

# Inventory Optimization for Network Device Lifecycle Tracking and Deployment Readiness in Distributed Banking Environments

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Publication Date: 2022/11/30

## Abstract

Efficient management of network device inventories is essential for maintaining operational continuity and infrastructure scalability in distributed banking environments. Financial institutions operate complex network infrastructures that require timely deployment of routers, switches, firewalls, and other security appliances across data centers and branch offices. However, fragmented asset records and inefficient procurement practices often lead to device shortages, delayed deployments, and increased inventory holding costs. This study proposes an analytical framework for optimizing network device inventory management by integrating lifecycle tracking with mathematical inventory optimization and deployment readiness modeling. The proposed framework incorporates procurement databases, configuration management databases (CMDB), network monitoring platforms, and deployment scheduling systems to provide centralized lifecycle visibility and improve infrastructure governance. A mathematical optimization model is developed to minimize total inventory costs while maintaining adequate device availability and deployment readiness across distributed banking infrastructures. Simulation experiments compare the performance of the optimized model with traditional inventory management approaches using metrics such as device availability, deployment readiness, inventory holding costs, and deployment delays. The results demonstrate that lifecycle-aware inventory optimization significantly improves infrastructure deployment readiness, reduces stockout probability, and lowers inventory management costs. The study further highlights operational benefits for banking institutions, including faster branch network rollout, improved cybersecurity patch deployment, enhanced regulatory compliance, and stronger disaster recovery preparedness. The proposed framework provides a practical and scalable approach for improving infrastructure asset management in modern financial networks while supporting strategic infrastructure expansion and operational resilience.

**Keywords:** *Network Device Lifecycle Management; Inventory Optimization; Deployment Readiness Modeling; Banking IT Infrastructure; Infrastructure Asset Management.*

## I. INTRODUCTION

### ➤ *Background of Network Infrastructure Management in Banking*

Modern banking institutions operate highly distributed and mission-critical network infrastructures that support financial transactions, customer service platforms, cybersecurity monitoring, and regulatory reporting systems. These infrastructures typically consist of heterogeneous network devices such as routers, switches, firewalls, load balancers, and intrusion detection appliances deployed across headquarters, regional data centers, disaster recovery sites, and hundreds of branch offices. The continuous operation of these systems is

essential because financial institutions rely heavily on digital connectivity to maintain payment processing, online banking services, and real-time interbank communications (Alsmadi & Xu, 2019; Basel Committee on Banking Supervision, 2021). As banking services increasingly shift toward digital platforms, the reliability and scalability of underlying network infrastructure have become central components of operational resilience strategies.

Network device lifecycle management within banking environments involves multiple stages including procurement, configuration, deployment, maintenance, upgrade cycles, and eventual retirement or replacement of

hardware assets. Effective lifecycle tracking ensures that devices remain compliant with security standards, firmware updates, and regulatory requirements while maintaining optimal operational performance (Cisco Systems, 2022). However, the distributed nature of banking infrastructure introduces significant complexity in coordinating these lifecycle activities across geographically dispersed locations. Branch expansion, mergers and acquisitions, and rapid digital transformation initiatives frequently lead to heterogeneous network environments where device versions, firmware levels, and operational configurations vary across sites (Khan et al., 2020).

Regulatory compliance further intensifies the need for structured lifecycle management in banking network infrastructure. Financial regulators increasingly require banks to demonstrate operational resilience, cybersecurity readiness, and robust technology governance frameworks. International standards such as the Basel Committee's principles for operational resilience and technology risk management emphasize the importance of asset visibility, configuration management, and infrastructure readiness across banking systems (Basel Committee on Banking Supervision, 2021). Inadequate lifecycle tracking of network devices can therefore expose financial institutions to regulatory penalties, operational disruptions, and increased cyber risk.

Inventory management plays a critical role in supporting lifecycle governance for network infrastructure. Banks must maintain adequate inventories of network devices and spare components to ensure rapid deployment during system upgrades, branch rollouts, and emergency replacements. However, traditional inventory management approaches often rely on static asset registries or fragmented asset databases that lack real-time synchronization with operational network monitoring systems (Shin & Lee, 2020). These fragmented records can lead to inaccurate asset visibility, delayed hardware replacement, and inefficient procurement cycles.

Inefficient inventory management also affects deployment readiness for new network infrastructure projects. For example, when banks expand branch networks or upgrade security infrastructure, the availability of preconfigured network devices becomes a critical determinant of project timelines. Delays in device availability can slow branch activation schedules, postpone security upgrades, and disrupt technology modernization initiatives (Nguyen & Dang, 2021). Furthermore, poor inventory forecasting can result in either device shortages leading to deployment delays or excessive stock accumulation, which increases capital expenditure and warehouse holding costs.

The rapid pace of technological innovation in networking equipment further complicates lifecycle and inventory management. New device generations frequently introduce enhanced capabilities such as software-defined networking (SDN), advanced encryption modules, and integrated cybersecurity analytics. Financial

institutions must therefore coordinate inventory planning with device lifecycle upgrades to ensure compatibility with evolving technology architectures (Alharbi et al., 2022). Without optimized inventory strategies, banks risk deploying outdated hardware that cannot support modern network security or high-bandwidth transaction processing.

Recent studies highlight the need for integrated inventory optimization frameworks that combine lifecycle tracking with predictive demand modeling and infrastructure readiness metrics (Bouras et al., 2021). Such frameworks can enable financial institutions to align procurement planning with operational network requirements while minimizing inventory holding costs and deployment delays. By leveraging mathematical optimization models and infrastructure monitoring data, banks can improve visibility into device availability and enhance readiness for infrastructure deployment across distributed environments.

Despite the growing importance of network device lifecycle management in banking systems, limited research has examined the intersection of inventory optimization and infrastructure deployment readiness. Existing studies primarily focus on enterprise IT asset management or general inventory control without addressing the specific operational challenges associated with distributed banking infrastructures (Tao et al., 2020). Consequently, there remains a need for research frameworks that integrate device lifecycle tracking with inventory optimization strategies tailored to the operational and regulatory constraints of financial institutions.

Addressing these challenges requires the development of analytical models capable of predicting network device demand, monitoring lifecycle status, and optimizing inventory levels across distributed banking networks. Such models can support improved infrastructure deployment planning, reduced operational risk, and enhanced compliance with financial technology governance standards.

#### ➤ *Problem Statement*

Financial institutions increasingly depend on complex and geographically distributed network infrastructures to support critical banking operations, including transaction processing, online banking services, regulatory reporting systems, and interbank payment networks. These infrastructures typically consist of a wide range of network devices such as routers, switches, firewalls, load balancers, and security monitoring appliances deployed across data centers and branch offices. Managing the lifecycle of these devices requires accurate tracking of procurement records, configuration states, deployment locations, maintenance histories, and retirement schedules. However, many banking organizations continue to manage these assets using fragmented inventory systems that operate independently across procurement platforms, configuration management

databases (CMDB), and network monitoring tools (Shin & Lee, 2020; Zhang et al., 2021).

Fragmentation of inventory records creates significant challenges for infrastructure governance and operational reliability. Procurement systems typically track financial acquisition and vendor information for network devices, while CMDB platforms maintain configuration and topology information related to deployed infrastructure assets. Operational monitoring systems, on the other hand, capture real-time performance metrics and device health data within the production network. When these systems operate without proper integration, inconsistencies frequently arise between recorded inventory data and the actual operational state of network infrastructure (Gupta & George, 2019; Bouras et al., 2021). As a result, banks may lose visibility into the lifecycle status of critical devices, leading to inaccurate records of hardware availability, firmware versions, and maintenance schedules.

This lack of unified asset visibility significantly affects deployment readiness in distributed banking environments. Network infrastructure upgrades, branch expansion projects, and cybersecurity modernization initiatives depend heavily on the availability of properly configured network devices. When inventory records are inconsistent or incomplete, infrastructure teams may struggle to identify whether suitable devices are available for deployment or require procurement from vendors. Such delays can slow branch activation timelines, postpone system upgrades, and disrupt strategic technology transformation initiatives within financial institutions (Nguyen & Dang, 2021; Rahman et al., 2022).

In addition to operational delays, fragmented lifecycle tracking introduces cybersecurity and compliance risks. Financial regulators increasingly emphasize the importance of asset visibility and infrastructure resilience as part of enterprise technology governance frameworks. Network devices that are not accurately tracked within lifecycle management systems may remain in operation with outdated firmware or missing security patches, exposing banking infrastructure to cyber threats and regulatory compliance violations (Alsmadi & Xu, 2019; Basel Committee on Banking Supervision, 2021). Without accurate lifecycle data, security teams may also struggle to identify vulnerable devices across distributed networks during vulnerability assessments or incident response activities.

Operational inefficiencies also arise when inventory management processes are not supported by optimization-driven analytical models. Traditional inventory approaches often rely on static reorder thresholds or manual forecasting methods that fail to capture dynamic demand patterns associated with infrastructure expansion, device failures, or technology upgrades. Consequently, financial institutions may maintain excessive inventories of certain devices while simultaneously experiencing shortages of critical equipment required for urgent deployments (Khan et al., 2020; Tao et al., 2020).

Excessive inventory leads to increased capital expenditure and storage costs, whereas device shortages can delay infrastructure rollout and reduce operational agility.

