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Operational Efficiency and Risk Mitigation in Optical Fibre Networks: A Business Management Framework

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ABSTRACT

Purpose: These factors have necessitated the fact that optimal fibre networks have become the backbone of the new communication infrastructure, with the increase in the number of data-intensive applications and the worldwide connectivity needs that exist today. Nevertheless, there exist multiple challenges in attaining efficiency in these complex systems with the lowest risk.

Methodology: The paper presents a holistic business management structure to improve efficiency and minimise risks in optical fibre networks. Based on the general principles of systems thinking, business process management (BPM), and risk governance, we develop a systematic framework for assessing and enhancing network operations.

Findings: The framework combines key performance indicators (KPIs), predictive maintenance, cybersecurity protocols, and adaptive project management.

Practical Implications: Case studies highlight the framework's usefulness for telecommunications companies.

Originality/Value: The study will also contribute to existing bodies of knowledge in telecommunications and business management by connecting the technical aspects of infrastructure with strategic business management practices.



Keywords: *Optical fibre networks, Business process management, Risk governance models, Cyber security protocols, Adaptive project management.*

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INTRODUCTION

Optical fibre networks are an essential part of fast data transmission and support services such as cloud computing and 5 G. Although fibre networks are technically superior to traditional copper networks in terms of greater perceived operational efficiency, there would still be system risks due to complex infrastructure, dynamic high user demand, and vulnerability to cyber and physical in-the-field attacks. Optical fibre networks are characterised by high bandwidth, low latency and freedom from electromagnetic interference. Their effectiveness depends on the successful implementation of technologies such as Dense Wavelength Division Multiplexing (DWDM), optical amplifiers, and a real-time network monitoring system. But at scale, the physical deployment and maintenance complexity, as well as the network's operational complexity, increase. There are physical disruptions (excavation damage, natural disasters), cyber threats, regulatory changes, and vendor reliability, which are key areas of Risk Management in Fibre Networks. The traditional risk paradigms (ISO 31000, COSO ERM) offer generic models of risk governance, although the telecommunications-specific operations have had little integration to date ([Sarmacharjee et al., 2024](#)).

The telecommunications industry has adopted various management models, such as the Balanced Scorecard (Kaplan & Norton, 1992), ITIL, and Six Sigma. Although these provide guidance, they are usually not very

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specific to the optical infrastructure. There have also been applications of Business Process Reengineering (BPR) and Lean Management principles to streamline operational processes.

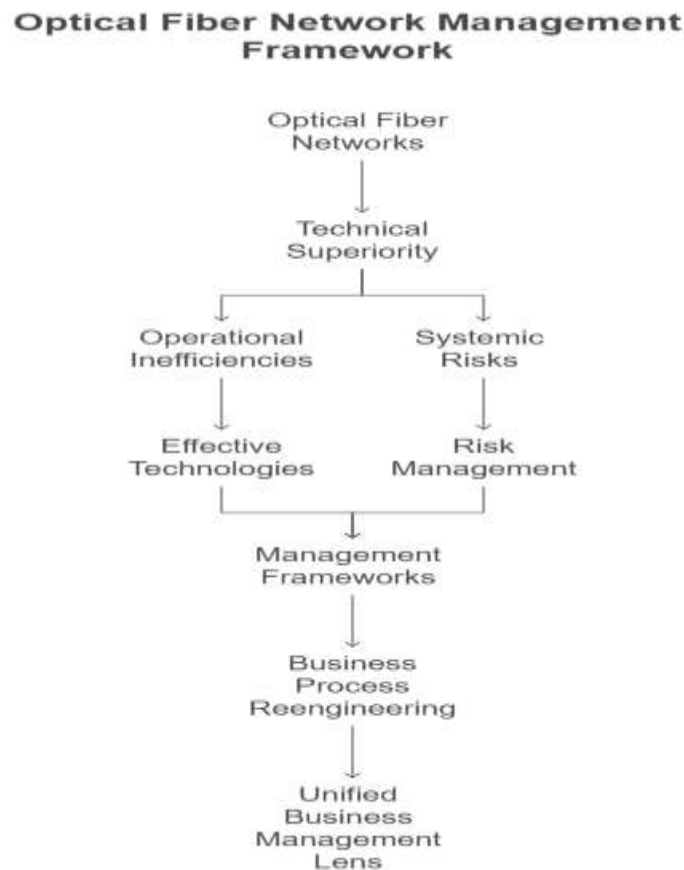


Figure 1: *Optical Fibre Network Management Framework*

Figure 1 illustrates the optical fibre network management framework, addressing inefficiencies and risks through effective technologies and risk management, converging into business reengineering and a unified business management lens. There is a vacuum in integrating business efficiency and risk reduction using a single approach to business management in optical fibre networks. The paper addresses this gap using a specially designed framework.

