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Root Cause Analysis Implementation to Improve Tissue Mill Automation System Availability in a Mill of the Biggest Indonesia Pulp Paper Industry: A Systematic Literature Review Approach

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ABSTRACT: Increasing rivalry enforces Indonesia pulp paper industry to focus on competitive products in the market and the choice is to develop a Tissue Mill which is equipped with an automation system that has less manpower but require high availability that ensures production runs continuously. The minimum target for the availability of automation systems is 99.95%, which since commissioning in 2019 has not been reached on average per year until April 2021. Analysis of system failures that causing downtime was conducted. Analysis by comparing similar cases in various literatures and references as well for corrective actions and summarize suggested improvements to reduce downtime possibility in order to obtain 99.95% availability or even higher.

KEYWORDS: Root cause analysis, Availability, Downtime, Distributed Control System, Automation

1. INTRODUCTION

1.1 General

Based on McKinsey report in 2019 [1], pulp & paper industry began to enter digital revolution. Applying digital technology in production process requires expensive investment. However, reduction in total costs will eventually be achieved, in case of pulp & paper industry is estimated to reach 15%.

In general, automation systems implemented in every kind of industry must go through an assessment stage before an appropriate digital technology is decided, and the same applies to pulp & paper industry particularly at tissue mill system that has less manpower hence requires high availability of the automation system for 24 hours 7 days per week expectation. The automation system at the jumbo-roll tissue factory (or commonly called tissue mill) located in Riau province successfully passed commissioning in 2019 with the latest ABB brand DCS (Distributed Control System) with lifecycle up to 20 years.

On the spread-sheet data taken from maintenance check-sheet of the Tissue Mill, it was noted that the target availability 99.95% value had not been achieved during the first year of production after commissioning and start-up of the factory (see Fig. 1).

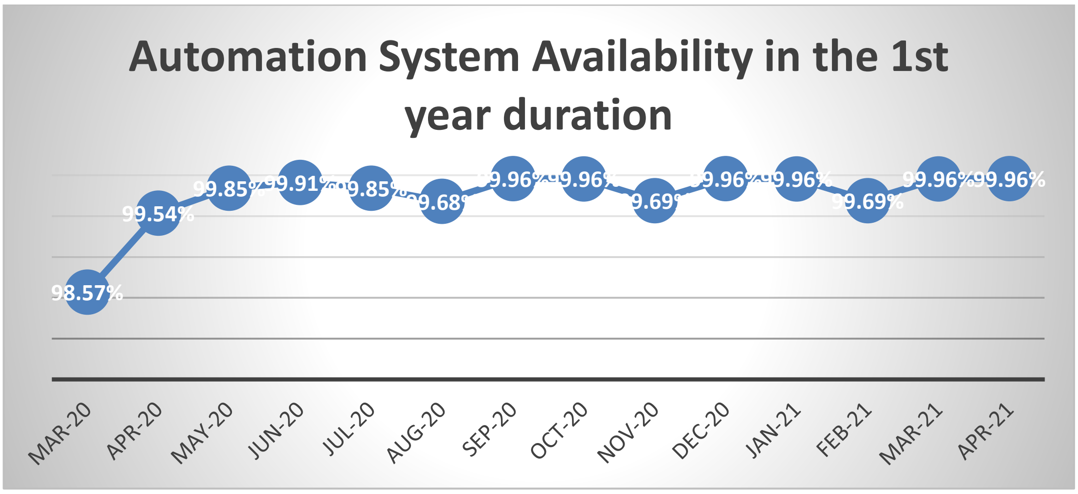

Fig. 1 Automation System DCS Availability of a Tissue Mill

(**Source:** Maintenance Check-sheet of RTM)

This availability value is a comparison between the actual operation time against planning time of the automation system. Availability targeted by management is 99.95%, but the average availability during that period (1st year) was not achieved only reaches 99.75%. For this reason, data collection was carried out again for 18 months as shown on Table 1.

