

Risk and Performance Analysis of Fiber Optic Maintenance Activities at PT X Using a Risk-Based Performance Management Approach

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ABSTRACT

As one of the largest telecommunications infrastructure providers in Indonesia, PT X plays a crucial role in maintaining network performance through routine preventive maintenance (PM) activities. However, the high number of trouble tickets in several regions, particularly North Sumatra, indicates that PM activities have not been fully effective in preventing network disruptions. This condition highlights the need for an integrated risk management approach to improve the effectiveness of maintenance activities. This study aimed to identify, evaluate, and provide risk management recommendations for PT X's fiber optic maintenance activities. Using Risk-Based Performance Management (RBPM) integrated with Failure Mode and Effects Analysis (FMEA), this study identified potential failure modes, calculated Risk Priority Numbers (RPNs), and developed mitigation strategies aligned with the identified risk profiles. The identification results revealed 20 risks that could affect the achievement of PT X's two fiber optic maintenance Key Performance Indicators (KPIs). Among these identified risks, 2 were categorized as extreme risks, 7 as high risks, 8 as medium risks, and 3 as low risks. Based on the Pareto principle, 12 priority risks were identified, with avoidance and mitigation selected as the appropriate risk response strategies. The proposed risk management recommendations are expected to help PT X improve customer satisfaction and operational performance by reducing the number of trouble tickets requiring additional corrective maintenance (CM) activities, which may result in additional costs. This study also supports PT X in identifying and prioritizing risks associated with fiber optic maintenance activities.

INTRODUCTION

The development of telecommunications technology in Indonesia has continued to increase alongside the growing number of internet users (Alsubaih & Sepehrnoori, 2026; Lawall & Drozdzyński, 2026; Pencheva et al., 2025). The high public demand for internet services has encouraged telecommunications infrastructure providers to deliver reliable and high-quality networks. One of the main components supporting these services is the fiber optic network, which offers advantages in terms of high data transmission speed, signal stability, and extensive coverage capability (Oluwaleke, 2025; Pendão & Silva, 2022; Wellbrock et al., 2023; Xu et al., 2025). PT X is one of the telecommunications infrastructure providers in Indonesia that provides fiber optic services and routinely conducts preventive maintenance (PM) activities to maintain network reliability and minimize service disruptions.

Although preventive maintenance activities have been conducted periodically, company data indicate that a high number of trouble tickets remain, particularly in the North Sumatra region (Fitriana et al., 2022; Nainggolan, 2025; Pasurangga & Baltasar, 2025; Wibowo et al.,

2022). This condition requires the implementation of corrective maintenance (CM), resulting in additional costs, time, and resource utilization. These circumstances indicate that preventive maintenance activities have not been fully effective in preventing disruptions because they have not been optimally integrated with risk management processes. Therefore, an approach capable of identifying, evaluating, and controlling risks that may affect the performance of fiber optic network maintenance activities is required (Cruzes, 2024; Liu et al., 2026; Natalino et al., 2022; Santoso et al., 2026; Wang et al., 2022).

Several previous studies have examined risk management in the telecommunications sector. Pratami (2018) identified risks in the initial installation process of fiber optic infrastructure, focusing on project-based risk assessment before network operation. Rodrigueis (2022) analyzed risks related to occupational safety and health among technicians during fiber optic network installation and maintenance in Manaus, with a primary focus on worker safety rather than strategic performance improvement. Lestari (2024) conducted a risk assessment of fiber optic production lines using the HIRADC method, which similarly emphasized occupational safety and health aspects without linking risk analysis to organizational performance indicators. Meanwhile, Birudaraju (2025) proposed a conceptual business management framework for operational efficiency and risk mitigation in optical fiber networks; however, the study remained prescriptive, lacked empirical case validation, and did not specifically explain how risk analysis could be translated into measurable performance improvements.

Compared with previous studies, this research offers novelty by integrating Risk-Based Performance Management (RBPM) with Failure Mode and Effects Analysis (FMEA) in the context of fiber optic preventive maintenance activities (Gomaa, 2025; Nair, 2026). This approach directly links risk identification with Key Performance Indicators (KPIs), such as trouble ticket ratio and on-time trouble ticket handling. Unlike previous studies that focused on installation projects, occupational safety, or conceptual frameworks, this research provides a comprehensive and empirical risk assessment that connects risk profiles with maintenance performance outcomes, enabling the formulation of targeted mitigation strategies to support the achievement of PT X's operational targets.

This study aimed to identify, analyze, and evaluate risks in PT X's fiber optic maintenance activities using the RBPM approach integrated with the FMEA method. The integration of these methods enabled risk assessment through Risk Priority Number (RPN) calculation, risk prioritization, and the development of mitigation strategies aligned with the company's performance indicators. Compared with previous research that primarily focused on installation projects, occupational safety aspects, or general risk management frameworks, this study focused on the integrated implementation of RBPM in fiber optic network preventive maintenance activities.

The research problems addressed in this study included the identification of risks in PT X's fiber optic maintenance activities, the evaluation and analysis of risks and maintenance performance, and the formulation of appropriate strategy recommendations to improve performance based on identified risk profiles. Accordingly, the objectives of this research were to identify risks, analyze the risk profiles and performance of maintenance activities, and develop risk management recommendations that could support improvements in the effectiveness of fiber optic network maintenance.

The results of this research are expected to provide practical benefits for PT X by enabling the identification of potential risks, determination of risk management priorities, and improvement of maintenance performance to minimize trouble tickets and the need for corrective maintenance activities. Furthermore, this research contributes academically to the development of risk management studies in the telecommunications sector, particularly regarding the application of RBPM in fiber optic network maintenance activities. This study was limited to fiber optic maintenance activities in PT X's North Sumatra region, focusing on risks that negatively affected KPI achievement. The study assumed that the company's performance indicators remained unchanged during the research period and that all collected data were valid.

