Analysis of Scissorlift Unit Maintenance Strategy With Failure Mode and Effect Analysis (FMEA) Method and Reliability Centered Maintenance Method at PT. XYZ

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Abstract.
PT. XYZ rents out heavy equipment, particularly scissor lifts, so unit readiness and reliability determine service quality. Maintenance is still dominated by corrective actions, which leads to repetitive failures and unit downtime. This study maps the critical failure potential of scissor lift units and develops a risk-based maintenance strategy by combining Failure Mode and Effect Analysis (FMEA) with Reliability Centered Maintenance (RCM). FMEA was used to identify 20 failure modes across four subsystems (hydraulic, electrical, mechanical and structural, and drive) and to calculate the Risk Priority Number (RPN) from Severity, Occurrence and Detection scores obtained through discussion with mechanics. The FMEA results were then processed with RCM decision logic to determine failure consequence categories and suitable maintenance tasks. The highest RPN was found in the hydraulic cylinder seal (315), followed by the pivot pin (280), the hydraulic pump and control valve (240 each), and the bearing/bushing (210). The hydraulic subsystem accounts for 36.3% of the total RPN. The RCM analysis places 6 components under safety consequences, 2 under hidden protective functions (limit switch and emergency stop), and 12 under operational consequences. The proposed strategy combines on-condition inspection, scheduled restoration and discard, and function tests of safety components before units are rented out. A framework for calculating maintenance intervals and reliability from time-to-failure (TTF) and time-to-repair (TTR) data is also provided for use once failure history is fully documented.
***Keywords** : Maintenance FMEA, Reliability Centrad Maintenance and Sciccorlift Rsik Priority Number.*

I. INTRODUCTION

Increasingly fierce industrial competition demands that companies maintain operational continuity through effective asset management and maintenance systems. In heavy equipment rental companies, service quality is significantly influenced by the reliability and availability of rental units. A unit that breaks down while in use disrupts customer operations, increases repair costs, and erodes trust in the company (Noor, 2022; Assauri, 2025).

PT. XYZ provides rental, sales, and maintenance services for Mobile Elevated Work Platforms (MEWP), including scissor lifts and boom lifts. The company has implemented maintenance based on Standard Operating Procedures (SOPs) which include periodic inspections, preventive maintenance, replacement of components that have reached their service life, and repairs when damage occurs. However, observations during the internship from February 9 to April 30, 2026, showed that some units still experienced repeated damage even though they had been maintained according to procedures, and some damage was only discovered after the unit's performance decreased or the unit could not be operated. This condition makes maintenance dominated by corrective maintenance with impacts such as increased downtime, reduced rental-ready units, and increased repair costs.

*Failure Mode and Effect Analysis (FMEA)*FMEA is often used to identify failure modes, causes, and impacts, and prioritize repairs based on the Risk Priority Number (RPN) (Hanif et al., 2015; Yazdad et al., 2022). However, FMEA stops at determining risk priorities. FMEA does not yet answer the most appropriate maintenance actions for each component and when they need to be taken. This gap can be filled by Reliability-Centered Maintenance (RCM), a method that utilizes facility reliability information to obtain effective, efficient, and easy-to-implement maintenance strategies (Kurniawan, 2013, in Prastiawan et al., 2021). Prastiawan et al. (2021) showed that the RCM stage, initiated by FMEA, can determine critical components, maintenance intervals, and reliability improvements in multiplex sanding machines.

Previous studies have applied FMEA to production processes, quality control, and occupational safety (Arifianto & Briliana, 2021; Kuncoro et al., 2022; Hardiansah et al., 2024), while studies combining FMEA and RCM for scissor lifts in heavy equipment rental companies are still limited. Scissor lifts are high-altitude work equipment, so functional failures not only cause economic losses but also safety risks. Based on this

description, this study aims to (1) identify scissor lift component failure modes, (2) determine risk priorities based on RPN values, and (3) develop an RCM-based maintenance strategy to reduce recurring damage and downtime at PT. XYZ.

