LOGIC
Journal of Engineering Design and Technology
Vol. 21 No.1 March 2021; p. 52 - 63

p-ISSN : 1412-114X
e-ISSN : 2580-5649
http://ojs.pnb.ac.id/index.php/LOGIC

PLANNING FOR MAINTENANCE AND REPAIR OF CONTINUOUS SHIP UNLOADER USING THE IRRO METHOD

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Abstract. The problem faced is damage, especially to the screw conveyor from the Continuous Ship Unloader (CSU) as a dry bulk material transfer equipment (phosphate rock) which is taken from the ship's hold which is flowed by a screw conveyor followed by the belt conveyor to the material warehouse to be processed into a type of fertilizer. The purpose of planning is to obtain a schedule and estimated cost of maintenance and repair of CSU for the period 2022 to 2025, and to obtain the ratio of maintenance-repair costs to the profit of the machine. Planning methods uses the IRRO (Inspection, Replace, Repair, and Overhoul) method include data collection of machine maintenance history and component breakdowns, checking CSU specifications, making a list of component life predictions and component prices, predicting costs and duration of component dissasembly, screw conveyor repair, maintenance and repair scheduling, and maintenance and repair cost estimates. The real results of planning in the form of a maintenance and repair schedule for the period of 2022 to 2025; maintenance and repair costs respectively for the years 2022 to 2025 are IDR 136,873,000; IDR 335,986,000; IDR 160,687,000; and IDR 464,733,000; and the ratio between maintenance costs to profit for the years 2022 to 2025 is 0.51, 1.22, 0.57, and 1.63 which means the machine is still fit for use without the need for refurbishment because it is still prospective.

Keywords : Continuous ship unloader, screw conveyor, dry bulk material, phosphate rock, belt conveyor, IRRO.

1. INTRODUCTION

Industrial development in Indonesia, especially the chemical industry has increased from year to year. Progress in the industrial sector has a very important role in national development in all fields in order to improve people's welfare. Especially in industries that have a role to support the provision of national fertilizers to achieve food self-sufficiency program and support the economy, especially the agricultural sector. The expansion of the agricultural sector in the early 1970-1980s was inseparable from the role of the fertilizer industry which enabled farmers to optimize the results of the green revolution to increase their production. Along with the increasing area of agricultural land and plantations in Indonesia, the need for fertilizer is increasing from year to year. One of the fertilizer industries in Gresik, east Java, Indonesia is the port of Terminal for Own Activities for loading and unloading activities, one of the equipment used in the loading and unloading process is the CSU (Continuous Ship Unloader). Raw materials that are transported/unloaded are phosphate rock, ZA steel grade, ZA-caprolactam, MOP-red, MOP-white, MOP-pink, sulfur and SP 36. The way CSU works is that the material in the hold of the ship is sucked in through the feeder inlet then followed by a vertical screw conveyor through the horizontal screw conveyor then the material falls through the hopper and the material dust is sucked in by the dust collector at the end of the hopper, so that the material falls on the belt conveyor to be forwarded to the warehouse. Due to the important role of CSU at Terminal for Own Activities, an effective maintenance and repair plan must be made to avoid damage that causes breakdown.

Maintenance is an attempt to eliminate the causes of the breakdown, if possible before the congestion occurs. These efforts can take the form of cleaning, lubrication, periodic inspections, servicing, and tune-ups so that their performance remains within the expected performance range. Repair is the treatment of the effects of a congestion event. So the difference between maintenance and repair lies in the effort before the congestion/damage occurs and treatment of the effects after the congestion incident [1]

Screw conveyors are generally right-hand with screw designs that are selected according to the material being moved, trough screw or continuous screw is selected to move dry granules or powder. Screw normally made of steel sheet which is welded to the shaft [2].

In operational, maintenance and repair activities must comply with the principles of occupational health and safety (OHS). Safe and healthy at work is the condition of workers that must be realized in the workplace, of course with all efforts based on science and thought to protect workers in accordance with human rights and applicable laws and standards [3].

Total Productive Maintenance/TPM is a treatment related to all elements of the company with the aim of achieving zero product defects, zero breakdown and zero accident. TPM as a maintenance method that maximizes efficiency, solidifies preventive maintenance systems, maximizes productivity, reduces downtime, and motivates all company production lines to avoid sudden repairs and minimize unscheduled maintenance [4]-[5].

