DEVELOPING A SCALABLE IOT SECURITY COMPLIANCE FRAMEWORK FOR STRENGTHENING THE SECURITY POSTURE OF FINTECH MSMES: A QUANTITATIVE APPROACH

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Dedication

This dissertation is dedicated to the pillars of my life—whose sacrifices, love, and unwavering support have shaped the very foundation of this journey.

To my parents, who rose from modest beginnings and endured lifes many struggles so that I could pursue opportunities they never had. Their resilience and selflessness provided me with the education, values, and determination needed to reach the pinnacle of academic and professional success. Though my beloved mother is no longer with us, her blessings continue to guide me each day. I know, with certainty, that she would have been the proudest and happiest to see her son walk this path toward earning a Doctorate in Business Administration.

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ABSTRACT

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This research investigates the security challenges posed by Internet of Things (IoT) technologies within Fintech Micro, Small, and Medium Enterprises (MSMEs) and proposes a scalable compliance framework tailored to their unique needs. As IoT adoption grows in the Fintech sector, these organizations face significant vulnerabilities that threaten their financial stability and operational efficiency, while also navigating complex regulatory environments.

A quantitative study was conducted, collecting data from diverse Fintech professionals across various organizational sizes and sectors. Statistical analyses, including regression and variance tests, identified critical IoT vulnerabilities such as insecure firmware and weak authentication protocols as major risks. The frequency of IoT security incidents was found to have a significant impact on financial losses and operational disruptions. The study also examined the role of security metrics, revealing that proactive measures like risk assessments, real-time monitoring, and automated compliance reporting are strongly associated with improved regulatory adherence and reduced security breaches.

The proposed IoT security compliance framework emphasizes modularity and scalability to accommodate the varying resources and complexities of Fintech MSMEs. Incorporating emerging technologies such as blockchain and fog computing, the framework provides an affordable and adaptable solution to enhance security posture and maintain compliance with standards like GDPR and PCI DSS. Despite challenges related to financial constraints and technical expertise, implementation of the framework resulted in measurable improvements in compliance levels, reduction in audit penalties, and increased stakeholder trust.

Findings highlight the importance of structured, data-driven security practices and the need for external support mechanisms to help resource-limited organizations adopt effective IoT security measures. The research concludes that a scalable, standardized framework is essential for Fintech MSMEs to mitigate IoT-related risks while enabling growth and innovation within a rapidly evolving digital ecosystem. Future work is recommended to explore advanced AI-based threat detection, develop standardized IoT security metrics, and assess the practical implementation of decentralized security solutions for small and medium enterprises.

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INTRODUCTION

1.1 Introduction

Developing a Scalable IoT Security Compliance Framework for Strengthening the Security Posture of Fintech MSMEs addresses a critical and emerging issue in the modern digital environment. The adoption of Internet of Things (IoT) technologies has become a fundamental operational strategy for businesses, including those within the fintech industry. Financial Technology (Fintech) is a rapidly growing sector that encompasses a wide range of innovative solutions aimed at enhancing the efficiency, accessibility, and effectiveness of financial services. MSMEs within the fintech sector can leverage IoT technologies to drive business development and improve service delivery. However, these technological advancements also present significant security challenges, particularly in protecting sensitive financial data and defending against cyberattacks.

The growth of the IoT device market brings various benefits, including enabling real-time data analysis and automating systems that enhance decision-making processes. At the same time, IoT devices introduce multiple security risks due to their extensive vulnerabilities, which attract cybercriminals (Grigaliūnas et al., 2024). As fintech MSMEs increasingly rely on IoT devices, they must implement robust security measures. Security breaches and compliance failures in this environment can lead to severe financial losses, reputational damage, and substantial legal penalties.

This research aims to develop an adaptable IoT security compliance framework specifically designed for fintech MSMEs. The proposed framework addresses the unique security challenges these organizations face by providing a systematic approach to

strengthening their security defenses. This study adopts quantitative methods to evaluate whether the proposed framework achieves its objectives and identifies strategies that enable fintech MSMEs to enhance their security measures while maintaining compliance with regulatory requirements (Niemimaa, 2024). The research is of vital importance as it seeks to offer security solutions that match the rapid growth of IoT technology while addressing the urgent need for enhanced security in fintech MSMEs. The findings of this study will contribute to the development of scalable security frameworks that align with the specific requirements of IoT-dependent fintech MSMEs, thereby building a knowledge base for further research and practical implementation in this field (Anselmi et al., 2023).