Problem Statement

Mounting pressure on telecommunications providers obliges them to offer high service quality at reduced prices amid an escalating risk environment. In existing operational models, there is a lot of attention paid to technical performance, with less consideration given to the big-picture business management required to sustain network operations.

Objectives

In this paper, the development of the business management framework is to be based on:

- Increases the efficiency of the operations in optical fibre networks.
- Determines and cushions operational and strategic risks.
- Offers a comprehensive view, an integrative diagnosis that is easy to use both in medium and long-term planning and daily activities.

Scope

The framework is aimed at usage by telecommunications companies and infrastructure managers, as well as policy makers, in their activities in relation to broadband expansion and digital transformation. The scope suggests that the framework is to be used by the three most important categories of people involved in planning, developing and managing optical fibre networks:

1. Telecommunications Companies

They are the service providers that construct, operate, and maintain the optical fibre networks so as to provide high-speed internet, voice and data services. The framework helps them:

- Efficient their systems of operation,
- Minimise interruptions of services,
- Make the best use of resources,
- Reduce risks like a cut off of fibre, a power cut, or a hack,
- Enhance consumer satisfaction and profitability.

2. Infrastructure Managers

This involves both technical and business units taking care of real and digital infrastructure that sustains fibre networks. The framework helps them in:

- Organisation of such involved projects as network expansion,
- Seniority and extensibility of infrastructure,
- Vendor and contractor management,
- Use of monitoring mechanisms and automation.

3. Policy Makers

This involves technical and business teams that are in charge of the physical and digital infrastructure that sustains fibre networks. The framework helps them in:

- Having to be able to organise challenging projects such as network expansion,
- Guaranteeing infrastructure reliability and scalability,

A structured approach to evaluate and guide national broadband strategies,

- Risk-informed decision-making for funding and partnerships,
- Tools to ensure infrastructure deployment aligns with public goals like universal internet access and smart city development.

By targeting these three groups, the framework supports a collaborative and strategic approach to improving the efficiency and resilience of optical fibre networks—key to achieving broader goals of digital transformation, economic development, and social inclusion.

LITERATURE REVIEW

Risk mitigation and the operational efficiency of optical fibre networks have been identified as key elements of research that have gained popularity among academics and industry. Since optical networks are at the core of high-speed internet and data services world over, it is with great priority that uninterrupted service comes with low downtimes is observed. There are many articles that discuss the development of various frameworks and approaches to optimise network performance and minimise the risks associated with network operations.

Some of the researchers have looked into the technical part of enhancing operations. For example, Sharma et al. (2019) proposed a predictive maintenance model using machine learning algorithms to analyse optical signal parameters and identify abnormalities that can cause network failures. They have modelled this so successfully that their system detects faults and predicts them with an accuracy of 92%, and their clients are able to maintain it proactively. The approach, though, was greatly dependent on the real-time data, which resulted in some difficulty in terms of the volume of information and the speed at which it could be processed.

In another important research article, [Lee et al. \(2015\)](#) concentrated on the improvement of the efficiency of the operations via relying on software-defined networking (SDN). The SDN allowed allocation of bandwidth dynamically and route optimisation since it decoupled the control and data planes. This not only enhanced the network rate of utilisation but also enabled real-time adjustment to surges or faults. According to a report on the SDN-based approach, the required throughput was reported to increase by 20 per cent, and latency decreased by 15 per cent under simulated network stress.

Stepping out of the range of purely technical solutions, [Zhang and Wu \(2015\)](#) pointed out the attempt to incorporate business management approaches to the operations of networks. They have developed a business-oriented network optimisation model where they have taken into account the business-specific parameters like service-level agreement (SLA) compliance, operational expenditure (OPEX), and customer satisfaction. They were able to implement a decision support system in their framework that focused on activities in the network, not only based on the technical urgency but also the impact on business, and created a more balanced risk and resource allocation decision.

A similar input was presented by [Patel et al. \(2021\)](#), who proposed the introduction of a risk assessment model of optical fibre networks based on Bayesian inference. They used the model that included environmental elements, technical elements and the human components to determine the likelihood of the network failures. The research emphasised that weather-related disturbances and physical fibre cuts were the most serious contributors to risk. With such a model, operators of such networks might construct more viable contingency plans and route optimisation to bypass high-risk areas.