Preventive Maintenance (PM) policy is a proactive technique that has been used since the inception of maintenance systems research [6]. The efficiency of PM when applied to leased objects is considered the determinant of revenue for the next rental period [7].

The total average cost per unit time which includes production costs, warranty, and system maintenance is applied to the useful life of the equipment [8].

The case study model of multi-objective genetic algorithm can increase availability, reduce maintenance costs, increase plant profits, can be applied in a continuous operating system for chemical plants with modifications to its operating characteristics [9].

An increase in the predictive maintenance level can lead to a lower quality control cost [10].

The balance between preventive maintenance and corrective maintenance to minimize costs varies between organization and assets, but there is a rule of thumb for balancing preventive maintenance and corrective maintenance with an 80/20 ratio [11].

Preventive maintenance and predictive maintenance are based on a history of maintenance which gives an indication of the degree of damage periodically with possible shifting of component life due to the possible variation in the operating conditions of an equipment. Corrective maintenance is possible if an equipment condition requires adjustment without changing its basic principles in order to keep it functioning. Maintenance and repair costs can increase sharply if good planning is not done, because early symptoms of deterioration are not immediately stopped or reduced through scheduled treatment planning. With scheduled maintenance, unexpected losses can be minimized.

2. METHODS

Planning methods uses the IRRO (Inspection, Replace, Repair, and Overhoul) method include collecting data on CSU operational history and component failure, reviewing CSU specifications, formulating damage problems, making a list of components to be handled, predicting component life, predicting spare parts prices, predicting repair costs, predicting duration and maintenance costs for components assembly, maintenance and repair scheduling, estimated total annual costs for the period of 2022 to 2025.

Figure 1. Continuous Ship Unloader/CSU

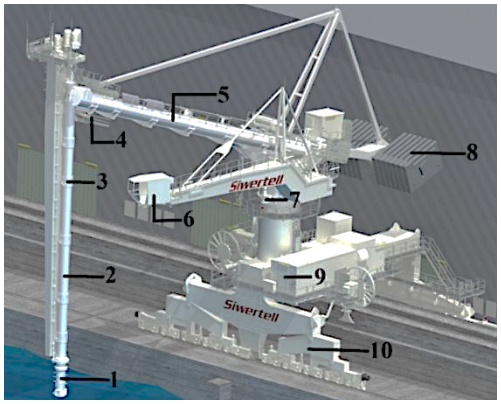
The CSU as the object of maintenance and repair planning is shown in Figure 1 which is marked by an oval line, the material in the hold of the ship in the right side is sucked in through the feeder inlet then followed by a vertical screw conveyor through the horizontal screw conveyor (yellow color) then the material falls through the hopper and the material dust is sucked in by the dust collector at the end of the hopper, so that the material falls on the belt conveyor to be forwarded to the warehouse in the left side.

The CSU specification is shown in Table 1 [12].

Table 1. The CSU Specification [12]

No.	Unit		Description
1	Inlet Feeder		
	Transmission	:	Enclosed oil lubricated gear
	Motor Type	:	Electrical
	Control System	:	Stepless control or automatic mode
	Motor Location	:	On top of vertical conveyor
	Other	:	Overload protection
2	Vertical Arm Conveyor		
	Type	:	VST-640
	Length	:	22 m
	Transmission	:	Enclosed oil lubricated gear
	Motor Type	:	AC-motor
	Control System	:	Direct Start
	Other	:	Speed guard
3	Horizontal Arm Conveyor		
	Type	:	HST-1000
	Length	:	28,75 m
	Transmission	:	Enclosed oil lubricated gear
	Motor Type	:	AC-motor
	Control System	:	Direct Start
4	Hydraulic System		
	Location	:	Main unit on the horizontal arm
	Working Preassure	:	250 bar (max)
	Motor Type	:	AC-motor
	Control System	:	Direct Start
	Insulation	:	No
5	Electrical System		
	Supply Voltage Power	:	6 kV
	Frequency	:	50 Hz
	Voltage On The Ship Unloader		
	Motor Voltage	:	380 V/50 Hz
	Operating Voltage	:	230 V/50 Hz
	Transformer	:	2500 kVA
	Type	:	Dry insulated
	Location	:	In the electrical container
	Power		
	Installed	:	1629 kW
	Largest Motor	:	400 kW

The sections of the CSU are shown in Figure 2 [12].