Table 1 Automation System DCS Availability of a Tissue Mill

Month, Year	**Running target (hrs)**	**Downtime (hrs)**	**Actual operation (hrs)**	**Availability**	**Remark**
February 2022	5208	2	5206	99.96%	Production
March 2022	5040	72	4968	98.57%	Production
April 2022	5208	24	5184	99.54%	Production
May 2022	5208	8	5200	99.85%	Production
June 2022	4704	4	4700	99.91%	Production
July 2022	5208	8	5200	99.85%	Production
August 2022	5040	16	5024	99.68%	Production
September 2022	5208	2	5206	99.96%	Production
October 2022	5040	2	5038	99.96%	Production
November 2022	5208	16	5192	99.69%	Production
December 2022	5208	2	5206	99.96%	Production
January 2023	5040	2	5038	99.96%	Production
February 2023	5208	16	5192	99.69%	Production
March 2023	5040	2	5038	99.96%	Production
April 2023	5208	2	5206	99.96%	Production
May 2023	5040	72	4968	98.57%	Production
June 2023	4704	4	4700	99.91%	Production
July 2024	5208	8	5200	99.85%	Production
			Average	**99.82%**	**Increase 7%**

(Source: Maintenance Check-sheet of RTM)

1.2 Purpose of research

Accordingly, this article come to query how to elaborate system disruption root-causes that lead to downtime and how to reduce downtime period which will eventually increase the availability of automation system at that tissue mill? The goal of this article is to identify all relevant failure factors that cause disruption or downtime of mill tissue automation system Distributed Control System (DCS) and provide recommendations for improvement and determine appropriate suggestions in order to achieve 99.95% availability target.

2. LITERATURE REVIEW

In order to meet automation demand, many complex manufacturing systems use sophisticated control systems such as Distributed Control System (DCS) instead of an old-fashioned relay-based control system [2], [3], [4], [5], [6], [7]. However, due to current technology complexity of DCS system both hardware and software, maintenance & operator ability to diagnose and inspect any failure is unsatisfied because of knowledge constraint. Operation errors related to control process often confuse maintenance team, although sometimes problems arise not because of the control system but rather equipment problem or field sensor fault or alarm indications (for example high-high vibration alarms) that stop production lines which are essentially as protection of machine or engine.

According to [3], main problem in a relay-based control system is longer time needed by maintenance to diagnose failures of the control system. Another article describes similar issue that when failure occur in the control system about 80% of downtime is spent for searching of the source and only 20% is spent on repairs [5]. The length of downtime will affect the company in terms of employees and equipment idle, loss of productivity, data, customer and damaged reputation as well [8]

Sadukhan [8] outlines 10 causes of system failures i.e. natural disasters, hardware failures, software failures, human errors, overloaded systems, workstations attacked by viruses, lost network connectivity, lost power, maintenance failures and vandalism. A significant but costly solution is converting the old system into a new system which is certainly done in several stages to minimize downtime [6].

Based on downtime losses, there are two types of costs: direct and indirect costs. Two costs are directly related to system improvement that are repair costs and compensation for overtime work. Indirect costs resulting from repairing failures, loss of customers and loss of productivity of both equipment and employees, also means loss of 3rd party income and compensation [8]. This article managed to collect 24 literatures considered relevant with downtime problem solving and related to control systems, electronic components or software.

3. METHODOLOGY

This article uses literature study approaching; thus, analysis and solutions are obtained from 35 (Thirty five) literatures that have similar concern but different industry. During writing of this article, it is assumed that all factors that affect to the recorded downtime are constant. And presume also there is no distinction between planned downtime and unplanned downtime.

First step for writing this article is to formulate the problem that occurred at tissue mill, second find literatures and study them to look for and understand theories related to objective research so that it can support and be used further. Parallelly, the third step is data collecting as necessary to support this research and obtained secondary data from maintenance check-sheet. The fourth is collected cases & solutions that were selected from literatures that deal with similar problems. The fifth is improvement plans which plan and determine proper solution. The improvement plan will deliver possible solution that will be documented as improvement suggestion. The sixth is results and conclusions in accordance to research objectives and findings.

4. RESULT AND DISCUSSION

One article summarized major steps to reduce downtime through integration approach in quality management [9] which can be applied in this article, i.e.:

1. Identify the right method.
2. Select compatibilities and differences among the methods.
3. Select and specify implementation strategies.

Identification of failure factors is taken from several literatures is arranged on Table 2 below. It is categorized according to man, machine, material, measurement, method and environment factors.