METHOD

This research methodology was developed as a guideline for conducting the study systematically, beginning with problem identification, data collection, data processing, analysis, and the formulation of conclusions and recommendations. The research process began by identifying PT X's existing conditions through observations and interviews with the Operation Maintenance and Execution (OME) Section Head of the Northern Sumatra Region to understand the fiber optic maintenance process and the challenges encountered. Based on the identification results, the research problems, objectives, benefits, limitations, and assumptions were formulated, followed by a literature review on risk management, maintenance management, Risk-Based Performance Management (RBPM), Failure Mode and Effects Analysis (FMEA), and relevant previous studies.

The next stage involved data collection, which included maintenance process identification, risk identification, and determination of risk levels and criteria. Process identification was conducted to understand the maintenance activity flow and the Key Performance Indicators (KPIs) applied by PT X. Subsequently, risk identification was carried out through direct observations and interviews with relevant personnel to identify potential risks that could hinder KPI achievement. All identified risks were then validated to ensure their relevance to the company's operational conditions.

After data collection was completed, risk levels were determined based on three main parameters in the FMEA method: severity (impact level), occurrence (likelihood of occurrence), and detection (ability to detect risks). The assessment of these parameters was conducted based on interviews with relevant personnel at PT X to evaluate the impact, frequency, and detectability of each identified risk.

The data processing stage involved analyzing each risk using the FMEA method through the calculation of the Risk Priority Number (RPN), obtained by multiplying the severity, occurrence, and detection scores. The RPN values were used to determine risk priorities and identify risks requiring immediate action. The prioritized risks were then categorized and analyzed using the Pareto principle to identify the most dominant risk factors. Based on these results, risk management recommendations were formulated using appropriate strategies, including risk avoidance, mitigation, transfer, or acceptance, according to the characteristics of each risk and PT X's operational requirements.

The final stage involved analyzing and interpreting the research findings, including discussions of risk identification results, risk level evaluations, and the effectiveness of

proposed mitigation strategies. The analysis results were used as the basis for drawing conclusions that addressed the research objectives and developing recommendations for PT X to improve fiber optic maintenance performance. In addition, suggestions were provided for future research aimed at expanding studies on risk management in the telecommunications sector.

RESULTS AND DISCUSSION

Risk Evaluation of PT X's Fiber Optic Maintenance Activities

After identification related to causes, impacts, as well as risk Severity, Occurrence, and Detection assessments have been carried out, the next stage is to calculate the Risk Priority Number (RPN) and determine the risk level (Low Risk, Medium Risk, High Risk, Extreme Risk) for each risk that has been identified. From the results of the RPN calculation, risk assessment mapping will be carried out which will be the basis for determining risk priorities based on the pareto principle.

1. Risk Priority Number Calculation

In this section, RPN calculation will be carried out by multiplying the Severity, Occurrence, and Detection of each risk that has been identified which can affect the achievement of the KPI of PT X's fiber optic maintenance activities based on the Risk Severity Assessment Attachment

Sheet, Risk Occurrence Assessment Sheet, and Risk Detection Assessment Sheet. The results of the RPN calculation will be the basis for determining the level and priority of risk. The results of the RPN calculation are shown in tables 1 and 2.

Table 4.15 RPN Results for KPI Risk Trouble Ticket Ratio per Kilometer

Risk Code	Risk	Risk Impact	Severity	Occurrence	Detection	RPN
R1	Physical damage to fiber optic cables	Increase in the number of <i>Trouble Tickets</i> >1 per KM, mass disruption to customers	3	5	4	60
R2	Theft of fiber optic cables	Increase in the number of <i>Trouble Tickets</i> >1 per KM, mass disruption to customers	4	2	3	24
R3	Late payment of bills by customers	<i>Trouble Ticket recording error</i> by the system, causing <i>additional technical</i> <i>Trouble Ticket</i>	2	2	3	12
R4	Land conflicts	Delays in maintenance activities, increased <i>overtime</i> maintenance costs, increased number of <i>Trouble Tickets</i> >1 per KM due to destruction of site cables, and so on	4	4	3	48
R5	Signal attenuation in fiber optic fiber	<i>Packet loss</i> , modem downtime (ONT), spike in the number of <i>Trouble Tickets</i> on a given cluster	3	4	2	24
R6	Overheat on Optical Line Terminal (OLT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a given cluster	3	2	4	24
R7	<i>Recurring Trouble Ticket</i> on the same cluster/area	Repetitive corrective maintenance <i>activities</i> incur additional costs	3	4	4	48
R8	Modem (ONT) is problematic	Internet connection disruption, increase in the number of <i>Trouble Tickets</i> from related customers	2	5	2	20
R9	Overheat pada Fiber Distribution Terminal (FDT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a given cluster	4	3	4	48

Risk Code	Risk	Risk Impact	Severity	Occurrence	Child	RPN
R10	Overheat at Fiber Access Terminal (FAT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a given cluster	4	3	4	48
R11	<i>Aging</i> in fiber optic device components	Weak internet signal, internet disruption, surge in the number of <i>Trouble Tickets</i>	4	1	4	16
R12	Damage to FDT/FAT seals	Fiber optic connection breakdown, mass outage, spike in the number of <i>Trouble Tickets</i> on a given cluster	4	1	4	16

Source: Researcher's calculation based on FMEA assessment and interviews with PT X's OME Section Head (2024).