1	Inlet feeder	6	Operator cabin
2	Vertical arm conveyor	7	Upper turret
3	Intermediate bearing and shaft	8	Counter weight
4	Auxiliary hoist	9	Electrical system
5	Horizontal arm conveyor	10	Travelling beam

Figure 2. Parts of the CSU [12]

3. RESULTS AND DISCUSSION

CSU maintenance is carried out to obtain stable performance by conducting inspection, replace, repair, and overhaul.

Inspection activities to check the cleanliness, good or bad condition of existing components, check whether the existing lubricant/oil/grease is sufficient, insufficient, contaminated or dirty. CSU inspections are carried out every 3-4 months for components and for lubricants, inspections are carried out once a month. Weekly inspections, before and after full retrieval of one hold is carried out by the CSU operator, but by visual inspection and from inside the cabin by checking from the monitor or from the control room. The good synergy between the operator and the maintenance mechanic makes equipment maintenance better.

One such inspection with an example of greasing the end bearing is shown in Figure 3 [12].

Figure 3. Greasing of the end bearing [12]

An example of an inspection of intermediate shaft and screw conveyor is shown in Figure 4 [12].

Figure 4. Inspection of intermediate shaft and screw conveyor [12]

Checking the conveyor screw by hearing or from the sound of the motor that increases the load whether the material coming out is unstable or not suitable, if so, then the horizontal arm conveyor casing is opened to check the clearance between the flight screw and the inside of the vertical arm conveyor casing, in case of overclearance due to friction from the material, then the screw conveyor is immediately replaced with a spare screw conveyor, after that contact the Fabrication Department and report the conveyor screw to be repaired or reconditioned.

Replacement of spare parts according to the predicted component life is shown in Table 1 [12]. The price and lifetime predictions of the CSU components are shown in Table 1 [12]. Indonesian currency unit is Rp which is stated in IDR.

Spare parts are replacement components that are prepared based on the limited life time prediction of components due to the limited nature of the material, the shorter the component's life time, the more spare parts

that must be prepared. The price of spare parts can be predicted based on the purchase note of the same spare parts in the previous period by adding the price related to inflation to the previous purchase period, for example an increase in price of about 4% per year, if inflation is expected (decrease in the value of money due to the influence of the amount of money in circulation is more than required [1] Calculation of the price of spare parts using formula (1).

N = (Initial Price x 4%) + Initial Price (1)

where:

N : Price prediction for the next period
Initial Price: The price of the current/initial period
4% : Inflation per year (as an example)

Predictions of spare parts prices can be obtained from sources including: 1) Purchase notes for spare parts, 2) Information from shops selling or supplying spare parts, 3) Price information from the internet online, 4) Workshop where to order spare parts, and 5) Maintenance planners can make predictions based on the function of components relative to other components [1].

Table 1. Price and Life Time Predictions of CSU Components [12]

No.	CODE	UNIT/PART	PRICE (X1,000 IDR)	LIFE TIME		PRICE PREDICTED/YEAR (X1,000 IDR)				PCS
				HOUR	WEEK	2022	2023	2024	2025	
1	BCSU1-1-IF	Inlet Feeder								
	BCSU1-1-IF-FS	Flange Shaft	70	10,000	178	70	71	71	71	8
	BCSU1-1-IF-HB	Hanger Bearing	90	6,000	107	90	91	91	92	16
	BCSU1-1-IF-UJC	U-Joint Shaft	1,80	6,000	107	1,81	1,82	1,83	1,84	2
	BCSU1-1-IF-P	Pinion	85	6,000	107	85	86	86	87	1
	BCSU1-1-IF-SB	Slewing Bearing	45,00	12,000	214	45,45	45,67	45,90	46,13	1
	BCSU1-1-IF-GB	Gearbox-IF	600,00	15,000	268	606,01	609,04	612,09	615,15	1
2	BCSU1-2-VC	Vertical Arm Conveyor								
	BCSU1-2-VC-SC	Screw Conveyor	75,00	15,000	268	75,75	76,13	76,51	76,89	5
	BCSU1-2-VC-EB	End Bearing	3,50	6,000	107	3,53	3,55	3,57	3,58	2
	BCSU1-2-VC-IBS	Intermediate Bearing and Shaft	78,70	15,000	268	79,48	79,88	80,28	80,68	4
	BCSU1-2-VC-GB	Gearbox-VC	600,00	15,000	268	606,01	609,04	612,09	615,15	1
3	BCSU1-3-HC	Horizontal Arm Conveyor								
	BCSU1-3-HC-SC	Screw Conveyor	75,00	15,000	268	75,75	76,13	76,51	76,89	6
	BCSU1-3-HC-EB	End Bearing	3,50	6,000	107	3,53	3,55	3,57	3,58	2
	BCSU1-3-HC-IBS	Intermediate Bearing and Shaft	78,70	15,000	268	79,48	79,88	80,28	80,68	5
	BCSU1-3-HC-GB	Gearbox-HC	600,00	15,000	268	606,01	609,04	612,09	615,15	1
4	BCSU1-4-DC	Dust Collector								
	BCSU1-4-DC-FB	Fan/Blower	4,50	12,000	214	4,54	4,56	4,59	4,61	1
	BCSU1-4-DC-FB	Filter Bag	12	6,000	107	12	12	12	12	9
5	BCSU1-5-HS	Hydraulic System								

