabling maintenance teams to act before operational impact, as discussed by (Williams, et al., 1994).

5.3.5. Reactive Maintenance

Reactive or corrective maintenance is undertaken after equipment failure. (Mobley, 2001) describes this approach as sometimes necessary but generally the least efficient, due to its

unpredictability and the high costs from production losses. (Higgins, et al., 2008) further detail how this maintenance type negatively affects the KPI- Availability.

5.4. Benefits and Drawbacks of Current Practices

The current methods of maintenance offer many benefits and drawbacks,

5.4.1. Benefits

- Regular preventive maintenance significantly decreases the chance of unexpected breakdowns, contributing to more reliable operations (Mobley, 2001).
- Early identification of potential issues through regular maintenance prevents the escalated costs linked to emergency repairs and production stoppages (Girdhar, 2004)
- Properly maintained equipment operates more efficiently, consuming less energy for the same output. (Firdaus, et al., 2023)
- Condition Monitoring provides visibility of the BWR's condition, enabling more informed decisions that minimize the risk of unforeseen failures, thereby improving reliability and availability. (Jardine & Tsang, 2021)

5.4.2. Drawbacks

- A comprehensive maintenance program for the BWR necessitates significant investment in time, personnel, and resources.
- Predictive maintenance effectively demands specialized skills and training, potentially creating skill gaps in the maintenance workforce, as (Smith & Hawkins, 2004) highlight.
- Sourcing spare parts for older or specialized machinery like the BWR poses challenges due to limited availability, resulting in extended downtimes for repair. (Gopalakrishnan & Banerji, 2004)
- Although preventive and predictive maintenance is perceived as more cost-effective than reactive maintenance due to lower production losses, it requires a greater financial commitment within maintenance budgets. (Mobley, 2002)
- Current condition monitoring is not “live” and does not detect issues in real time, and therefore cannot fully protect the asset from failure.
- Frequency based maintenance may result in replacing components prematurely (Davies, 2012)
- Current maintenance requires asset to be non-operational for a period of 12 hours every week, to complete condition monitoring.
- Only some BWR components have condition monitoring, the main bucket drive assembly does not due to access restrictions.

5.5. Justification

Numerous justifications support the existing maintenance approaches for the BWR. The foundational level of maintenance is mandated by health and safety legislation, with

enhanced requirements stemming from performance standards and accreditation needs. (Swanson, 2001) suggests the most effective maintenance practices are adopted by mature, leading organizations that employ data-driven decision-making. Such entities enhance efficiency and achieve long-term sustainability by integrating advanced maintenance strategies, including real-time condition monitoring and predictive maintenance.

5.5.1. Legal Obligations

The maintenance strategy for the BWR adheres to a broad spectrum of legal requirements, ensuring compliance with several key regulations. These include the Health and Safety at Work Act 1974 (HASWA), Lifting Operations and Lifting Equipment Regulations 1998 (LOLER), Electricity at Work Regulations 1989 (EAWR), Workplace Health, Safety and Welfare Regulations 1992, and Pressure Systems Safety Regulations 2000 (PSSR), among others.

Additionally, the Provision and Use of Work Equipment Regulations 1998 (PUWER) mandate that all work equipment, encompassing machinery, tools, and apparatus, must be suitable and safe for intended use, maintained in a safe condition, and undergo regular inspections to verify proper installation and maintenance. This ensures equipment does not degrade in performance or safety. According to the (Health and Safety Executive, 2018), adhering to these guidelines through regular visual and physical inspections, along with subsequent maintenance activities, fulfils the legal obligations set out by the regulations.

5.5.2. Contractual Obligations

Compliance with standards is not just ‘best practice’ or ‘industry standard’, but also a contractual requirement from our customers in the automotive and construction industries. Regular audits are conducted by our customers to ensure that we are adhering to the standards, we also conduct similar audits of our suppliers for the same purpose.

An example of some of the ISO standards we work to are;

5.5.2.1. ISO 55000, 55001 & 55002: Asset Management Systems

The ISO 55000 series outlines a comprehensive framework for effective asset management. Applying these standards requires developing maintenance strategies in concert with long-term organizational goals, prioritizing activities based on risk, and focusing on optimizing assets' lifecycle costs for greater long-term value (Jardine, et al., 2016). This approach promotes a culture of continuous feedback and learning, essential for adapting to operational shifts and sustaining asset-intensive operations. Ultimately, adherence to ISO 55000 standards transforms maintenance from a reactive task to a strategic asset management pillar, driving both performance and value throughout assets' lifecycles.

5.5.2.2. ISO 50001: Energy Management Systems

ISO 50001 emphasizes energy efficiency within an organization's management system, indirectly influencing maintenance practices. It requires regular maintenance to keep equipment and systems operating at optimal energy efficiency and contribute to the

continuous enhancement of energy usage. (International Standards Organisation, 2018) This includes identifying and correcting issues like friction losses, leaks, or insulation degradation that lead to increased energy consumption. (Oung, 2016) argues accurate documentation and communication of maintenance activities is key for energy performance monitoring.