Table 2. RPN Results for KPI Risk Ontime Trouble Ticket Handling

Risk Code	Risk	Risk Impact	Severity	Occurrence	Child	RPN
R13	Traffic disruptions	Handling of <i>Trouble Tickets</i> exceeding the SLA by technicians (partners)	3	4	5	60
R14	Measuring instrument damage (OTDR)	Misdiagnosis of cable damage that could potentially cause <i>Trouble Ticket handling</i> to exceed the SLA	2	2	2	8
R15	Limited number of certified technicians	Handling <i>Trouble Tickets</i> exceeding SLAs and stacking the number of <i>Trouble Tickets</i>	2	2	1	4
R16	Lack of troubleshooting capabilities of technicians	Handling <i>Trouble Tickets</i> exceeding SLAs and stacking the number of <i>Trouble Tickets</i>	2	2	1	4
R17	Difficulty accessing the site	Handling <i>Trouble Tickets</i> exceeding the SLA	4	4	3	48
R18	Trouble ticket <i>misclassification</i>	Handling <i>Trouble Tickets</i> exceeding the SLA	3	2	3	18
R19	Delayed response by regional partner PICs	Delay in field technician execution so that <i>Trouble Ticket</i> handling exceeds SLA	4	3	4	48
R20	Delay in delivery of fiber optic components	Delay in repair of fiber optic components, <i>spare parts</i> are not available, so that <i>Trouble Ticket</i> handling exceeds SLA	4	3	4	48

Source: Researcher's calculation based on FMEA assessment and interviews with PT X's OME Section Head (2024)

2. Determination of Risk Level

The risk level is determined based on the mapping of the risk assessment matrix. The risk level consists of 4 levels, namely extreme, high, medium, and low. This risk level is determined based on the results of the calculation of the Risk Priority Number (RPN), where usually the RPN with the highest value is considered as extreme risk. Likewise, the RPN with the lowest value is considered low risk. The risk level here is the level of risk recognized by the company which is determined from the results of discussions with the Operation Maintenance and Execution (OME) Section Head of the Northern Sumatra regional office of PT X. The following is the risk level of PT X's fiber optic maintenance activities as shown in table 3.

Table 3. Risk Level Based on PT X Severity, Occurrence, Detection Indicators

Rank	Severity	Occurrence	Detection
5	Extreme	High	Medium
4	Extreme	High	Medium
3	High	Medium	Low
2	Medium	Low	Low
1	Low	Low	Low

Source: Researcher's analysis based on PT X's risk assessment matrix and discussion with the OME Section Head (2024)

The table above shows the level of risk based on the severity, occurrence, and detection indicators in the risk assessment matrix. Table 4.18 below shows the risk level based on the RPN calculation results.

Table 4. Risk Level Based on RPN Calculation Results

Risk Level	RPN
Extreme	>50
High	30>RPN>=50
Medium	10>RPN>=30
Low	RPN <=10

Source: Researcher's analysis based on FMEA RPN calculation results (2024)

After the risk level based on the results of the RPN calculation has been determined, the next step is to map the risks that have been identified that can affect the achievement of PT X's fiber optic maintenance activity KPIs based on the results of the calculation of the highest to the lowest RPN into the risk assessment matrix listed in tables 5 and 6 below.

Table 5. Risk Level for KPI Risk Trouble Ticket Ratio per Kilometer

Risk Code	Risk	Risk Impact	RPN	Level Risk
R1	Physical damage to fiber optic cables	Increase in the number of <i>Trouble Tickets</i> >1 per KM, mass disruption to customers	60	Extreme
R4	Land conflicts	Delays in <i>maintenance</i> activities, increased <i>overtime maintenance</i> costs, increased number of <i>Trouble Tickets</i> >1 per KM due to destruction of <i>site</i> cables, and so on	48	High
R7	<i>Recurring Trouble Ticket</i> on the same cluster/area	Repetitive corrective <i>maintenance activities</i> incur additional costs	48	High
R9	Overheat pada Fiber Distribution Terminal (FDT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a <i>given</i> cluster	48	High
R10	Overheat at Fiber Access Terminal (FAT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a <i>given</i> cluster	48	High
R2	Theft of fiber optic cables	Increase in the number of <i>Trouble Tickets</i> >1 per KM, mass disruption to customers	24	Medium
R5	Signal attenuation in fiber optic fiber	<i>Packet loss, modem downtime (ONT), spike in the number of</i> <i>Trouble Tickets</i> on a <i>given</i> cluster	24	Medium
R6	Overheat on Optical Line Terminal (OLT)	Mass outages, spikes in the number of <i>Trouble Tickets</i> on a <i>given</i> cluster	24	Medium

Risk Code	Risk	Risk Impact	RPN	Level Risk
R8	Modem (ONT) is problematic	Internet connection disruption, increase in the number of <i>Trouble Tickets</i> from related customers	20	Medium
R11	Aging in fiber optic device components	Weak internet signal, internet disruption, surge in the number of <i>Trouble Tickets</i>	16	Medium
R12	Damage to FDT/FAT seals	Fiber optic connection breakdown, mass outage, spike in the number of <i>Trouble Tickets</i> on a given cluster	16	Medium
R3	Late payment of bills by customers	Trouble Ticket <i>recording error</i> by the system causing <i>additional technical</i> Trouble Ticket	12	Medium

Source: Researcher's calculation based on RPN results and risk level mapping (2024)