Furthermore, the rapid evolution of network technologies—including software-defined networking (SDN), virtualization-based security appliances, and high-performance routing platforms—requires banks to manage frequent hardware refresh cycles. Without predictive inventory optimization mechanisms, organizations may struggle to align procurement strategies with device lifecycle transitions and future infrastructure demands (Alharbi et al., 2022; Zhang et al., 2021). This misalignment can result in the continued use of outdated hardware that lacks compatibility with modern security frameworks or high-performance banking applications.

Another challenge arises from the scale of distributed banking networks. Large financial institutions may operate thousands of network devices across hundreds of branches, making manual asset reconciliation processes inefficient and error-prone. As infrastructure scale increases, the complexity of maintaining synchronized inventory records across multiple systems grows exponentially. This complexity highlights the need for automated lifecycle tracking and mathematically optimized inventory models capable of maintaining accurate device availability information while supporting efficient procurement planning (Bouras et al., 2021; Rahman et al., 2022).

Despite the importance of network asset governance in financial institutions, existing research has largely focused on general enterprise IT asset management rather than the specific operational challenges associated with distributed banking infrastructures. Limited attention has been given to the integration of device lifecycle tracking, infrastructure deployment readiness metrics, and inventory optimization models within banking environments (Shin & Lee, 2020; Gupta & George, 2019). Addressing this research gap is essential for developing intelligent inventory management frameworks capable of improving operational resilience and infrastructure scalability in modern financial networks.

Therefore, the central problem addressed in this study is the lack of integrated and optimization-driven inventory management models for tracking network device lifecycles and ensuring deployment readiness across distributed banking infrastructures. Without such frameworks, financial institutions remain vulnerable to operational inefficiencies, infrastructure deployment delays, cybersecurity risks, and increased technology management costs.

#### ➤ *Research Objectives*

The primary objective of this study is to investigate how optimized inventory management strategies can improve network device lifecycle tracking and deployment readiness within distributed banking infrastructures. Financial institutions operate large-scale, geographically dispersed network environments that require continuous infrastructure availability, rapid device deployment, and

strict compliance with technology governance frameworks. Achieving these operational requirements necessitates analytical models capable of aligning procurement planning, lifecycle monitoring, and infrastructure deployment processes. Consequently, this research seeks to develop quantitative and analytical mechanisms that enhance inventory visibility, improve infrastructure readiness, and minimize operational inefficiencies associated with network device management in banking environments.

The first objective of the study is to develop an analytical framework for optimizing network device inventory across distributed banking environments. Banking networks typically consist of thousands of interconnected devices deployed across data centers, branch offices, and disaster recovery sites. Managing inventory across these locations requires an integrated framework capable of consolidating device records from procurement systems, configuration management databases (CMDB), and operational monitoring platforms. The proposed analytical framework aims to model inventory dynamics and procurement policies that ensure adequate device availability while minimizing excess stock and storage costs. This objective focuses on designing a mathematical optimization model that determines optimal inventory levels based on device demand, procurement lead times, and deployment schedules across distributed banking infrastructures.

The second objective is to model lifecycle states of network devices and evaluate their deployment readiness probability. Network devices in banking infrastructures typically transition through multiple lifecycle stages, including procurement, storage, deployment, operation, maintenance, upgrade, and retirement. Each stage reflects a different operational status that affects the device's readiness for deployment or replacement within the network. By mathematically modeling these lifecycle states, the study aims to quantify the probability that a device is available and compliant with operational requirements at any given time. This modeling process allows financial institutions to predict infrastructure readiness levels and identify potential delays caused by device shortages, firmware incompatibilities, or maintenance constraints.

The third objective is to quantitatively evaluate inventory optimization policies that minimize deployment delays and excess stock accumulation. Traditional inventory management approaches often rely on fixed reorder thresholds that do not account for fluctuations in device demand associated with infrastructure upgrades, branch expansion projects, or emergency hardware replacements. This research therefore seeks to evaluate optimization-based inventory control policies using mathematical models that balance procurement costs, holding costs, and stockout risks. The evaluation will assess how optimized policies improve device availability and reduce infrastructure deployment delays compared with traditional inventory management strategies.

By addressing these objectives, the study aims to establish a quantitative foundation for improving network infrastructure governance in banking environments. The integration of lifecycle modeling and inventory optimization is expected to enhance infrastructure deployment readiness, reduce operational costs, and strengthen the resilience of distributed banking networks.

➤ *Mathematical Representation of Inventory Readiness*

Efficient network infrastructure deployment in distributed banking environments depends largely on the availability of network devices at the time they are required for installation or replacement. Inventory readiness therefore becomes a critical operational metric that determines whether infrastructure teams can deploy network equipment without delay. To analytically represent this concept, the study formulates a mathematical model that captures the relationship between device demand, available inventory, procurement orders, and deployment readiness probability. The objective of this representation is to quantify the likelihood that sufficient devices are available to meet deployment requirements across distributed banking branches and data centers.

Let the following variables define the system state at time  $t$ :

$$D_t = \text{device demand at time } t$$

$$I_t = \text{available inventory at time } t$$

$$R_t = \text{deployment readiness probability at time } t$$

$$L = \text{procurement lead time for new devices}$$

In a distributed banking infrastructure, deployment readiness occurs when the available inventory of network devices is sufficient to satisfy the demand generated by infrastructure expansion, device failures, or scheduled hardware upgrades. Therefore, the readiness probability can be expressed as the probability that available inventory meets or exceeds the demand for devices during a given time period.

$$R_t = P(I_t \geq D_t)$$

This probability reflects the likelihood that network infrastructure teams can immediately deploy the required devices without waiting for additional procurement. When inventory levels fall below demand, deployment delays may occur while new devices are ordered and delivered.

To track inventory dynamics over time, the system uses an inventory balance equation that models how device stocks evolve as procurement orders are received and devices are deployed.

$$I_{t+1} = I_t + O_t - D_t$$

Where:

$$O_t = \text{number of devices ordered at time } t$$

This equation describes the transition of inventory levels from one time period to the next. The available inventory at the next time step  $I_{t+1}$  depends on the current inventory  $I_t$ , the number of devices procured  $O_t$ , and the number of devices deployed or consumed to meet demand  $D_t$ .

Procurement lead time plays an important role in this dynamic system because ordered devices are not immediately available for deployment. If the lead time for device delivery is denoted by  $L$ , then orders placed at time  $t$  become available in inventory at time  $t + L$ . Consequently, the effective inventory update can be expressed as

$$I_{t+1} = I_t + O_{t-L} - D_t$$

This formulation highlights the importance of proactive procurement planning in banking infrastructure management. If inventory planning does not account for procurement lead times, the network may experience temporary shortages of devices even when orders have already been placed.

To further quantify deployment readiness over a planning horizon of  $T$  periods, the average readiness level can be defined as

$$R_{avg} = \frac{1}{T} \sum_{t=1}^T P(I_t \geq D_t)$$

This metric represents the overall readiness performance of the inventory management system across the entire observation period. Higher values of  $R_{avg}$  indicate that the organization consistently maintains sufficient inventory levels to support infrastructure deployment activities.

The mathematical framework presented above enables financial institutions to evaluate inventory policies and determine optimal procurement strategies that maximize deployment readiness while minimizing inventory holding costs. By integrating demand forecasting and lifecycle tracking data into this model, banks can improve the availability of network devices across distributed environments and reduce delays associated with infrastructure deployment and technology upgrades.

#### ➤ *Research Contributions*

This study makes several theoretical and practical contributions to the domain of banking infrastructure management by introducing a quantitative framework that integrates network device lifecycle tracking with inventory optimization and deployment readiness modeling. As financial institutions increasingly rely on complex and geographically distributed network infrastructures, efficient asset lifecycle governance and inventory

management have become essential components of operational resilience, cybersecurity readiness, and infrastructure scalability. The contributions of this research therefore focus on bridging the gap between traditional IT asset management approaches and optimization-driven infrastructure deployment strategies suitable for distributed banking environments.

The first major contribution of this study is the development of a lifecycle-aware inventory optimization model tailored specifically for network device management in banking infrastructures. Unlike conventional inventory management frameworks that primarily focus on static reorder thresholds or simple stock control policies, the proposed model explicitly incorporates the lifecycle stages of network devices—including procurement, storage, deployment, maintenance, upgrade cycles, and retirement. By integrating lifecycle tracking with inventory planning, the model enables financial institutions to maintain accurate visibility into the operational status of network devices while ensuring that adequate inventory levels are maintained for future infrastructure deployments. This lifecycle-aware approach improves procurement planning, reduces the risk of device shortages during network upgrades, and prevents excessive accumulation of obsolete hardware within inventory systems.

The second contribution of the study is the introduction of a deployment readiness probability framework for evaluating infrastructure preparedness within distributed banking networks. In large financial institutions, infrastructure readiness depends not only on the availability of network devices but also on their operational compatibility, configuration status, and security compliance. The readiness probability framework proposed in this research quantifies the likelihood that sufficient devices are available and ready for deployment at a given time. By modeling deployment readiness as a probabilistic function of device demand, available inventory, and procurement lead times, the framework provides a measurable indicator of infrastructure preparedness. This contribution enables banking organizations to monitor readiness levels across distributed environments and proactively identify potential deployment bottlenecks before they affect operational continuity.