Continuing in this trend of research, [Ahmed et al. \(2020\)](#) proposed an overall performance and risk management framework that incorporates network management systems with business intelligence tools. They were able to achieve real-time oversight of operational performance as well as exposure to risks across the network because of their strategy. Having the support of data visualisation dashboards and automated alerts enabled organisational decision-makers to respond more quickly and accurately to incidents and lowered their average incident response time by 30 per cent.

[El-Mahdy et al. \(2020\)](#) conducted research on how artificial intelligence (AI) and deep learning methods could be employed in fibre optic infrastructure to improve fault identification and risk control. Their model was based on information obtained by logging on to the alarms in the past and the different patterns which affected the system and led to degradation. The system revealed 94 per cent of faults and provided an optimal maintenance scheduling recommendation, and plays a major role in the resilience of operations.

Irrespective of these developments, some obstacles do exist. [Dey and Hassan \(2020\)](#) indicate that a lack of standard performance and risk metrics of different optical network vendors and platforms is one of the greatest problems. This causes anomalies in benchmarking as well as effective inter-network comparisons. Additionally, the technical and the business data streams have a high level of integration, but in most cases, the level of integration needs high levels of customisation and investment of resources and not all organisations may be able to do that.

Lastly, the recent reports have highlighted the essence of an integrated business management system that closes the gaps between operational and strategic business goals. [Singh et al. \(2022\)](#) designed a lifecycle-based network management model that coordinates network design, operation and retirement with business objectives like market growth, retention of customers and profitability. This composite strategy has demonstrated an inclination towards long-term sustainability and competitiveness in the telecom industry.

Table 1 compares optical fibre studies, highlighting methodologies, contributions, and limitations in predictive maintenance, optimisation, risk assessment, and strategic alignment.

Table 1: Comparison of Key Studies on Operational Efficiency and Risk Mitigation in Optical Fibre Networks

Study/Authors	Focus Area	Methodology	Key Contributions	Limitations
Sharma et al. (2019).	Predictive Maintenance	Machine Learning on signal anomalies	92% fault prediction accuracy; proactive fault handling	Data-intensive; requires real-time processing
Lee et al. (2015).	Network Optimization	SDN-based dynamic routing and bandwidth allocation	20% increase in throughput; 15% latency reduction	Complex integration with legacy systems
Zhang and Wu (2015).	Business-Driven Optimisation	Decision Support System with business KPIs	Balanced technical and business impact-based decision making	Requires business and technical data integration
Patel et al. (2021).	Risk Assessment	Bayesian Risk Modeling	Identification of high-risk failure causes (e.g., weather, cuts)	A probabilistic model depends on the quality and quantity of input data
Ahmed et al. (2020).	Performance + Risk Management	BI Dashboards integrated with NMS	30% faster response to incidents; enhanced visibility	High implementation cost; needs cross-departmental collaboration
El-Mahdy et al. (2020)	Fault Detection via AI	Deep Learning on alarm logs	94% detection rate; predictive maintenance recommendations	Requires extensive training data
Dey and Hassan (2020).	Standardisation & Metric Gaps	Literature-based Analysis	Highlighted inconsistencies in network performance metrics	Lacks a practical implementation model
Singh et al. (2022).	Strategic Business Alignment	Lifecycle Management Framework	Aligns network operations with long-term business goals	Still at the conceptual stage; needs field validation

METHODOLOGY

The Research Design

The study maintains a qualitative, exploratory design and therefore aims to investigate complex problems rather than verify a particular hypothesis. This design suits the subject matter when its full comprehension has yet to be attained, e.g., the impact of the business management frameworks in enhancing the operations of optical fibre networks. There are three main methods applied:

- **Case Analysis:** looking through the real-world examples in the telecom industry to get the idea of what the challenges are and how to practically address them.
- **Thematic Review:** The ability to find patterns of issues and revelations in different sources of information.
- **Model Development:** Developing a framework to manage business management using the patterns and themes that are found.

At the practical level, a grounded theory approach implies that the research develops theories bottom-up, i.e., through the systematic analysis of practical (non-hypothetical) data (not through the application of pre-defined theories). Data does not impose themes and patterns, but rather reveals them.

Collection of Data

The research obtained two data categories.

