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Analysis of Preventive Maintenance Line Dosing using Modularity Design and Mean Time Between Failure (MTBF)

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ABSTRACT

Maintaining operational continuity requires effective maintenance of production equipment. The dosing line at PT XYZ experienced a total downtime of 7,597 minutes between October 2024 and September 2025, indicating the need for a structured and data-driven maintenance strategy. This study aims to classify maintenance modules, identify failure root causes using a modularity design approach, determine optimal inspection intervals and preventive maintenance frequencies, and evaluate actual availability against standard availability based on mean time between failure (MTBF) and operational time. The dosing line was divided into six main modules, followed by root cause analysis and calculation of MTBF, inherent availability, and operational availability to determine optimal inspection intervals. The results indicate that failures are mainly caused by material blockages, pneumatic issues, component aging, and programmable logic control (PLC) disturbances. The dosing weight module requires the highest preventive maintenance frequency (71 times per year), with optimal inspection intervals ranging from 16 to 53 days across modules. All modules exceeded standard availability thresholds, with inherent availability above 99% and operational availability above 90%. These findings confirm that integrating modularity design and MTBF analysis effectively supports systematic and data-driven preventive maintenance planning.

Keywords: Availability, Fault Tree Analysis, Modularity Design, MTBF, Preventive Maintenance.

I. Introduction

Maintaining industrial equipment and machinery is essential in today's increasingly competitive business world. This is due to intensifying global competition, which forces companies to adjust their operational strategies to maintain production process productivity (Rahmadsyah & Safirin, 2024; Iwarue, 2025). To ensure the smooth operation of the production process, the machine maintenance system is a crucial factor in determining operational effectiveness. To achieve this goal, machines must always be in optimal and reliable condition. Therefore, maintenance activities must be carried out in a preventive and planned manner. In addition to maintaining machine performance, preventive maintenance demonstrates the company's commitment to the effectiveness of the maintenance system. Machine failures have the potential to cause downtime, hinder the production process, and reduce production capacity. By

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implementing preventive maintenance on machinery, reliability is maintained, productivity is enhanced, and downtime caused by machine failures is minimized (Setiawan & Windyatri, 2024; Bafandegan Emroozi et al., 2025).

PT XYZ is an animal feed manufacturing company that operates continuously 24 hours a day with a complex and integrated production process, including intake, grinding, dosing, pelleting, and bagging lines. Based on company data, the dosing line had the highest frequency of downtime from October 2024 to September 2025 compared to other production lines. This condition is caused by unstructured machine maintenance practices and the absence of an effective classification of machines and components, making it difficult for the maintenance team to determine priorities and plan preventive actions. During the observation period, the total downtime on the dosing line due to system or machine failure was recorded at 7,597 minutes. Such unexpected failures can reduce production capacity, disrupt material flow between processes, and create bottlenecks that affect overall operational efficiency. Therefore, an improved maintenance approach that is more systematic and data-driven is required to minimize failures and reduce downtime. In this context, maintenance decisions can also be viewed as managerial decisions influenced by operational, technical, and economic considerations to ensure that equipment performance meets production requirements and supports efficient production processes (Zahran et al., 2026). In response to this issue, this study focuses on the dosing line as the main object of analysis to evaluate maintenance practices and propose improvements that support more reliable production operations.

This study offers a novel approach by integrating modularity design and mean time between failure (MTBF) for preventive maintenance, addressing two research gaps: first, the fact that modularity design approaches typically calculate mean time to repair (MTTR) and mean time to failure (MTTF) without analyzing availability; and second, the lack of a specific integration between modularity design and mean time between failure (MTBF). This study also focuses on the dosing line as the subject of research, rather than being limited to a single machine. This study applies modularity design by grouping units on the dosing line into functional modules and analyzing the root causes of failure using fault tree analysis (FTA), so that maintenance and repairs can be planned more efficiently per module (Hidayah & Widjajati, 2023). Furthermore, the mean time between failure (MTBF) approach is integrated to calculate the availability value of each module and is used as the basis for determining the preventive maintenance schedule (Habibi et al., 2025). The combination of these two approaches is expected to facilitate the determination of maintenance priorities, reduce the frequency of dosing line failures, and improve operational efficiency. In addition, the integration of analytical approaches into a structured framework is considered important to improve the effectiveness of problem identification and decision-making in operational systems. A systematic mapping of concepts and methods can help researchers connect theoretical approaches with practical applications, thereby strengthening the analytical framework used in a study (Nurani & Rajab, 2026). Through this integration, maintenance analysis can be conducted more comprehensively, enabling the evaluation of system performance and reliability from various perspectives.