No.	CODE	UNIT/PART	PRICE (X1,000 IDR)	LIFE TIME		PRICE PREDICTED/YEAR (X1,000 IDR)				PCS
				HOUR	WEEK	2022	2023	2024	2025	
	BCSU1-5-HS-HP	Hydraulic Pump								
	BCSU1-5-HS-HP-HP	Pump Hose	3,00	5,000	89	3,03	3,04	3,06	3,07	1
	BCSU1-5-HS-HP-CV	Control Valve	35,00	12,000	214	35,35	35,52	35,70	35,88	1
	BCSU1-5-HS-HP-HF	Hydraulic Filter	1,20	5,000	89	1,21	1,21	1,22	1,23	1
	BCSU1-5-HS-HP-GP	Gear Pump	15,00	12,000	214	15,15	15,22	15,30	15,37	1
	BCSU1-5-HS-HP-HOC	Hydraulic oil cooler	10,00	12,000	214	10,10	10,15	10,20	10,25	1
	BCSU1-5-HS-HP-S	Seal	1,80	5,000	89	1,81	1,82	1,83	1,84	1
6	BCSU1-6-HCI	Hydraulic Cylinder Pendulum								
	BCSU1-6-HCP-S	Seal	2,10	5,000	89	2,12	2,13	2,14	2,15	2
	BCSU1-6-HCP-OR	O ring	1,20	5,000	89	1,21	1,21	1,22	1,23	2
	BCSU1-6-HCP-RP	Piston Rod	15,10	13,000	232	15,25	15,32	15,40	15,48	2
7	BCSU1-7-HCI	Hydraulic Cylinder Luffing								
	BCSU1-7-HCL-S	Seal	2,10	5,000	89	2,12	2,13	2,14	2,15	2
	BCSU1-7-HCL-OR	O ring	1,20	5,000	89	1,21	1,21	1,22	1,23	2
	BCSU1-7-HCL-RP	Rod piston	15,10	13,000	232	15,25	15,32	15,40	15,48	2
8	BCSU1-8-HS	Hydraulic Slewing								
	BCSU1-8-HS-SB	Slewing Bearing	150,00	13,000	232	151,50	152,26	153,02	153,78	1
	BCSU1-8-HS-PSG	Pinion Spur Gear	1,80	6,000	107	1,81	1,82	1,83	1,84	1
	BCSU1-8-HS-HM	Hydraulic Motor	75,00	15,000	268	75,75	76,13	76,51	76,89	1
9	BCSU1-9-AH	Auxiliary Hoist								
	BCSU1-9-AH-WR	Wire Rope	36,00	9,000	160	36,36	36,54	36,72	36,90	90m
	BCSU1-9-AH-H	Hook	13,00	10,000	178	13,13	13,19	13,26	13,32	1
	BCSU1-9-AH-GB	Gearbox-Auxiliary Hoist	600,00	15,000	268	606,01	609,04	612,09	615,15	1
10	BCSU1-9-AH	End Carriage								
	BCSU1-9-AH-IW	Idler Wheel	7,80	15,000	268	7,87	7,91	7,95	7,99	40
	BCSU1-9-AH-GB	Gearbox-EC	200,00	15,000	268	202,00	203,01	204,03	205,05	8
11	BCSU1-9-O	Oil								
	BCSU1-9-O-H46	Hydraulic Oil	5,50	2,000	36	5,55	5,58	5,61	5,63	209l
	BCSU1-9-O-G32	Gearbox Oil	4,90	2,000	36	4,94	4,97	4,99	5,02	209l
	BCSU1-9-O-GFC	Grease	8,20	500	9	8,28	8,32	8,36	8,40	209l

The costs and duration of disassembly and assembly of CSU are shown in Table 2 [12].