- **Primary Data:** The 12 semi-structured interviews were carried out with professionals working in different areas: network operations, project management and cybersecurity. Out of three telecom companies, these participants were selected so that the research would receive direct information about modern industry practices and problems.

The semi-structured interviews are flexible in a way that the researcher is free to ask probing questions as well as pursue new lines of ideas initiated as the interview progresses.

- **Secondary Data:** Reliable and acceptable sources of information were used, including:
 - o International Telecommunication Union (ITU)
 - o Institute of Electrical and Electronics Engineers (IEEE)
 - o National broadband schemes: The documents provide background, policy insights, technical requirements, and good practice within the fields of fibre optic networks.

Critical Model: Data processing and analysis were carried out as follows after the data were collected:

- **NVivo Software:** It is a qualitative analysis software which helped to code the information, which is the content of the information that was divided into themes, e.g.:
 1. Inefficiency bottlenecks (e.g., slippage, cost overruns)
 2. Types of risk (e.g. cyber threat, physical damage)
 3. Operation and managerial approaches (e.g., automation, predictive maintenance)
- **Cross-Case Triangulation:** The fused method known as Cross-Case Triangulation compares and confirms results of more than one source (cases or interviews) to make sure the findings are similar and sound. When a theme is revealed in another context, it becomes possible that it is influential and universal.

FRAMEWORK DEVELOPMENT

It is a proposal for the following Business Management Framework for Optical Fibre Networks, also known as the OptiRisk-BM Framework. This is an End-to-End Operational Efficiency + Risk Management Framework. It is a system that integrates technical performance monitoring, financial key performance indicators, service-level agreement monitoring, and risk prediction to create a single, integrated decision-support system. This framework is divided into 6 modules that relate to each other (Figure 2):

OptiRisk-BM Framework Structure

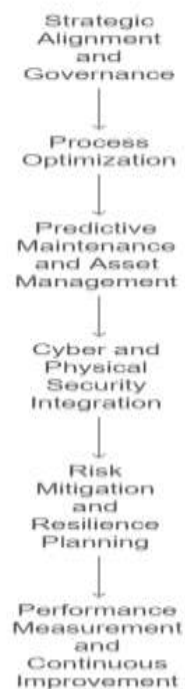


Figure 2: *OptiRisk-BM Framework Structure*

Strategic Alignment and Governance: The component has to do with safeguarding that the management of optical fibre networks is not similarly transacted without the categorisation, but rather in requisition of societal

and organisational guidance. It also stresses the importance of a systematic governance that would offer control and responsibility.

Link the Network Strategy to the Organisation's Goals

- Fibre network is an important element of the business of a telecom or infrastructure firm. Thus, the plan of construction, growth, and sustenance of this network must reinforce a relative plan of the company vis-à-vis:
 - o Gaining additional market share
 - o Ensuring better customer satisfaction
 - o Cut down on operational costs
 - o Empowerment of smart services (IoT, 5G, etc.)

Part of strategic alignment is the alignment of investment decisions, planning performance goals, and the schedule of projects within the fibre network with the business priorities. Say a company is aiming at underserved rural locations as its growth strategy, then the company must ensure that its network deployment is aligned with that strategy.

Install Control Systems to Control Governance

- **Governance-** This is the set of rules, roles and accountability procedures used to govern the decision-making process and compliance.

Important governance mechanisms can comprise:

- o **Steering Committees:** Cross-functional teams that manage the Implementation of strategy, set budgets and control results.
- o **Compliance Boards:** Authorities that will guarantee that the network operations are in agreement with the guidelines (data privacy, safety, environmental requirements).

The structures are able to avoid siloed decision-making, proactive risk management and openness to both internal and external stakeholders.

Link with business viability and the Digital Transmutation Approach

The optical fibre-based networks are key in the digital transformation, as they provide high-speed connectivity that is essential to cloud-based computing, AI, IoT, and so on.

Along the lines of sustainability objectives, alignment makes it clear that:

- There are operations of networks that are less impactful to the environment (e.g. efficient energy consumption of data centres, recycling of fibre materials, etc.),
- A Level access to broadband enables digital inclusion.
- By incorporating the network strategy in these bigger agendas, organisations will create lasting value, not in terms of financial value, but also environmental and social value.

Optimisation of the Process

This section describes the method that can be applied by telecom organisations to elevate the work of their fibre networks in terms of efficiency, accuracy, and responsiveness. It concentrates on technologies and systems that simplify the work processes, minimise mistakes, and improve transparency.