II. Literature Review and Hypothesis Development

2.1. Maintenance

Maintenance is an activity carried out to restore or maintain the condition of a machine so that it can always function properly. The purpose of maintenance is to keep machinery in good working condition by restoring or maintaining its condition. In addition, maintenance is a supporting activity that ensures machinery and equipment continue to function as intended when needed. Therefore, maintenance activities consist of a series of measures taken to keep machinery and equipment safe and operational and to prevent potential damage (Pranowo, 2019). In industrial discussions, maintenance can also be defined as the act of maintaining components or machines and renewing their service life when they are deemed unusable or damaged (Nursanti et al., 2019). The purpose of maintenance activities is to ensure that production capacity

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can meet demand in accordance with the production plan (Dhamar Jati et al., 2024). A maintenance strategy is a standard concept to be implemented by maintenance operators while prioritizing work safety, so that machines can be repaired properly and operate optimally (Simatupang & Susanti, 2021). This strategy includes tasks, procedures, resources, and time, which are carried out according to a schedule to achieve maintenance objectives (Soepardi & Chaeron, 2019). The implementation of an effective maintenance strategy aims to optimize economic benefits, extend component life, reduce sudden repairs, reduce overtime costs, and reduce work pressure due to unexpected damage (Ren et al., 2021). Maintenance management is an activity that establishes maintenance requirements, objectives, strategies, and responsibilities, which are implemented through planning, control, and improvement of maintenance activities and their economic aspects (Dinis, 2025).

2.2. Modularity Design

Modularity design is an approach for structuring a system into discrete, combinable modules so that design, production, and maintenance become more efficient and flexible. In this approach, the system is not viewed as a fully integrated whole, but rather as a structured collection of functional units. Modules are divided based on functional similarities (Zhang & Tan, 2025). Modularity refers to the grouping of components with similar functional structures, which facilitates the repair and replacement of these components (Habibi et al., 2025). The modularity design method is an approach to preventive maintenance that helps maintenance teams repair machines within a specific timeframe. This approach involves grouping machines with similar functions, with the aim of improving system efficiency and reducing maintenance costs for the company. Additionally, components that are directly or indirectly related have a cause-and-effect relationship. The primary objective of modularity design is to simplify the repair process for the company, thereby reducing the frequency of production machine downtime during the operational period (Mentari & Hidayat, 2021). Modular design will simplify production and assembly procedures and reduce their costs. Modular design has been widely implemented across various industrial sectors, particularly in the context of manufacturing machinery maintenance. The primary principles of applying modular design in industry are to minimize downtime, reduce maintenance costs, and enhance production flexibility. With this approach, modular design not only improves machinery maintenance efficiency but also helps companies achieve continuous improvement in their operations (Fadhli et al., 2025).

2.3. Reliability Functions and Parameters

Reliability functions and parameters consist of three, as follows.

a. Mean Time to Repair (MTTR)

Mean time to repair (MTTR) is the average time required to repair a component or system after it has failed. The lower the MTTR, the faster the system can be restored after a failure, thereby reducing downtime. MTTR is calculated by dividing the total downtime by the number of failures that occurred during that period (Nurdiansyah & Hariadi, 2024).

b. Mean Time to Failure (MTTF)

Mean time to failure (MTTF) is a reliability metric that estimates the average time a system or component will function correctly before failing. MTTF is calculated by dividing the total operating time by the number of failures during that period (Zieja et al., 2023). The following are formulas for calculating MTTR and MTTF (Ebeling, 2019).

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1) Weibull Distribution

$$\mathrm{MTTR/MTTF}=\eta\Gamma\left(1+\frac{1}{\beta}\right)$$

2) Lognormal Distribution

$$\mathrm{MTTR/MTTF}=t_{med}.e^{\left(\frac{s^2}{2}\right)}$$

c. Mean Time Between Failure (MTBF)

Mean time between failure (MTBF) is a measure that describes the average time between one system failure and the next. The higher the MTBF value, the more reliable the system is, which means it can operate longer without experiencing disruptions. MTBF is extremely useful for maintenance planning and repair scheduling, as it helps determine optimal maintenance intervals and reduce the risk of downtime (Santoso & Rusindiyanto, 2025).

$$\mathrm{MTBF}=\frac{\text{Total Operating Time}}{\text{Number of Failures}}$$

2.4. Availability

Availability is considered one of the most important reliability performance metrics for maintained systems, as it encompasses both the failure rate and the repair rate of the system. Availability is defined as the probability that a component or system is performing its required functions at a given moment in time, when operated under specified conditions, there are two types of availability:

a. Inherent Availability

Inherent availability measures the readiness of a system or equipment to operate under ideal conditions, considering only reliability and repair capabilities, without being influenced by readiness time, logistics, or waiting time (Elsayed, 2021).

$$A_i=\frac{\mathrm{MTBF}}{\mathrm{MTBF+MTTR}}\times 100\%$$

b. Operational Availability

Operational availability measures the probability that a machine is available for operation, considering all types of downtime (Putra & Aidil, 2021).

$$A_o=\frac{\text{Uptime}}{\text{Operating Cycle}}\times 100\%$$

III. Research Methodology

3.1. Data Collection Method

a. Literature Study

A data collection method conducted through a review of literature sources relevant to the research topic, namely modularity design and mean time between failure (MTBF), to obtain a theoretical and empirical basis that supports the research analysis.