BASIC THEORY

A. Maintenance

Maintenance is a series of planned and unplanned activities to maintain or restore equipment to its standard operating condition (Assauri, 2025). Good maintenance reduces the frequency of breakdowns, extends component lifespan, and improves operational effectiveness (Mustaqim et al., 2022). Maintenance is generally divided into preventive maintenance (prevention before damage occurs), predictive maintenance (condition monitoring to identify problems before they develop), and corrective maintenance (repairs after damage occurs) (Hadi, 2019, in Prastiawan et al., 2021).

B. Scissor Lift Characteristics

*Scissor lift*is a MEWP that lifts workers and materials vertically using a scissor arm mechanism (pantograph). The unit consists of four subsystems: (1) hydraulic, which generates lifting force through a pump, control valve, hose, and cylinder; (2) electrical, which includes a battery, charger, controller, cables, and safety sensors; (3) mechanical and structural, which includes the scissor arm, hinge pin, frame, and platform fence; and (4) drive, which includes the motor, brakes, gearbox, and wheels (Pratama, 2024). The reliability of the unit is influenced by the condition of each subsystem, so damage to one main component can reduce performance and increase the risk of work accidents.

C. *Failure Mode and Effect Analysis (FMEA)*

*FMEA*is a structured method for identifying and preventing potential failures in a system, process, or service, and prioritizing repairs based on the RPN (Yazdad et al., 2022). The RPN value is obtained by multiplying three parameters: Severity (S), Occurrence (O), and Detection (D), each on a scale of 1 to 10:

$$RPN = S \times O \times D$$

*Severity*assesses the severity of the failure impact, Occurrence assesses the frequency or likelihood of the failure cause occurring, and Detection assesses the ability of current controls to detect failures before they have an impact (a value of 10 means undetected). The higher the RPN, the higher the priority of handling (Prastiawan et al., 2021).

D. *Reliability Centered Maintenance (RCM)*

*RCM*is a maintenance method based on facility reliability. According to Prastiawan et al. (2021), the implementation steps include (1) FMEA analysis, (2) analysis of the time interval between failures (time to failure (TTF) and time to repair (TTR), (3) identification of data distribution, (4) calculation of mean time to failure (MTTF) and mean time to repair (MTTR) parameters, and (5) determination of maintenance intervals. Reliability itself is defined as the probability of a component or system performing its function for a certain period under specified operating conditions (Sayuti, 2013, in Prastiawan et al., 2021).

In addition to the quantitative approach, RCM has a decision logic for selecting maintenance tasks based on the consequences of failure. Failures are grouped into safety consequences, operational consequences, and hidden failures in protective devices. From these groups, one of the following tasks is selected: scheduled on-condition inspection, scheduled restoration, scheduled discard, scheduled failure-finding, or run-to-failure if the consequences are acceptable (Moubray, 1997).

II. RESEARCH METHOD

This research is descriptive qualitative with quantitative processing in the form of RPN calculation. The object of the research is the scissor lift unit in the Mechanic division of PT. XYZ. Data were collected through direct observation in the workshop, structured interviews with the Mechanic Supervisor and Senior Mechanic, and company service report documentation. Components are grouped into four subsystems: hydraulic (lift cylinder, valve, hose, pump, oil), electrical (battery, charger, joystick, cable, limit switch, emergency stop), mechanical and structural (scissor arm, hinge pin, bearing/bushing, platform fence, frame), and drive (motor, brake, gearbox, solid tire). The analysis was conducted in four stages that combine FMEA

and RCM:

1. **FMEA preparation.**Failure modes, causes, and effects were identified for each component. The S, O, and D values were determined through discussions with branch mechanics using a scale of 1–10 (Irawan, 2025), then the RPN was calculated using equation (1) and sorted from the highest.
2. **Criticality classification.**Components are divided into four levels based on RPN: very critical (RPN ≥ 250), critical (200–249), medium (150–199), and low (< 150). These limits were set by researchers to ensure the distribution of RPN values was proportional and could be adjusted by the company.
3. **Determination of RCM consequence categories.**Failures with a Severity ≥ 9 that directly impact the operator are categorized as safety consequences. Protection devices (limit switches and emergency stops), whose failures are only apparent when needed, are categorized as hidden functions. Failures with a Severity ≤ 8 are categorized as operational consequences.
4. **Selection of maintenance tasks.**Based on the consequence category, wear pattern causing failure, and proposed improvements from the FMEA results, the appropriate RCM task type is selected for each component, then grouped into an integrated maintenance program.