Table 2. Cost and Duration of disassembly and assembly of CSU [12]

No.	PART	TECH. LEVEL	DURATION (HR/PART)	COST/HR (X1,000 IDR)			
				2021	2023	2024	2025
1	Inlet Feeder						
	Flange Shaft	SHS	0.5	19	21	22	23
	Hanger Bearing	SHS	0.5	19	21	22	23
	U-Joint Shaft	SHS	0.5	19	21	22	23
	Pinion	SHS	2	19	21	22	23
	Slewing Bearing	3-Year Dipl.	8	21	23	24	25
	Gearbox-IF	SHS	4	19	21	22	23
2	Vertical Arm Conveyor						
	Screw Conveyor	3-Year Dipl.	4	21	23	24	25
	End Bearing	SHSl	2	19	21	22	23
	Intermediate Bearing and Shaft	3-Year Dipl.	3	19	21	22	23
	Gearbox-VC	SHS	4	19	21	22	23
3	Horizontal Arm Conveyor						
	Screw Conveyor	3-Year Dipl.	4	21	23	24	25
	End Bearing	SHS	2	19	21	22	23
	Intermediate Bearing and Shaft	3-Year Dipl.	3	21	23	24	25
	Gearbox-HC	SHS	4	19	21	22	23
4	Dust Collector						
	Fan Blower	SHS	1	19	21	22	23
	Filter Bag	SHS	0.25	19	21	22	23
5	Hydraulic System						
	Hydraulic Pump						
	Hose pump	SHS	1	19	21	22	23
	Control Valve	SHS	1	19	21	22	23
	Hydraulic Filter	SHS	1	19	21	22	23
	Gear Pump	SHS	2	19	21	22	23
	Hydraulic oil cooler	SHS	2	19	21	22	23
	Seal	SHS	1	19	21	22	23
6	Hydraulic Cylinder Pendulum						
	Seal	SHS	2	19	21	22	23
	O ring	SHS	4	19	21	22	23
	Rod piston	SHS	4	19	21	22	23
7	Hydraulic Cylinder Luffing						
	Seal	SHS	2	19	21	22	23
	O ring	SHS	4	19	21	22	23
	Rod piston	SHS	4	19	21	22	23
8	Hydraulic Slewing						
	Slewing Bearing	3-Year Dipl.	168	21	23	24	25
	Pinion Spur Gear	SHS	4	19	21	22	23
	Hydraulic Motor	SHS	4	19	21	22	23
9	Auxiliary Hoist						
	Wire Rope	SHS	4	19	21	22	23
	Hook	SHS	2	19	21	22	23
	Gearbox-Auxiliary Hoist	SHS	3	19	21	22	23
10	End Carriage						
	Idler Wheel	SHS	3	19	21	22	23
	Gearbox-EC	SHS	3	19	21	22	23
11	Oil						
	Hydraulic Oil	SHS	2	19	21	22	23
	Gearbox Oil	SHS	2	19	21	22	23
	Grease	SHS	2	19	21	22	23

Note: SHS: Senior High School

CSU repairs, especially in the reconditioning of screw conveyors, are carried out every 6000 hours or 107 weeks provided that they operate in one day with 1 shift for 8 working hours [12]. The repair work is carried out by the Fabrication Department who has a special duty or a specialist in screw conveyor repair.

The damage that occurs due to erosion of the flight surface due to friction causes the conveyor screw to wear out. The friction that occurs is the friction between the screw conveyor and the material and the casing, because if the material between the flight/blade of screw conveyor and the casing is left alone, the effect will be even greater. The effect of screw conveyor damage is less optimal/efficient in the transportation process. If the friction that occurs is greater, it can cause motor power to be wasted to overcome the friction and a lot of residual material settles on the casing due to not being moved. If this is continued, it can cause more fatal energy wasted because the efficiency of transportation of materials decreases.