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b. Filed Study

The data collection method involved on-site visits to the research location to empirically observe and identify downtime issues on the dosing line. The data collection techniques used in this field observation are included:

1) Data on machines and critical machine components on the dosing line
2) Data on dosing line operating time
3) Data on machine failure and repair times on the dosing line
4) Data on causes of dosing line machine component failures

3.2. Data Processing Method

After all the necessary data has been collected, data analysis is conducted to solve the research problems and answer the research questions. The data processing process consists of the following stages.

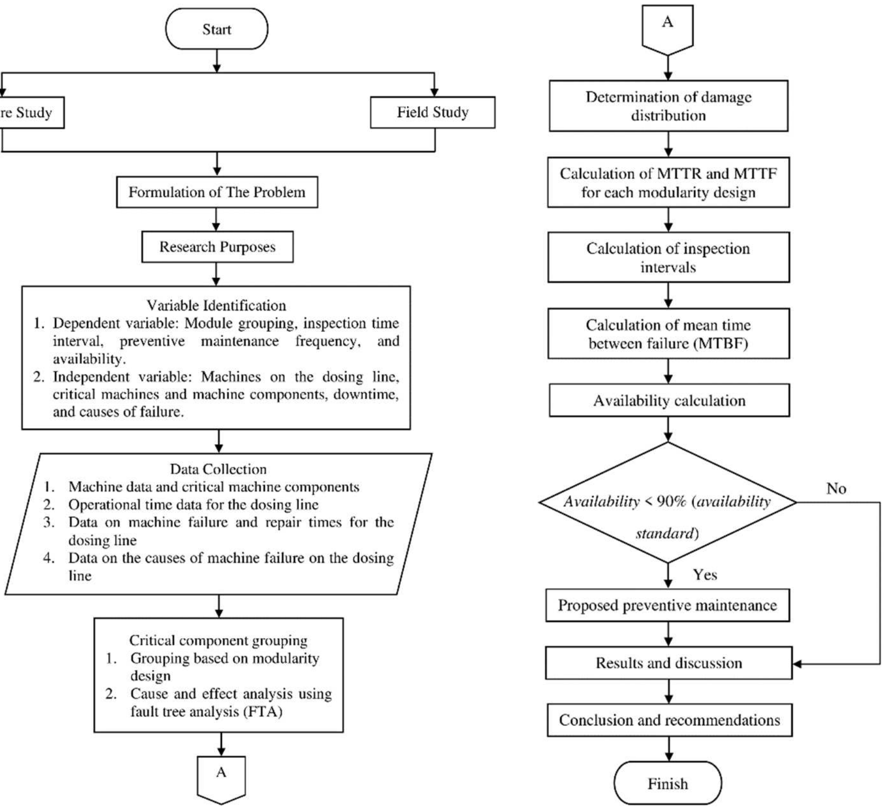

Figure 1. Flowchart

The study began with problem identification and the formulation of a plan, followed by a literature review and field study to understand the actual conditions of the dosing line. Based on the problem formulation, the research objectives and related variables were established (module grouping, inspection intervals, preventive maintenance frequency, availability, as well as machinery, downtime, and failure causes as independent variables). Data was collected from operational records, failure logs, repair times, and interviews with technicians. Machines and critical components were grouped based on modular design, then their root causes were analyzed using fault tree analysis (FTA). Failure patterns were tested to determine the appropriate distribution model (e.g., weibull, lognormal) using Minitab 18, thereby obtaining distribution parameters for calculating mean time to repair (MTTR) and mean time to falure (MTTF) for each module.

Based on the MTTR and MTTF, the MTBF and inherent and operational availability values for each module were calculated, serving as the basis for determining optimal inspection intervals and preventive

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maintenance schedules. Action decisions were based on a comparison of actual availability against a standard threshold (≥90%); if <90%, a proposed preventive maintenance schedule based on MTBF was developed; if ≥90%, the study proceeded to the analysis of results. The final stage includes the presentation of results and discussion, the formulation of conclusions and implementable recommendations for improving the maintenance system and suggestions for further research, followed by comprehensive documentation to conclude the study.

IV. Results and Discussion

4.1. Module Identification and Classification

In this stage, the machinery units on the dosing line are grouped into several modules. This grouping is carried out using a modular design approach to classify the machinery units based on their functional similarities and operational characteristics. The following table presents the modular breakdown of the machinery units analyzed in this study.

Table 1. Line Dosing Machine Unit Module

Module	Machine Unit	Components
Module 1	Chain Conveyor 2410M1	Chain, Motor, PLC
	Chain Conveyor 3012M1	
Module 2	Bin 307	Screw, Motor
	Bin 317	
	Bin 310	
	Bin 325	
	Bin 309	
	Bin 313	
	Bin 327	
	Bin 319	
	Bin 320	
	Bin 321	
	Bin 308	
	Bin 312	
Module 3	Dosing weight 1	Slide, Air cylinder, PLC, Body
	Dosing weight 2	Slide, PLC, Air cylinder
Module 4	Frequency Measuring Equipment (FME)	Screw, Slide, Pneumatic hoses, PLC, Filter
	Hand added	Spouting, PLC
	Dosing weight 7	PLC, Pneumatic hoses
	Dosing weight 8	Pompa
	Dosing weight 3	PLC, Slide, Rotary
Module 5	Mixer Machine	Bumpdoor
Module 6	Elevator 3013M1	Motor, Belt, PLC, Bucket