5.5.3. Data analysis

To justify the current levels of maintenance, we regularly review and analyse the quantitative and qualitative data shown in Table 5;

Table 5 - Data Sources for analysis

Quantitative	Qualitative
Condition Monitoring Data	Operation Reports
Downtime & OEE Data	Maintenance Reports
Planned Maintenance Costs	
Unplanned Maintenance Costs	
Energy Efficiency	

5.5.3.1. Condition Monitoring Data

Condition monitoring data plays a crucial role in justifying the extent of maintenance activities for the bucket wheel reclaimer. This data enables the identification of wear, degradation, or signs of impending failure through anomalies in vibration patterns, temperatures, and other condition indicators, making a strong case for pre-emptive maintenance interventions. This proactive approach ensures that maintenance efforts are efficiently targeted, optimizing resource utilization and reducing unnecessary actions. Condition monitoring data allows for timely and targeted maintenance interventions, circumventing the costs tied to unplanned downtime and extensive repairs. The economic benefits of condition-based maintenance, when weighed against the potential financial losses from equipment failures, provide a compelling justification for the investment in and execution of these maintenance strategies.

5.5.3.2. Overall Equipment Effectiveness (OEE) Data

An improvement in OEE over time can serve as a justification for the current maintenance strategies employed.

OEE Availability data reflects the impact of maintenance activities on equipment availability. A reduction in unplanned downtime can often be attributed to effective preventive and predictive maintenance practices. As detailed by (Palmer, 2019), analysing downtime data helps identify maintenance strategies that minimize disruptions and optimize equipment availability. By comparing periods of high downtime against maintenance records, it's possible to adjust strategies to address recurrent issues.

OEE Performance indicates whether a piece of equipment is operating at its maximum capacity. Regular maintenance and calibration can prevent performance degradation, justifying the maintenance strategy through sustained or improved performance levels. Maintenance practices significantly impact output quality by ensuring equipment operates within set tolerances, reducing defects or rework. (Wireman, 2004) highlights how strategic maintenance boosts production efficiency and reliability.
(Kennedy, 2017) supports using OEE as a key metric in Total Productive Maintenance (TPM), directly linking maintenance to equipment effectiveness improvements. (Ng, et al., 2015) show empirical evidence of maintenance enhancing OEE metrics. However, OEE analysis primarily examines past performance, capturing losses already incurred, which may seem like a limitation due to its retrospective nature. Despite this, historical OEE data can reveal patterns, such as recurring equipment issues, enabling maintenance teams to forecast and pre-empt future failures. This predictive, data-driven strategy facilitates continuous maintenance refinement, enhancing overall operational efficiency and financial performance.

6. Evaluation of improvement opportunities

6.1. Target Performance

The analysis of planned maintenance costs contributes to understanding the Total Cost of Ownership (TCO) of the bucket wheel reclaimer. TCO includes purchase price, operation, maintenance, and eventual disposal costs. Efficient planned maintenance strategies can significantly reduce TCO by extending the useful life of the equipment and optimizing its operational efficiency. According to (Agustiady & Cudney, 2016) a well-executed maintenance plan directly influences TCO by mitigating the need for costly emergency repairs and replacements.

One target is to improve the OEE by reducing downtime, enhancing performance efficiency, and ensuring high-quality operations. (Muchiri, et al., 2011) indicate a target OEE increase of 10-20% is considered achievable with the implementation of advanced maintenance strategies such as remote condition monitoring.

Reducing operation costs by optimizing reclamation rates, improving operator efficiency, and minimizing idle times is a key goal. (Mobley, 2002) states a target reduction of 5-15% in operation costs is realistic with streamlined processes, more reliable equipment, and improved equipment efficiency.
The primary rationale for planned maintenance is to prevent equipment failures before they occur, aiming to minimize unplanned downtime and associated costs. As detailed by (Jardine & Tsang, 2021) the cost of planned maintenance must be balanced against the costs of potential failures, including the direct costs of repairs and the indirect costs of downtime. Industry benchmarks and case studies suggest that lowering maintenance costs by 10-25% through the adoption of proactive maintenance strategies is achievable. (Mobley, 2002)

Energy efficiency is a vital metric for the BWR, signifying the machine's capability to convert energy into work efficiently. Given the significant energy usage, even minor efficiency enhancements can result in considerable cost savings and environmental advantages. Maintenance ensures optimal operation of all machinery components, decreasing energy consumption. Activities like lubrication, alignment, and part replacement can lower friction and resistance, necessitating less operational energy. This link between maintenance and reduced energy use underscores the value of regular and preventive maintenance. (Firdaus, et al., 2023) suggests analysing energy efficiency before and after maintenance interventions can demonstrate these activities' effectiveness.

Analysing operator or operation reports is key to justifying and refining maintenance strategies for a bucket wheel reclaimer. These reports, filled with both qualitative and quantitative insights from personnel directly engaged with the equipment, offer valuable

feedback on operational performance, encountered issues, and the effectiveness of previous maintenance efforts. Analysing these can reveal patterns or issues not detected by automated systems, allowing for earlier and more targeted maintenance interventions. (Smith & Hinchcliffe, 2003) argue that recurring problems highlighted in these reports can justify changes in maintenance routines, such as more frequent inspections or part replacements, particularly if specific components are repeatedly problematic.
(Gulati & Smith, 2009) point out that positive performance reports post-intervention supports the effectiveness of these strategies, while consistent issues post-maintenance may indicate a need for strategy revision. This approach not only justifies the existing maintenance practices but also guides continuous improvements, ensuring the equipment's reliability, performance, and longevity are optimized.