The third contribution lies in the analytical evaluation of inventory control policies for banking IT environments. Traditional inventory management strategies often fail to account for the dynamic demand patterns associated with network infrastructure expansion, hardware refresh cycles, cybersecurity upgrades, and emergency device replacements. This study introduces a mathematical evaluation framework that compares different inventory control policies based on their impact on deployment readiness, procurement costs, and inventory holding costs. Through quantitative modeling and simulation-based analysis, the research demonstrates how optimized inventory strategies can significantly reduce deployment delays while maintaining cost-efficient

inventory levels. This analytical evaluation provides banking infrastructure managers with a decision-support mechanism for selecting appropriate inventory policies that balance operational readiness and financial efficiency.

Collectively, these contributions advance the understanding of infrastructure asset governance within financial institutions by integrating lifecycle analytics, probabilistic readiness modeling, and inventory optimization techniques. The proposed framework offers a structured approach for improving network device availability, reducing operational risk, and supporting scalable infrastructure deployment across distributed banking environments. In addition to its theoretical

significance, the research provides practical insights that can assist banking IT departments in designing more resilient and efficient infrastructure inventory management systems.

Figure 1 illustrates a three-dimensional architectural representation of a distributed banking network infrastructure integrated with a network device lifecycle management ecosystem. The diagram visually presents how banking institutions coordinate infrastructure deployment, device lifecycle processes, and inventory governance across geographically dispersed network environments.



Fig 1 Integrated Network Device Lifecycle and Inventory Management Architecture for Distributed Banking Infrastructure

At the center of the architecture is the Centralized Inventory Management Platform, represented by a monitoring dashboard and server stack. This platform acts as the operational control hub that aggregates device inventory records, lifecycle status information, and deployment readiness data from across the entire banking network. The central platform maintains visibility into device availability, configuration status, and lifecycle stage, enabling infrastructure teams to coordinate procurement, storage, and deployment decisions efficiently.

Surrounding the centralized platform are core infrastructure nodes, including the Central Banking Data Center and Regional Data Centers. These facilities host critical banking applications such as transaction processing systems, payment gateways, and customer service platforms. The central data center represents the primary infrastructure hub where core banking systems operate, while regional data centers support redundancy, disaster recovery, and regional network distribution. Bidirectional network links connect these data centers to the centralized inventory platform, illustrating continuous

synchronization of device lifecycle and infrastructure monitoring data.

Extending outward from the regional infrastructure are branch network nodes, represented as multiple branch office clusters. These nodes symbolize geographically distributed banking branches that rely on routers, switches, and security appliances to maintain connectivity with the central banking systems. The diagram shows network communication pathways linking branch offices to both regional and central data centers, emphasizing the distributed nature of banking infrastructure and the operational dependence on reliable network device deployment.

Above the infrastructure layer, the figure presents a circular lifecycle workflow that represents the operational stages of network device management. The lifecycle begins with procurement, where network hardware is acquired from vendors and registered in the inventory system. Devices then move into storage, representing warehouse or staging environments where hardware is prepared for deployment. The next stage, deployment, illustrates the installation and

activation of devices within branch offices, data centers, or other network locations.

Following deployment, the lifecycle progresses to maintenance, where devices undergo firmware upgrades, security patching, and operational monitoring to ensure compliance with cybersecurity and performance requirements. Finally, devices enter the retirement stage, where outdated or end-of-life hardware is removed from operational environments and replaced with newer equipment. The circular arrangement of these stages indicates the continuous and cyclical nature of network infrastructure lifecycle management within banking institutions.

Directional arrows connect the lifecycle stages to the central infrastructure components, illustrating the flow of device information and operational data between lifecycle management processes and the centralized inventory system. This integration ensures that each device's operational status—whether stored, deployed, under maintenance, or retired—is accurately recorded and synchronized across the banking infrastructure.

Overall, the figure demonstrates how centralized inventory governance, distributed infrastructure architecture, and lifecycle management processes interact to support efficient network device deployment across banking environments. By visually linking lifecycle stages with physical infrastructure nodes and a centralized management platform, the diagram highlights the importance of coordinated asset visibility and inventory optimization in maintaining operational readiness within distributed banking networks.

## II. LITERATURE REVIEW

### ➤ *Network Device Lifecycle Management in Enterprise Infrastructure*

Network device lifecycle management has become a critical component of enterprise infrastructure governance as organizations increasingly rely on complex digital networks to support operational processes, cybersecurity controls, and service delivery platforms. Enterprise networks typically consist of a wide range of hardware assets including routers, switches, firewalls, and other security appliances that must be systematically managed throughout their operational lifespan. Lifecycle management frameworks are designed to oversee the entire process from procurement and configuration to maintenance, upgrades, and eventual retirement of network devices. Effective lifecycle governance ensures infrastructure reliability, security compliance, and optimal resource utilization within large-scale IT ecosystems (Shin & Lee, 2020).

The lifecycle of network devices typically begins with the procurement stage, where organizations acquire hardware assets based on operational requirements, infrastructure expansion plans, and technology roadmaps. Procurement decisions are influenced by factors such as device performance specifications, vendor reliability,

lifecycle support duration, and compatibility with existing network architectures. Research shows that strategic procurement planning plays an important role in minimizing long-term infrastructure costs and avoiding technology obsolescence within enterprise networks (Gupta & George, 2019). In addition, procurement processes often incorporate asset registration procedures that ensure newly acquired devices are recorded within enterprise asset management systems before deployment.

Following procurement, devices enter the configuration and deployment phase, where network engineers integrate hardware assets into operational infrastructure environments. Configuration management systems play an important role in maintaining consistent device configurations across enterprise networks. Configuration management databases (CMDB) store detailed information about device attributes, firmware versions, network topology relationships, and operational dependencies (Zhang et al., 2021). Proper configuration management ensures that deployed devices maintain standardized operational parameters, which is essential for maintaining network stability and preventing configuration-related security vulnerabilities.

Firmware lifecycle management represents another critical dimension of network device lifecycle governance. Firmware updates are regularly released by device vendors to address security vulnerabilities, improve performance, and introduce new features. Failure to implement timely firmware updates can expose enterprise networks to cyber threats and operational disruptions. Consequently, organizations often establish structured patch management programs that coordinate firmware updates across distributed network infrastructures while minimizing service downtime (Alsmadi & Xu, 2019). Studies have emphasized that automated update management systems significantly improve patch compliance rates and reduce cybersecurity risks associated with outdated device software.

Lifecycle management frameworks also incorporate monitoring and maintenance activities that ensure the continued reliability of deployed network infrastructure. Monitoring tools collect operational metrics such as device health status, performance indicators, network traffic levels, and security alerts. These monitoring systems enable infrastructure teams to detect anomalies, predict potential hardware failures, and schedule preventive maintenance activities before operational disruptions occur (Rahman et al., 2022). Predictive maintenance models have recently emerged as valuable tools for improving infrastructure reliability by analysing historical device performance data to anticipate hardware degradation and optimize replacement schedules.

As network devices approach the end of their operational lifespan, retirement and replacement strategies become necessary to maintain infrastructure performance and security standards. Hardware retirement policies typically consider vendor support expiration dates, firmware update availability, performance limitations, and

compatibility with emerging technologies. When devices reach end-of-life status, organizations must safely decommission them and replace them with newer models that support modern network capabilities (Cisco Systems, 2022). Effective retirement strategies are particularly important in highly regulated industries such as banking, where outdated infrastructure can create security vulnerabilities and regulatory compliance risks.

Recent research has also highlighted the importance of integrating lifecycle management with broader enterprise asset management frameworks. Modern lifecycle governance systems increasingly incorporate automation technologies, data analytics, and centralized asset visibility platforms that allow organizations to monitor device status across distributed infrastructures in real time (Bouras et al., 2021). These integrated systems enable IT departments to maintain accurate asset inventories, coordinate infrastructure upgrades, and align lifecycle planning with long-term technology strategies.

Despite these advancements, challenges remain in implementing effective lifecycle management across distributed enterprise infrastructures. Organizations often struggle with fragmented asset records, inconsistent configuration documentation, and limited integration between procurement, monitoring, and asset management systems. These limitations highlight the need for more comprehensive lifecycle management frameworks that combine infrastructure monitoring with predictive analytics and inventory optimization strategies. Such integrated approaches can improve asset visibility, enhance operational resilience, and support more efficient infrastructure governance in enterprise network environments.

#### ➤ *Inventory Optimization Models in IT Infrastructure*

Inventory optimization models play a crucial role in ensuring efficient management of technology equipment within enterprise IT environments. Organizations operating large-scale digital infrastructures must maintain sufficient inventories of network devices, servers, storage equipment, and cybersecurity appliances to support operational continuity and rapid infrastructure deployment. However, maintaining excessive inventory increases holding costs and capital expenditure, while insufficient inventory levels can lead to deployment delays and operational disruptions. Consequently, inventory optimization models have been widely studied as analytical tools for balancing inventory availability with cost efficiency in technology infrastructure management (Silver et al., 2017).

Traditional inventory control theory provides several mathematical models that help organizations determine optimal procurement quantities and reorder strategies. Among these models, the Economic Order Quantity (EOQ) model is one of the most widely applied frameworks for minimizing total inventory cost by balancing ordering costs and holding costs. The EOQ model determines the optimal quantity of items that should be ordered each time a procurement action occurs. When

applied to IT infrastructure management, the model helps organizations determine how many network devices should be ordered in each procurement cycle to minimize overall inventory management costs (Nahmias & Olsen, 2015).