Table 6. Risk Level for KPI Risk Overtime Trouble Ticket Handling

Risk Code	Risk	Risk Impact	RPN	Level Risk
R13	Traffic disruption by technicians (partners)	Handling <i>Trouble Tickets</i> exceeding the SLA	60	Extreme
R17	Difficulty accessing the <i>site</i>	Handling <i>Trouble Tickets</i> exceeding the SLA	48	High
R19	Delayed response by regional partner PICs	Delay in field technician execution so that <i>Trouble Ticket</i> handling exceeds SLA	48	High
R20	Delay in delivery of fiber optic components	Delay in repair of fiber optic components, <i>spare parts</i> are not available, so that <i>Trouble Ticket</i> handling exceeds SLA	48	High
R18	Trouble ticket <i>misclassification</i>	Handling <i>Trouble Tickets</i> exceeding the SLA	18	Medium
R14	Measuring instrument damage (OTDR)	Misdiagnosis of cable damage that could potentially cause <i>Trouble Ticket</i> handling to exceed the SLA	8	Low
R15	Limited number of certified technicians	Handling <i>Trouble Tickets</i> exceeding SLAs and stacking the number of <i>Trouble Tickets</i>	4	Low
R16	Lack of troubleshooting capabilities of technicians	Handling <i>Trouble Tickets</i> exceeding SLAs and stacking the number of <i>Trouble Tickets</i>	4	Low

Source: Researcher's calculation based on RPN results and risk level mapping (2024)

Based on the risk level mapping table based on the RPN above, it was found that of the 20 risks identified that could affect the achievement of PT X's fiber optic maintenance activity KPIs, there are 2 risks classified as extreme risks, 7 risks classified as high risks, 8 risks classified as medium risks, and 3 risks classified as low risks.

3. Priority Risk Determination

Once the risk level is determined, the next step is to determine the priority risk using the pareto principle. Where the pareto principle explains that 80% of RPN is a risk classified as a priority risk, where the remaining 20% is not classified as a priority risk. The following is a pareto diagram used to determine the priority risk of PT X's fiber optic maintenance activities as shown in figure 4.1

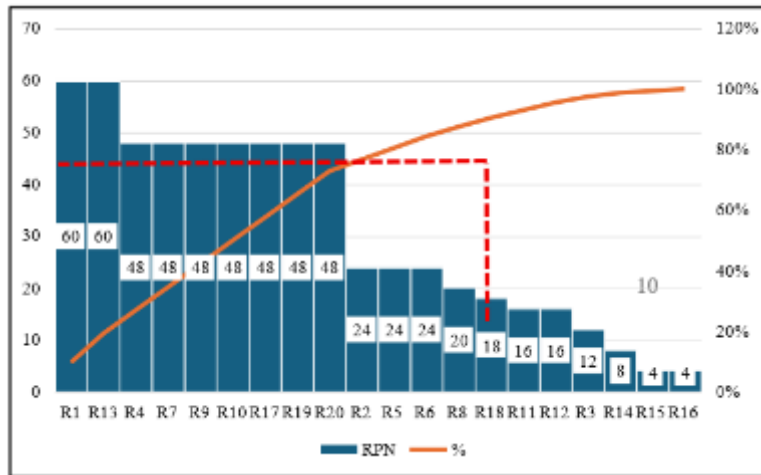


Figure 1. Pareto Chart of Priority Risks of PT X's Fiber Optic Maintenance Activities
Source: Researcher's analysis based on RPN calculation results using Pareto principle (2024)

The grouping in the pareto chart above is carried out based on the largest to smallest RPN values. The X axis shows the code of each risk identified during fiber optic maintenance, the left Y axis shows the RPN range of each risk code, and the Y axis on the right shows the percentage of accumulation of RPNs from each risk code which is also marked with an orange curved line. The red dotted line indicates the point where the accumulation of RPN has reached 80%, where the risk code with an accumulation range of 0 – 80% will be classified as a priority risk.

Based on the pareto chart above, of the 20 risks identified that can affect the achievement of KPIs for PT X's fiber optic maintenance activities, only 12 risks are classified as priority risks (2 extreme risks, 7 high risks, and 3 medium risks). The 12 risks are found in tables 7 and 8 below.

Table 7. Priority Risks for KPIs Trouble Ticket Ratio per Kilometer

Risk Code	Risk	RPN	Risk Level
R1	Physical damage to fiber optic cables	60	Extreme
R4	Land conflicts	48	High
R7	Recurring Trouble Ticket on the same cluster/area	48	High
R9	Overheat pada Fiber Distribution Terminal (FDT)	48	High
R10	Overheat at Fiber Access Terminal (FAT)	48	High
R2	Theft of fiber optic cables	24	Medium
R5	Signal attenuation in fiber optic fiber	24	Medium
R6	Overheat on Optical Line Terminal (OLT)	24	Medium

Source: Researcher's analysis based on Pareto principle application to RPN results (2024)

Table 8. Priority Risks KPI Ontime Trouble Ticket Handling

Risk Code	Risk	RPN	Level Risk
R13	Traffic disruption by technicians (partners)	60	Extreme
R17	Difficulty accessing the <i>site</i>	48	High
R19	Delayed response by regional partner PICs	48	High
R20	Delay in delivery of fiber optic components	48	High

Source: Researcher's analysis based on Pareto principle application to RPN results (2024)

Recommendations for Risk Management of PT X's Fiber Optic Maintenance Activities

After obtaining priority risks that affect the achievement of PT X's fiber optic maintenance activities, the next step is to prepare risk management recommendations. The handling strategy used refers to four main approaches, namely avoid risk, mitigate risk, transfer risk, and accept risk. However, based on the operational characteristics of PT X, the most widely applied recommendations are the mitigate, transfer, and accept risk strategies, as most risks cannot be avoided completely.