Figure 5. Examples of worn screw conveyor blades [12]

The prediction of material prices for CSU repair activities is shown in Table 3 [12].

Table 3. Predictions of material prices for CSU repair activities [12]

No.	PART NAME	PRICE (X1,000 IDR)	PRICE PREDICTION/YEAR (X1,000 IDR)				PCS
			2022	2023	2024	2025	
1	Plate Duplex	250	253	254	255	256	34
2	Electrode E2209	1,500	1,515	1,523	1,530	1,538	4
3	Electrode E8838	1,700	1,717	1,726	1,734	1,743	7
4	Cleanser SKC-S	90	91	91	92	92	2
5	Liquid Penetrant Red SKL	90	91	91	92	92	2
6	Developer SKD-S2	95	96	96	97	97	2

The process of repairing screw conveyors includes the following stages:

1) The cutting of a duplex plate of 16 mm thick with a width of 25 mm using plasma cutting is shown in Figure 6 [12].

Figure 6. Cutting duplex plates with Plasma Cutting [12]

2) Installation of cylinder shock at both ends of the screw conveyor shaft which serves as a support for the bearings/rollers is shown in Figure 7 [12].

Figure 7. Installation of cylinder shock at both ends of the screw conveyor shaft as a support for the bearing/roller [12]

3) Reduction of the flight screw conveyor to ϕ 585 mm with a lathe is shown in Figure 8 [12].

Figure 8. Reducing the diameter of the flight screw conveyor to ϕ 585 mm with a lathe [12]

4) Coating flight screw conveyor with coating material from duplex plate with a thickness of 16 mm and a width of 25 mm using welding with an electrode E22209 which follows the Welding Procedure Standard. The welding is carried out along the flight screw conveyor on 2 sides which a process called layding/lining is shown in Figure 9 [12].

Figure 9. Coating flight screw conveyor with coating material from duplex plate [12]

5) After cleaning from the crust, the duplex plate is then overlaid or coated on both sides of the duplex plate using the E8838 electrode to exceed ϕ635 mm. The electrode used is similar to the E2209 electrode, but has a higher hardness value, so that the flight screw conveyor surface becomes harder [12].
6) The finishing process of a flight screw conveyor with a turning using a 6000 mm lathe, the diameter of the flight screw conveyor turned into 635 mm is shown in Figure 10 [12].

Figure 10. The finishing process of a flight screw conveyor with a turning using a 6000 mm lathe [12]

7) The screw conveyor is carried out by a balancing process with a balancing machine to balance its rotation when used and to minimize vibration.
8) Visual check, dye penetrant test, and dimensional check to ensure the quality of repairs, if the screw conveyor does not meet the requirements, it is repaired and if it meets the requirements, then the screw conveyor shown in Figure 11 [12] is ready to be installed into the CSU.

Figure 11. Screw conveyor after repaired [12]

Overhaul at CSU is carried out every 15,000 hours or 268 weeks provided that it has been operating for one day with 1 shift for 8 hours [12]. Some large and expensive components such as gearbox, motor, and slewing bearings replacement can take up to 2 weeks to take apart with additional overtime. Since CSU maintenance and repair planning has a period limit of 4 years or 11,648 hours or 208 weeks while the overhaul schedule is 15,000 hours or 270 weeks, the overhaul activity does not go into details and cost estimates.

The CSU has a loading/unloading capacity of up to 1000 tons per hour which makes CSU the backbone of loading/unloading activities, however, with the high utility of CSU, the number of damage also increases, even CSU often experiences a breakdown [13].

CSU 1 experienced a breakdown of 52 times from November 2015 to January 2016, so it is necessary to analyze the damage data for the formulation of its maintenance policy by using two alternative policy models, namely repair maintenance policy and preventive maintenance policy. From the calculation results, it is found that the maintenance policy is better for preventive maintenance which has an average machine runtime/period and a smaller repair cost compared to the maintenance repair policy, which is carried out every 7 weeks at a cost of IDR 4,291,241.00 [14].

Using the CSU greatly affects the productivity of loading and unloading activities, because the tonnage yield achieved when unloading using the CSU tool is greater than using other tools, and the unloading is completed faster [15].