1.2 Background of the Study

Security Challenges in IoT Integration

The adoption of Internet of Things (IoT) technologies in fintech Micro, Small, and Medium Enterprises (MSMEs) has significantly impacted the efficiency with which these businesses conduct operations and deliver services. However, it also presents several security challenges that these companies must address. One of the main issues is the vulnerability of IoT devices to cyberattacks. Many IoT devices lack robust built-in security features, making them easy targets for hackers who can exploit these weaknesses to gain unauthorized access to critical financial data (Ngwenya & Ngoepe, 2020). Additionally, the ability to implement advanced security protocols is often limited by the computational power of many IoT devices, which makes them susceptible to malware, data breaches, and denial-of-service attacks (Hussein et al., 2024). Furthermore, IoT networks in fintech MSMEs are dynamic and interconnected, creating a complex attack

surface where each connected device can serve as a potential point of entry for malicious actors (Hussain et al., 2023). Moreover, there is a shortage of standardized security frameworks for IoT in the fintech sector, leaving MSMEs with the challenge of employing a unified approach to securing their IoT devices and networks. At the same time, fintech MSMEs must balance innovation with the need to comply with regulatory requirements such as GDPR and PCI DSS, which increases the risk of noncompliance (Zhang, 2024).

Evolution of IoT Adoption in Fintech

Over the last decade, the integration of IoT technologies in fintech MSMEs has significantly enhanced the customer experience and improved backend operational efficiency. Through the use of IoT devices such as smart payment terminals, biometric authentication systems, and connected sensors, real-time data collection and better decision-making capabilities have become possible, thus boosting operational efficiency. With these advancements, MSMEs can offer their services to a broader range of customers. However, the increasing dependence on IoT technologies introduces several security concerns. One key issue is the rapid growth of IoT devices, which has expanded the number of potential entry points for cyber threats. For instance, IoT-enabled payment systems and digital wallets expose businesses to fraudulent transactions and identity theft. Furthermore, many IoT devices are not designed with adequate security features, making them vulnerable to cyberattacks (Grigaliūnas et al., 2024). As IoT networks become more integrated with fintech services, risks related to data privacy and integrity have escalated, as cybercriminals target vulnerabilities in both the devices and the networks they operate on (Chatterjee et al., 2024). Additionally, maintaining regulatory compliance has become more difficult as the pace of IoT adoption outstrips the development of adequate security standards and policies (Khan et al., 2025).

Existing IoT Security Frameworks

Several frameworks have been developed to address IoT security, particularly in the fintech sector. For example, the cybersecurity framework proposed by Hussain et al. (2023) includes multi-layered security protocols such as end-to-end encryption, AI-based threat detection, and blockchain to secure data sharing. This framework aims to protect sensitive customer data and enhance the robustness of fintech systems. Case studies have demonstrated its effectiveness in minimizing risks, improving data protection, and reducing breach incidents. Additionally, the use of blockchain technology in IoT security has been proven to enhance data integrity and transparency. A proposal by Haj Hussein et al. (2024) suggests a blockchain-based dual identity management and authentication framework for IoT security, which provides a decentralized approach to data exchange between IoT devices. This framework addresses the limitations of centralized authentication systems, particularly in terms of scalability and security. It also improves accountability by tracking device registration, ensuring that only authorized entities can access the IoT network. However, despite these advancements, existing frameworks remain limited in effectiveness. Many proposed solutions are still in the early stages of development or have not been thoroughly tested in real-world applications (Dinde, 2024). Additionally, the complexity of the IoT ecosystem in fintech, coupled with the rapidly evolving threat landscape, makes it challenging to maintain an effective security posture at scale. This complexity, combined with resource constraints, makes it difficult for smaller fintech MSMEs to fully implement these advanced security frameworks.

1.3 Statement of the Problem

Gaps in current IoT security frameworks

However, Internet of Things (IoT) devices are being rapidly adopted across different industries, which also includes fintech, yet the current security compliance frameworks tend to neglect key challenges related to the adoption and usage of such devices by Fintech MSMEs. A major gap is that existing frameworks are not sufficiently scalable for small and medium enterprises (SMEs) which are almost always underfinance. Some of the available frameworks are intended for bigger organizations and these are very complex to implement into small scale environment wherein budget constraints and scarcity of technical expertise impede full compliance (Hussain et al., 2023). Furthermore, as far as existing frameworks are concerned, they provide for high level security measures only; however, the diversity of IoT devices and networks call for more granular, specific, device specific security protocol.

For example, IoT devices in the fintech sector range from simple payment terminals to advanced biometric authentication systems, each with distinct security requirements (Ngwenya & Ngoepe, 2020). Most frameworks nowadays fail to present this information in a detailed and specific way, due to how diverse devices like these are. A key gap is there is no robust framework for risk assessment existing in the context of the IoT environment. Like ISO 27001 and NIST frameworks, while these do set up general security guidelines that apply to the majority of organisations, they don't sufficiently explain the vulnerabilities that are specific to IoT systems, for example, malicious links, sought after access points, and hijacking devices (Zhang, 2024). Given an absence of an IoT specific risk management framework, fintech MSMEs do not have clear strategies for how to identify, assess and mitigate these same risks in real time.