In the KPI Trouble Ticket Ratio per Kilometer, the highest priority risks include physical damage to fiber optic cables, land conflicts with residents, repeated trouble tickets in the same area, and overheating conditions at Fiber Distribution Terminals (FDT) and Fiber Access Terminals (FAT). To reduce these risks, various mitigation measures are recommended, such as cleaning vegetation around the site, preparing work guidelines and training technicians, installing safety fences, periodic temperature and device hygiene checks, installing adequate ventilation, and providing a documentation system for preventive maintenance results. In addition, companies are also advised to provide backup cables, install temperature detectors and early warning systems, and apply insurance for fiber optic cables as a form of risk transfer.

Other risks included in the medium priority category are theft of fiber optic cables, signal attenuation in fiber optics, and overheating of Optical Line Terminals (OLTs). Recommended handling includes the installation of CCTV and lighting in the site area, coordination with the surrounding community to increase supervision, enforcement of legal proceedings against the perpetrators of theft, training technicians on proper cable installation procedures, regular inspection of network devices, and the provision of backup cables and protection through insurance. These various actions are expected to be able to reduce the possibility of disruption while minimizing their impact on company operations.

In the KPI Ontime Trouble Ticket Handling, the main risks identified include traffic disruptions experienced by technicians, difficulty accessing the site, delayed response from Person in Charge (PIC) regional partners, and delays in the delivery of fiber optic components. Handling recommendations include the preparation of alternative routes to the location, the implementation of an alert system for technicians and PICs, the scheduling of operational vehicle services, the digitization of site passes, the provision of technician identification, the preparation of a list of technicians on duty at each location, the preparation of an escalation matrix in the event of a delay in response, as well as the planning of minimum component requirements and the determination of minimum stock in regional warehouses. These efforts are expected to be able to increase the speed of response to outages while maintaining a smooth network maintenance process.

Overall, the proposed risk management recommendations focus on reducing the likelihood of occurrence, reducing the severity of the impact, and improving detection capabilities. The implementation of these recommendations is expected to increase the effectiveness of preventive maintenance activities, reduce the number of trouble tickets, minimize the need for corrective maintenance, and improve operational performance and customer satisfaction of PT X.

Risk Identification Analysis of PT X's Fiber Optic Maintenance Activities

PT X is always committed to maintaining the application of their fiber optic infrastructure so that it can run smoothly so that people can enjoy a fast and stable internet

connection by performing Preventive Maintenance (PM) regularly. However, based on PT X, it was found that Northern Sumatra is the region with the highest number of fiber optic trouble tickets with 2939 trouble tickets. Trouble ticket here indicates a failure that is real-time or occurs instantly, so it requires corrective maintenance activities by PT X. Where this is contrary to the principles of preventive maintenance applied by PT X with the aim of solving potential risks before the risk occurs. Preventive maintenance is indeed carried out by PT X to resolve risks before these risks occur, but it has not been able to provide maximum results because there is no involvement in risk management activities in it.

Identification of possible risks or failures focuses on risks that can hinder the achievement of PT X's fiber optic maintenance KPIs through direct observation and interviews with the Operation Maintenance and Execution (OME) Section Head of PT X's Northern Sumatra regional office. The first KPI is the number of trouble tickets per kilometer, where the management of PT X has determined that the number of trouble ticket ratios per kilometer for the Northern Sumatra region must be at least 1 trouble ticket per 36 kilometers. Then the second KPI explains the timeliness of resolving trouble tickets in accordance with the SLA (Service Level Agreement) set by the operator.

The results of the risk identification showed that there were a total of 20 total risks that could affect the achievement of 2 KPIs of PT X's fiber optic maintenance where KPI 1 had 12 risks and KPI 2 had 8 risks. After the risk identification is carried out, the next step is to identify the cause of the existing risk. Identifying the cause of risk involves 5 aspects, including man, method, material, machine, and environment, where each risk can have more than 1 cause. Of the 20 risks identified, there are 51 identified causes of each of these risks. Figure 4.2 below shows a recapitulation of the number of risk causes that have been classified in 5 aspects of man, method, material, machine, and environment.

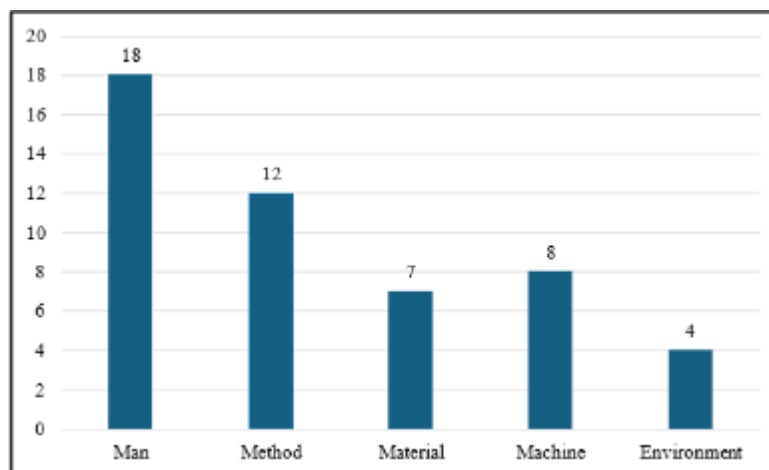


Figure 2. Number of Risk Causes Based on 5 Aspects (Man, Method, Material, Machine, Environment)

Source: Researcher's analysis based on risk identification results and interviews with PT X's OME Section Head (2024)

Based on the diagram above, it is found that the human aspect is the cause of the most risks identified in each existing risk, which is involved in almost every risk that can affect the

achievement of PT X's fiber optic maintenance activity KPIs. The risks caused by the human aspect occur due to several things, such as poor implementation of maintenance activities, lack of understanding of technicians about maintenance mechanisms, delay in technician response, and so on. The results of the risk identification in this section answer the purpose of assisting PT X in knowing what risks can occur when fiber optic maintenance activities take place.