6.2. Potential Improvements

6.2.1. Total Productive Maintenance (TPM)

(Wireman, 2004) explores how TPM strategies can be applied to improve OEE. TPM emphasizes involving all employees in preventive maintenance, thereby improving productivity through the optimization of equipment reliability and performance. By engaging all levels of an organization in maintenance activities, from operators to senior management, TPM aims to create a culture where maintenance supports optimal production efficiency.
(Stamatis, 2010) shows that by integrating OEE metrics with TPM principles, it is possible to justify the current maintenance practices but also identify opportunities for significant improvements. This holistic approach ensures that maintenance activities are aligned with the overall objectives of the organization, contributing to enhanced operational efficiency, reduced costs, and improved product quality.

6.2.2. Predictive Maintenance

Integrating real-time condition monitoring using IoT, Industry 4.0 technologies, and machine learning can predict equipment failures before they occur, significantly reducing unplanned downtime and maintenance costs (Lee, et al., 2014) discuss a case study involving a large mining operation and the implementation of a predictive maintenance program. Utilizing condition monitoring and data analytics, led to a significant reduction in unplanned downtime and maintenance costs. The program focused on critical equipment such as conveyors and crushers, similar in criticality to bucket wheel reclaimers. By analysing equipment data in real-time, the mine was able to predict failures before they occurred, resulting in a 20% reduction in maintenance costs and a 10% increase in equipment availability.

6.2.3. Upgrade of Bucket Drive System to Hydraulic System

Upgrading the bucket drive system to a hydraulic system offers multiple advantages over traditional mechanical or electric drive systems. Hydraulic systems provide superior

precision, control, and flexibility in operation, which is particularly beneficial for the complex movements required by the bucket wheel reclaimer. (Nicholas, et al., 2008) suggests they are also inherently more reliable and easier to maintain, as they have fewer moving parts subject to wear. Additionally, hydraulic systems can be more energy-efficient, particularly in applications requiring variable speed and torque. Upgrading to a hydraulic drive can lead to significant improvements in reliability and operational efficiency, lower maintenance costs, and reduced energy consumption. The initial investment in upgrading can be offset by the extended equipment lifecycle and the operational savings achieved through improved efficiency and reduced downtime

In a case study, a large mining operation decided to upgrade its conveyor system by replacing the mechanical drives with hydraulic drive systems. The hydraulic drives offered better control and efficiency under variable load conditions and were more reliable and easier to maintain than the mechanical systems. (Kruczek, et al., 2019) describes how after the upgrade to hydraulic drives, the mining operation experienced a 30% reduction in energy consumption due to the higher efficiency of the hydraulic system. Additionally, maintenance costs dropped by 20% due to the increased reliability and lower wear and tear on the system. The operation also benefited from improved operational flexibility, allowing for smoother and more efficient handling of different materials.

6.3. Justification of Improvements

6.3.1. Impact Assessment

Evaluating the impact of the proposed improvements on the reclaimer's performance, including potential increases in OEE, reductions in operation and maintenance costs, and overall productivity improvements is crucial before undertaking any project or upgrade.

6.3.1.1. Benefits of Predictive Maintenance

1. Predictive maintenance can significantly reduce unplanned downtime by identifying potential equipment failures before they occur. Case studies in the mining industry have shown reductions in downtime by up to 20-30%, leading to increased production capacity and revenue. (Kruczek, et al., 2019)
2. By performing maintenance only when necessary, predictive maintenance can lower maintenance costs by 10-40% compared to traditional preventive maintenance strategies. (Agustiady & Cudney, 2016)
3. Continuous monitoring and timely maintenance can extend the operational life of equipment, delaying capital expenditures for replacements. (Mobley, 2002)

6.3.1.2. Costs of Predictive Maintenance

1. The setup for predictive maintenance includes costs for sensors, data analytics software, and integration with existing systems. However, these costs are often recouped within a few years through savings in maintenance and operational efficiencies.

2. Training and Implementation: Staff may require training on new technologies and processes, and there may be costs associated with change management and implementation. (Davies, 2012)
3. The ROI of predictive maintenance is typically positive, with payback periods ranging from one to three years, depending on the scale of implementation and the baseline costs of maintenance and downtime. (Jardine & Tsang, 2021)

6.3.1.3. Benefits of implementing Hydraulic Drives

1. Hydraulic drive systems offer superior control and efficiency, especially for variable speed and load applications. This can lead to energy savings and improved operational performance. (Meehan, 2012)
2. Hydraulic systems have fewer moving parts and are less prone to wear and tear, resulting in lower maintenance costs and higher reliability. (Rydberg, 2015)
3. Hydraulic drives can be more easily adjusted or reconfigured for different operational needs, providing greater flexibility in mining-type operations. (Meehan, 2012)

6.3.1.4. Costs of implementing hydraulic drives

1. Upgrading to hydraulic drives involves capital expenditure for new equipment and installation. (Norton, 2019) However, this cost is offset by the long-term savings and operational benefits.
2. There may be a transition period during which productivity is impacted as the new system is installed and commissioned.
3. While the initial investment for hydraulic drive systems is higher than some alternative solutions, (Rydberg, 2015) states the long-term savings in maintenance and operational efficiencies, as well as potential increases in production capacity, contribute to a favourable ROI.