Use Lean 6 Sigma on Installation, Provisioning and fault resolution processes

- Lean Six Sigma is a tried and tested process improvement tool that integrates:
 - o **Lean principles:** These are focused on getting rid of waste, delays, and enhancing flow.

- o **Six sigma methods:** Emphasis on resolving variation and errors by utilising quantitative statistics.

The use of Lean Six Sigma in the development of the operations of a fibre network can assist in enhancing:

- o **Installation:** Curtail the gaps in the sites, materials acquisition, and laying of the fibre.
- o **Provisioning:** Make the activation of services easier after the installation of the fibre.
- o **Troubleshooting:** Decrease ATO and ATR to contract the mean time to determine and resolve issues to boost uptime and consumer delight.

It is efficiency and quality, faster delivery, and less rework and error.

Mechanisation of system work of flow using AI/ML Tools

- **Automation and optimisation of complex operational processes:** Artificial Intelligence (AI) and Machine Learning (ML) tools allow automation and optimisation of complex operational processes ([Wang et al., 2022](#)), including:
 - o **Predictive maintenance:** The usage of data to predict failures and prevent them before they happen.
 - o **Ticket triage:** High-priority and routing support tickets automatically.
 - o **Field resource assignment:** Assigning technicians to a job according to their desired location, expertise and priority.

Automation reduces operational costs but has the added benefit of increasing the speed and reliability of the delivery of services through the elimination of manual bottlenecks.

Business Process Modelling Notation (BPMN) to be clearer and more manageable

- BPMN (Business Process Modelling Notation) is a standard visual language that allows one to map and document business processes.

It enables the telecom teams to:

- o Be able to visualise all the processes of workflow operations (such as how a fibre fault is located, escalated and fixed).
- o Point out the duplicates or non-efficient activities.
- o Track performance based on real-time information against every step.
- BPMN presents processes in a way that allows inter-departmental understanding to help in collaborations and continuous improvement.

Forecasting Resource and Service Management

The present section is dedicated to the aspect of management of fibre optic network infrastructure in a more intelligent and proactive way, through the use of modern technologies. Instead of solving issues that have already occurred, predictive maintenance should be used because it helps predict the problems and eliminate downtime and prolong asset life.

Real-Time Monitoring Systems and Embed IoT Sensors

- Critical components of the network to which Internet of Things (IoT) sensors may be added include:
 - o Optic cables
 - o Junction box
 - o Switches in the network and nodes

These sensors track the variables, including:

- o Temperature
- o Vibration

- o Signal integrity
- o Power variations
- o Dampness or physical abuse

These sensors with real-time monitoring systems can provide constant visibility into the health and performance of the network infrastructure and allow the operator to observe early warning indicators of degradation or possible failure.

Make harmful component failures predictable with Predictive Analytics

Predictive analytics means modelling massive amounts of data--typically sensors in the IoT, previous maintenance records and network performance indicators--to find trends that indicate an upcoming failure.

High technologies such as machine learning algorithms would be able to:

- o Determine in advance when a fibre link or a network node might fail,
- o Terminate the components in a state of stress or those at the end of their life,
- o Suggest an optimal period and process of maintenance or replacement.

This minimises the use of methods that involve regular manual checks and directs attention to a specific area, where it is most required, making the process even more efficient and reliable.

Regular Inspection to cut down on the end-of-session

- Predictive insights help the maintenance teams carry out the interventions in advance of a failure event as opposed to carrying out corrective actions after they have been forced into action by a fault.

The pluses of proactive maintenance are:

- o reduced cases where customers could not be served,
- o Lower costs of emergency repair,
- o Increased longevity of network and fibre resources,
- o Improved planning (Technicians, tools, and parts).

The strategy facilitates changes in the direction of operations, that is, from corrective to preventive, which increases the quality of service and customer satisfaction overall.

Integration of Cyber and Physical Security

In this part, special emphasis is placed on the significance of protecting the digital and physical assets of the optical fibre systems. Since data transferred in these networks is sensitive and may involve large volumes, breaches of these networks, whether cyber- or physical, may be disastrous. The concept of holistic security involves layering the cyber aspects of the security with the physical infrastructure ones to provide end-to end security.

Use the Zero Trust Architecture (ZTA) Principles to protect data flow.

- Zero Trust architecture (ZTA) is the latest in cybersecurity architecture that follows the zero-trust approach, which holds that trust should never be granted and that everything must be verified regularly.