IoT Framework Limitations for Fintech

Generally, existing IoT security frameworks provide a one solution fits all solution which does not even consider the operational constraints and resources of fintech MSMEs. Since these enterprises work with fewer IT resources and possess limited budget available for cybersecurity infrastructure, it is virtually impossible for them to fully implement complex frameworks. For example, large scale framework, which involves sophisticated threat detection systems, extending employee training, and high-end security systems may exceed the financial and operational capabilities of MSMEs (Grigaliūnas et al., 2024). Additionally, the regulatory compliance related challenges that fintech MSMEs often face, were not tackled properly by many frameworks. Larger organizations may have compliance teams as well as the ability to meet requirements of the General Data Protection Regulation (GDPR) or the Payment Card Industry Data Security Standard (PCI DSS) whereas fintech MSMEs are often challenged to meet administrative and monetary constraints of staying compliant. Current IoT security frameworks do not provide a way to simplify, economically, the fulfilment of these regulations, hence IoT security regulation seems unachievable to smaller businesses (Harkácsi & Szegfű, 2021). Additionally, the requirement is not to present an integrated view of both security and compliance requirements. As a result, compliance and security are treated independently in most frameworks and thus inefficiencies and duplications come to the fore. This bifurcation also leads to a gap in fintech MSMEs' capacity to adopt holistic security strategy that includes risk management, security policies and compliance with industry standard (Hussain et al., 2023).

Risks of Inadequate IoT Security

The operative risks of IoT security and lack of an adequate IoT security compliance framework can frustrate valid MSME fintech which could potentially cause

operational and reputational issues for the business. Data breaches are one of the biggest risks of an IoT device as any information that is on the devices, like any other piece of hardware, can be hacked by any unauthorized person. Because these breaches can potentially lead to financial losses, legal consequences and damage to the customer trust, such events create intense damage to a brand, especially a payment gateway. The consequences of such breaches in a highly sensitive sector, such as customer data, are devastating to the business (Zhang, 2024). Offering yet another major risk, is a lack of compliance to regulatory standards, such as GDPR or PCI DSS, and then the fines and penalties that await. Failing to comply with these regulations can impact not only the financial aspects but also the loss of market credibility which is particularly damaging for businesses among businesses in highly competitive industries (Hussain et al., 2023). On top of that, fintech MSMEs lack a cohesive IoT security framework which makes them more vulnerable towards the cyber-attacks. There are lots of attack vectors of IoT devices, especially unsecured ones. Some of these attacks can be as simple as a Denial of Service (DoS) attack to more complex ones like manipulation of data or device hijacking where the attackers are manipulating critical systems stealing financial data (Ngwenya & Ngoepe 2020). Also, fintech MSMEs that do not have proper measures of IoT security are at risk of reputation damage. In this digital age, having consumers very aware of security and privacy risks such as a breach or not protecting sensitive data can result in customers losing trust. In the highly competitive fintech sector, reputation is the most valuable asset that can take toll for a very long time when egged on. Finally, the lack of a strong IoT security framework will cause inefficiencies and operational disorganization. Without a constant watch over emerging threats and vulnerabilities, fintech MSMEs can miss-out-on threats, vulnerabilities, downtime and loss of service, and this can also lead to failing. This business disruption not only impacts the business bottom line, but it also

harms client and customer relationships, who depend on the availability and security of fintech services (Harkácsi & Szegfű, 2021).

1.4 Pros and Cons of IoT in Fintech MSMEs

Benefits and Security Impact

There are several advantages of the Internet of Things (IoT) technology in integrating fintech MSMEs that make operations more efficient, service delivery as well as customer experience better. This is one of the major advantages because it is very useful in terms of improving operational efficiency. IoT devices make it possible to collect, analyze and automate otherwise routine processes with real time data. This will help fintech MSMEs to simplify their operations, lessen manual error and form better decisions (Kusnendi & Hadiyati, 2024). For example, smart payment terminals and biometrics authentication systems could fasten the execution of financial matters, make the consumer experience better as well as reduce operational costs (Putri & Akbary, 2021). Another important advantage is this. The use of IoT based solutions by fintech MSMEs offers them the opportunity to reach unattained populations such as those in remote places without access to traditional banking services (Adaramola et al., 2024). One application area where IoT can be used is in creating mobile banking applications and digital wallets, which facilitate carrying out financial transactions by users thus encouraging financial inclusion. Moreover, the data acquired from IoT devices can also be leveraged to develop custom financial products that meet the immediate needs of the individual customers much better. Furthermore, IoT in fintech also provides better customer services. When IoT devices are used for real time monitoring of transactions and rapid coming up with solutions or tackling customer issues problems, businesses derive greatest advantages. As a result of this, customer support is better and trust is