6.3.2. Lifecycle Analysis

A comprehensive analysis considering the entire lifecycle of the BWR will demonstrate the long-term benefits and cost savings resulting from the proposed upgrades and different maintenance strategies. (Sonnemann & Margni, 2015)

6.3.2.1. Environmental Analysis

1. Using Equation 1, and the values in Table 6, it is possible to calculate the current Annual Energy Usage for both Materials reclaimed.

$$Current\ Annual\ Energy\ Usage\ (Material\ A) = 7800\ x\ 132\ x\ 0.95 = 978{,}120 kWh.$$

$$Current\ Annual\ Energy\ Usage\ (Material\ B) = 7800\ x\ 132\ x\ 0.98 = 1{,}009{,}008\ kWh.$$

2. Using Equation 2 , a CO2 emission factor of 0.233 kgCO2/kWh (Department for Energy, Security and Net Zero, 2023), and the values in Table 6, it is possible to calculate the Current CO2 Emissions.

$$Current\ CO2\ Emissions\ (Material\ A) = 978120\ x\ 0.233 = 227{,}901.96\ kg$$

$$Current\ CO2\ Emissions\ (Material\ B) = 1009008\ x\ 0.233 = 235{,}098.66\ kg$$

3. Using Equation 1 , and the values in Table 7, it is possible to calculate the Future Annual Energy Usage.

$$Future\ Annual\ Energy\ Usage\ (Material\ A) = 8712\ x\ 132\ x\ 0.50 = 574{,}992\ kWh.$$

$$Future\ Annual\ Energy\ Usage\ (Material\ B) = 8712\ x\ 132\ x\ 0.55 = 632{,}491.20\ kWh.$$

4. Using Equation 2, and the values in Table 7, it is possible to calculate the future CO2 Emissions.

$$Future\ CO2\ Emissions\ (Material\ A) = 574992\ x\ 0.233 = 133{,}973.14\ kg$$

$$Future\ CO2\ Emissions\ (Material\ B) = 632491.20\ x\ 0.233 = 147{,}370.45\ kg$$

Table 6 – Current Operating Parameters

Material	Runtime (T) [h]	Power rating (P) [kW]	Load Factor (X) [%]	Annual Energy Usage [kWh]	Annual Running Cost [£]	Annual Co2 [kg]
A	7800	132	0.95	978,120.00	146,718.00	227,901.96
B	7800	132	0.98	1,009,008.00	151,351.20	235,098.86

These are the current operating parameters for the electric bucket drive motor, for our two different material bulk-densities, with 12 hours maintenance per week and 168-hour maintenance period every 6 months.

Table 7 - Future Operating Parameters

Material	Runtime (T) [h]	Power rating (P) [kW]	Load Factor (X) [%]	Annual Energy Usage [kWh]	Annual Running Cost [£]	Annual Co2 [kg]
A	8712	132	0.50	574,992.00	86,248.80	133,973.14
B	8712	132	0.55	632,491.20	94,873.68	147,370.45

This is the proposed operating parameters for the hydraulic bucket drive, for our two different material bulk-densities, with 24-hour maintenance period every 6 months (the increased runtime due to increased reliability and reduced maintenance requirements of the hydraulic system).

Equation 1 (Beaty, 2000)

$$Annual\ Energy\ Usage\ [kwh] = Power\ Rating\ (\mathrm{P}) \times Load\ Factor(X) \times Runtime\ (T)$$

Equation 2 (Beaty, 2000)

$$CO2\ Emissions\ [kg] = Energy\ Usage\ [kWh] \times CO2\ Emission\ Factor\ [kgCO2\ /\ kWh]$$

Equation 3

$$Forcasted\ Energy\ Savings[kWh] = Current\ Energy\ Usage\ [kWh] - Future\ energy\ usage[kWh]$$

Equation 4

$$CO2\ Emission\ \mathrm{Reduction}[kg] = Current\ CO2\ Emissions\ [\mathrm{kg}] - Future\ CO2\ Emissions[kg]$$

Equation 5

$$Estimated\ Cost\ Savings[£] = Current\ Energy\ Costs[£] - Future\ energy\ Costs[£]$$

6.3.2.2. Economic Analysis

Initial Investment = £180,000,
Predictive Maintenance upgrade = £10,000,
Hydraulic System Upgrade = £140,000 +£30,000 (Appendix A: Hydraulic Upgrade Quotation) + (Appendix C: Hydraulic upgrade steelwork quotation).