Table 2 Failure factors and long downtime causes

Subject	Reference	Description
Man	[10], [8], [11], [12]	Technicians / operators have no experience
		Personnel too confidently ignore the protocol
		Personnel are not focused on their work
	[8]	Vandalism/sabotage
Machine	[8]	System overload
		Lost network connectivity
	[8], [13], [14]	Virus/malware attack to workstation
	[8], [15], [16], [11]	Hardware failure, e.g. blown fuse, short-circuit, sensor damage, broken channel, card/module malfunction.
	[8], [17], [6], [15], [11]	Software failure (due to update or migration or modification process)
	[3], [18], [19]	Old-fashion control system /relay system/pneumatic system
Material	[8], [20], [21]	All channel & terminal is fully occupied, no idle channel nor spare space.
	[22]	Spare part is not available in storage.
Measurement	[10]	Inspection is inaccurate.
		Checking cycle is not enough
Method	[19], [22]	There is no maintenance SOP or SOP is not updated
	[19], [10], [22]	Daily maintenance check is not applied / ineffective
	[20], [11]	Tools are not proper
	[11],	Maintenance planning & scheduling problem
Environment	[10], [8]	High humidity.

Subject	Reference	Description
	[8]	No air condition in cabinet room, temperature increases exceeding allowable limit for electronic component of DCS
	[8], [21]	Black-out, no electric & UPS malfunction.
	[8], [11]	Natural disasters, floods, fires or other dangerous incidents related to safety.

Start from human factors, according to [10], [8], [11], and [12] the factors are new or inexperienced technicians & operators, personnel are too confident ignoring protocol, personnel are not focused on their work, and according to [8] another human factor is vandalism or sabotage. Related to machine factor, according to [8] the factor is the system is overload and loss of network connectivity. Furthermore, [8], [13] and, [14] mentioned that the workstation can be attacked by virus or malware. [8], [15], [16], and [11] added the cause factor is a hardware problem, for example fuse breaking, short circuit, dead channel, module/card malfunction. According to [8], [17], [6], [15], and [11] the cause is software problems (due to the process of updating or migration or modification). According to [3] dan [18], the cause is old model of control system like relay or pneumatic system.

Material factor takes affect also in causing long downtime which is fully occupied channels & terminals thus no idle channel nor spare space. are full channel & terminal, and there is no spare part available in storage for replacement [8], [22]. As for measurement factor, according to [10] the failure occurs as results of inaccurate routine inspections and irregular checking cycles. Method factor according to [19], [22] is Maintenance SOP (standard operational procedure) does not exist or does not update, Daily maintenance check is not applied or ineffective [19] [10], [22], inappropriate tools [20] [11], and maintenance planning & scheduling problem [11]. Environmental factors (environment) are high humidity [10] [8], no air condition in cabinet room hence temperature increases exceeding allowable limit for electronic component of DCS [8], Black-out or no electricity & UPS malfunction [8] [21], and natural disasters, floods, fires or other dangerous incidents related to safety [8] [11].

Recommendations for improvement and prevention to avoid long downtime are selected from several literatures based on the maintenance point of view and shown on Table 3.

Table 3 Recommendation for Improvement & Mitigation

No	Recommendation	Reference
1	Utilize maintenance system that is integrated with the control system (CBM, CMMS, ERP, or artificial intelligent systems for failure detection and action recommendations)	[5], [19], [16], [22], [23], [24], [25], [26]
2	Improved maintenance management in methods, planning and scheduling.	[15], [11], [22], [26], [16], [29], [35]
3	Autonomous Maintenance	[24], [27], [16], [28], [19], [29], [30], [31]
4	Training for all level of employees on TPM, operations, equipment knowledge (including DCS) in order to strengthen sense of belonging and responsibility.	[10], [13], [16], [33]
5	Upgrade control system	[3], [13], [18]
6	Using proper tools	[17], [20], [11]
7	Task & assignment should be stages according to critical level.	[6], [11], [34], [35]
8	Protect network access and secure USB ports on every workstation to avoid malware and virus	[13], [14]

Many researchers highlight necessity of an integrated system like "condition-based maintenance monitoring" or "CBM", "computerized maintenance management system" or "CMMS", "enterprise resource planning" or "ERP", and any type of artificial intelligent system for failure detection and able to recommend suitable action [5], [19], [16], [22], [23], [24], [25], [26]. As a matter of fact, many industries are still running with earlier technology of control system like relay system and pneumatic and hydraulic system, so upgrading the control system to current technology is also recommended facing Industry 4.0 minded [3], [13], [18], [33]. Other researcher stated improvement of maintenance management particularly in methods, planning and scheduling as mitigation to reduce downtime period or even possibility [15], [11],

[22], [26], [16], [29], [35]. This will be relevant with one concern manage maintenance task & assignment which should be stages or step-by-step completion according to critical level [6], [11], [34], [35].