The EOQ model is mathematically expressed as:

$$EOQ = \sqrt{\frac{2DS}{H}}$$

Where:

$D$  represents the annual demand for devices,  
 $S$  represents the ordering cost associated with procurement activities, and

$H$  represents the holding cost per unit of inventory.

The model assumes that demand remains relatively stable over time and that procurement lead times are predictable. In enterprise IT environments, this model can be applied to determine the optimal number of network devices that should be maintained within inventory systems to ensure deployment readiness without excessive storage costs (Chopra & Meindl, 2019).

While the EOQ model provides a foundational framework for inventory optimization, many modern IT infrastructures experience demand patterns that are uncertain or highly variable due to factors such as infrastructure upgrades, hardware failures, cybersecurity incidents, and organizational expansion. To address such uncertainties, stochastic inventory models have been developed to incorporate probabilistic demand distributions and variability in procurement lead times. Stochastic demand models allow organizations to estimate the probability of inventory shortages and determine appropriate safety stock levels that reduce the risk of deployment delays (Zipkin, 2000).

In IT infrastructure contexts, stochastic inventory models are particularly relevant because device demand often arises from unpredictable events such as equipment failures, emergency replacements, and security patch requirements. Researchers have therefore proposed probabilistic inventory frameworks that incorporate demand variability, lead time uncertainty, and service-level constraints to improve infrastructure readiness. These models often use probabilistic demand distributions to determine reorder points and safety stock levels that maintain acceptable service levels for infrastructure deployment (Simchi-Levi et al., 2021).

Another important extension of traditional inventory models involves multi-echelon inventory optimization frameworks. In distributed enterprise environments, technology equipment may be stored across multiple inventory locations such as central warehouses, regional storage facilities, and branch-level equipment repositories. Multi-echelon inventory models analyse how inventory should be allocated across these distributed locations to

minimize transportation costs and reduce deployment delays. Such models are particularly applicable to distributed banking infrastructures where network devices must be rapidly deployed across geographically dispersed branch networks (Axsäter, 2015).

Recent research has also explored the integration of data analytics and predictive modeling into inventory optimization for technology infrastructure. Data-driven inventory management approaches use historical device consumption data, infrastructure expansion plans, and predictive maintenance analytics to forecast future demand patterns. These predictive models allow organizations to dynamically adjust procurement strategies and inventory levels based on anticipated infrastructure requirements (Ivanov et al., 2019). By combining predictive demand forecasting with optimization-based inventory policies, enterprises can significantly improve inventory efficiency while maintaining high levels of deployment readiness.

Despite these advances, the application of inventory optimization models specifically to network device management in distributed financial infrastructures remains relatively limited. Many banking organizations still rely on static procurement policies or manual forecasting methods that do not fully capture demand variability or lifecycle dynamics of network devices. This limitation highlights the need for integrated inventory optimization frameworks that combine stochastic demand modeling, lifecycle tracking, and deployment readiness metrics to support efficient infrastructure management in distributed banking environments.

➤ *Deployment Readiness and Infrastructure Availability Models*

Deployment readiness and infrastructure availability represent fundamental components of enterprise IT operations, particularly within sectors that require continuous service delivery such as banking and financial services. Distributed digital infrastructures must maintain high levels of operational readiness to support transaction processing, cybersecurity monitoring, and regulatory reporting systems. Consequently, researchers have increasingly focused on developing analytical frameworks that evaluate infrastructure readiness through metrics related to device availability, system redundancy, operational resilience, and service continuity (Hwang et al., 2019). These frameworks help organizations determine whether sufficient technological resources are available to support infrastructure deployment, maintenance operations, and rapid recovery from disruptions.

Infrastructure readiness metrics are commonly used to measure the preparedness of technology environments to support operational workloads. These metrics typically evaluate factors such as hardware availability, network capacity, configuration compliance, and security patch status. In enterprise environments, readiness metrics provide a quantitative basis for assessing whether infrastructure components are capable of supporting new deployments or upgrades without causing operational disruptions. Studies on IT service management

frameworks emphasize that readiness assessment plays a critical role in ensuring service reliability and minimizing operational risks in complex digital infrastructures (Galliers & Leidner, 2018).

Operational resilience has become another important concept associated with infrastructure readiness modeling. Resilience refers to the ability of technology systems to maintain operational functionality during adverse events such as cyberattacks, hardware failures, or network congestion. Within banking infrastructures, resilience frameworks often integrate infrastructure monitoring systems with predictive analytics to identify vulnerabilities and ensure that sufficient device capacity exists to support continuous operations. Research shows that infrastructure resilience is strongly influenced by the availability and redundancy of critical network devices within distributed systems (Linkov et al., 2020). Maintaining adequate device availability therefore becomes an essential requirement for sustaining operational resilience in enterprise networks.

To quantify infrastructure readiness, researchers have proposed several availability-based metrics that evaluate the proportion of operational resources relative to total infrastructure capacity. One commonly used indicator is the Deployment Readiness Index (DRI), which measures the ratio of available and operational devices relative to the total number of devices required within the infrastructure environment. This index provides a simple but effective measure of infrastructure preparedness for deployment activities.

The Deployment Readiness Index is defined as:

$$DRI = \frac{N_{ready}}{N_{total}}$$

Where:

$N_{ready}$  represents the number of network devices that are available and ready for deployment, and  $N_{total}$  represents the total number of devices required to support infrastructure operations.

A higher value of the Deployment Readiness Index indicates that a greater proportion of infrastructure resources are available and prepared for deployment. In distributed enterprise environments, maintaining a high DRI value is essential for supporting infrastructure upgrades, branch expansions, and emergency hardware replacements without operational delays.

Device availability modeling also plays an important role in understanding infrastructure readiness. Availability models often incorporate reliability engineering concepts that estimate the probability that a device remains operational during a given time period. These models frequently consider factors such as device failure rates, maintenance intervals, and repair times. Reliability-based availability models allow organizations to estimate the expected operational capacity of infrastructure assets and

determine whether sufficient redundancy exists to maintain service continuity during component failures (Trivedi & Bobbio, 2017).

Another important aspect of deployment readiness involves monitoring the lifecycle status of infrastructure assets. Devices that are outdated, under maintenance, or awaiting firmware updates may not be immediately available for deployment. Lifecycle-aware readiness models therefore integrate asset lifecycle tracking systems with infrastructure monitoring platforms to provide real-time visibility into device availability across distributed networks. Such integrated monitoring frameworks enable infrastructure managers to assess readiness levels dynamically and respond quickly to changes in infrastructure demand (Bouras et al., 2021).

Recent research has also emphasized the importance of predictive analytics in infrastructure availability modeling. Machine learning techniques can analyse historical device performance data to forecast future failure probabilities and anticipate infrastructure capacity shortages. Predictive readiness models enable organizations to proactively procure additional equipment or schedule maintenance activities before infrastructure shortages affect operational continuity (Zhang et al., 2021). These predictive capabilities are particularly valuable in banking environments where infrastructure disruptions can have significant financial and reputational consequences.

Despite the growing interest in infrastructure readiness metrics, many enterprise organizations still rely on fragmented monitoring systems that do not fully integrate device lifecycle data with deployment planning processes. This lack of integration can lead to inaccurate readiness assessments and delayed infrastructure deployment activities. As digital infrastructures continue to expand across geographically distributed networks, there is a growing need for integrated readiness models that combine device lifecycle tracking, inventory management, and reliability analytics to provide comprehensive assessments of infrastructure availability.

#### ➤ *Gaps in Current Research*

The management of IT assets and network infrastructure has been widely studied in the context of enterprise systems, supply chain optimization, and digital infrastructure governance. Numerous studies have examined asset lifecycle management frameworks, configuration management systems, and infrastructure monitoring platforms designed to improve asset visibility and operational reliability within enterprise IT environments (Shin & Lee, 2020). These studies have provided important insights into how organizations can track technology assets across procurement, deployment, maintenance, and retirement stages. However, despite these contributions, several critical gaps remain in the existing literature, particularly in relation to integrated lifecycle analytics and deployment readiness modeling within distributed financial infrastructures.

One major limitation in current research is the predominant focus on traditional IT asset management systems, which primarily emphasize asset registration, configuration tracking, and compliance reporting. While these systems provide visibility into hardware inventories and software configurations, they often lack analytical capabilities that link asset lifecycle data with operational deployment requirements. Studies on enterprise asset management highlight that many organizations rely on static asset databases that record device ownership and configuration attributes but do not support predictive analysis of infrastructure readiness or inventory optimization (Gupta & George, 2019). As a result, organizations may maintain accurate asset records but still experience delays in infrastructure deployment due to insufficient device availability or poor lifecycle coordination.

Another research gap relates to the limited integration between lifecycle management and infrastructure availability modeling. Existing research on lifecycle management has largely focused on maintaining accurate configuration records and ensuring compliance with security standards (Zhang et al., 2021). Meanwhile, studies on infrastructure availability and reliability have typically examined system uptime, redundancy strategies, and fault tolerance mechanisms within distributed computing systems (Trivedi & Bobbio, 2017). These two streams of research are often treated as independent domains, despite the fact that device lifecycle status directly influences infrastructure readiness and operational continuity. The lack of integrated analytical frameworks that combine lifecycle tracking with availability modeling represents a significant limitation in current infrastructure management research.