When considering a fibre network, it makes sure that:

- o All the devices, users and systems have to be authenticated and permitted entry.
- o Information channels between network devices (i.e. routers, switches, servers) are always being monitored and encrypted.
- o No automatic trust exists between parties within the network perimeter, even if the internal communications are prepared to be hostile.

- Using ZTA makes the network more secure against the threats of network insider, rogue devices, and unauthorised access in a distributed architecture such as fibre networks.

Maintain Consistent audit and acute testing against resilience.

- Penetration testing (or ethical hacking) is used to imitate a cyberattack in order to identify the weak points of the network before actual attackers find them.

The tests ought to be conducted on a regular basis in order to evaluate:

- Control systems resilience
- Weaknesses of remote access tools or network management devices,
- Reveal of shopper data or credentials.

One of the benefits of compliance audit is that the network complies with the regulatory and industry standards (e.g., GDPR, NIST, ISO/IEC 27001), thereby preventing the legal risks and fines that plague organisations.

In combination, these measures foster a culture of ever-improving security, which is not a reactionary or isolated one.

Establish Geofencing and Physical security sensor.s

Geofencing involves the utilisation of location-based services and GPS to establish simulated fences around facilities and locations of critical infrastructure (e.g., data centres, base stations, fibre hubs). It can:

- Raise alerts when unauthorised people or vehicles get into the no-go zone,
- Automate the lockdowns or turn on surveillance.

Physical intrusion detection systems (PIDS) consist of:

- Sensor motion,
- AI analytics CCTV,
- Tamper detectors of doors and cabinets.

The tools can be used to protect on-ground assets, which are often distributed over a wide area, in remote and/or vulnerable locations to fight interruption of fibre, theft of equipment or sabotage.

Risk Alleviation and Compliance Planning

In this section, the authors describe the best ways in which telecommunications organisations can openly respond to uncertainty, disruptions and possible failures within the fibre optic networks. It is based on a planned and information-based game plan of identifying risks as well as preparing and ensuring operational resilience in the long run.

- ***Carry out Frequent Risk Evaluation by means of Failure Mode and Effects Analysis (FMEA)***

FMEA is a methodological way of pinpointing:

- Possible failure modes (the manner in which components or processes may fail),
- The impacts of such failures on the system,
- Their causes, chances and severity.

In fibre networks, FMEA may be used on the following areas:

- Loss of cables or damage,
- Equipment failure (e.g. optical amplifiers, routers),
- Installation or fault recovery process failures.

According to [Kumar et al. \(2019\)](#), FMEA enables the ranking of these risks using the Risk Priority Number (RPN), allowing critical failure modes to be prioritised for mitigation. This prioritisation can help reduce the likelihood of service disruptions and associated financial losses.

Prepare a policy for unexpected incidents.

Business Continuity Plans (BCPs) guarantee that vital services are able to carry on working through, and after an interruption, including:

- o Cyberattacks,
- o Natural calamities (e.g. flood, earthquakes).
- o Failure in infrastructures.

Disaster Recovery Plans (DRPs) are concentrated narrowly on the restoration of:

- o Data,
- o Systems,
- o Links within the shortest time immediately after a major incident.

The two plans specify:

- o Responsibilities and functions,
- o Rescue sites and backup systems,
- o Communication guidelines,
- o The Recovery Point Objectives (RPO) and Recovery Time Objectives (RTO).

These are essential for the purposes of customer confidence, regulatory compliance, and financial safety inclusive cases.

Monte Carlo Simulation helps in Investment and operational risk Modeling.

- Monte Carlo simulations are sophisticated tools of risk analysis built through probability distributions and random sampling of uncertainty in complicated systems.

On a telecom project, they are capable of modelling thousands of potential scenarios involving:

- o costs overruns,
- o Slow rollouts,
- o Reliability of equipment,
- o Demand variations.

This enables the decision-makers to:

- o Consideration of the spectrum of the resultant outcomes,
- o Determining worst and best scenarios,
- o Be able to make better capital investment and operating strategies.

It is particularly helpful for long-term fibre infrastructure planning when the risks are affected due to technical, economic, and environmental factors.

Performance Measurement and Continuous Improvement

In this section, we concentrate on the development of measures and models so that the fibre network operators and telecom managers may evaluate their performance, clarify how they may be enhanced, and prompt lasting operational excellence. It combines quantitative KPIs and strategic management tools, helping to develop over the long term and be competitive.

KPIs to choose include Mean Time to Repair (MTTR), Network Availability (NA), Customer Churn Rate, Down Time and Cost.