Using the Equation 5, the anticipated energy savings in Table 6 and Table 7, and the average UK energy cost of £0.15 per kWh. (Office of Gas and Electricity Markets, 2024).

$$Annual\ Energy\ Cost\ Savings\ (Material\ A)\ =\ 146{,}718.00\ -\ 86{,}248.80\ =\ £60{,}470$$

$$Annual\ Energy\ Cost\ Savings\ (Material\ B)\ =\ 151{,}351.20\ -\ 94{,}873.68\ =\ £56{,}477.52$$

(Marquez, et al., 2008) suggests 20% - 40% reduction in maintenance costs between electro-mechanical systems and hydraulic systems.
A conservative estimate of a 20% reduction in 2023 maintenance costs of £1.6m, leads to savings of ***<u>£320,000 per annum.</u>***

By avoiding 1 incident of unplanned downtime per year, costing £50,000 in mobile plant equipment alone, savings amount to ***<u>£50,000</u>*** ***<u>annually.</u>***

6.3.2.3. Social Analysis

(Davies, 2012) states the workforce requires training on the new systems, software, and procedures. Thus, enhancing skills but requiring upfront time and resource investment.

6.3.2.4. Environmental Impact Assessment

The implementation significantly reduces energy consumption and CO2 emissions, contributing positively to environmental sustainability goals.

6.3.2.5. Economic Impact Assessment

Using Equation 6, it is possible to calculate the total annual savings.

$$Total\ annual\ savings\ =\ £56{,}477.52\ +\ £320{,}000\ +\ £50{,}000\ =\ £426{,}477.52$$

Using Equation 7 it is possible to calculate a Return on Investment (ROI)

$$Return\ on\ Investment\ (ROI)\ =\ £426{,}477.52\ /\ £180{,}000\ \times\ 100\ =\ \mathbf{236.93}\%$$

This ROI value indicates a payback period of less than 6 months.

<u>Equation 6</u>

$$Total\ Annual\ Savings\ =\ Energy\ Cost\ Savings\ +\ Maintenance\ Cost\ Savings\ +\ Downtime\ Cost\ Savings$$

<u>Equation 7</u>

$$Return\ on\ Investment\ (ROI)\ =\ (Total\ Annual\ Savings)/(Initial\ Investement)\ \times 100$$

6.3.2.6. Social Impact Assessment

(Davies, 2012) argues that the introduction of new technologies and systems enhances workforce capabilities, promoting a culture of continuous learning and adaptation. However, this change must be managed to be successful.

6.3.2.7. Recommendations

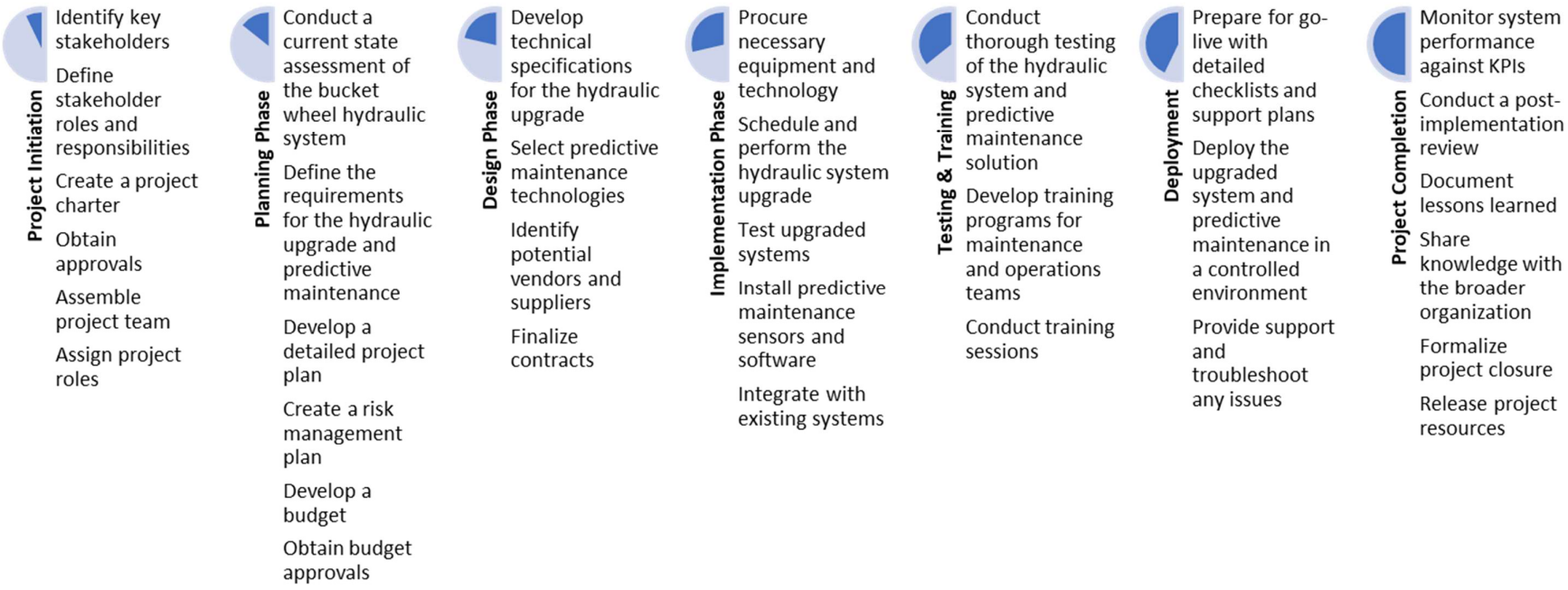
1. Engage with all stakeholders, including the workforce, management, and environmental bodies, to ensure transparency and gain support for the initiative.
2. Proceed with the upgrades to predictive maintenance and hydraulic drives, given the strong ROI and positive environmental impact.
3. Establish continuous monitoring of the implemented systems to gather real-time data, allowing for ongoing optimization and further improvements.