A further gap exists in the application of inventory optimization models to network device management in financial institutions. While inventory optimization models such as economic order quantity (EOQ), stochastic demand modeling, and multi-echelon inventory frameworks have been extensively applied in manufacturing and supply chain contexts, their application within IT infrastructure management remains relatively limited (Silver et al., 2017). Research in enterprise IT environments has traditionally focused more on configuration management and service availability rather than on optimizing the procurement and storage of infrastructure hardware. Consequently, many organizations continue to manage technology inventories using static procurement policies rather than analytical optimization models.

Another important research gap concerns the lack of deployment readiness metrics tailored specifically to financial network infrastructures. The concept of operational readiness has been widely explored in fields such as cloud computing, distributed systems, and critical infrastructure resilience (Hwang et al., 2019). However, relatively few studies have developed quantitative indicators that measure the readiness of network device inventories to support infrastructure deployment within

distributed banking environments. Financial institutions operate under strict regulatory requirements and must maintain high levels of operational resilience, yet the literature provides limited guidance on how inventory availability and lifecycle status influence deployment readiness in such environments (Basel Committee on Banking Supervision, 2021).

In addition, existing research has not adequately addressed the complexity introduced by geographically distributed banking networks. Large financial institutions often operate hundreds or thousands of branch offices connected to central and regional data centers. Managing infrastructure assets across these distributed environments requires integrated systems capable of synchronizing lifecycle data, inventory records, and deployment schedules across multiple locations. While distributed resource management has been studied extensively in cloud computing and enterprise networking, these studies rarely incorporate asset lifecycle tracking and inventory planning into the same analytical framework (Bouras et al., 2021). This separation limits the ability of organizations to coordinate procurement strategies with infrastructure deployment requirements across geographically dispersed networks.

Another emerging gap relates to the lack of predictive and data-driven approaches for infrastructure lifecycle planning. Recent research in predictive maintenance and infrastructure analytics demonstrates the potential of machine learning techniques to forecast equipment failures and optimize maintenance scheduling (Zhang et al., 2021). However, these predictive approaches have not yet been widely integrated with inventory management systems or deployment planning processes. As a result, organizations may be able to predict device failures but still lack the inventory optimization

mechanisms necessary to ensure that replacement equipment is available when needed.

Overall, the existing body of research provides valuable insights into IT asset lifecycle management, infrastructure availability, and inventory optimization as separate domains. However, there remains a significant gap in the development of integrated analytical frameworks that combine lifecycle analytics, inventory optimization, and deployment readiness modeling for distributed financial network infrastructures. Addressing this gap is particularly important for banking environments, where infrastructure availability directly affects financial transaction systems, cybersecurity monitoring platforms, and regulatory compliance mechanisms. The present study therefore seeks to bridge this gap by developing a lifecycle-aware inventory optimization model that integrates device lifecycle tracking with deployment readiness metrics for distributed banking networks.

Table 1 summarizes the major inventory optimization models commonly applied to IT infrastructure management. The table compares each model based on its fundamental concept, its practical application to managing network devices, and its operational limitations. It shows that deterministic models such as EOQ are useful for stable demand conditions, while stochastic and safety stock models address uncertainty in device demand and supply. Multi-echelon models support inventory coordination across distributed infrastructure locations such as data centers and branch offices. Overall, the table highlights how different optimization models contribute to improving infrastructure readiness while balancing procurement and inventory holding costs.

Table 1 Summary of Inventory Optimization Models in IT Infrastructure Management

Model	Core Concept	Application in IT Infrastructure	Limitations
Economic Order Quantity (EOQ)	Determines optimal order quantity that minimizes the combined ordering and holding costs using deterministic demand assumptions.	Used to estimate optimal procurement quantities for network devices such as routers, switches, and firewalls in enterprise infrastructure inventories.	Assumes constant demand and fixed lead time, which may not reflect fluctuating infrastructure requirements or emergency device replacements.
Stochastic Inventory Model	Incorporates probabilistic demand and lead time variability to determine reorder points and safety stock levels.	Applied to technology inventories where device demand arises from unpredictable events such as hardware failures, network upgrades, or cybersecurity incidents.	Requires reliable statistical demand data and complex probability modeling for accurate implementation.
Multi-Echelon Inventory Model	Optimizes inventory allocation across multiple storage locations within a supply network.	Used for distributing network devices across central warehouses, regional data centers, and branch-level equipment repositories.	Computational complexity increases with the number of inventory nodes and transportation constraints.
Safety Stock Model	Maintains additional inventory buffer to protect against demand variability and supply delays.	Ensures that critical networking equipment is available for emergency deployment or infrastructure recovery operations.	Excessive safety stock can increase storage costs and tie up capital in unused hardware assets.

Just-in-Time (JIT) Inventory	Minimizes inventory levels by synchronizing procurement with actual demand and deployment schedules.	Applied in IT procurement strategies where devices are ordered shortly before infrastructure deployment projects.	Vulnerable to supply chain disruptions and vendor delivery delays that may affect infrastructure readiness.
Predictive Analytics-Based Inventory	Uses historical usage data and predictive algorithms to forecast future device demand.	Enables proactive procurement planning for infrastructure expansion, hardware refresh cycles, and maintenance activities.	Requires accurate historical datasets and advanced analytical capabilities for effective forecasting.

Table 2 presents a comparative overview of major device lifecycle management frameworks used in enterprise IT environments. The table evaluates each framework based on the extent of lifecycle coverage, the level of automation supported, and its applicability to banking infrastructures. It shows that frameworks such as ITIL SACM and CMDB provide strong governance and

configuration visibility for regulated environments. Vendor-driven and predictive lifecycle frameworks offer higher automation through monitoring and analytics capabilities. Overall, the comparison highlights that integrated lifecycle management frameworks are essential for maintaining secure, compliant, and scalable banking network infrastructures.

Table 2 Comparative Review of Device Lifecycle Management Frameworks

Framework	Lifecycle Coverage	Automation Level	Suitability for Banking Systems
ITIL-Based Asset & Configuration Management (SACM)	Procurement, asset registration, configuration tracking, change management, retirement	Moderate to High (CMDB integration and workflow automation)	Highly suitable; supports governance, auditability, and regulatory compliance in banking environments
ISO/IEC 19770 IT Asset Management	Asset identification, licensing, lifecycle control, disposal and compliance management	Moderate	Suitable for financial institutions requiring standardized asset governance and audit compliance
Enterprise Asset Management (EAM) Systems	Procurement, inventory tracking, maintenance scheduling, lifecycle analytics, retirement	High (integrated monitoring and asset analytics)	Highly suitable for large banking infrastructures with distributed assets
Vendor-Based Lifecycle Management (e.g., Cisco Lifecycle Services)	Design, procurement, deployment, optimization, maintenance, end-of-life replacement	High (vendor-managed automation and lifecycle analytics)	Suitable for banks using standardized network equipment ecosystems
Configuration Management Database (CMDB) Framework	Asset registration, configuration monitoring, dependency mapping, change tracking	High (automated discovery and configuration synchronization)	Highly suitable for banking IT governance and infrastructure monitoring
Predictive Lifecycle Management with Analytics	Lifecycle tracking, predictive maintenance, failure forecasting, upgrade planning	Very High (AI-driven monitoring and predictive analytics)	Emerging approach; increasingly suitable for large banking networks seeking proactive infrastructure management
Framework	Lifecycle Coverage	Automation Level	Suitability for Banking Systems

### III. METHODOLOGY

#### ➤ System Architecture for Inventory Monitoring

The proposed methodology develops a centralized architecture for monitoring network device inventory and lifecycle states across distributed banking infrastructures. Modern banking networks consist of numerous interconnected devices deployed across headquarters, regional data centers, and branch locations, making accurate lifecycle monitoring essential for infrastructure governance and operational resilience. To address this challenge, the study proposes a centralized lifecycle tracking system that integrates procurement records, configuration management systems, operational

monitoring platforms, and deployment scheduling mechanisms. The objective of this architecture is to provide real-time visibility into device availability and lifecycle states while supporting optimized inventory planning for infrastructure deployment activities (Shin & Lee, 2020).

The system architecture follows a layered structure in which multiple enterprise data sources feed information into a centralized lifecycle analytics platform. At the foundational layer, procurement databases store acquisition records for network equipment including purchase orders, vendor information, device specifications, and delivery schedules. These procurement

datasets provide the baseline inventory information necessary for tracking device availability and forecasting future infrastructure requirements. Integrating procurement records with lifecycle monitoring systems ensures that newly acquired devices are immediately registered within the enterprise inventory ecosystem and can be tracked throughout their operational lifecycle (Gupta & George, 2019).

The second architectural component involves configuration management databases (CMDB), which maintain detailed configuration records for devices deployed across the banking network. CMDB platforms typically store attributes such as device identifiers, firmware versions, network topology relationships, and configuration dependencies between infrastructure components. By synchronizing lifecycle tracking systems with CMDB repositories, the proposed architecture ensures that operational devices are continuously mapped to their corresponding inventory records, enabling accurate monitoring of configuration status and device readiness (Zhang et al., 2021).

The architecture also integrates network monitoring platforms that collect real-time operational metrics from deployed devices. Monitoring systems capture information such as device health indicators, network traffic levels, security alerts, and hardware performance statistics. These operational metrics provide valuable insights into the functional state of network devices and allow infrastructure managers to detect anomalies or performance degradation that may require maintenance or device replacement. Incorporating monitoring data into the lifecycle tracking framework improves infrastructure visibility and supports predictive maintenance strategies for distributed banking networks (Bouras et al., 2021).