improved, which is vital for fintech MSMEs in competitive market (Rahmalia et al., 2024). Nevertheless, these benefits involve specific security requirements. The use of IoT devices is growing tremendously leading to multiple vulnerability points to be dealt with carefully. Fintech is such a sector being highly dependent on data privacy and cybersecurity, due to the high sums of sensitivity financial information getting transmitted around devices constantly. IoT Systems with the gathering of enormous information will require fintech MSMEs to work out solid encryption ways of communicating, and Tinder Flip ins security affirmations to shield client information from unapproved access (Kumari, 2021). And the more such connected devices there are, the more complicated securing the IoT network becomes. Cyber-attacks via an IoT device can be each and every one a potential entry point, and fintech MSMEs have to adopt comprehensive security measures to have protection of their distinctive vulnerabilities of IoT units (Harkácsi & Szegfű, 2021).

Later on, fintech MSMEs also find it harder and harder to comply with regulation, as IoT technologies lead to greater volumes and sensitivity of data handled by fintech MSMEs. For IoT to be adopted by businesses, there are various data protection regulations such as the General Data Protection Regulation (GDPR) and the Payment Card Industry Data Security Standard (PCI DSS) that need to be made sure the systems comply with. However, these regulations lay strict obligations on fintech MSMEs to process the customer data collecting, storing and transmitting the customer data in particular ways such that they are bound to invest in compliance infrastructure (Hussain et al., 2023). Finally, we conclude that whereas IoT potential integration in fintech MSMEs is substantial, it comes with potential security problems that need to be handled carefully. These challenges include data security, making sure of implementation of Encryption and Authentication protocol robustly, as in maintaining the regulatory

compliance. However, operational efficiency and financial inclusion that are enabled by IoT are based on MSMEs' capacity to mitigate these risks effectively.

IoT Security Risks and Mitigation

However, adopting Internet of Things (IoT) technologies in fintech MSMEs make financial gain achievable but the security risks it brings along are quite high. The sheer volume of IoT devices on the internet is one of the most pressing risks in cybersecurity due to vulnerabilities. Though these smart payment terminals and other devices are sometimes poorly protected, they can become a way for the cybercriminals to enter. For example, weak authentication mechanism and insecure communication network protocols expose the sensitive customer data to potential theft (Shepherd et al., 2017). With IoT devices an inner part of financial operations, their increased attack surface provides malicious actors with more points for data breaches, fraud, and system manipulation. The second major risk is data privacy concerns. Fintech IoT systems are always collecting and communicating this kind of sensitive data as transactions and personal identification data. These systems are inherently vulnerable to data interception and manipulation and may become a breach of customer privacy and non-compliant to the regulatory requirements like the General Data Protection Regulation (GDPR) if these systems are not secured as expected (Wangyal et al., 2020). Furthermore, many IoT devices are mostly absent powerful encryption and are generally left unpatched, which relates to increased exploitable of attackers (Kane et al., 2020). This is why fintech MSMEs need to adopt a multi layered security approach to mitigate such risks. Encryption protocols that keep data in transit and at rest strong is included, namely customer information is securely transmitted and stored. Additionally, securing devices at the physical level with implementation of advanced authentication techniques like multi-factor authentication

and biometrics is extremely effective for preventing unauthorized finance related data. Security gaps in regular software and firmware are also closed through regular software and firmware updates and exploits against these are minimized. Fintech MSMEs should finally develop comprehensive security monitoring system which can detect the unusual activities and respond to the potential threats immediately (Gaur et al., 2023).

IoT Impact on Cost and Efficiency

The use of IoT technologies in fintech MSMEs results in great improvement in both operational efficiency and cost management. Monitoring of real time data and automation of routine tasks, which takes out decision making and wait time to maintain a routine task. Smart ATMs and biometric authentication systems are also used so as to enhance customer interactions and reduce transaction time for example (Kane et al., 2020). IoT can be used in predictive maintenance for banking equipment so as to ensure that devices are able to be serviced before they fail to minimize downtime whist curbing maintenance costs. From the cost point of view, IoT reduces operational costs by automation of processes, thereby optimizing the resources for fintech MSME (Gaur et al., 2023). Consider IoT enabled cash flow management system which can optimize cash usage and reduce the requirement of manual accounting and hence reduce the labor costs of financial management. Similarly, real time monitoring and adjusting operations helps in getting better resource allocation and reducing wastage in overall process which leads to better efficiency.