Numerical determination of maintenance intervals using the quantitative RCM method requires documented TTF and TTR data (Prastiawan et al., 2021). Such data were not yet available in complete time series form during the internship period, so this section serves as a calculation framework in subsection IV.E.

III. RESULTS AND DISCUSSION

A. Identify Failure Modes and RPN Values

The results of identification and brainstorming with [Supervisor Mechanic and senior mechanics] found 20 failure modes in four subsystems: five in hydraulic, six in electrical, five in mechanical and structural, and four in drive. The dominant causes are component wear due to service life, irregular lubrication, dust and oil contamination in the hydraulic system, and suboptimal periodic inspections. The Severity (S), Occurrence (O), and Detection (D) values were determined based on the results of joint consensus [related parties] using a scale of 1-10, then the RPN was calculated using Equation (1). Table 1 presents 11 failure modes with RPN ≥ 150 (very critical to medium level), while all 20 failure modes are presented in Appendix A.

Table 1.S, O, D, RPN Values, and Failure Mode Criticality Levels

No	Component	Failure mode	S	O	D	RPN	Ranking	Level · Subsystem
1	*Hydraulic Cylinder*	Leaking cylinder seal	9	7	5	315	1	Very critical · Hydraulic
2	*Pivot Pin*	Worn pin	8	7	5	280	2	Very critical · Mechanical & structural
3	*Hydraulic Pump*	Pump pressure decreases	8	5	6	240	3	Critical · Hydraulic
4	*Control Valve*	Stuck valve	8	5	6	240	3	Critical · Hydraulic
5	*Bearing/Bushing*	Bearing wear	6	7	5	210	5	Critical · Mechanical & structural
6	*Limit Switch*	Sensor not working	10	4	5	200	6	Critical · Electric
7	*Hydraulic Hose*	Hydraulic hose leaking or broken	8	8	3	192	7	Intermediate · Hydraulic
8	*Wiring Harness*	Broken cable / short circuit	8	4	6	192	7	Intermediate · Electric
9	*Joystick Controller*	Joystick not responding	9	5	4	180	9	Intermediate · Electric
10	*Hydraulic Oil*	Oil is contaminated or reduced	7	8	3	168	10	Intermediate · Hydraulic
11	*Brake System*	The brake system is not optimal	10	5	3	150	11	Intermediate · Driver
12	*Drive Motor*	Motor loses power	6	4	5	120	12	Low · Driver
13	*Battery*	Battery voltage drops	7	8	2	112	13	Low · Electric
14	*Solid Tire*	Tires are worn out	7	8	2	112	13	Low · Driver
15	*Gearbox*	Gear wear	6	3	6	108	15	Low · Driver
16	*Scissor Arm*	Scissor arm cracked or deformed	10	2	4	80	16	Low · Mechanical & structural

17	*Chassis Frame*	Cracked frame	10	2	4	80	16	Low · Mechanical & structural
18	*Battery Charger*	Charging is not optimal	6	4	3	72	18	Low · Electric
19	*Guardrail Platform*	*Guardrail*loose	9	4	2	72	18	Low · Mechanical & structural
20	*Emergency Stop*	Emergency button fails to work	10	3	2	60	20	Low · Electric

Source: FMEA data processing results (2026). Values are arranged from the highest RPN; the same rank is given to the same RPN.

Table 1 shows that the hydraulic cylinder seal has the highest RPN (315) due to a combination of high Severity (9), high Occurrence (7), and weak detection (5). Seal leaks are difficult to detect early because they are only visible when the pressure has decreased, while the impact is the platform lowering itself which risks causing work accidents. Pivot pins are ranked second (280) due to frequent wear (O = 7) and less easily detected looseness (D = 5). Hydraulic pumps and control valves both scored 240, and