When compared to previous research, (Pratami, 2018) identified risks in the initial installation process before fiber optic infrastructure was used, while the research focused on identification for the maintenance process of fiber optic infrastructure.

Risk Assessment and Risk Evaluation of PT X's Fiber Optic Maintenance Activities

After the identification of risks as well as the impact and causes of the risk is carried out, the next stage is to conduct a risk assessment by entering severity, occurrence, and detection values for each risk that can affect the achievement of KPIs of PT X's fiber optic maintenance activities. field. The assessment of severity, occurrence, and detection of each risk uses a scale of 1 – 5 where the smaller the value, the smaller the impact produced by the risk. Severity is the severity or consequences that must be faced if a risk occurs, then occurrence is how often the risk occurs, and detection is how well the system is able to detect possible failures before the failure occurs

After the severity, occurrence, and detection assessment is carried out, the next step is to evaluate the risk, by calculating the Risk Priority Number (RPN) of each identified risk. The RPN calculation is carried out by multiplying the severity, occurrence, and detection of each risk. Based on the results of the RPN calculation, it was found that the highest RPN value was owned by R1 with "physical damage to the fiber optic cable" and R13 "traffic disturbance by technicians" with an RPN value of 60 each. Both risks have a major impact on mass disruption to customers as well as the handling of Trouble Tickets that exceed the SLA. In addition, the high occurrence value and weak detection ability by the system owned by PT X. Conversely, the lowest RPN is owned by R4 with "limited number of certified technicians" and R14 with "lack of technician troubleshooting capabilities". This risk has a low RPN value due to the frequency of rare occurrences and the detection ability of PT X to find out which technicians need further development by providing training about maintenance and handling of trouble tickets.

After calculating the RPN, the next step is to determine the level of risk. The risk level is determined based on the mapping of the risk assessment matrix. The risk level consists of 4 levels, namely extreme, high, medium, and low. This risk level is determined based on the results of the calculation of the Risk Priority Number (RPN), where usually the RPN with the highest value is considered as extreme risk. Likewise, the RPN with the lowest value is considered low risk. The risk level here is the level of risk recognized by the company which is determined from the results of discussions with the Operation Maintenance and Execution (OME) Section Head of the Northern Sumatra regional office of PT X based on the severity, occurrence, and detection of the existing risks. After the risk level can be determined based on the RPN value of each risk. Diagram 4.3 below shows the recapitulation of the risk assessment matrix mapping that can affect the achievement of PT X's fiber optic maintenance activity KPIs based on RPN.

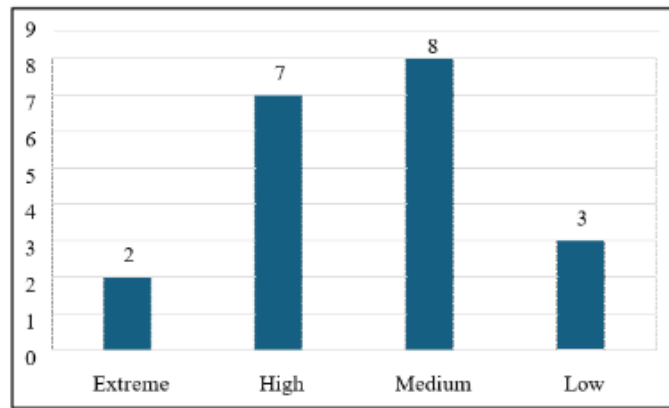


Figure 3. Risk Mapping of PT X's Fiber Optic Maintenance Activities

Source: Researcher's analysis based on RPN results and risk level mapping (2024)

Based on the risk mapping diagram above, it was found that of the 20 risks identified that could affect the achievement of PT X's fiber optic maintenance activity KPIs, there are 2 risks classified as extreme risks, 7 risks classified as high risks, 8 risks classified as medium risks, and 3 risks classified as low risks. Once the risk level is determined, the next step is to determine the priority risk using the pareto principle. Where the pareto principle explains that 80% of RPN is a risk classified as a priority risk, where the remaining 20% is not classified as a priority risk. The following is a pareto diagram used to determine the priority risk of PT X's fiber optic maintenance activities as shown in figure 4.4.

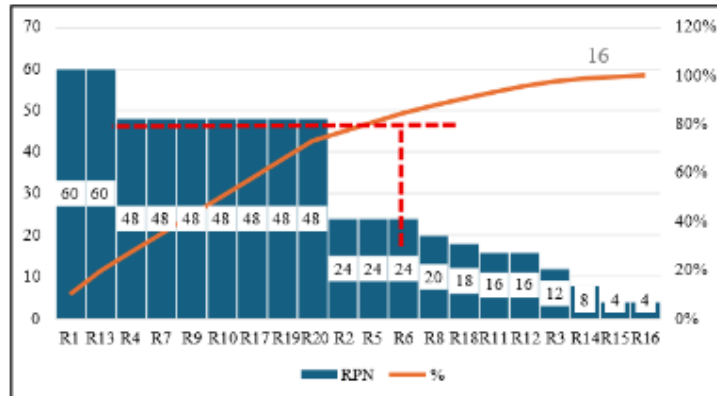


Figure 4. Pareto Priority Risks of PT X's Fiber Optic Maintenance Activities

Source: Researcher's analysis based on RPN calculation results using Pareto principle (2024).