6.4. Strategy for Implementation

6.4.1. Project Roadmap

A detailed project roadmap outlining each phase of the implementation process, including timelines, responsible parties, and milestones, is essential for successful execution. (Imbarrato, 2021)

Figure 9 - Roadmap Process Diagram



6.4.2. Risks to Implementation

Identifying potential challenges such as big data handling, initial costs, and resistance to change will be critical. Mitigation strategies should be developed for each identified risk.

6.4.2.1. Data Handling

Implementing predictive maintenance powered by real-time condition monitoring is not without its challenges, primarily due to the complexities associated with handling "big data." These challenges include managing the volume, variety, velocity, veracity, and value of the data. AI and Machine learning can offer solutions to these challenges by enabling the analysis of time-series data and high-dimensional spaces, making it easier to uncover correlations that are difficult for humans to identify.

6.4.2.2. Initial Costs

Using the lifecycle analysis as justification for the implementation of the upgrades shows significant financial benefits to the organisation, with a payback period of less than 6 months.

6.4.2.3. Management of Change

Successfully managing change, particularly in the context of maintenance technicians and machine operators, hinges on securing their buy-in from the outset. Early engagement not only facilitates smoother transition processes but also enhances the likelihood of successful implementation of new maintenance practices or technologies. (Kotter, 2012) underscores the importance of involving employees in the change process, noting that participation fosters a sense of ownership and commitment to the change, thereby increasing the probability of its success. This approach is critical in the maintenance domain, where the practical insights and experience of technicians and operators can significantly inform the optimization of maintenance strategies and practices. By actively involving these key stakeholders in planning and decision-making phases, organizations can ensure that changes are not only technically sound but also practically viable, leading to improved operational efficiency and reduced resistance to change.

Implementing these improvements will require a structured change management process, including training for operators and maintenance staff on new technologies and processes, communication strategies to ensure stakeholder alignment, and continuous improvement mechanisms to adapt and refine practices over time.

There a is also a legal obligation to effectively manage change. The Management of Health and Safety at Work Regulations 1999 state employers must document and implement a change management process for maintenance activities that affect health and safety, ensuring that any changes do not introduce new hazards and that all equipment remains safe to use and adequate training and information must be provided to all employees affected by such changes. (Health and Safety Executive, 1999)

ISO standards 9001 and 45001 provide a lot of information to assist with the safe and effective management of change within an organisation.

ISO 9001:2015 requires organizations to plan changes to their quality management system. Transitioning to predictive maintenance would involve assessing the risks and opportunities and setting quality objectives to guide the change. The organization is required to monitor, measure, analyse, and evaluate the performance of the Quality Management System (QMS). Predictive maintenance practices should be evaluated against the quality objectives set to ensure they are enhancing the system's performance (International Standards Organisation, 2015)

ISO45001:2018 includes managing changes that can impact Occupational Health and Safety (OH&S) performance. Predictive maintenance can reduce unexpected breakdowns, which in turn can minimize workplace incidents and hazards. When changing to predictive maintenance, organizations must ensure that the changes are planned and implemented in a way that mitigates any OH&S risks, which could include new risks introduced by using predictive technologies or changes in workflow. (International Standards Organisation, 2018)

7. Recommendations

To enhance Overall Equipment Effectiveness (OEE), reduce operational costs, and prolong the lifecycle of assets, a systematic approach encompassing short-term, medium-term, and long-term recommendations is essential. These recommendations consider the opportunities for improvement and acknowledge the potential challenges that might arise during their implementation.

7.1. Short-Term Recommendations

Optimizing maintenance schedules based on the actual frequency and impact of issues encountered during routine maintenance checks can be an effective strategy. This approach requires no additional investment but can lead to a reduction in maintenance costs by prioritizing tasks that have a direct impact on equipment performance. However, it's important to note that solely relying on such adjustments may increase the risk of unforeseen failures due to the potential for overlooking critical maintenance needs.

7.2. Medium-Term Recommendations

Medium-term strategies might include investing in advanced diagnostic tools or training for maintenance staff to enhance their ability to identify and address issues proactively. Although these measures take longer to put in place and may involve moderate investment, they contribute to a sustainable improvement in equipment reliability and efficiency.

7.3. Long-Term Recommendations

Upgrading critical equipment components to more efficient alternatives—like transitioning the bucket wheel drive system to a hydraulic system—falls into this category. Additionally, integrating advanced condition monitoring technologies can drastically improve the predictability of equipment failures. These upgrades not only require a significant upfront

investment but also a solid business case to justify the expenditure. Furthermore, improving access arrangements to facilitate easier maintenance activities can enhance safety and efficiency. Although these long-term recommendations demand more resources and planning, they offer the most substantial benefits in terms of extending the asset lifecycle, reducing operational costs, and improving overall equipment effectiveness.