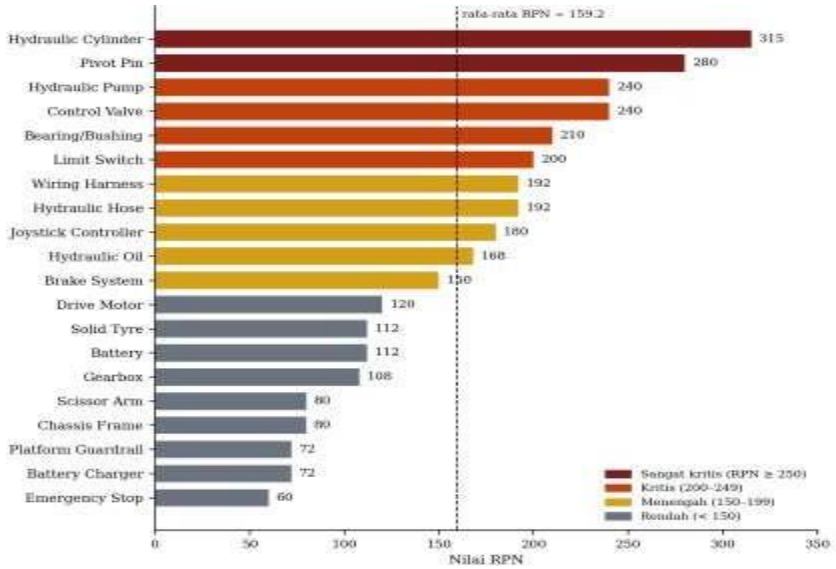


Fig. 1. Scissor Lift Unit Failure Mode RPN Rating

both were affected by the quality and schedule of hydraulic oil changes. Fifth place was taken by bearings/bushings (210). The top five components contributed 40.4% of the total RPN, so concentrating maintenance resources on this group had a significant impact on reducing risk. Figure 1 shows the distribution of RPN across all failure modes against the average RPN of 159.2.

B. Risk Analysis per Subsystem

The aggregated RPNs per subsystem in Table 2 show that the hydraulic subsystem is the source of the greatest risk. This subsystem has a total RPN of 1,155 (36.3%) and an average RPN of 231.0, significantly higher than other subsystems. This is consistent with the unit's operating conditions in a dusty industrial environment, which accelerates seal wear and contaminates hydraulic oil. The electrical subsystem ranks second in terms of total RPNs (816; 25.6%), but its average (136.0) is lower than the mechanical and structural subsystem (144.4) due to its greater number of components. The drive subsystem has the lowest risk (490; 15.4%).

Table 2. Recapitulation of RPN per Subsystem

Subsystem		**Number of modes**	**Total RPN**	**Average RPN**	**Contribution**	**Highest RPN**
Hydraulic		5	1,155	231.0	36.3%	Hydraulic Cylinder (315)
Electric		6	816	136.0	25.6%	Limit Switch (200)
Mechanical & structural		5	722	144.4	22.7%	Pivot Pin (280)
Driver		4	490	122.5	15.4%	Brake System (150)
Total		**20**	**3,183**	**159.2**	**100%**	—

Source: Data processing results (2026).

One important note in reading RPNs is that their multiplication can hide components that are highly impactful but rarely fail. The emergency stop (RPN 60), scissor arm (80), and chassis frame (80) are in the

low level, even though all three have a Severity of 10. Therefore, determining maintenance actions should not be based solely on the RPN rating. Consideration of failure consequences, as done in the RCM analysis in the following subsection, needs to be added.

C. RCM Analysis: Consequence Categories and Maintenance Task Selection

The FMEA results are forwarded to the RCM decision logic. Based on the criteria in the methodology section, six components include safety consequences (cylinder seal, joystick, brake, scissor arm, guardrail, and frame), two components include hidden protection functions (limit switch and emergency stop), and twelve components include operational consequences. For safety consequences and hidden functions, a run-to-run strategy is used.

*failure*unacceptable, requiring preventive action. For operational consequences, actions are selected based on the failure pattern. Components damaged by wear and tear are handled with scheduled repair or replacement, while components whose condition can be measured are handled with condition-based inspections. Table 3 summarizes the results.