The dosing line system is divided into six functional modules. Module 1, the chain conveyor, distributes materials from the intake process to the dosing bins and from the mixing process to the elevator. It consists of two machines, chain conveyors 2410M1 and 3012M1, with critical components including the chain, motor, and programmable logic control (PLC). Module 2, the dosing bin, serves as temporary storage for raw materials before the weighing process and consists of twelve units, namely bin 307, 317, 310, 325, 309, 313, 327, 319, 320, 321, 308, and 312, with critical components screw and motor. Module 3, the dosing weight,

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functions to weigh the main raw materials according to a predetermined formula and consists of two units, dosing weight 1 and dosing weight 2, with critical components slide, air cylinder, programmable logic control (PLC), and body.

Module 4, the small dosing weight, weighs additional materials such as powdered and liquid vitamins and consists of five units, namely frequency measuring equipment (FME), hand added, dosing weight 7, dosing weight 8, and dosing weight 3, with critical components slide, air cylinder, screw, programmable logic control (PLC), pneumatic hoses, pump, and rotary. Module 5, the mixer, mixes the weighed raw materials and consists of one machine unit with the critical component bumpdoor. Module 6, the elevator 3013M1, distributes semi-finished materials to the pelleting process with critical components motor, belt, programmable logic control (PLC), and bucket.

4.2. Fault Tree Analysis

This section involves the preparation of a fault tree analysis (FTA) to analyze the causes of failure in the dosing line system. To facilitate the identification of failures, each module with the same components is grouped together so that the relationship between failures can be identified clearly and concisely (Suprapto & Donoriyanto, 2024).

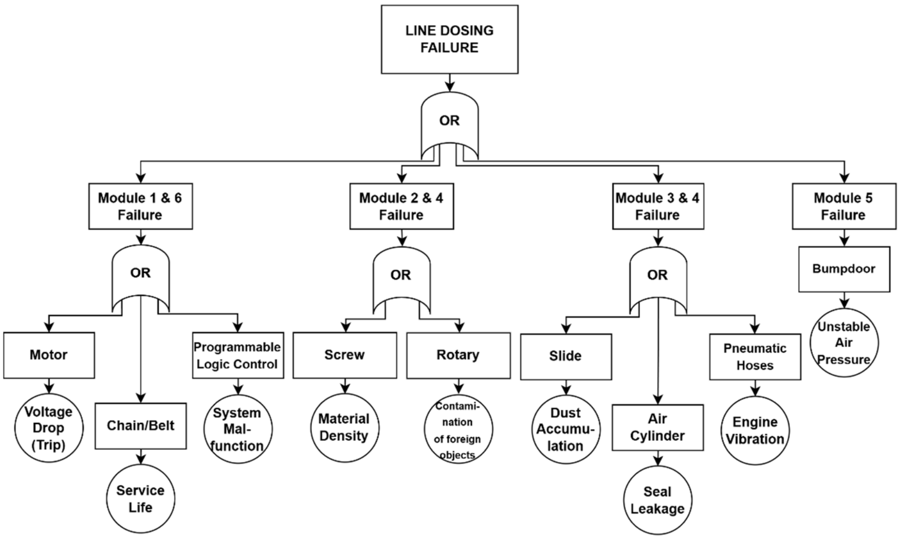

Figure 2. Fault Tree Analysis Line Dosing

According to the Fault Tree Analysis (FTA), the top event in the dosing system can be caused by multiple interrelated modules connected through OR logic gates, meaning a single component failure may disrupt the entire system. The main contributing factors include mechanical issues, pneumatic failures, and electrical disturbances. Mechanical failures mainly occur due to component wear, material blockage, or foreign objects that interfere with the movement of critical components such as chains, screws, and rotating parts. Pneumatic failures are generally related to air cylinder seal damage, leakage in pneumatic hoses, or unstable air pressure that affects the operation of actuators and control mechanisms. Meanwhile, electrical disturbances are associated with problems in programmable logic control (PLC), motor voltage drops, and control system errors that interrupt machine operation. The FTA structure also shows that failures from different subsystems can interact and trigger the top event, indicating that the reliability of the dosing system depends on the performance of mechanical, pneumatic, and electrical components. In addition, the analysis highlights that certain components act as critical points whose failures have a higher probability of propagating through the system. Therefore, identifying these relationships is important to support more effective preventive maintenance, determine maintenance priorities for critical components, and improve the overall reliability of the dosing line system.

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4.3. Data Failure and Distribution Conformity Test

In this section, adjustments are made to the distribution of failure data for the period October 2024 to September 2025, which has been summarized and grouped into each specified module. This grouping allows the failure characteristics of each functional module to be analyzed more systematically and facilitates further reliability analysis.