The fourth component of the system architecture involves deployment scheduling systems, which coordinate the allocation and installation of network devices during infrastructure rollout or upgrade projects. Deployment scheduling tools maintain records of planned installation activities across data centers and branch locations. By linking these scheduling systems with inventory monitoring platforms, organizations can ensure that sufficient devices are available prior to scheduled deployment activities. This integration minimizes deployment delays and improves coordination between procurement planning and infrastructure expansion initiatives.

To analytically represent the dynamics of inventory monitoring within this architecture, the lifecycle state of each device can be represented using a discrete state variable. Let

$$S_i(t) \in \{P, W, D, M, R\}$$

Where:

$P$  represents procurement stage,  
 $W$  represents warehouse storage,

$D$  represents deployed devices,  
 $M$  represents maintenance stage, and  
 $R$  represents retired devices.

The transition between lifecycle states can be modeled using a probabilistic state transition framework:

$$P_{ij}(t) = P(S(t+1) = j | S(t) = i)$$

Where  $P_{ij}$  represents the probability that a device transitions from lifecycle state  $i$  to state  $j$  during the next time interval. This Markov-based lifecycle representation allows the system to estimate device availability and predict future inventory requirements.

The centralized monitoring system also evaluates overall infrastructure readiness by aggregating inventory states across the network. Let  $N_d(t)$  denote the number of deployable devices at time  $t$ , and  $N_r(t)$  represent the required number of devices for scheduled infrastructure deployment. Deployment readiness at time  $t$  can therefore be expressed as:

$$R(t) = \frac{N_d(t)}{N_r(t)}$$

Where  $R(t)$  represents the infrastructure readiness ratio for deployment activities.

To optimize procurement decisions within this architecture, the system also evaluates inventory holding costs and procurement costs using an optimization objective function:

$$\min C = \sum_{t=1}^T (HI_t + SO_t + P \max(D_t - I_t, 0))$$

Where:

$H$  represents holding cost per device,  
 $I_t$  represents inventory level at time  $t$ ,  
 $S$  represents ordering cost,  
 $O_t$  represents procurement orders, and  
 $P$  represents penalty cost associated with device shortages.

This cost minimization framework enables infrastructure managers to determine optimal procurement policies that maintain adequate inventory levels while minimizing operational costs.

Overall, the proposed system architecture integrates multiple enterprise information sources into a centralized lifecycle monitoring platform that supports predictive analytics and optimized inventory management. By combining procurement data, configuration records, real-time monitoring information, and deployment schedules, the architecture provides a comprehensive mechanism for managing network device lifecycles within distributed banking infrastructures.

Figure 2 illustrates a centralized framework for managing network device inventory and lifecycle

processes within distributed banking infrastructures. The process flow begins with the device procurement pipeline, where equipment is acquired and registered in the procurement database. Devices are then transferred to warehouse inventory tracking, where stock levels and asset records are maintained. The deployment scheduling engine coordinates installation plans and allocates devices

to required infrastructure locations. Lifecycle monitoring continuously tracks device performance, configuration status, and operational health, while retirement management handles device decommissioning, data wiping, and asset disposal at the end of the lifecycle.



Fig 2 Lifecycle-Aware Inventory Optimization Framework for Network Device Management in Distributed Banking Infrastructure

➤ *Mathematical Inventory Optimization Model*

Efficient management of network device inventories within distributed banking infrastructures requires analytical models capable of balancing procurement costs, storage costs, and the operational risks associated with device shortages. Traditional inventory management approaches often rely on static reorder thresholds or heuristic procurement rules, which may not adequately address the dynamic demand patterns associated with infrastructure upgrades, hardware failures, and branch network expansions. Consequently, this study adopts an optimization-based mathematical framework designed to minimize the total cost of maintaining network device inventories while ensuring sufficient availability for infrastructure deployment activities (Silver et al., 2017).

The optimization model considers three major cost components associated with inventory management: inventory holding costs, procurement ordering costs, and stockout penalties. Holding costs represent the expenses incurred from storing and maintaining unused devices within inventory systems. Ordering costs represent the administrative and logistical costs associated with

procurement transactions. Stockout penalties reflect the operational losses that occur when device demand exceeds available inventory, resulting in deployment delays or service disruptions (Nahmias & Olsen, 2015).

The objective of the optimization model is therefore to minimize the total inventory cost over a planning horizon  $T$ . The objective function is expressed as:

$$\text{Minimize } C = C_h + C_o + C_s$$

Where:

$C_h$  represents total holding cost,  
 $C_o$  represents total ordering cost, and  
 $C_s$  represents stockout penalty cost.

The holding cost component is defined as:

$$C_h = H \sum_{t=1}^T I_t$$

Where:

$H$  denotes the unit holding cost per device per time period, and

$I_t$  represents the inventory level at time  $t$ .

This term captures the cost of storing network devices in warehouses or staging facilities before they are deployed across the banking infrastructure.

The procurement ordering cost is defined as:

$$C_o = S \sum_{t=1}^T O_t$$

Where:

$S$  denotes the cost associated with each procurement order, and

$O_t$  represents the number of devices ordered at time  $t$ .

This component reflects the operational expenses associated with procurement activities such as vendor coordination, logistics management, and inventory processing.

The stockout penalty component accounts for the risk that device demand may exceed available inventory. When such shortages occur, infrastructure deployment activities may be delayed, resulting in operational and financial consequences. The stockout penalty cost is therefore defined as:

$$C_s = P \sum_{t=1}^T \max(0, D_t - I_t)$$

Where:

$P$  represents the penalty cost associated with each unit of unmet demand, and

$D_t$  represents device demand at time  $t$ .

The expression  $\max(0, D_t - I_t)$  ensures that penalties are only incurred when demand exceeds available inventory.

Combining these components yields the overall inventory cost function:

$$C = H \sum_{t=1}^T I_t + S \sum_{t=1}^T O_t + P \sum_{t=1}^T \max(0, D_t - I_t)$$

This optimization function provides a comprehensive representation of the economic trade-offs associated with inventory management in distributed network infrastructures.

To capture the dynamic evolution of inventory levels across time, the model incorporates an inventory balance constraint defined as:

$$I_{t+1} = I_t + O_t - D_t$$

Where:

$I_{t+1}$  represents the inventory level at the next time period.

This constraint ensures that inventory levels are updated according to procurement inflows and device consumption resulting from infrastructure deployment activities.

In large-scale banking infrastructures, procurement lead time also influences inventory availability. Let  $L$  represent the lead time required for device delivery after an order is placed. Inventory updates must therefore account for delayed order arrivals:

$$I_{t+1} = I_t + O_{t-L} - D_t$$

To ensure that sufficient devices are available for deployment activities, the model also incorporates a service-level constraint that maintains minimum inventory availability:

$$P(I_t \geq D_t) \geq \alpha$$

Where:

$\alpha$  represents the required service level for deployment readiness.

This constraint ensures that the probability of meeting device demand remains above a predefined threshold, which is particularly important for maintaining operational resilience in banking infrastructures.

Finally, the optimization problem can be summarized as:

$$\min_{I_t, O_t} C$$

Subject to

$$I_{t+1} = I_t + O_{t-L} - D_t$$

$$I_t \geq 0$$

$$P(I_t \geq D_t) \geq \alpha$$

The resulting optimization framework provides a quantitative mechanism for determining optimal procurement policies that balance infrastructure readiness with inventory cost efficiency. By incorporating demand variability, procurement lead times, and service-level constraints, the model supports strategic inventory planning for distributed banking networks where device availability is critical for maintaining operational continuity.

➤ *Deployment Readiness Modeling*

Deployment readiness is a critical performance indicator for distributed banking infrastructures because the availability and operational status of network devices directly influence the ability of financial institutions to deploy new infrastructure, perform upgrades, and respond to operational incidents. In large banking networks, devices must not only be physically available in inventory but must also meet configuration, firmware, and security compliance requirements before they can be deployed into production environments. Consequently, deployment readiness is modeled as a composite metric that captures multiple operational attributes of network devices, including availability, firmware compliance, and security patch status (Linkov et al., 2020).

To quantitatively measure infrastructure preparedness, this study introduces a Deployment Readiness Score (RS) that integrates several device-level indicators into a single readiness metric. The readiness score is modeled as a weighted linear combination of device availability, firmware compliance status, and security patch compliance.

$$RS = \alpha A + \beta F + \gamma S$$

Where:

$A$  represents the device availability index,  $F$  represents the firmware compliance score, and  $S$  represents the security patch compliance score.

The weighting parameters satisfy the normalization constraint:

$$\alpha + \beta + \gamma = 1$$

Where  $\alpha$ ,  $\beta$ , and  $\gamma$  represent the relative importance assigned to each readiness factor.

The device availability index  $A$  measures the proportion of devices that are physically available and operational within the inventory system. This metric captures the readiness of hardware assets to be deployed within the network infrastructure. The availability index is expressed as:

$$A = \frac{N_{available}}{N_{required}}$$

Where:

$N_{available}$  represents the number of deployable devices currently available in inventory, and  $N_{required}$  represents the number of devices required for planned infrastructure deployments.

Firmware compliance  $F$  reflects the degree to which network devices meet required firmware standards defined by infrastructure governance policies. Firmware compliance is essential because outdated firmware may contain vulnerabilities or performance limitations that

compromise operational reliability. The firmware compliance index is defined as:

$$F = \frac{N_{firmware\_compliant}}{N_{total}}$$

Where:

$N_{firmware\_compliant}$  represents devices operating with approved firmware versions, and  $N_{total}$  represents the total number of devices under evaluation.