- Key Performance Indicators (KPIs) are measurable items which show the level at which an organisation works to attain its operational objectives. Key metrics for fibre networks include (table 2):

Table 2: Key Performance Indicators (KPIs) for Evaluating Network Performance and Reliability

KPI	Description	Why It Matters
Mean Time to Repair (MTTR)	The average time taken to identify, diagnose, and fix a network failure or fault. $MTTR = \text{Total Repair Time} / \text{Number of Incidents}$.	Lower MTTR means faster recovery, better service reliability, and reduced customer dissatisfaction.
Network Availability (NA)	The percentage of time the network is operational and accessible. Often calculated as: $NA = [(\text{Total Time} - \text{Downtime}) / \text{Total Time}] \times 100$	High network availability is essential to meet SLAs and ensure continuous data/service delivery.
Customer Churn Rate	The percentage of customers who leave or unsubscribe from the network service over a specific period.	A high churn rate often reflects poor service quality, frequent downtimes, or unsatisfactory experiences.
Downtime	The total duration during which the network or a portion of it is non-functional or unavailable. Includes planned and unplanned outages.	Directly impacts customer experience and can lead to revenue loss and SLA violations.
Cost	Refers to both operational (OPEX) and capital (CAPEX) expenditures, including repair, maintenance, manpower, and equipment costs.	Effective cost management helps ensure the profitability and long-term sustainability of the network.

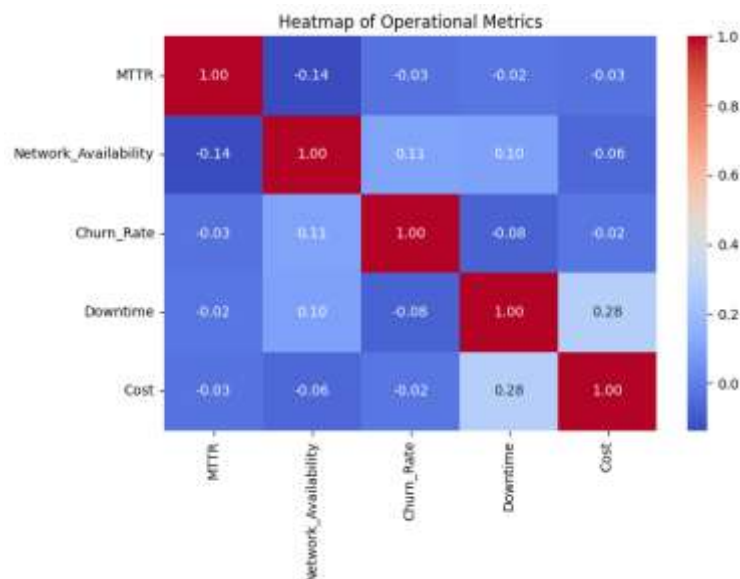


Figure 3: Heatmap of Operational Metrics

In Figure 3, we see a correlation heatmap of important operational stats in optical fibre networks. It makes us realise the relationship of the various performance indicators with each other, either in the positive, in the negative, or not at all. This heatmap indicates the correlation between various metrics of operations. The majority of the

values have gone near zero, which means that there is no or weak linear dependence between the metrics. The next and only moderate correlation is between Downtime and Cost (0.28), indicating that the higher the level of downtimes, the slightest rise in cost. There are weak relationships that include the relationship between MTTR and Network Availability (-0.14), which would not be significant.