Based on the pareto diagram above, it is obtained that the priority risks from PT X's fiber optic maintenance activities start from R1 with RPN 60 to R6 with RPN 24 with a total of 12 risks (2 extreme risks, 7 high risks, and 3 medium risks) which are classified as priority risks including risks for KPI 1 and KPI 2 which are contained in tables 9 and 10 below.

Table 9. Priority Risks for KPIs Trouble Ticket Ratio per Kilometer

Risk Code	Risk	RPN	Risk Level
R1	Physical damage to fiber optic cables	60	Extreme
R4	Land conflicts	48	High
R7	Recurring Trouble Ticket on the same cluster/area	48	High
R9	Overheat pada Fiber Distribution Terminal (FDT)	48	High
R10	Overheat at Fiber Access Terminal (FAT)	48	High
R2	Theft of fiber optic cables	24	Medium
R5	Signal attenuation in fiber optic fiber	24	Medium
R6	Overheat on Optical Line Terminal (OLT)	24	Medium

Source: Researcher's analysis based on Pareto principle application to RPN results (2024)

Table 10. Priority Risks for Ontime Trouble Ticket Handling KPIs

Risk Code	Risk	RPN	Level Risk
R13	Traffic disruption by technicians (partners)	60	Extreme
R17	Difficulty accessing the site	48	High
R19	Delayed response by regional partner PICs	48	High
R20	Delay in delivery of fiber optic components	48	High

Source: Researcher's analysis based on Pareto principle application to RPN results (2024)

When compared to previous studies, (Rodrigueis, 2022) explained that risk analysis focuses on researching the safety and health conditions of technicians, to ensure that maintenance activities run smoothly,

does not include continuous performance improvements. (Lestari, 2024) explained that risk analysis that also prioritizes occupational safety and health only, is not oriented towards strategic performance. Meanwhile, (Birudaraju, 2025) explained that risk analysis is conceptual and prescriptive, without being accompanied by real case studies and does not explain specifically how the concept of risk analysis used can result in improved performance in the aspects being studied.

Analysis of Risk Management Recommendations for PT X's Fiber Optic Maintenance Activities

The determination of recommendations for handling the risk of PT X's fiber optic maintenance activities is carried out after the priority risk is determined using the pareto principle in the previous section. The determination of risk management recommendation activities is based on various considerations and discussions together with the Operation Maintenance and Execution (OME) Section Head of the Northern Sumatra regional office PT X. There are 4 types of risk management, namely avoid risk (eliminating risks that are considered harmful to the company's sustainability and the safety of the company's workers), mitigate risk (reducing the severity and frequency of each risk that is considered negotiable), Transfer risk, which is transferring risk to a third party in a condition where the company feels unable to control all aspects of existing business processes, or accept risk, which is accepting risk because the company does not consider the risk as a threat that can endanger the company's sustainability. The determination of risk management recommendations is based on the cause and source of each risk event that has been identified in the previous section.

Based on the results of discussions and joint considerations with the Operation Maintenance and Execution (OME) Section Head of the Northern Sumatra regional office of

PT X, the type of risk management chosen is mitigate, transfer, and accept risk. The type of avoidance risk handling was not chosen because in the context of telecommunications operations, risks are almost certain to be avoided due to the many external factors that cannot be fully controlled.

Some examples of activities that can be carried out by PT X to mitigate risk are providing routine training/guidebook for field technicians regarding the procedures for executing fiber optic cable installation including inspecting the physical condition of the cable before installation, installing safety fences around the site, especially on sites located far from residential areas to maintain site security, installing CCTV in the site area, cleaning fiber optic components on site regularly, installing vents on FDT to minimize potential overheating and so on. The transfer risk activity that can be carried out by PT X is to apply insurance to fiber optic cables. Meanwhile, some of the accept risk activities that PT X can carry out are installing temperature detectors, designing alarm alerts for technicians, preparing cable backups, and so on.

The risk management recommendations in this study are aimed at reducing the severity (impact), occurrence (frequency of occurrence), and improving the detection ability of PT X on various fiber optic maintenance risks that have been identified. Reducing severity and occurrence as well as increasing detection directly has an impact on reducing the number of trouble tickets generated. The fewer trouble tickets, the lower the corrective maintenance costs incurred by PT X. This indicates an increase in the effectiveness of preventive maintenance on the existing fiber optic infrastructure, which improves service quality, operational efficiency and customer satisfaction. However, it should also be noted that this study is limited to the northern part of Sumatra, where the resulting risk management recommendations are not necessarily fully applicable in other regions because the diversity of community characteristics, environmental conditions, and so on can produce different cases.

CONCLUSION

Based on the results of the study, it was concluded that the identification of risks in PT X's fiber optic maintenance activities resulted in 20 risks that had the potential to affect the achievement of two Key Performance Indicators (KPIs), consisting of 12 risks related to KPI 1 and 8 risks related to KPI 2. These risks were derived from 51 identified risk causes, which were predominantly associated with human factors, followed by methods, machines, materials, and environmental factors. The analysis using Failure Mode and Effects Analysis (FMEA) showed that the risks with the highest Risk Priority Number (RPN) values were physical damage to fiber optic cables and traffic disruptions affecting technicians during maintenance activities. Based on risk priority classification, there were 2 extreme risks, 7 high risks, 8 medium risks, and 3 low risks, with 12 risks identified as priority risks based on the Pareto principle.