Similarly, the security patch compliance score  $S$  measures the proportion of devices that have received the latest security updates required to protect infrastructure from known vulnerabilities. This metric is particularly important in financial institutions where cybersecurity risks can directly impact operational resilience and regulatory compliance.

$$S = \frac{N_{secure}}{N_{total}}$$

Where:

$N_{secure}$  represents devices with up-to-date security patches.

The composite readiness score  $RS$  therefore provides a normalized measure of the operational preparedness of network devices across the infrastructure environment. Values of  $RS$  close to 1 indicate high deployment readiness, whereas lower values indicate that devices require firmware updates, security patching, or additional procurement before they can be deployed.

For infrastructure-level analysis across distributed banking networks, the overall readiness score can be aggregated across all network segments. Let  $RS_i$  represent the readiness score of infrastructure node  $i$ , and  $n$  represent the total number of nodes in the network. The global deployment readiness index can then be expressed as:

$$RS_{global} = \frac{1}{n} \sum_{i=1}^n RS_i$$

This aggregated metric provides infrastructure managers with a network-wide assessment of deployment preparedness across data centers, regional hubs, and branch offices.

To support predictive readiness analysis, the model can also incorporate time-dependent readiness dynamics. Let  $RS(t)$  represent readiness at time  $t$ . The temporal change in readiness can be approximated as:

$$\frac{dRS(t)}{dt} = \alpha \frac{dA(t)}{dt} + \beta \frac{dF(t)}{dt} + \gamma \frac{dS(t)}{dt}$$

This formulation allows infrastructure managers to monitor how deployment readiness evolves over time as devices are procured, updated, or retired.

By integrating availability, firmware compliance, and security patch status into a unified readiness metric, the proposed model provides a structured mechanism for evaluating infrastructure preparedness within distributed banking networks. The readiness score can also be incorporated into inventory optimization models to ensure that procurement and maintenance strategies maintain sufficient infrastructure readiness for operational deployment activities.

Table 3 summarizes the key parameters used in the inventory simulation model for evaluating network device availability in distributed banking infrastructures. The table defines operational variables such as device demand, available inventory levels, procurement orders, and supplier lead times. It also includes economic parameters such as holding costs, ordering costs, and stockout penalty costs that influence the optimization model. In addition, the table presents weighting coefficients used in the deployment readiness score model. Collectively, these parameters provide the quantitative inputs required to simulate inventory dynamics and evaluate infrastructure readiness performance.

Table 3 Experimental Parameters for Inventory Simulation

Parameter	Description	Value Range	Units
$D_t$	Device demand per time period representing the number of network devices required for deployment or replacement within the banking infrastructure	10 – 120	Devices / period
$I_t$	Inventory level representing the number of devices available in storage or staging facilities at time $t$	50 – 500	Devices
$O_t$	Procurement order quantity representing the number of devices ordered from vendors during each procurement cycle	20 – 200	Devices
$L$	Procurement lead time representing the delay between device order placement and delivery to the inventory warehouse	2 – 8	Weeks
$H$	Holding cost associated with storing each device within the inventory system per time period	5 – 25	USD / device / period
$S$	Ordering cost incurred during each procurement transaction including logistics, vendor processing, and administrative costs	200 – 800	USD / order
$P$	Stockout penalty cost incurred when device demand exceeds available inventory, representing deployment delays and operational risks	100 – 600	USD / device
$\alpha$	Weight coefficient for device availability in the deployment readiness score model	0.3 – 0.5	Dimensionless
$\beta$	Weight coefficient for firmware compliance in the deployment readiness score model	0.2 – 0.4	Dimensionless
$\gamma$	Weight coefficient for security patch compliance in the deployment readiness score model	0.2 – 0.4	Dimensionless

#### IV. RESULTS AND DISCUSSION

##### ➤ Inventory Optimization Results

The simulation experiments were conducted to evaluate the performance of the proposed inventory optimization model compared with traditional inventory management strategies commonly used in enterprise IT environments. The simulation environment represents a distributed banking infrastructure where network devices must be maintained across centralized warehouses and deployed to multiple branch offices and regional data centers. The objective of the simulation is to assess how optimized procurement policies influence infrastructure

readiness, inventory efficiency, and operational cost management.

Two inventory management strategies were evaluated. The first represents a traditional inventory approach, where procurement decisions are based on fixed reorder thresholds and periodic manual forecasting. The second represents the proposed optimization-driven strategy, where procurement orders are determined using the mathematical cost minimization model introduced in Section 3.2. The simulation was conducted across multiple time periods to capture fluctuations in device demand resulting from infrastructure expansion, equipment failures, and scheduled technology upgrades.

The first evaluation metric focuses on device stock availability, which measures the proportion of infrastructure demand that can be satisfied using available inventory. Simulation results show that the optimized inventory model maintains significantly higher stock availability compared with traditional inventory management approaches. Under the traditional strategy, inventory shortages occurred during peak demand periods, particularly when infrastructure upgrades required large numbers of network devices simultaneously. In contrast, the optimization model dynamically adjusted procurement quantities based on projected demand and lead time constraints, ensuring that adequate inventory levels were maintained across the planning horizon.

The second metric examined is deployment readiness, which measures the ability of the infrastructure to support device installation without procurement delays. Deployment readiness was calculated using the readiness model introduced in Section 3.3, which integrates device availability, firmware compliance, and security patch status into a unified readiness score. Simulation results indicate that the optimized inventory strategy consistently achieved higher readiness scores compared with the baseline model. This improvement occurs because optimized procurement decisions ensure that devices remain available in sufficient quantities to support infrastructure deployment schedules.

The third evaluation metric focuses on inventory holding costs, which represent the financial burden associated with maintaining hardware inventories within storage facilities. Although maintaining higher inventory levels may improve deployment readiness, excessive inventory can increase storage costs and capital expenditures. The optimization model addresses this trade-off by balancing holding costs with stockout penalties through the objective function introduced in Section 3.2. Simulation results demonstrate that the optimized strategy reduced average holding costs while still maintaining adequate inventory availability. This improvement was achieved by adjusting procurement timing and order quantities according to predicted demand patterns.

Another important performance metric evaluated in the simulation is device deployment delay, defined as the average time required to deploy devices once infrastructure demand is generated. Deployment delays typically occur when the required devices are not available in inventory and must be ordered from vendors. The simulation results show that the optimized procurement model significantly reduced deployment delays compared with the traditional inventory approach. Because the optimization framework incorporates procurement lead

times into the inventory planning process, the system is able to place orders in advance of expected demand peaks, thereby reducing the probability of inventory shortages.

From a mathematical perspective, the improvement in infrastructure performance can be explained by examining the reduction in expected stockout probability. Let the probability of inventory shortage under the traditional strategy be denoted as  $P_s^{trad}$ , and the probability under the optimized strategy be denoted as  $P_s^{opt}$ . Simulation results demonstrate that

$$P_s^{opt} < P_s^{trad}$$

Which directly contributes to improvements in deployment readiness and infrastructure reliability.

Furthermore, the total inventory cost associated with the optimized model is significantly lower than the cost generated by traditional inventory management strategies. If  $C_{trad}$  represents the cost of traditional inventory policies and  $C_{opt}$  represents the cost of the optimized model, simulation results consistently show that

$$C_{opt} < C_{trad}$$

This cost reduction occurs because the optimization model simultaneously minimizes holding costs, ordering costs, and stockout penalties while maintaining acceptable service levels.

Overall, the results demonstrate that integrating lifecycle tracking with inventory optimization significantly improves infrastructure management within distributed banking networks. The proposed model enhances device availability, reduces deployment delays, and minimizes inventory management costs. These findings highlight the potential benefits of adopting optimization-driven inventory policies for managing network device lifecycles in complex enterprise infrastructures.

Figure 3 illustrates the relationship between total inventory cost and deployment readiness probability under two inventory management strategies. The optimized inventory strategy demonstrates higher readiness levels at lower or moderate cost levels compared with the traditional inventory approach. As inventory investment increases, readiness improves for both strategies, but the optimized model reaches higher efficiency earlier. The shaded region highlights the optimal trade-off zone where infrastructure readiness is maximized while maintaining controlled inventory costs.



Fig 3 Comparative Analysis of Inventory Cost and Deployment Readiness Under Optimized and Traditional Inventory Management Strategies

➤ *Deployment Readiness Analysis*

Deployment readiness represents the ability of banking infrastructure teams to rapidly deploy network devices when new installations, upgrades, or replacements are required. In distributed banking environments, deployment readiness is strongly influenced by inventory availability, firmware compliance, and device security status. The simulation results demonstrate that incorporating lifecycle-aware inventory optimization significantly enhances deployment readiness across branch networks, regional data centers, and central banking infrastructure. By aligning procurement policies with predicted infrastructure demand and lifecycle compliance requirements, the optimized model ensures that deployable devices remain readily available across operational environments.

To quantify the improvement achieved through the proposed optimization strategy, deployment readiness under the optimized inventory policy was compared with readiness achieved under the traditional inventory management approach. The difference in readiness levels is expressed as

$$\Delta R = R_{\text{optimized}} - R_{\text{traditional}}$$

Where:

$R_{\text{optimized}}$  represents the deployment readiness score obtained using the lifecycle-aware optimization model, and

$R_{\text{traditional}}$  represents readiness under conventional procurement and inventory practices.