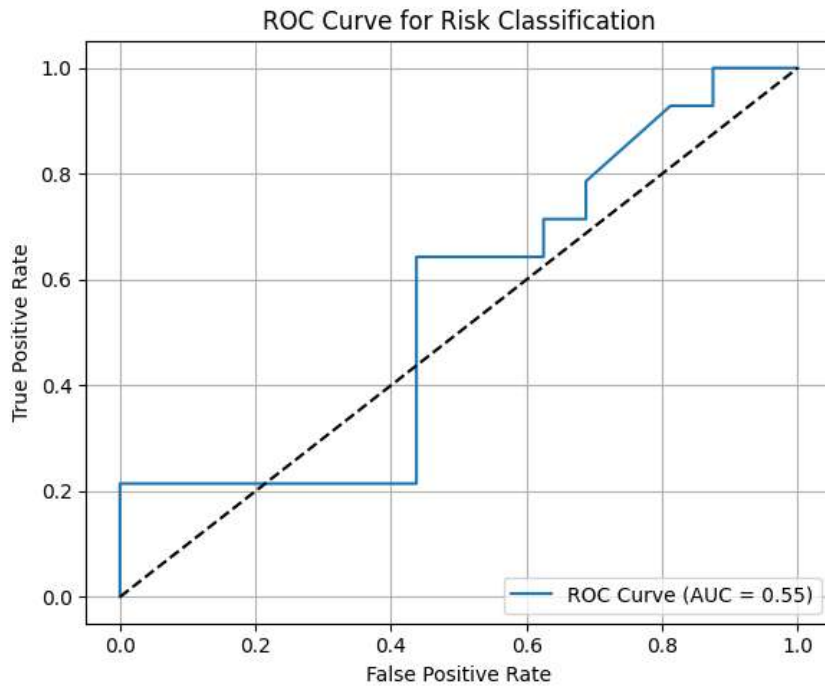


Figure 4: ROC Curve for Risk Classification

This ROC (Receiver Operating Characteristic) curve (figure 4) measures the effectiveness of a risk classification model. It is a graph that explains the True Positive Rate (sensitivity) against the False Positive Rate at different thresholds. The AUC (Area Under Curve) is 0.55, which is just a bit over random guessing (0.5). It shows that the discriminatory power of the given model is low and requires refinement either by the addition of more appropriate features, the optimisation of the given data, or better algorithm performance.

Table 3: Metrics: key operational and performance indicators

	Metric	Mean	Std Dev
0	MTTR	4.875384	1.089802
1	Network_Availability	99.504461	0.190734
2	Churn_Rate	0.053859	0.024768
3	Downtime	3.042405	0.400821
4	Cost	1995.395784	325.720907

The mean column (table 3) provides, within a dataset, an indication of the average observed value, whereas the standard deviation (Std Dev) shows the amount of deviation relative to that average. This provides meanings regarding the consolidated tendency and conformity of each metric.

Employ Balanced Scorecard Perspectives: Financial, Customer, Internal Processes, Learning and Growth

- The Balanced Scorecard is a management system that can be used to make an organisation think beyond financial performance. It employs four views:
 - o **Financial:** Are network investments paying off? Is the cost of the operations under control?

- o **Customer:** Do users find speed, reliability and service support satisfactory?
 - o **Internal Processes:** Are they efficient processes? Are cycles on installations and repair peaks?
 - o **Learning and Growth:** Is the workforce even skilled and adaptive? Is there an adoption of new technologies?
- Through this framework, telecom managers will be able to make short-term actions in line with longer-term strategic objectives, and when they will be able to pursue performance in a more wholesome way.

Facilitate Continuous Learning Through Training and Feedback Loops

- ***The sustainability of continuous improvement is based on learner-organisational flexibility:***
 - o A consistent training (technical, process, cybersecurity, customer service) maintains staff informed of best practices and the development of technologies.
 - o Field team and customer feedback loops and data analytics provide feedback loops that guarantee timely recognition of problems and assimilation of lessons into operations.
- A learning culture is encouraged, which promotes innovation, time in solving problems and enhanced service delivery in the future.

DISCUSSION

The OptiRisk-BM framework brings notable strategic and operational value to telecom organisations by reshaping their perception of network infrastructure from purely technical systems to strategic, value-generating assets. It fosters a synergistic interaction between technical teams and corporate management, promoting strategic alignment in infrastructure planning and decision-making. Organisations that have implemented the framework report improved operational efficiency, including faster service provisioning, reduced maintenance costs, and increased service uptime factors directly linked to enhanced customer satisfaction and revenue assurance. Furthermore, the integration of dynamic risk models within the framework enables smarter resource allocation and proportional risk management. However, the adoption of such digital solutions is not without limitations. Initial implementation can be costly due to technology investments and staff training requirements. Additionally, tailoring the framework to comply with regional regulations and market conditions may be necessary. Its success also hinges on effective interdepartmental collaboration, which could face resistance in traditionally siloed organisations. Despite these challenges, the OptiRisk-BM framework offers a forward-looking blueprint for strategic resilience and operational agility in modern telecom environments.

CONCLUSION

The main contribution of this paper has been to introduce the OptiRisk BM framework, which is a holistic business management approach that can be applied to improve the efficiency of optical fibre networks and reduce risks. The framework is based on the science of management as well as telecom engineering, which cuts a major gap in the existing literature and practice. The future exploration may be aimed at examining how it is implemented in other markets, its integration into 6G networks, and its roles in sustainability reporting in the ESG disclosures.

AUTHOR DECLARATIONS

CRediT Author Statement / Author contributions

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