Table 2. Recapitulation of Failure Data Grouping based on Modules

Module	Number of failures	Total		Average	
		TTR (Minute)	TTF (Minute)	TTR (Minute)	TTF (Minute)
Module 1	4	180	570.240	45	285.120
Module 2	54	2.081	3.001.680	38,537	71.468,571
Module 3	62	1.779	963.360	28,694	16.056
Module 4	55	1.845	1.581.120	33,545	31.622,4
Module 5	12	409	257.760	34,083	23.432,727
Module 6	45	1.303	508.320	28,956	11.552,727

Based on the table showing the number of failures as well as the Time to Repair (TTR) and Time to Failure (TTF) values, differences in failure characteristics are evident across each dosing line module. Module 1 had the fewest failures, at 4, with an average repair time of 45 minutes and an average time to failure of 285,120 minutes, indicating a relatively high level of reliability. Module 5 also shows a relatively low number of failures, namely 12 times, with an average TTR of 34,083 minutes and an average TTF of 23,432,727 minutes. In contrast, Modules 2, 3, and 4 had higher failure counts of 54, 62, and 55 instances, respectively. The average repair time for these three modules ranged from 28 to 38 minutes, while their average failure times were lower compared to the other modules. Module 6 had 45 failures with an average TTR of 28.956 minutes and an average TTF of 11.552,727 minutes. In general, modules related to the weighing process exhibit a higher failure frequency compared to other modules in the dosing line system. This indicates that these modules have a higher workload intensity and require greater attention during maintenance activities to ensure the stability of the production process.

Minitab 18 software was then used to test the distribution. The time to repair (TTR) data was used for the first test (distribution 1), and the time to failure (TTF) data for each module was used for the second test (distribution 2). The distribution selection used in determining the distribution type for each module is based on the smallest Anderson-Darling value (Rahman, 2026), which indicates the best fit between the statistical model and the observed failure data. The selected distribution is subsequently used to determine the distribution parameters that will be applied in the calculation of mean time to repair (MTTR) and mean time to failure (MTTF).

Table 3. Anderson-Darling Value for Each Module

Module	Description	Anderson Darling			
		Weibull	Lognormal	Exponential	Normal
Module 1	Distribution 1	2,930	2,966	3,135	2,931
	Distribution 2	4,859	4,865	4,918	4,865
Module 2	Distribution 1	1,068	0,454	2,281	3,462
	Distribution 2	1,065	1,030	4,758	3,876
Module 3	Distribution 1	2,260	1,236	4,419	4,501
	Distribution 2	1,202	0,579	1,233	5,273
Module 4	Distribution 1	1,716	0,871	2,696	4,356

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	Distribution 2	0,953	0,702	2,326	5,172
Module 5	Distribution 1	1,581	1,517	1,557	2,282
	Distribution 2	1,591	1,598	2,948	2,519
Module 6	Distribution 1	1,178	0,550	4,936	2,200
	Distribution 2	1,173	1,032	1,220	3,601

The test results show that Module 1 follows a Weibull distribution for both types of distributions. Meanwhile, Modules 2, 3, 4, and 6 mostly follow a log-normal distribution because they have the smallest Anderson-Darling statistic for that distribution. In Module 5, Distribution 1 follows a log-normal distribution, while Distribution 2 follows a Weibull distribution. The distribution type for each module is determined based on the highest correlation coefficient value, which indicates the best fit between the data and the tested distribution. The correlation coefficient values for each module are presented in the following table (Soedira et al., 2022).

Table 4. Correlation Coefficient Value for Each Module

Modul	Description	Correlation Coefficient			
		Weibull	Lognormal	Exponential	Normal
Module 1	Distribution 1	0,996	0,980	*	0,994
	Distribution 2	1,000	1,000	*	1,000
Module 2	Distribution 1	0,957	0,994	*	0,886
	Distribution 2	0,960	0,975	*	0,886
Module 3	Distribution 1	0,925	0,979	*	0,902
	Distribution 2	0,968	0,992	*	0,859
Module 4	Distribution 1	0,924	0,982	*	0,842
	Distribution 2	0,958	0,991	*	0,811
Module 5	Distribution 1	0,908	0,957	*	0,857
	Distribution 2	0,906	0,901	*	0,828
Module 6	Distribution 1	0,966	0,994	*	0,928
	Distribution 2	0,934	0,975	*	0,889

The test results show that in Module 1, Distribution 1 had the highest value for the Weibull distribution at 0.996, while Distribution 2 showed very high values that were nearly identical across several distributions. In Modules 2, 3, 4, and 6, the highest correlation coefficient values were generally found in the Lognormal distribution, indicating that the data in those modules better follow the Lognormal distribution. Meanwhile, in Module 5, Distribution 1 had the highest value in the Lognormal distribution at 0.957, while Distribution 2 had the highest value in the Weibull distribution at 0.906. Once the Anderson-Darling and correlation coefficient values for each module are known, the distribution selected for each module can be determined and presented in the following table.