Training for all level of employees on Total Productive Maintenance (TPM), operations, equipment knowledge (including DCS) in order to strengthen sense of belonging and responsibility is also important according to [10], [13], [16], [33]. While others are specifically mention Autonomous Maintenance [24], [27], [16], [28], [19], and [29], [30], [31]. Another general practice at user-level is protection of network access and secure USB ports at every work-stations to avoid malware and virus intrusion [13], [14].

Finally, we combine Table 1 and Table 2 to make a better understanding which improvement or mitigation should be taken for each failure. This combination is provided in Table 4.

Table 4. Combine Table 1 and 2 (Failure factors/causes and Improvement and Mitigation

Subject	Failures factors/causes	Improvement and Mitigation
Man	Technicians / operators have less experience Personnel too confidently ignore the protocol Personnel are not focused on their work Vandalism/sabotage	1. Training for all level of employees on TPM, operations, equipment knowledge (including DCS) in order to strengthen sense of belonging and responsibility. 2. Autonomous Maintenance 3. Task & assignment should be relevant with employee level
Machine	System overload Lost network connectivity Virus/malware attack to workstation Hardware failure, e.g., blown fuse, short-circuit, sensor damage, broken channel, card/module malfunction. Software failure (due to update or migration or modification process) Old-fashion control system /relay system/pneumatic system	1. Utilize maintenance system that is integrated with the control system (CBM, CMMS, ERP, or artificial intelligent systems for failure detection and action recommendations). 2. Protect network access and secure USB ports on every workstation to avoid malware and virus. 3. Task & assignment should be stages according to critical level. 4. Upgrade control system 5. Develop diagnostic warning and alarm notification in the system
Material	All channel & terminal is fully occupied, no idle channel nor spare space. Spare part is not available in storage.	1. Improved maintenance management in methods, planning and scheduling. 2. Task & assignment should be stages according to critical level. 3. Order critical spare part immediately once being used and make it ready on hand
Measurement	Inspection is inaccurate. Checking cycle is not enough	1. Improved maintenance management in methods, planning and scheduling 2. Task & assignment should be stages according to critical level
Method	There is no maintenance SOP or SOP is not updated Daily maintenance check is not applied / ineffective Tools are not proper Maintenance planning & scheduling problem	1. Improved maintenance management in methods, planning and scheduling 2. Autonomous Maintenance 3. Using proper tools
Environment	High humidity. No air condition in cabinet room, temperature increases exceeding allowable limit for electronic component of DCS Black-out, no electric & UPS malfunction.	1. Upgrade environment control system regarding humidity and natural disaster (early warning system). 2. Task & assignment should be stages according to critical level.

Subject	Failures factors/causes	Improvement and Mitigation
	Natural disasters, floods, fires or other dangerous incidents related to safety.	3. Autonomous Maintenance

Regarding the real-time & integrated system, there is case studies in three Australian companies show their efforts to avoid production losses due to electrical equipment failures along with reducing downtime and increasing efficiency by applying additional algorithms in existing control systems to obtain real-time data access with the aim of getting a quick response from production and maintenance personnel [21].

5. CONCLUSION AND SUGGESTION

All relevant failure factors are identified and recommendations for improvement is also provided. Implementing sophisticated system for maintenance will be very beneficial, but the investment costs that must be incurred by the company will be huge so it must be elaborated further and budgeted in CAPEX (Capital Expenditures) and this can be planned for future of long-term goal.

In case of short-term goal maintenance team can take preventative actions by conducting daily regular checks via DCS engineering workstation to observe system healthiness and identify any alarm & error. Person in-charge should be chosen dedicated for DCS and he/she to make planning & prepare recommendations for immediate action and corrective action in case warning alarm occur prior failure happening. The PIC importantly to ensure spare parts are placed at maintenance storage that should be in case replacement needed. Consultation with control system expert can be done by giving remote access to the advisor or vendor to get immediate response.

Further research can be conducted for impact of novel Industry 4.0 (I4.0) technology implementation in Total Productive Maintenance (TPM) performance particularly to see zero-downtime possibility.