While IoT increases operational efficiency it also adds new security costs. For IoT systems, you need to invest hardware and software for the robust security measures. Specifically, the investments include buying of the advance security infrastructure such as firewalls and intrusion detection systems, as well as the ongoing costs involved in the

regular software updates and patching of vulnerabilities (Gaur et al., 2023). Besides this, fintech MSMEs should allocate resources to train employees so that staff can deal and respond to security incidents pertaining to IoT devices. Though a necessary expenditure which MSMEs cannot do without, they constitute a heavy burden on these businesses who work with limited capabilities. Quite a balance is found between the purpose of improving operational efficiency and security costs in the security decisions. The benefits of IoT, such as, cost savings, better service delivery, are easy to see, but how to invest in cybersecurity and compliance framework is often a difficult decision. The cost of implementing security measures for fintech MSMEs IoT networks must be balanced against the inherent risks of not using security, i.e. data breach and regulatory penalty. Thus, risk-based approach can guide companies in selecting the top security requirements and allocate investments with the highest return of investment (ROI) (Wyss et al., 2011). Fintech MSMEs who want IoT implementation to be secure and cost effective must think about adopting risk-based security models which focus on high-risk areas like protecting customer data, compliance with various regulations and so on. This puts them in a state where they can best deal with security costs to the benefit of both operating and operational benefits of IoT technologies.

1.5 Characteristics of Effective IoT Security Compliance Frameworks

Scalable IoT Security Framework

In the context of fintech Micro, Small, and Medium Enterprises (MSMEs), an effective IoT security compliance framework needs to be scalable, adaptable, and capable of addressing the unique challenges posed by both IoT technologies and the financial industry. Several key characteristics define an ideal framework for IoT security compliance in these enterprises.

Scalability and Flexibility: A key characteristic of an effective scheduling system is scalability. The system should be capable of expanding as the fintech MSME grows by incorporating new IoT devices and services. Unlike large corporations, MSMEs typically operate with limited resources within constrained budgets. Therefore, the framework must remain adaptable while avoiding prohibitive cost increases in response to the evolving needs of the business. MSMEs should be able to incrementally scale their security posture through scalable frameworks, rather than starting over each time their business expands in compliance practices (Anselmi et al., 2023).

Integration with Existing Compliance Standards: IoT security compliance frameworks must align with established security standards and regulatory guidelines relevant to the fintech industry, such as the General Data Protection Regulation (GDPR), Payment Card Industry Data Security Standard (PCI DSS), and other national or regional financial regulations. The framework should address IoT-specific vulnerabilities while ensuring businesses comply with legal obligations. By integrating these standards effectively, the framework provides clear guidance for compliance without requiring MSMEs to adopt overly complex or disjointed security solutions (Gaur et al., 2023).

Automated Compliance and Monitoring: Automation is another crucial characteristic. Given the limited resources of most MSMEs, it is essential that compliance checks and security assessments are automated to reduce human effort and minimize the risk of human error. Automated compliance frameworks, particularly those enhanced by machine learning and blockchain technologies, enable continuous monitoring of security postures without requiring significant personnel involvement (Oranekwu et al., 2024). Automation also allows for an immediate response in the event of a security breach, minimizing potential damage.

Device-Specific Security Measures: An IoT security compliance framework should provide guidelines that are tailored to the specific devices used by the fintech MSME, rather than a one-size-fits-all approach. Different IoT devices, such as smart terminals, biometric authentication systems, and digital payment platforms, have unique vulnerabilities that require specific security measures. The framework should include security protocols such as secure authentication methods and data encryption standards to ensure that all devices connected to the network are protected from cyberattacks (Kagita et al., 2021).

Vulnerability Management: The dynamic nature of IoT systems necessitates a robust framework capable of performing real-time risk assessments and managing vulnerabilities. This means that an IoT network scanner must continuously monitor for emerging threats, new vulnerabilities, and potential compliance violations. Fintech MSMEs should be able to conduct real-time risk assessments of security threats, enabling timely responses to prevent data breaches and financial fraud, and recover funds if necessary. This is especially critical for MSMEs without dedicated security teams, as they still need an efficient method to manage risk (Sotoudeh et al., 2020).

Cost-Effectiveness: Cost is a significant consideration for fintech MSMEs when selecting a security framework. A framework that requires substantial resources or expensive security tools may not be suitable for smaller companies. Therefore, an effective IoT security compliance framework must be cost-effective, providing solutions that address most security issues while minimizing financial burden. Cloud-based tools, for example, offer scalability without the need for upfront investment in security infrastructure, making them an ideal solution for MSMEs. Additionally, open-source security solutions provide strong protection at a lower cost (Kagita et al., 2021).