Table 5. Probability Plot for Each Module

Module	Description	Anderson-Darling	Correlation Coefficient	Selected Distribution
Module 1	Distribution 1	2,930	0,996	Weibull
	Distribution 2	4,859	1,000	Weibull
Module 2	Distribution 1	0,454	0,994	Lognormal
	Distribution 2	1,030	0,975	Lognormal
Module 3	Distribution 1	1,236	0,979	Lognormal
	Distribution 2	0,579	0,992	Lognormal
Module 4	Distribution 1	0,871	0,982	Lognormal
	Distribution 2	0,702	0,991	Lognormal
Module 5	Distribution 1	1,517	0,994	Lognormal

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	Distribution 2	1,591	0,906	Weibull
Module 6	Distribution 1	0,550	0,994	Lognormal
	Distribution 2	1,032	0,975	Lognormal

Based on the results of the Anderson-Darling test and the correlation coefficient, the distribution was selected by considering the smallest Anderson-Darling value and the highest correlation coefficient. The results show that Module 1 follows a Weibull distribution for both types of distributions. Modules 2, 3, 4, and 6 follow a Lognormal distribution for distribution 1 and distribution 2. Meanwhile, module 5 exhibits a different pattern, where distribution 1 follows a Lognormal distribution and distribution 2 follows a Weibull distribution. In general, these results indicate that most failure data in the line dosing system follow a Lognormal distribution, while the Weibull distribution appears only in certain modules. After the distribution type for each module was determined using probability plots, tests were conducted to obtain the distribution parameters used in calculating MTTR and MTTF. The results of the distribution tests for each module are presented in the following table.

Table 6. Distribution Test Results for Each Module

Module	Description	Type Distribution	Weibull Parameters		Lognormal Parameters	
			β (shape)	η (scale)	s (scale)	tmed (location)
Module 1	Distribution 1	Weibull	1,97953	50,8702	-	-
	Distribution 2	Weibull	7,85691	303939	-	-
Module 2	Distribution 1	Lognormal	-	-	0,762748	28,6616
	Distribution 2	Lognormal	-	-	1,65890	25212,3
Module 3	Distribution 1	Lognormal	-	-	0,652506	22,8793
	Distribution 2	Lognormal	-	-	0,978619	10125,1
Module 4	Distribution 1	Lognormal	-	-	0,741565	24,8049
	Distribution 2	Lognormal	-	-	1,28741	14574,6
Module 5	Distribution 1	Lognormal	-	-	0,940865	21,3275
	Distribution 2	Weibull	0,668339	17170,9	-	-
Module 6	Distribution 1	Lognormal	-	-	0,554918	24,7828
	Distribution 2	Lognormal	-	-	1,08860	6630,52

Based on the table, the shape parameter (β) and the scale parameter (η) are used to describe the characteristics and failure patterns of the Weibull distribution. Meanwhile, the scale parameter (s) and the location parameter (tmed) are used to describe the characteristics of the distribution in the log-normal distribution. Based on the results of the distribution tests for each module, it appears that the Time to Repair (TTR) and Time to Failure (TTF) data exhibit different distribution characteristics. Module 1 shows that both datasets follow a Weibull distribution with a β parameter value of 1.97953 for distribution 1 and 7.85691 for distribution 2. A β value greater than 1 indicates that failures in this module tend to increase with increasing operating time, suggesting the influence of component wear. In modules 2, 3, and 4, both distribution 1 and distribution 2 follow a long-normal distribution. This suggests that variations in repair time and time between failures in these modules are influenced by operational process uncertainty and varying component conditions. The differing scale and location parameters across each module reflect variations in the severity of damage and system recovery time. Module 5 exhibits a different pattern, where Distribution 1 follows a log-normal distribution, while Distribution 2 follows a Weibull distribution with a β parameter of 0.668339. A β value less than 1 indicates that failures during the early stages of operation are more dominant than those caused by wear. Meanwhile, Module 6 again exhibited a log-normal distribution pattern for both types of distributions, indicating that variations in failure and repair times are influenced by non-uniform operational conditions. Overall, the results of these distribution tests show that most modules exhibit failure patterns that follow a long-normal distribution, while a Weibull distribution appears in some modules, indicating component wear characteristics.

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The distribution parameter values are obtained from test results, which then serve as the basis for calculating the mean time to repair (MTTR) and the mean time to failure (MTTF) in the next stage.

4.4. Reliability Analysis

a. Mean Time to Repair (MTTR) dan Mean Time to Failure (MTTF)

At this point, each module mean time to failure (MTTF) and mean time to repair (MTTR) are determined using the distribution type that was chosen. The formulas for calculating MTTR and MTTF in the Weibull distribution are the same, as are those used in the lognormal distribution to calculate MTTR and MTTF (Cahyati et al., 2024). The MTTR and MTTF calculations for each module are as follows:

Table 7. MTTR and MTTF Calculation Results

Module	MTTR (Minute)	MTTF (Minute)
Module 1 (Chain Conveyor)	45,101	285.672,266
Module 2 (Bin dosing)	38,337	99.799,573
Module 3 (Dosing weight)	28,307	16.343,257
Module 4 (Small Dosing weight)	32,654	33.378,321
Module 5 (Mixer Machine)	33,205	22.825,277
Module 6 (Elevator 3013M1)	28,909	11.996,108