REFERENCES

1. P. Berg and O. Lingqvist. (2019). Pulp, paper, and packaging in the next decade: Transformational change, McKinsey Co. Pap. For. Prod., vol. August, pp. 1–18.
2. M. M. Rashid, M. M. I. Bhuiyan, I. B. Muzni, M. E. B. Mustafa, and M. Ferdaus. (2013). Design field controller for level, flow, temperature and networking using Yokogawa DCS, in 5th International COnference on Mechatronics (ICOM'13), vol. 53, no. 1, doi: 10.1088/1757-899X/53/1/012094.
3. S. Ardi and A. Hidayat. (2015). Otomatisasi sistem kontrol mesin turning head NTVS-485 berbasis sistem kendali PLC Omron CS1G-CPU42H, Sinergi, vol. 19, no. 2, pp. 159–164.
4. M. Khalgui and H. M. Hanisch. (2011). Reconfigurable embedded control systems: Applications for flexibility and agility. Hershey PA, US: Information Sciience Reference of IGI GLobal US.
5. J. Fan, Y. Xie, and M. Ding. (2015). Research on embedded PLC control system fault diagnosis: A novel approach. pp. 1876–1879, doi: 10.2991/isrme-15.2015.383.
6. D. Sadhukhan and J. Mihevic. (2013). The I ntegration of DCS I/O to an existing PLC, in ISA Automation Week 2013: Technology and Solutions Event, 2013, vol. 497, no. 1, pp. 454–458.
7. S. R. Schröder. (2019). Three weeks oil production shutdown avoided and tremendous cost savings achieved with no downtime during largescale replacement of electrical equipment, in SPE Western Regional Meeting Proceedings, p. 13.
8. Q. Li. (2016). Estimation of the costs of IS downtime in organisations.
9. S. M. Saad and M. A. Khamkham. (2018). Development of an Integrated Quality Management Conceptual Framework for Manufacturing Organisations," Procedia Manuf., vol. 17, pp. 587–594, doi:10.1016/j.promfg.2018.10.100.
10. Y. Zhai and J. Zhang. (2017). Applying TPM on production line of Huanwei," MATEC Web Conf., vol. 100, pp. 20–23, doi: 10.1051/matecconf/201710002035.
11. J. Bokrantz, A. Skoogh, T. Ylipää, and J. Stahre. (2016). Handling of production disturbances in the manufacturing industry," J. Manuf. Technol. Manag., vol. 27, no. 8, pp. 1054–1075, doi: 10.1108/JMTM-02-2016-0023.
12. R. A. Surya, L. D. Fathimahhayati, and F. D. Sitania. (2018). Analisis pengaruh shift kerja terhadap beban kerja mental pada operator Distributed Control System (DCS) dengan metode NASA-Taks Load Index (TLX), studi kasus PT. CFK, Matrik, vol. 19, no. 1, pp. 63–76, doi:10.30587/matrik.v19i1.510.
13. D. Bhamare, M. Zolanvari, A. Erbad, R. Jain, K. Khan, and N. Meskin. (2020). Cybersecurity for industrial control systems: A survey," Comput. Secur., vol. 89, no. February, doi: 10.1016/j.cose.2019.101677.
14. A. Zarrech, H. Da Wan, Y. Lee, C. Saygin, and R. Al Janahi. (2019). Cybersecurity concerns for Total Productive Maintenance in smart manufacturing system," Procedia Manuf., vol. 38, pp. 532–539.