Table 3.RCM-Based Maintenance Consequence and Task Categories

No	Components (RPN)	Consequence	RCM Tasks	Maintenance actions	Time
1	Hydraulic Cylinder (315)	Safety	On-condition + scheduled discard	Inspectionleak and platform drop test; replace seals before the service life limit; keep the cylinder rod clean	re-ship; PM; shelf life
2	Pivot Pin (280)	Operational	On-condition + restoration + discard	Scheduled lubrication; measure clearance; replace pins and bushings if they exceed tolerance.	PM; condition
3	Hydraulic Pump (240)	Operational	On-condition + restoration	Test the pump pressure; change the oil and clean the filter at regular intervals.	PM
4	Control Valve (240)	Operational	On-condition + restoration	Test valve function; clean system; replace contaminated oil.	PM
5	Bearing/Bushing (210)	Operational	Restoration + on-condition + discard	Regular lubrication; check for wear; replace before serious damage	PM; condition
6	Limit Switch (200)	idden (protection)	Failure-finding + discard	Test sensor function before unit delivery; replace abnormal sensors.	Pre-ship
7	Hydraulic Hose (192)	Operational	On-condition + discard	Check for cracks, leaks, and friction; replace hoses that show signs of damage.	Daily; PM
8	Wiring Harness (192)	Operational	On-condition	Inspect cables and connectors; clean up any rubbing lines; replace damaged insulation.	PM
9	Joystick Controller (180)	Safety	On-condition(function test) + discard	Test response before use; clean; replace if damaged.	owned; pre-shipped
10	Hydraulic Oil (168)	Operational	Discard + on-condition	Change oil and filter as scheduled; keep tank clean	PM
11	Brake System (150)	Safety	On-condition + restoration + discard	Measure the thickness of the brake pads; adjust the brakes; replace worn components.	Pre-ship; PM
12	Drive Motor (120)	Operational	On-condition	Measure the current and condition of the motor; clean the dust.	PM
13	Battery (112)	Operational	On-condition + discard	Check voltage; ensure normal charging; replace battery at end of life	Daily; PM
14	Solid Tire (112)	Operational	On-condition + discard	Check tire thickness before use; replace if below the minimum limit	Pre-used
15	Gearbox (108)	Operational	On-condition + restoration	Check oil and lubrication; replace worn gears.	PM
16	Scissor Arm (80)	Safety	On-condition (structural inspection)	Visual inspection for cracks and periodic structural testing; stop the unit if cracks are found.	PM; periodic

17	Chassis Frame (80)	Safety	On-condition(structural inspection)	Inspect the frame; repair cracks according to welding procedures or replace parts.	PM; periodic
18	Battery Charger (72)	Operational	On-condition(light)	Check output; clean connector; replace if not within specifications.	PM
19	Guardrail Platform (72)	Safety	On-condition	Check and tighten bolts; replace any deformed components.	owned; pre-shipped
20	Emergency Stop (60)	idden (protection)	Failure-finding + discard	Test button functionality before unit is shipped; replace if malfunctioning.	Pre-ship

Source: Author's analysis based on RPN, RCM consequence categories, and proposed FMEA improvements (2026). PM = periodic preventive maintenance.

Several key findings emerge from Table 3. First, protection components such as limit switches and emergency stops require failure-finding because their failures are not apparent until they are needed. A better approach is to make functional testing a mandatory checklist item before the unit is shipped to the customer. Second, components with low RPN but significant safety consequences (scissor arms, frames, guardrails, emergency stops) remain in the mandatory maintenance program, so the strategy is not limited to RPN ratings alone. Third, most hydraulic and mechanical failures are age-related and wear-related, so a combination of lubrication, oil and filter changes, and seal or pin replacement based on service life is more effective than waiting for failure.

D. Integrated Maintenance Strategy

Based on the FMEA and RCM results, a maintenance strategy for the scissor lift unit is proposed in four layers:

- **Daily and pre-shipment inspections.**A structured checklist for hydraulic components (hoses, cylinder leaks), safety systems (emergency stop, limit switch, guardrail, joystick), brakes, tires, and battery is provided before the unit is operated or rented. This layer covers safety-related components and hidden functions.
- ***Preventive maintenance*periodically.**Pivot pin and bearing/bushing lubrication, hydraulic oil and filter changes, pump pressure tests, control valve function tests, cable inspections, and brake and gearbox checks. Initially, intervals follow manual recommendations and company standard operating procedures.
- **Age and condition based replacement.**Cylinder seals, hoses, pins, bearings, tires, and batteries are replaced when they approach their service life or when measurement results exceed tolerance limits, not after they fail.
- **Documentation of treatment history.**Each failure is recorded, including the time the failure started, the time the repair was completed, the components replaced, and the unit's operating hours. These records form the basis for calculating the TTF and TTR, allowing maintenance intervals to be calculated from data, not just estimates.