The recommended risk management strategies included mitigation, risk transfer, and risk acceptance through various improvement actions, such as technician training, the preparation of work guidelines, installation of safety fences and CCTV at work sites, periodic cleaning of components, installation of vents in FDTs, use of fiber optic cable insurance, installation of temperature detectors and early warning systems, and provision of backup cables. Meanwhile, the risk avoidance strategy was considered less suitable due to the

operational characteristics of the telecommunications industry. Based on these findings, future research is recommended to develop risk analysis using quantitative approaches and integrate network and service performance aspects. For PT X, it is recommended to implement the proposed risk management strategies, expand risk management practices across all business lines, and evaluate the feasibility of each mitigation strategy to improve maintenance performance, reduce trouble tickets, minimize the need for corrective maintenance, and enhance customer satisfaction.

REFERENCES

- Alsubaih, A., & Sepehrnoori, K. (2026). Data Management and Key Performance Indicators (KPIs). In *Well Integrity for Oil, Gas, and Subsurface Storage Operations: Lifecycle Management, Technologies, and Energy Transition Challenges* (pp. 305–320). Springer.
- Birudaraju. (2025). Operational Efficiency and Risk Mitigation in Optical Fiber Networks: A Business Management Framework. *Journal of Emerging Technologies and Innovation Management*, 19-33.
- Cruzes, S. (2024). Failure management overview in optical networks. *IEEE Access*, 12, 169170–169193.
- Fitriana, R., Sukmawati, M., Salam, M. Y., & Hidayat, T. N. (2022). Analysis and Exploratory Study of Preventive Maintenance Implementation: A Case Study from Coffee Shops in Bandung, West Java. *12th Annual International Conference on Industrial Engineering and Operations Management*.
- Gomaa, A. H. (2025). Enhancing Failure Mode and Effects Analysis with Industry 4.0 (FMEA 4.0): A Comprehensive Review and Strategic Framework. *International Journal of Darshan Institute of Engineering Research and Emerging Technologies*, 14(2), 1–12.
- Lawall, A., & Drozdzyński, M. (2026). Executive Cyber Risk Governance Using Integrated Key Performance and Key Risk Indicators: The BCCR-Card Framework. *Obstacles in Implementation, Integration, and Security of Self-Sovereign Identity and Proposed Solutions*, 73.
- Lestari. (2024). THE ANALYSIS OF RISK ASSESSMENT ON FIBER OPTIC PRODUCTION LINE USING THE HAZARD IDENTIFICATION RISK ASSESSMENT AND DETERMINING CONTROL (HIRADC). *Journal of Information Technology and Computer Science (INTECOMS)*, 314-318.
- Liu, L., Chen, J., Liu, J., Li, Q., Duan, X., Yuan, L., & Yang, C. (2026). Research on Multidimensional Application Effect Evaluation of Pipeline Fiber-Optic Early Warning System. *Journal of Sensors*, 2026(1), 2163353.
- Nainggolan, P. (2025). *Optimizing the Performance of the Serdang Bedagai Police in Overcoming Traffic Incidents*.
- Nair, K. (2026). Evolution of business failure mode and effects analysis (BFMEA): A strategy to reduce failure rates of small technology businesses (STBs). *IEEE Engineering Management Review*.
- Natalino, C., Schiano, M., Di Giglio, A., & Furdek, M. (2022). Root cause analysis for autonomous optical network security management. *IEEE Transactions on Network and Service Management*, 19(3), 2702–2713.
- Oluwaleke, A. A. (2025). Performance metrics evaluation and technical comparative analysis of 5G and fibre optics networks technology for real-time video streaming. *Journal of African Sustainable Development*.
- Pasurangga, D., & Baltasar, S. (2025). Data Driven Predictive Maintenance Framework for Railway Safety in Indonesia. *ADI Journal on Recent Innovation (AJRI)*, 7(1), 75–87.
- Pencheva, V., Asenov, A., Georgiev, A., Mineva, K., & Kulev, M. (2025). System of key

- performance indicators for monitoring the effectiveness of urban public transport. *Transport Problems*, 20.
- Pendão, C., & Silva, I. (2022). Optical fiber sensors and sensing networks: Overview of the main principles and applications. *Sensors*, 22(19), 7554.
- Pratami. (2018). Designing Risk Qualitative Assessment on Fiber Optic Instalation Project in Indonesia. *International Journal of Innovation in Enterprise System*, 44-56.
- Rodrigueis. (2022). Modernization of the Data Transmission System: Assessment of Risks Arising from the Insertion and Maintenance of Fiber Optic Networks in Manaus- AM. *European Academic Research*, 6275-6286.
- Santoso, E., Ferdian, W., Iriawan, N., & Raharjo, A. B. (2026). External fault prediction maintenance modeling for fiber optics telecommunication networks. *Procedia Computer Science*, 284, 355–362.
- Wang, D., Zhang, C., Chen, W., Yang, H., Zhang, M., & Lau, A. P. T. (2022). A review of machine learning-based failure management in optical networks. *Science China Information Sciences*, 65(11), 211302.
- Wellbrock, G. A., Xia, T. J., Huang, M.-F., Han, S., Chen, Y., Wang, T., & Aono, Y. (2023). Explore benefits of distributed fiber optic sensing for optical network service providers. *Journal of Lightwave Technology*, 41(12), 3758–3766.
- Wibowo, A., Siregar, M., & Pandjaitan, L. (2022). Improvement of Performance Availability of Cellular by analyzing the Preventive Maintenance and Trouble Ticket Data. *2022 11th Electrical Power, Electronics, Communications, Controls and Informatics Seminar (EECCIS)*, 201–206.
- Xu, Y., Fei, L., Zhu, Y., Chen, X., Hu, W., & Zhuge, Q. (2025). Advanced radio-over-fiber interfaces and high-speed optical links toward 6G large-capacity fronthaul networks. *Journal of Optical Communications and Networking*, 17(11), E17–E36.