Simulation results consistently show positive values of  $\Delta R$ , indicating that the optimized model produces higher deployment readiness across all simulated infrastructure scenarios. The improvement occurs because the optimization framework maintains sufficient device availability while simultaneously ensuring that devices meet firmware and security compliance requirements prior to deployment. This lifecycle-aware approach reduces delays caused by missing firmware updates, incomplete device configurations, or security patch deficiencies.

Another factor contributing to improved readiness is the integration of procurement lead-time awareness within the optimization framework. By accounting for vendor delivery delays, the model anticipates demand spikes and places procurement orders in advance of deployment requirements. As a result, the probability that required devices are unavailable during infrastructure deployment events is significantly reduced.

From an operational perspective, the improvement in deployment readiness directly translates into faster infrastructure rollouts, reduced downtime during equipment replacements, and improved operational resilience within banking networks. Branch expansions, network upgrades, and cybersecurity device replacements can therefore be executed more efficiently when lifecycle-aware inventory optimization is implemented.

Overall, the results indicate that integrating device lifecycle monitoring with inventory optimization provides a measurable improvement in infrastructure readiness for distributed banking systems. The positive readiness differential  $\Delta R$  observed in the simulations confirms that optimized procurement and lifecycle tracking strategies can significantly enhance the operational efficiency of enterprise network infrastructure management.

➤ *Operational Impact for Banking Infrastructure*

The results obtained from the inventory optimization and deployment readiness analysis have significant operational implications for distributed banking infrastructures. Modern banking institutions operate extensive branch networks that require reliable, secure, and rapidly deployable network infrastructure. Inefficient device lifecycle management and fragmented inventory systems can delay infrastructure expansion, reduce operational resilience, and increase exposure to cybersecurity risks. By integrating lifecycle-aware inventory optimization with deployment readiness modeling, financial institutions can improve operational efficiency across several critical infrastructure management domains.

One major operational impact relates to branch network rollout speed. Banking institutions frequently expand their physical presence through new branches, digital service centers, and regional operational hubs. Each of these facilities requires the rapid deployment of routers, switches, firewalls, and other network security appliances. The proposed inventory optimization framework ensures that sufficient devices are available in advance of infrastructure expansion activities. This reduces procurement delays and allows network engineering teams to deploy infrastructure components immediately when installation schedules begin. Consequently, the time required to activate new banking locations is significantly reduced, improving service availability and customer access to banking services.

Another important implication concerns cybersecurity patch deployment. Financial institutions operate within highly sensitive digital environments where network vulnerabilities can expose critical financial data and transaction systems to cyber threats. The lifecycle-aware readiness model introduced in this study incorporates firmware compliance and security patch status as core readiness variables. As a result, the inventory system continuously monitors device patch status and firmware versions prior to deployment. Devices that do not meet required security standards are automatically flagged for updates before they are

integrated into operational networks. This proactive lifecycle monitoring significantly improves the speed and consistency of cybersecurity patch deployment across the banking infrastructure.

The framework also contributes to improved regulatory infrastructure compliance, which is a critical requirement for financial institutions operating under strict regulatory frameworks. Banking regulators often require organizations to maintain auditable records of infrastructure assets, configuration states, and security patch levels. The centralized lifecycle tracking system proposed in this research integrates procurement databases, configuration management databases, and monitoring systems to maintain comprehensive device lifecycle records. These integrated records enable financial institutions to demonstrate compliance with infrastructure governance standards and cybersecurity regulations during regulatory audits and risk assessments.

Furthermore, the proposed inventory optimization model enhances disaster recovery readiness for banking infrastructure. During infrastructure failures, cyber incidents, or natural disasters, financial institutions must rapidly replace damaged or compromised network devices to restore operational services. If spare devices are unavailable, recovery times can increase significantly, resulting in service disruptions and financial losses. The optimized inventory management model ensures that sufficient backup devices remain available within centralized warehouses and staging facilities. This improves the institution's ability to rapidly restore network connectivity and maintain business continuity during emergency situations.

Overall, the integration of lifecycle-aware inventory optimization with infrastructure readiness modeling provides measurable operational benefits for distributed banking environments. Improvements in branch rollout speed, cybersecurity patch deployment efficiency, regulatory compliance monitoring, and disaster recovery readiness demonstrate the strategic value of adopting optimized device lifecycle management frameworks within modern financial institutions.

Table 4 compares the operational performance of traditional inventory management with the proposed optimized inventory model. The optimized approach shows higher device availability and deployment readiness while significantly reducing inventory holding costs and deployment delays. Overall, the results indicate substantial performance improvements in infrastructure readiness and reduced stockout risks under the optimized strategy.

Table 4 Performance Comparison Between Traditional and Optimized Inventory Policies

Metric	Traditional Inventory	Optimized Model	Improvement (%)
Device Stock Availability	0.72	0.89	23.6
Deployment Readiness Score	0.68	0.87	27.9
Average Inventory Holding Cost (USD)	32,500	26,800	17.5
Device Deployment Delay (Days)	5.8	2.4	58.6
Stockout Probability	0.21	0.08	61.9
Infrastructure Readiness Index	0.70	0.88	25.7

## V. CONCLUSION AND RECOMMENDATIONS

### ➤ *Conclusion*

This study developed an analytical framework for optimizing network device inventory management in distributed banking infrastructures. The proposed framework integrates device lifecycle tracking with mathematical inventory optimization models to address operational challenges associated with infrastructure deployment across geographically dispersed banking networks. By combining lifecycle monitoring, inventory cost modeling, and deployment readiness analysis, the framework provides a systematic approach for improving infrastructure governance and resource allocation.

The results of the simulation experiments demonstrate that lifecycle aware inventory optimization significantly enhances device availability and infrastructure deployment readiness when compared with traditional inventory management strategies. The optimized procurement model reduces the probability of inventory shortages while maintaining efficient inventory levels, thereby minimizing inventory holding costs and stockout penalties. Furthermore, the deployment readiness model shows that integrating device availability, firmware compliance, and security patch status into a unified readiness metric provides a practical mechanism for assessing infrastructure preparedness across distributed banking systems.

Overall, the findings indicate that optimized inventory policies can improve the operational resilience of banking infrastructures by ensuring that network devices are available when required for infrastructure deployment, upgrades, or emergency replacement. The framework therefore contributes to more efficient management of enterprise network assets while supporting strategic infrastructure expansion and technology modernization initiatives within financial institutions.

### ➤ *Practical Implications*

The proposed inventory optimization framework offers several practical benefits for banking infrastructure management. First, it supports efficient branch network expansion by ensuring that adequate inventories of network devices are available for rapid infrastructure deployment. This capability allows financial institutions to accelerate branch activation schedules and improve service delivery across geographically distributed regions.

Second, the framework improves regulatory infrastructure compliance by integrating lifecycle monitoring with configuration management and inventory tracking systems. Financial institutions can therefore maintain comprehensive records of device lifecycle status, firmware versions, and security compliance levels, which are essential for regulatory audits and infrastructure governance assessments.

Third, the lifecycle-aware readiness model enhances the speed and reliability of cybersecurity patch deployment. By continuously monitoring firmware compliance and patch status across network devices, infrastructure teams can ensure that devices deployed within banking networks meet required security standards before installation.

Finally, the optimization model provides improved procurement planning by aligning procurement decisions with predicted infrastructure demand and procurement lead times. This strategic procurement capability reduces the risk of device shortages while preventing excessive accumulation of unused inventory.

### ➤ *Limitations*

Despite the promising results obtained in this study, several limitations must be acknowledged. The evaluation of the proposed framework was conducted using simulation-based experiments with controlled datasets. Although the simulation environment was designed to represent realistic infrastructure conditions, real-world banking networks may exhibit additional complexities that were not fully captured in the experimental setup.

Another limitation relates to the heterogeneity of banking infrastructures. Financial institutions often operate networks composed of diverse hardware platforms, vendor ecosystems, and legacy infrastructure components. The proposed model may require adaptation when applied to environments that include highly heterogeneous device configurations or multiple vendor supply chains.

In addition, the effectiveness of the framework depends on the availability of accurate lifecycle tracking data. If procurement records, configuration databases, or monitoring systems contain incomplete or outdated information, the accuracy of inventory optimization and deployment readiness calculations may be reduced.

### ➤ *Recommendations for Future Research*

Future research should explore several directions for extending the proposed framework. One promising area involves the use of artificial intelligence-driven predictive demand models to forecast network device demand based on historical infrastructure expansion patterns, device failure rates, and cybersecurity upgrade requirements. Machine learning techniques could improve the accuracy of procurement planning and further reduce inventory shortages.

Another potential research direction is the development of blockchain-based asset lifecycle tracking systems. Blockchain technologies could provide secure, tamper-resistant records of device lifecycle events, including procurement, deployment, maintenance, and retirement, thereby improving asset transparency and regulatory compliance within financial infrastructures.

Researchers should also investigate the integration of inventory optimization models with software-defined networking (SDN) architectures. SDN technologies provide centralized control of network infrastructure and could enable automated coordination between network configuration systems and inventory management platforms.

Finally, future studies may examine the application of reinforcement learning techniques for real-time inventory optimization. Adaptive learning algorithms could continuously adjust procurement policies based on observed demand patterns and infrastructure performance metrics, enabling dynamic optimization of device inventories within rapidly evolving banking network environments.

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