This strategy aligns with the findings of Prastiawan et al. (2021), who showed that scheduled preventive maintenance on critical components can improve system reliability. In that study, the reliability of the pneumatic system increased from 85% to 92% after preventive maintenance. In this study, a similar effect is expected for the hydraulic subsystem, which contributes most to risk, but the extent of the reliability improvement will only be evident after collecting failure data before and after the strategy implementation.

E. Maintenance Interval and Reliability Calculation Framework

In order to determine the maintenance interval quantitatively as in Prastiawan et al. (2021) and Syahabuddin (2019), the following steps are carried out for very critical and critical components (cylinder seals, pivot pins, pumps, control valves, and bearings/bushings) after the TTF and TTR data are collected.

(1) Data distribution.*TTF*and TTR from the crash logs were fit against exponential, lognormal, and Weibull distributions. The selected distribution was the one with the largest index of fit (closest to 1), then validated with a goodness-of-fit test. The Weibull parameters, namely shape (β) and scale (θ), were obtained from linear regression on the Weibull plot.

(2) *MTTF*and MTTR.For the Weibull distribution:

$$MTTF = \theta \cdot \Gamma(1 + 1/\beta) \quad (2)$$

The reliability of a component at operating time t is calculated by:

$R(t) = exp[– (t/\theta)\beta]$ (3)

(3) Optimal maintenance interval. Following Syahabuddin (2019) in Prastiawan et al. (2021), the optimal examination frequency per month and maintenance interval are calculated by:

$n = \sqrt{(k \cdot i / \mu)}$ (4)

$tp = working\ hours\ per\ month / n$(5)

where k is the average number of defects per month, μ is the repair rate (1/average repair time), i is the inspection rate (1/average inspection time), n is the optimal inspection frequency per month, and t

(4) *Downtime*and availability.Once the interval is set, downtime and availability are calculated by D(n) = k/(μ·n) + 1/(i·n) and A = (1 – D(n)) × 100%, then the reliability before and after applying the interval is compared using equation (3).

This framework is intentionally left out of figures because complete TTF and TTR data for PT. XYZ's scissor lift units are not yet available. Further research will require collecting at least several months to a year of damage data to ensure the resulting interval and reliability figures truly represent field conditions.

IV. CONCLUSION AND SUGGESTION

Conclusion

Based on the research results, the following conclusions can be drawn.

1. An FMEA analysis identified 20 failure modes across four scissor lift unit subsystems. The dominant causes were wear and tear, inadequate lubrication, hydraulic system contamination, and suboptimal maintenance.
2. The highest RPN value was found in the hydraulic cylinder seal (315), followed by the pivot pin (280), the hydraulic pump and control valve (240), and the bearing/bushing (210). The hydraulic subsystem contributed 36.3% of the total RPN and was the top maintenance priority.
3. The RCM analysis categorizes six components into safety consequences, two components into hidden protection functions, and twelve components into operational consequences. Components with safety consequences must still be maintained even if their RPN is low, such as emergency stops, scissor arms, and frames.
4. The proposed maintenance strategy consists of daily and pre-delivery inspections, periodic preventive maintenance, age- and condition-based replacement, and documentation of maintenance history as a basis for calculating TTF and TTR-based intervals.

Suggestion

1. Companies are advised to implement daily and pre-delivery checklists, schedule preventive maintenance on the highest RPN components, and systematically manage maintenance records (breakdown time, repair completion time, replaced components).
2. Further researchers are advised to use TTF and TTR data over a longer period to calculate maintenance intervals and reliability with quantitative RCM, involve more experts in S, O, and D assessments, and compare RPN and reliability values before and after strategy implementation

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