User Education and Training: No security framework can be effective without proper user education and training. Staff in fintech MSMEs may lack advanced cybersecurity knowledge, so it is essential to include regularly scheduled employee training programs within the security compliance framework. All personnel involved with managing IoT devices should be familiar with security protocols, understand potential threats, and know how to respond in the event of a security breach. Furthermore, continuous learning opportunities are necessary to keep staff up to date with evolving threats and regulatory changes (Wangyal et al., 2020).

Summary: Therefore, the IoT security compliance framework for fintech MSMEs should be scalable, cost-effective, and responsive to the security and specific needs of the financial sector. The framework must integrate established compliance standards, support automation and monitoring, and provide device-specific security guidelines. Additionally, it should be flexible enough to adapt to changing conditions within the IoT network and offer tools for real-time risk management and vulnerability assessment. By incorporating these characteristics, fintech MSMEs can ensure that their IoT systems are secure, compliant, and capable of scaling with their business.

Flexible Compliance Framework Design

To ensure effective Internet of Things (IoT) security compliance framework for fintech Micro, Small, and Medium Enterprises (MSMEs), a flexible and adaptive working should be embedded in it. In the case of these enterprises, their business is moving quickly, and these enterprises often live in a dynamic market where technology is advancing rapidly and therefore their security frameworks need to be able to change in conjunction with their business operations. A way to achieve flexibility is that the framework is modular, and its design allows adding or removing different security layers

or components as they are needed. By keeping the IoT security modular, it allows MSMEs to scale without having to red empath their security infrastructure (Anselmi et al., 2023). For example, fintech MSMEs could deploy only a few IoT devices into the beginning, for example, such as payment terminals or smart sensors. In the event that the business will keep growing, the devices or services, for example, biometric authentication systems or more refined data analytics instruments, may be united. This would enable the ease of introducing new components of the IoT without compromising on the secure communication between the network and the new components of the IoT. Cloud based security solutions also provide the ability for flexibility by implementing security measures on cloud servers which are a cost-effective way to implement security intuitively and without requiring large up-front investments to build up the physical infrastructure (Kane et al., 2020).

Moreover, automated compliance monitoring in the framework it enhances the adaptability of the framework to changing regulatory requirements. Most fintech MSMEs tend to operate in highly regulated environment with lots of updates in standards such as GDPR and PCI DSS. An IoT security framework that is adaptable should include automation tools that check the status of security of IoT devices and check that the devices meet these ever-changing regulations. It automates this compliance check and frees the businesses of the manual need to check, and the responsibilities to be quick in responding to any changes in the regulatory landscape (Gaur et al., 2023). The important thing about flexibility is to be integrated with the emerging technologies. In this regard, a capable IoT security framework should be able to adapt to new technologies like artificial intelligence (AI), blockchain and machine learning that emerge as part of fintech to make it more secure. For instance, machine learning algorithms can detect strange behavior in the IoT networks, thus getting the real time alerts about the security threats and prompt

responses. Like that, blockchain can be used to safeguard financial transactions done between the IoT devices to make sure the information is reliable and protected from unauthorized operations (Kumari, 2021). In the last, the framework should have been cost sensitive, as MSMEs have budget constraints. Notwithstanding many security solutions that are effective in preventing odors from leaking out onto the property, implementation is costly and complex. An IoT security framework should be flexible and allow the MSMEs to opt for the protection which fits their financial resources and their operational needs. As the business expands and extra resources develop, the framework can be evolved to incorporate increasingly propelled security thoughts without stopping past exercises (Hussain et al., 2023).

Continuous Monitoring and Risk Management

The continued monitoring of security and risk responsibility of the fintech MSME is of critical importance and should be addressed as part of an IoT security compliance framework that is continuously maintained. As IoT devices and their corresponding cyber threats are constantly evolving, securing this environment requires that security measures are also on the same path, updated and effective to ensure a secure but also a compliant environment. For achieving that continuing security and risk management, there are numerous elements. In addition to this, if real time threat detection is not utilized in security monitoring it is doomed to failure. Due to the interaction of IoT devices with other devices and the fact that so many IoT devices are transmitting data, its exposed to numerous vulnerabilities at multiple points. To have a continuous monitoring system that spot the suspicious activity or potential breach of intrusion when it happens. Using artificial intelligence (AI) based threat detection systems will greatly increase the ability to detect the threat early. They already learn about patterns in network traffic and

users behavior and use it to detect anomalies which could be a sign of a security breach. The fintech MSMEs can also take the help of AI systems to prioritize the threats as per their severity and focus on the most critical risk at the very first. That is just one more element, data encryption in accounts. Furthermore, in the case of IoT devices in fintech, handling sensitive financial data means that the data must be encrypted both in transit as well as at rest. This means that in the event of a breach, the data stays unclean and cannot be read nor used by the attackers. Finest is the protection of monetary transactions throughout an IoT system through end-to-end encryption. Since the rise of data privacy laws like GDPR, fintech MSMEs are facing the necessity to escalate encryption to maintain compliance and trust with the customers.