Based on the table of Mean Time to Repair (MTTR) and Mean Time to Failure (MTTF) values for each dosing line module, differences in reliability characteristics and maintenance requirements are evident among the modules. Module 1 (chain conveyor) has the highest MTTF value of 285,672.266 minutes, indicating that this module has the longest average operating time before failure occurs. However, the MTTR value for this module of 45.101 minutes is also the highest compared to other modules, meaning the repair process takes relatively longer when a failure occurs. Module 2 (dosing bin) has an MTTF of 99,799.573 minutes with an MTTR of 38,337 minutes, indicating a fairly high level of reliability with a relatively shorter repair time compared to the chain conveyor module. Meanwhile, Module 3 (dosing weight), Module 4 (small dosing weight), and Module 5 (mixer) exhibit lower MTTF values compared to the previous two modules, specifically 16,343.257 minutes, 33,378.321 minutes, and 22,825.277 minutes, respectively. This indicates that these three modules have a relatively higher failure frequency, thus requiring greater attention during maintenance activities. On the other hand, module 6 (elevator 3013M1) has the lowest MTTF value of 11,996.108 minutes, with an MTTR of 28.909 minutes. This indicates that the elevator module has a higher potential for failure compared to other modules, although its repair time is relatively shorter.

b. Mean Time Between Failure (MTBF)

At this point, each module means time between failures (MTBF) is determined and shown in the accompanying table.

Table 8. MTBF Line Dosing Calculation Results

Module	Operating Time (Minute)	Number of Failures	MTBF (Minutes)
Module 1 (Chain Conveyor)	461.844	4	115.461
Module 2 (Bin dosing)	461.844	54	8.552,67
Module 3 (Dosing weight)	461.844	62	7.449,10
Module 4 (Small Dosing Weght)	461.844	55	8.397,16
Module 5 (Mixer Machine)	461.844	12	38.487
Module 6 (Elevator 3013M1)	461.844	45	10.263,2

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Based on the Mean Time Between Failure (MTBF) table, there are differences in reliability levels among the dosing line modules. Module 1 (chain conveyor) has the highest MTBF value of 115,461 minutes and the fewest failures, indicating the highest level of reliability. Module 5 (mixer) also exhibits fairly good reliability with an MTBF value of 38,487 minutes. Conversely, Module 2 (dosing bin), Module 3 (dosing weight), and Module 4 (small dosing weight) have higher failure rates, resulting in lower MTBF values: 8,552.67 minutes, 7,449.10 minutes, and 8,397.16 minutes, respectively. Module 6 (elevator 3013M1) has an MTBF value of 10,263.2 minutes, indicating a moderate level of reliability compared to the other modules. These differences in MTBF values indicate that each module has distinct failure characteristics, thus requiring appropriate maintenance strategies. The MTBF value for each module is obtained by dividing the operating time by the number of failures. Then, the MTBF value in minutes is converted to days for use in calculating the frequency of preventive maintenance.

Table 9. Calculation of PM Line Dosing Frequency

Module	MTBF (Minute)	MTBF (Day)	Frequency (Per Year)
Module 1 (Chain Conveyor)	115.461	80,18	5
Module 2 (Bin dosing)	8.552,67	5,94	61
Module 3 (Dosing weight)	7.449,10	5,17	71
Module 4 (Small Dosing Weght)	8.397,16	5,83	63
Module 5 (Mixer Machine)	38.487	26,73	14
Module 6 (Elevator 3013M1)	10.263,2	7,13	51

The frequency value of preventive maintenance per year is obtained by dividing the number of days in a year (365 days) by the MTBF value (days). Based on the MTBF table, the time between failures and maintenance frequency for each module shows significant differences. Module 1 (chain conveyor) has the highest MTBF value of 115,461 minutes, or 80.18 days, with a maintenance frequency of approximately 5 times per year, indicating the highest level of reliability. Module 5 (mixer) also has a relatively high MTBF of 38,487 minutes or 26.73 days, with a maintenance frequency of 14 times per year. Conversely, Module 2 (dosing bin), Module 3 (dosing weight), and Module 4 (small dosing weight) have lower MTBF values of 5.94 days, 5.17 days, and 5.83 days, respectively, thus requiring higher maintenance frequencies of 61, 71, and 63 times per year. Module 6 (elevator 3013M1) has an MTBF of 7.13 days with a maintenance frequency of 51 times per year. These differences indicate that modules related to the weighing process require more intensive maintenance compared to other modules.

4.5. Calculation of Inspection Time Intervals

At this point, the inspection interval for each module is calculated. The following is an example of the calculation steps used to determine the inspection interval for Module 1, the chain conveyor.