An important element in the electric steam power plant (*PLTU*) is the Ship Unloader (SU) as the main loading and unloading facility for coal fuel from the barge to the stockpile. SU is only treated after damage occurs which is analyzed for treatment planning using the Markov Chain method. The Markov Chain results show that the cost of preventive maintenance at moderate status is decreasing by 84.40% from IDR 1,505,211.50 to IDR 234,820.77 for SU 1 and the cost of preventive maintenance in mildly damaged status decreased by 86.22% from IDR 1,019,642. 35 to IDR 137,893.05 for SU 2 [16].

An example of the results of making a CSU Maintenance and Repair Schedule in the 2023 period is shown in Table 4 [12].

Table 4. Example of CSU Maintenance and Repair Schedule in the 2023 Period [12]

No.	COMPONENTS AND MAIN PARTS	WEEK OF THE YEAR OF 2023																											
		JAN			FEB		MAR		APR	MAY			JUNE				JUL		AUG			SEP			OCT		DEC		
		1	3	4	8	9	10	13	14	18	19	21	22	23	24	25	29	30	31	33	34	35	36	38	39	40	49	50	52
1	Inlet Feeder																												
	Flange Shaft				I								I										I					I	
	Hanger Bearing		Rc		I								I										I					I	
	U-Joint Shaft		Rc		I								I										I					I	
	Pinion		Rc		I								I										I					I	
	Slewing Bearing				I								I										I					I	
	Gearbox-IF				I								I										I					I	
2	Vertical Conveyor																												
	Screw Conveyor		Rr		I								I										I					I	
	End Bearing		Rc		I								I										I					I	
	Intermediate Bearing and Shaft		Rr		I								I										I					I	
	Gearbox-VC				I								I										I					I	
3	Horizontal Conveyor																												
	Screw Conveyor		Rr		I								I										I					I	
	End Bearing		Rc		I								I										I					I	
	Intermediate Bearing and Shaft		Rr		I								I										I					I	
	Gearbox-HC				I								I										I					I	
4	Dust Collector																												
	Fan				I								I										I					I	
	Filter Bag		Rc		I								I										I					I	
5	Hydraulic System																												
	Hydraulic Pump																												
	Hose pump				I								I										I					I	
	Control Valve				I								I										I					I	
	Hydraulic Filter				I								I										I					I	
	Gear Pump				I								I										I					I	
	Hydraulic oil cooler				I								I										I					I	
	Seal				I								I										I					I	
6	Hydraulic Cylinder Pendulum																												
	Seal			I									I													I			
	O ring			I									I													I			
	Rod piston			I									I													I			
7	Hydraulic Cylinder Luffing																												
	Seal			I									I													I			
	O ring			I									I													I			
	Rod piston			I									I													I			
8	Hydraulic Slewing																												
	Slewing Bearing			I									I													I			
	Pinion Spur Gear		Rc	I									I													I			
	Hydraulic Motor			I									I													I			
9	Auxiliary Hoist																												
	Wire Rope		Rc		I								I										I					I	
	Hook				I								I										I					I	
	Gearbox-Auxiliary Hoist				I								I										I					I	
10	End Carriage																												
	Idler Wheel			I									I													I			
	Gearbox-EC			I									I													I			
11	Oil																												
	Hydraulic Oil		I	Rc		I			I		I				I		I				I				I	Rc		I	
	Gearbox Oil		I	Rc		I			I		I				I		I				I				I	Rc		I	
	Grease			Rc				Rc					Rc						Rc							Rc	Rc		

Remarks: I: inspection, Rc: Replace, Rr: repair, O: Overhoul

In Table 4, due to the limited journal space, columns that do not have activity content are deleted to only display the column containing the activity contents.

From the CSU maintenance and repair schedule planning for the period 2022 to 2025 only shows an example for 2023 period where there are screw conveyor repair activities.

The ratio between maintenance cost and profit is shown in Table 5 [12].

Table 5. The ratio between maintenance costs and profits [12]

Year	Maintenance Cost (IDR)	Annual Profit (Idr)	Maintenance/Profit Ratio (%)
2022	136,873	26,829,682	0.51
2023	335,986	27,336,275	1.22
2024	160,687	27,883,000	0.57
2025	464,733	28,440,660	1.63

4. CONCLUSION

The results of planning in the form of a maintenance and repair schedule for the period of 2022 to 2025; maintenance and repair costs for the years 2022 to 2025 are IDR 136,873,000; IDR 335,986,000; IDR 160,687,000; and IDR 464,733,000; and the ratio between maintenance costs to profit for the years 2022 to 2025 is 0.51; 1.22; 0.57; and 1.63 respectively which means the machine is still fit for use without the need for refurbishment because it is still prospective.