There are also effective incident response protocols. Despite the most technologically advanced system in monitoring, it is possible for security breaches or threats to occur. For this reason, it is important that an IoT security compliance framework has clearly defined and preconfigured incident response plans. These are the plans on what to do if a security breach happens, what to do as soon as the incident happens, what to do to limit the effects, and what to do when viewing the results. A well-documented incident response protocol means if there is an incident, the business can respond fast and minimize the damage (Gaur et al., 2023). Moreover, regularly tested and updated are incident response protocols to what new threats and vulnerabilities appear. Continuous security involves risk assessment and management. IoT security risks have changing nature: the more devices are added to the network, or as threats evolve, the nature of the same risks will change. It then follows that fintech MSMEs should regularly assess the risks to determine if any new threats have emerged, or if their existing security measures are effective enough. This should also involve vulnerability scanning, penetration testing and analysis of device vulnerabilities. By implementing a risk-based

security approach, the businesses can allocate their resources to managing the critical security risks than addressing all potential risks (Oranekwu et al., 2024). Another important part in ongoing security monitoring is compliance automation. Because fintech MSMEs operate in a complex and often changing regulatory environment, tracking compliance is another area in which automation would greatly help to keep them up to speed with the state of the industry, such as PCI DSS or GDPR. Continuous monitoring of IoT devices' security status and notifying on any issues will be facilitated by automated compliance tools. This allows businesses to quickly close the style gap on compliance and prevent fines or damage to the business itself. And last but not least at all, effective IoT security is based equally on employee training and awareness. One of the weakest links of the security chain is the employees, because the human error or unawareness can make the security breaches. It is essential to continuously train on the newest security protocols, phishing scams and what techniques to use to handle IoT devices so that everyone plays their role in this ensuring a secure environment. Aiding awareness programs and regular security drills are a way to reinforce security across the organization (Sotoudeh et al., 2020).

1.6 Limitations and Challenges of Existing IoT Security Frameworks

Limitations of IoT Security Frameworks

Existing IoT security frameworks cannot be effectively applied to the fintech Micro, Small, and Medium Enterprises (MSMEs) sector due to several limitations that hinder their scalability and effectiveness. A primary limitation is the lack of scalability. Most IoT security frameworks are designed for large enterprises and require substantial resources, both in terms of infrastructure and personnel, to implement effectively in large

and complex systems. In contrast, fintech MSMEs operate on a smaller scale with limited resources, which makes customization of these frameworks challenging (Hussain, 2023). Furthermore, these frameworks are often too complex or too costly for smaller organizations with limited technical expertise and financial capacity.

Another limitation is the failure of most existing IoT security frameworks to address the specific needs of fintech MSMEs. Many of these frameworks do not account for the unique regulatory and compliance requirements of fintech companies. Regulations such as the Payment Card Industry Data Security Standard (PCI DSS) and the General Data Protection Regulation (GDPR) set clear guidelines for handling financial data. However, most of the current frameworks do not include built-in compliance checks for these regulations, necessitating the adoption of additional costly tools and systems for fintech MSMEs to meet their legal obligations. Furthermore, general IoT security frameworks often fail to address the specific vulnerabilities of fintech systems, particularly in transaction data processing, which requires more comprehensive and specialized protection.

A third limitation is the lack of real-time security monitoring and incident response. While large organizations often have Security Operations Centers (SOCs) to monitor IoT networks for threats, fintech MSMEs typically lack the infrastructure and personnel to provide continuous monitoring. As a result, MSMEs often focus on more static security measures rather than dynamic, real-time monitoring that can respond to evolving cyber threats such as Distributed Denial of Service (DDoS) attacks or advanced persistent threats (APTs). This lack of timely response to security breaches leaves MSMEs vulnerable to extended exposure to cyber threats (Grigaliūnas et al., 2024).

Scalability and Cost Challenges

The two primary barriers to the adoption of IoT security frameworks by fintech MSMEs are scalability and cost. The lack of scalability stems from the fact that most IoT security solutions are not designed with MSMEs in mind. Many of these solutions require significant infrastructure, tools, and personnel resources that are not feasible for smaller organizations to obtain. Additionally, the upfront cost of implementing a large-scale IoT security framework—whether in terms of hardware or software—is prohibitively high for fintech MSMEs that operate on limited budgets and with small, agile workforces (Kane et al., 2020).