8. Conclusion

In conclusion, this report has comprehensively evaluated the current maintenance strategies applied to the Bucket Wheel Reclaimer (BWR) at Port Talbot steelworks, with a keen focus on assessing the effectiveness and efficiency of these practices. Initially set objectives aimed to map existing maintenance routines, analyse the cost and effectiveness, suggest improvements leveraging the latest trends and technologies, and finally, evaluate the feasibility and potential impacts of proposed improvements.

Through critical analysis, it has identified the strengths and weaknesses inherent in the present maintenance framework, which predominantly revolves around preventive, predictive, and reactive strategies. While these strategies have ensured a certain degree of operational reliability and efficiency, the report highlighted significant opportunities for enhancement, notably through predictive maintenance technologies, the adoption of Total Productive Maintenance (TPM), and the strategic upgrade of the BWR's bucket drive system to a hydraulic system.

The justification for these proposed improvements is solidly grounded in a detailed evaluation of their potential impacts, including a lifecycle analysis and a project roadmap for implementation. Such improvements are anticipated not only to boost the overall equipment effectiveness (OEE) but also to reduce operational and maintenance costs substantially, thereby extending the asset's lifecycle.

Crucially, the report underscores the necessity of a planned approach to change management, emphasizing the importance of engaging all stakeholders and ensuring alignment with Legal regulations and ISO standards for maintenance management. By adhering to these guidelines, Port Talbot steelworks can enhance its maintenance strategy effectiveness, ensuring that the BWR operates at its optimum, thereby contributing significantly to the steelworks' overall productivity and sustainability goals.

From the findings and recommendations detailed in this report, it becomes clear that while the current maintenance practices provide a solid foundation, there is considerable scope for improvement in the form of short, medium, and long-term improvements and potential cost savings of over £400,000 per annum.

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10. Appendices

Appendix A: Hydraulic Upgrade Quotation

rexroth
A Bosch Company

Quote Line Items

Item	Description	Qty	List Each	Line Total
10	***Bosch Rexroth Hagglunds DUc Half*** cabinet style of hydraulic power unit, complete with a ***132kW*** electrical motor mounted to a closed loop axial piston pump which shall be supplied from a stainless-steel oil reservoir that comes with the system health monitoring sensors. these include a reservoir PT100 temperature sensor, system pressure transmitter, boost pressure transmitter, oil level sensor, suction valve isolation switch, 1 off return and 1 off drain filters with blocked indication switches. Also fitted are an air oil breather, oil level sight glass, oil sample point, oil reservoir drain down valve, oil tank heater and an oil filler point through a quick release coupling. Maximum system pressure is 350 bar giving a maximum torque from the CB840-680 drive motor of 221kNm. Maximum output flow will give a maximum shaft speed of 8 rpm. (Please note that the maximum torque and maximum speed are not achievable simultaneously due to the installed power) An air oil cooler is included which is mounted to the cabinet in which the interconnecting hoses are included. Fully variable speed of the feeder is via our "Spider" control unit, which is wired and mounted to the power unit. Speed input signal can be ±10vdc or 4-20mA. Health monitoring indication is displayed on the front screen showing the warnings and alarms. Electrical voltages are based on 400v-3ph-50hz and 110/220vac-1ph-50hz. All electrical motors are to IEC specifications. Electrical Motors are IP55 rated Spider Control Unit is IP65 rated Instrumentation is IP65 / IP67 rated Documentation includes: - Electronic copy in a pdf format of the Installation & Maintenance" manual. **Type : DUC-LS2-132-250+000-0-A-Y-S-E-400/50**	1		
20	***Bosch Rexroth Hagglunds CB 840 680*** direct drive motor complete with shrink disc coupling. **Type : CB 840 680 CA0N00 00 00**	1		
30	***Bosch Rexroth Hagglunds*** torque arm complete with pivot attachment and mounting bolts. **Type : TC A 0840 2 0 00**	1		
40	***Bosch Rexroth Hagglunds*** speed sensor to mount directly to the drive motor. **Type : SPDC CB—0 01856 00 00**	1		

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VAT Registration Number GB239306896
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rexroth
A Bosch Company

50	***Bosch Rexroth Hagglunds*** harsh environment kit to mount directly to the drive motor. **Type : HEK 26 CRN 00 00**	**1**

Total List Price	
Discount :	
Nett Price	**£136,585.37**
Material Surcharge @ 2.5%	**£3,414.63**
Total Nett Price	**£140,000.00**

Options

Item	Description	Qty	Budget Each	Line Total
OP10	Profibus Card	**1**	**£964.73**	
OP20	Hydraulic Oil can be quoted if requested.	**1**	**TBC**	
OP30	Assistance with installation & commissioning can be quoted if requested. Price shown is budgetary and based on 2 engineers for 5 days using Monday to Friday day rates.	**1**	**£6,000.00**	
OP40	Supply of interconnecting flexible hoses based on a 5m run	**1**	**£3,000.00**	

Note: Price is exclusive of the UK rate of Value Added Tax (VAT)
Exclusions apply: Please refer to section "Technical Notes".