1) Total Working Hours Per Month
   Total Working Hours Per Month = working days per month × working hours
   = 26,75 day × 24 hours
   = 642 hours
   = 38.520 minutes

2) The number of failures during 12 months in module 1 was 4 failures.
3) Average Repair Times

$$\frac{1}{\mu} = \frac{\text{MTTR}}{\text{Total working hours per month}}$$

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$$\frac{1}{\mu} = \frac{45{,}101 \text{ minutes}}{38.520 \text{ minutes}}$$

$\mu = 854{,}077$ minutes

4) Average Inspection Time

$$\frac{1}{i} = \frac{\text{Average examination time}}{\text{Total working hours per month}}$$

$$\frac{1}{i} = \frac{60 \text{ minutes}}{38.520 \text{ minutes}}$$

$i = 642$ minutes

5) Average Failures Rate

$$k = \frac{\text{Number of failures per 12 months}}{12 \text{ months}}$$

$$k = \frac{4}{12}$$

$k = 0{,}333$ failures per month

6) Optimal Inspection Frequency

$$n = \sqrt{\frac{k \times i}{\mu}}$$

$$n = \sqrt{\frac{0{,}333 \times 642}{854{,}064}}$$

$n = 0{,}501$ (inspection frequency index)

7) Inspection Interval

$$ti = \frac{\text{Total working hours per month}}{n}$$

$$ti = \frac{38.520 \text{ minutes}}{0{,}501}$$

$ti = 76.953{,}397$ minutes ≈ 53 days

The results of determining the inspection interval for each module are displayed in the following table after one hand calculation example.

Table 10. Calculation Results for Inspection Intervals

Module	Inspection Interval (Day)
Module 1 (Chain Conveyor)	53 day
Module 2 (Bin dosing)	16 day
Module 3 (Dosing weight)	17 day
Module 4 (Small Dosing weight)	17 day
Module 5 (Mixer Machine)	36 day
Module 6 (Elevator 3013M1)	20 day

Based on the inspection interval table, each module in the dosing line system has different inspection frequency requirements depending on its reliability level and operational characteristics. Module 1 (chain conveyor) has the longest inspection interval at 53 days, indicating that this module is relatively more stable and has a lower probability of failure compared to the other modules. Module 5 (mixer) also has a fairly long inspection interval of 36 days, so the inspection requirements for this module are not as frequent as for some of the other modules. Meanwhile, Module 2 (dosing bin), Module 3 (dosing scale), and Module 4 (small dosing scale) have shorter inspection intervals, specifically 16 days, 17 days, and 17 days, respectively. This indicates that these three modules require more intensive monitoring because they play a direct role in the raw material weighing process and have a higher potential for operational disruptions. On the other hand, Module 6 (Elevator 3013M1) has an inspection interval of 20 days, indicating a relatively higher frequency of inspections compared to the chain conveyor and mixer modules, though not as intensive as the modules involved in the

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weighing process. These differences in inspection intervals reflect the varying levels of criticality of each module in maintaining the smooth operation of the dosing line system.

4.6. Availability Calculation

At this point, availability is calculated using two types of availability, namely inherent availability and operational availability, using the formula found in point 2.4 literature review.

Table 11. Availability Calculation Results

Module	Inherent Availability	Operational Availability	Availability Standard (90%)
Module 1 (Chain Conveyor)	99,961%	90,319%	Achived
Module 2 (Bin dosing)	99,554%	90,025%	
Module 3 (Dosing weight)	99,621%	90,071%	
Module 4 (Small Dosing weight)	99,613%	90,061%	
Module 5 (Mixer Machine)	99,914%	90,283%	
Module 6 (Elevator 3013M1)	99,719%	90,145%	

Based on the availability table, all modules in the dosing line system demonstrate a very high level of availability. The inherent availability value for each module is above 99%, while operational availability is above 90%. This indicates that all modules have met and even exceeded the established availability standard of 90%. Module 5 (mixer) has the highest inherent availability value at 99.914% with an operational availability of 90.283%. Meanwhile, other modules such as the chain conveyor, dosing bin, dosing scale, small dosing scale, and elevator 3013M1 also demonstrate stable availability values that meet the standards. Overall, these results indicate that the dosing line possesses a high level of operational reliability, thereby effectively supporting the continuity of the production process.

V. Conclusion

Based on the results of the research conducted, the dosing line is classified into six main modules according to a modular design approach: the chain conveyor module, the dosing bin module, the dosing weight module, the small dosing weight module, the mixer module, and the 3013M1 elevator module. The analysis results indicate that the root causes of failures in the line dosing system are primarily due to malfunctions in the programmable logic control (PLC) system, wear and looseness of mechanical components, material blockages, and functional failures in pneumatic hose components. Calculations of optimal inspection intervals and preventive maintenance frequencies indicate that each module requires a different maintenance schedule based on its criticality level and operational characteristics. The chain conveyor module has an inspection interval of 53 days with a frequency of 5 times per year, the dosing bin has a 16-day interval with a frequency of 61 times per year, the dosing weight has a 17-day interval with a frequency of 71 times per year, the small dosing weight has a 17-day interval with a frequency of 63 times per year, the mixer has a 36-day interval with a frequency of 14 times per year, and the 3013M1 elevator has a 20-day interval with a frequency of 51 times per year. Furthermore, calculations of actual availability based on mean time between failure (MTBF) and operational time indicate that the inherent availability and operational availability values for each module are at a very high level. These values are 99.961% and 90.319% for the chain conveyor, 99.554% and 90.025% for the dosing bin, 99.621% and 90.071% for the dosing weight, 99.613% and 90.061% for the small dosing weight, 99.914% and 90.283% for the mixer, and 99.719% and 90.145% for the 3013M1 elevator. All of these values have exceeded the established availability standard threshold of over 90%.

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