15. G. J. Janakiraman, J. R. Santos, Y. Turner, and G. J. Janakiraman. (2004). Automated system design for availability,” in Internationall Conference on Dependable System and Networks, no. July, p. 11.
16. T. Slavina. (2018). Model of integrated system for monitoring and increasing availability and efficiency of production equipment,” Ann. Fac. Eng. Hunedoara, vol. 16, no. 1, pp. 13–20.
17. M. Tuovinen. (2015). Reducing downtime during software deployment.
18. A. Achour. (2015). Distributed control system - DCS- An application on Yokogawa centum VP,” Mohammed Khider University, Algeria.
19. V. M. Kalra, T. Thakur, and B. S. Pabla. (2018). Condition based maintenance management system for improvement in Key performance indicators of mining haul trucks – a Case Study, in IEEE International Conference on Innovative Research and Development (ICIRD), no. May, pp. 1–6.
20. S. Karunakaran. (2016). Innovative application of LSS in aircraft maintenance environment,” Int. J. Lean Six Sigma, vol. 7, no. 1, pp. 85–108, doi: 10.1108/IJLSS-01-2015-0001.
21. Dert_Australia. (2013). Systems optimisation to improve energy productivity: case studies. (https://www.energy.gov.au/sites/default/files/case_studies_in_systems_optimisation_to_improve_energy_productivity.pdf).
22. Sukma, D.I., Prabowo, H.A., Setiawan, I., Kurnia, H., Fahturizal, I.M. (2022). Implementation of Total Productive Maintenance to Improve Overall Equipment Effectiveness of Linear Accelerator Synergy Platform Cancer Therapy., International Journal of Engineering., Transaction A: Basic. Vol. 35, No. 05, pp. 1246-1256
23. M. R. Pfeifer. (2019). Research and development of computer support for maintenance , assembly and other auxiliary and service works, VŠB – Technická univerzita Ostrava.
24. R. McWilliam, S. Khan, M. Farnsworth, and C. Bell. (2018). Zero-maintenance of electronic systems: Perspectives, challenges, and opportunities, Microelectron. Reliab., vol. 85, April, pp. 122–139, doi:10.1016/j.microrel.2018.04.001.
25. M. Fadaeefath Abadi, F. Haghighat, and F. Nasiri. (2020). Data center maintenance: applications and future research directions,” Facilities, vol. April, doi: 10.1108/F-09-2019-0104.
26. I. Lopes et al. (2015). Requirement specification of acomputerized maintenance management system - a case study,” Procedia CIRP, vol. 3, pp. 268–273.
27. P. Guariente, I. Antoniolli, P. Ferreira, T. Pereira, and F. Silva. (2017). Implementing autonomous maintenance in an automotive components manufacturer, Procedia Manuf., vol. 13, pp. 1128–1134.
28. A. Shagluf, A. P. Longstaff, and S. Fletcher. (2014). Maintenance strategies to reduce downtime due to machine positional errors, in Proceedings of Maintenance Performance Measurement and Management (MPMM) Conference, no. November, pp. 111–118, doi: 10.14195/978-972-8954-42-0_16.
29. A. T. Shams, F. Rabby, and N. Istiak. (2019). Development of a Maintenance Schedule Plan to Improve the Equipment Efficiency of an Industry : A Case Study,” Int. J. Res. Ind. Eng., vol. 8, no. 2, pp. 140–157, doi: 10.22105/riej.2019.174907.1082.
30. S. Potter and J. Nieh. (2005). Reducing Downtime Due to System Maintenance and Upgrades,” in 19th Large Installation System Administration Conference (LISA ’05), vol. January, pp. 47–62.
31. Adesta, E.Y.T, Prabowo, H.A. (2018). Total Productive Maintenance (TPM) implementation based on lean manufacturing tools in Indonesian manufacturing industries, International Journal of Engineering & Technology, 7 (3.7), 156-159.
32. Herry A P, Farida F and Lutfia N I. (2018). Performance analysis of TPM implementation through Overall Equipment Effectiveness (OEE) and Six Big Losses, IOP Conf. Series: Materials Science and En gineering 453, 012061 doi:10.1088/1757-899X/453/1/012061.
33. Farida, F. Prabowo, H.A, Husnur, A. (2018). The Readiness of Human Resources and Organization in Implementing Total Quality Management (TQM) in Indonesia’s Manufacturing Industries, Journal of Engineering Research, Vol. 9. No. 4A, 246-261.
34. Wardianto, D., Mafrizal, M., Sufiyanto, S., Arief, R.K, Prabowo, H.A., Hilmy, I. (2023) The model selection of propeller turbine construction using Analytical Hierarchy Process (AHP). SINERGI journal. Vol. 27. Issue. 8.
35. Junawan, S., Jaqin, C., Prabowo, H.A., Roysen, U., Alam, F., Daruki, D. (2024). Implementation of Reliability Centered Maintenance (RCM) with Fuzzy Logic in Eliminating Off-Hangar Maintenance **on** Narrow Body Aircraft. Jurnal Teknologi. Vol.16. Issue 1.
    DOI: https://doi.org/10.24853/jurtek.16.1.137-152