5. ACKNOWLEDGEMENT

The authors gratefully Head of the Fabrication Department and Port Management Department (Lolapel) of PT. Petro Kimia Gresik for the support of information and data related to maintenance and repair planning for the Continuous Ship Unloader (CSU).

6. REFERENCES

[1] S. Hadi, *Maintenance and Repair for Industrial Machinery*, Yogyakarta: Andi Publisher, 2019.
[2] A.M. Zainuri, *Material Handling Equipment*, Yogyakarta: Andi Publisher, 2008.
[3] H. Rarindo, *Basic Principles of Work Safety*, Malang: Polinema Press, 2019.
[4] F. Kurniawan, *Industrial Maintenance Management, Engineering and Applications: Implementation of Total Productive Maintenance, Preventive Maintenance and Reliability Centered Maintenance*, Yogyakarta: Graha Ilmu, 2013.
[5] J. X. Wang, *Lean Manufacturing Bussiness Bottom-Line Based*, USA: CRC Press, Taylor and Francis Group, 2011,
[6] E. I. Basri, I. H. Abdul Razak, H. Ab-Samat, S. Kamaruddin, "Preventive maintenance (PM) planning: a review," *J. of Quality in Maint. Eng.*, vol. 23, no. 2, pp. 114-143, 2017.
[7] A. B. Mabrouk, A. Chelbi, M. Radhoui, "Optimal imperfect preventive maintenance policy for equipment leased during successive periods," *Int. J. of Prod. Research*, vol. 54, no. 17, pp. 5095-5110, 2016.
[8] M. N. Darghouth, D. Ait-Kadi, A. Chelbi, "Joint reliability based design and periodic preventive maintenance policy for systems sold with warranty," *J. of Qua. in Maint. Eng.*, vol. 22, no. 1, pp. 2-17, 2016.
[9] D. D. Adhikary, G. K. Bose, D. K. Jana, D.Bose, S. Mitra, "Availability and cost-centered preventive maintenance scheduling of continuous operating series systems using multi-objective genetic algorithm: A case study," *Qua. Eng.*, vol. 28, no. 3, pp. 352-357, 2015.
[10] M. Nourelfath, N. Nahas, M. Ben-Daya, "Integrated preventive maintenance and production decisions for imperfect processes," *Reliab. Eng. & Sys. Safety*, vol. 148, pp. 21-31, 2016.
[11] C. Stenström, P. Norrbin, A.Parida, U.Kumar, "Preventive and corrective maintenance-cost comparison and cost-benefit analysis." *Struc. and Infrastr. Eng.*, vol. 12, no. 5, pp. 603-617, 2015.
[12] A. A. Azis, "Planning for Maintenance and Repair of Siwertell Continuous Ship Unloader Capacity 1,000 Tons/Hour for the Period 2021 until 2025", *Final Project RME650, DIII Mech. Eng. Study Program,* Mech. Eng. Dept, State Polytechnics of Malang, 2020.
[13] I.R. Pramudya, "Maintenance System Planning Using Reliability Centered Maintenance (RCM) Method on Screw Conveyor Continous Ship Unloader-Case Study CSU 02 Dermaga Utama P.T. XY," *Undergraduate Thesis*, Sepuluh Nopember Institute of Technology, Surabaya, 2020.
[14] T. I. Khota and R. Purwaningsih, "Policy Analysis of Continous Ship Unloader 1 Machine Maintenance P.T. Petrokimia Gresik," *Proceeding of National Seminar IENACO-2017*, Industrial Engineering Study Program, Faculty of Engineering, Diponegoro University, Semarang.
[15] M. E. Pratama, E. Pujo A. A., I. Novianto, "Effect Utilization of Continuous Ship Unloaders Against Productivity of Loading and Unloading Dry Bulk (Phospate Rock) at Petrokimia Gresik Special Port," *J. of Shipping and Port App.*, vol. 7, no. 2, pp. 92-104, 2017.
[16] D. P. K. Ariel, "Ship Unloader Maintenance Planning with the Markov Chain Method to Prevent Work Accidents and Reduce Maintenance Costs at PLTU," *Final Project,* State Marine Polytechnic of Surabaya, 2019.