Rev.	Date	Name	Changes
AA	XX	XX	XX
AB			
AC			

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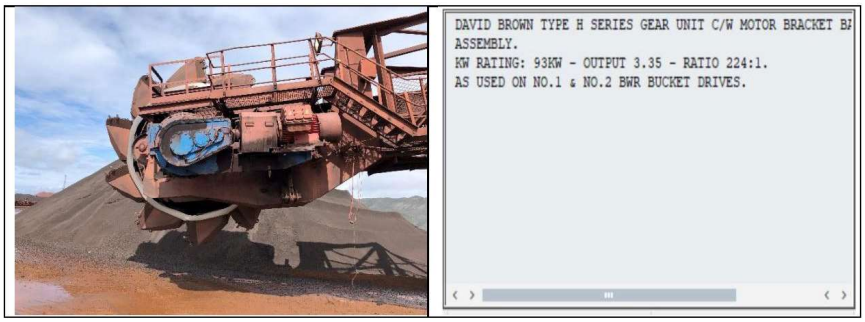
Appendix B: Hydraulic Upgrade Project Calculation

Existing Drive System : 130kW, 3300v-3ph-50hz electrical motor through a fluid coupling and a David Brown speed reduction gear box (details unknown, could be worm type).

Note gear box rating is 93 kW from SAP data.

The reclaim rate typically does not exceed 900 tph due to the downstream capabilities.



The bucket wheel speed was timed at 9.15 secs per revolution, giving a shaft speed of 6.6 rpm.

Electrical motor shaft speed of 1480 rpm through the 224 : 1 reduction gear box is 6.6 rpm

Full load current to be advised by for the installed electrical motor, calculated value is 26.76 Amps on a 4-pole electrical motor rated for 3300 volts.

Reclaim material was on Sinter Fines which is classed as a light material, operators target is to maintain the reclaim rate at 12 amps. Reclaim material DRI is the heaviest material, and the target is to maintain the load between 20 and 22 amps, any higher than these values it starts to put the cylinder luffing forces into an amber warning mode.

We have assumed the following efficiencies for the various components in the drive

Component Efficiencies	100% Load	50% Load
Electrical Motor	94	93
Electric Motor Power Factor (Pf)	0.85	0.84
Fluid Coupling	98	98
Gear Box	94	90

For the assessment of the absorbed power when reclaiming **Sinter Fines,** we shall base this on the values shown at 50% in the above table. The drive torque shall then be calculated from the running speed of 6.6 rpm.

Absorbed Power (kW) = (V x I x Pf x $\sqrt{3}$ x Eff.) / 1000

Torque = (Absorbed Power x 9550) / rpm

Power = 3300 x **12** x 0.84 x 1.732 x (0.93 x 0.98 x 0.9) / 1000 = 47.26 kW

Torque = (47.26 x 9550) / 6.6 = 68,381 Nm

For the assessment of the absorbed power when reclaiming **DRI,** we shall base this on the values shown at 100% in the above table. The drive torque shall then be calculated from the running speed of 6.6 rpm.

Absorbed Power (kW) = (V x I x Pf x √3 x Eff.) / 1000

Torque = (Absorbed Power x 9550) / rpm

Power = 3300 x **20** x 0.85 x 1.732 x (0.94 x 0.98 x 0.94) / 1000 = 84.14 kW

Torque = (84.14 x 9550) / 6.6 = 121,745 Nm

Power = 3300 x **22** x 0.85 x 1.732 x (0.94 x 0.98 x 0.94) / 1000 = 92.55 kW

Torque = (92.55 x 9550) / 6.6 = 133,920 Nm

The operator also mentioned that sometimes they do hit 24 amps but this is rare and typically caused by avalanching onto the wheel, which would calculate to be 146,000 Nm

Drive Motor Selection.

Based on this information we can select a CB840-680 direct drive hydraulic motor complete with shrink disc coupling.

The anticipated running pressures on **DRI** would be 195 bar to 220 bar

The anticipated running pressures on **Sinter Fines** would be 120 bar.

The anticipated running pressure at peak load of 24 amps is 235 bar.

The drive system would have a maximum torque capability of 221kNm at 350 bar.

Please note that as done on the slew drives on BW#2, these values can be adjusted during commissioning to an optimise the reclaiming rate.

Two styles of Hagglunds power units for the bucket wheel drive.

Appendix C: Hydraulic upgrade steelwork quotation

mii Engineering Ltd

Tata Steel UK Ltd

Port Talbot Steel Works
Harbour & Blending
SA13 2NG

Your Reference:	Tenderdoc1029873
Our Reference:	MII-E-24-23901
FAO:	Mr David Adams
Subject:	Quotation for Manufacture and Supply of BWR Steelwork

Dear Sir,

We thank you for your valued enquiry and we now have pleasure in submitting our quotation for the work as described.

Quote to manufacture and deliver to site the structural steelwork and walkways as per drawings provided in Tender document pack ref: 1029873.

This quote is for the sum of **£28,968.11** *(Twenty eight thousand, nine hundred and sixty eight pounds and eleven pence.)*

Note: Quotation is not confirmation of resource allocation. Further planning meetings are being held weekly where TATA will confirm site wide priorities.

We hope to have interpreted your enquiry requirements correctly and look forward to being of service to you, assuring you of our best attention at all time, we remain,

Yours Faithfully

For and on behalf of
MII Engineering Ltd

Andrew Davies

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