Given that most fintech MSMEs are just beginning to incorporate IoT into their operations, the cost factor is particularly relevant. These businesses often prioritize rapid service delivery and customer acquisition over investments in security infrastructure. As a result, security measures can become a secondary priority. Existing frameworks are expensive both in terms of initial capital investment and recurring annual costs such as compliance audits, software updates, and the employment of security personnel. This makes it difficult for MSMEs to meet stringent compliance regulations (e.g., PCI DSS), leaving them exposed to vulnerabilities and non-compliance (Harkácsi & Szegfű, 2021). Furthermore, scalability and cost challenges are exacerbated by the lack of flexible pricing models in many of the current IoT security frameworks. The tiered structures that these frameworks offer are often not suitable for MSMEs, making it difficult for smaller firms to strike a balance between security and affordability.

Compliance with Global IoT Standards

Fintech MSMEs face several challenges in ensuring their IoT systems comply with global security standards. In an increasingly fast-paced regulatory environment, particularly in the fintech sector, companies must navigate a complex array of national and international standards, including the GDPR in Europe and the PCI DSS. However,

many IoT security frameworks fail to provide sufficient guidance or tools to help fintech MSMEs comply with these standards, which could expose them to significant legal risks, fines, or reputational damage (Kane et al., 2020).

The complexity of compliance becomes even more pronounced when operating in multiple jurisdictions. For instance, the GDPR imposes strict requirements on data handling, whereas countries in Asia, the Americas, and Africa have their own data protection laws. Fintech MSMEs find it challenging to navigate this maze of regulations without the right security compliance framework that meets their specific needs. Moreover, regulatory compliance is not static; it evolves in response to new risks in the IoT and fintech sectors. Many MSMEs lack a real-time compliance management tool, which makes it difficult to adapt their security protocols as regulations change. Automation of compliance monitoring could address this challenge by continuously tracking compliance status and automatically adjusting security practices to maintain compliance with changing rules, reducing the need for constant manual intervention (Gaur et al., 2023).

Fintech MSMEs should invest in integrated security compliance platforms that consolidate security and compliance requirements into one system. These platforms should be scalable and flexible enough to meet the specific needs of MSMEs. For example, cloud-based compliance solutions can reduce the infrastructure burden on smaller businesses while ensuring compliance with global standards, thereby helping MSMEs maintain secure IoT systems while keeping costs manageable. Additionally, MSMEs may consider forming partnerships with compliance experts or engaging with industry bodies specializing in IoT security to mitigate the challenges of regulatory compliance.

1.7 Research Problem

This dissertation addresses the main research problem of developing the scalable IoT security compliance framework for Fintech Micro, Small, and Medium Enterprises (MSMEs). More and more fintech MSMEs, which harness IoT, face unusual problems during securing their operations and protecting sensitive financial data. IoT systems suffer from these challenges due to their dynamic nature and interconnection and are susceptible to many vulnerabilities that allow a variety of cyberattacks. Likewise, fintech MSMEs must face the maze of regulations, notably GDPR and PCI DSS and any of similar standards in the financial sector. Despite this, the existing IoT security frameworks rarely cater to the peculiar needs of these small organizations laced with low budgets, small personnel, and constrained resources. This means that fintech MSMEs find it hard to put in place secure measures to protect their data as well as observe regulatory requirements. Filling this, this research aims to address the gap by developing a scalable and versatile security compliance framework appropriate for a particular fintech MSMEs. The framework facilitates IoT systems security prerequisites and at the same time equipped to fit in places of enterprises, where practical limitations and cost-effectiveness of these enterprises must be considered in the framework. The difficulty is not only in developing a framework to deal with the breadth of the current IoT security risks, but to create flexibility with it to accommodate changes in technology and regulations in the future. Scalability of the framework is essential as fintech MSMEs require a solution that will grow with them including adding new devices and enhancing security measures because its operations are growing. The goal of this research is to supply a pragmatic substitute which fulfils the distinctive security and compliance needs of fintech MSMEs at minimal priced and controllable.

1.8 Purpose of the Research

From an overall perspective, this research attempts to improve the security place of fintech Micro, Small and Medium Enterprises (MSMEs) by defining a working, scalable IoT security compliance framework. The trend of the adoption of Internet of Things (IoT) technologies for efficiency and better service delivery by fintech MSMEs is creating more security challenges to the protection of sensitive financial data and compliance with elaborate regulatory standards. In pursuit of this, this research develops a context specific framework to help fintech MSMEs incorporate IoT solutions securely while controlling the associated risks inherent to such technologies. With this proposed framework, we shall be providing a structured and scalable way to address securing the IoT systems in the appropriate fintech environments so that financial firms can enhance their systems without requiring them to hitch the resources and costs. And it will support that flexibility required to facilitate ever changing nature of fintech MSMEs so they can build with security and scale with security as they grow. Furthermore, this framework will assist these enterprises to comply with the industry regulation like, the GDPR and PCI DSS by embedding compliance requirements right in the security protocol. Through the development of this research framework, it is keenly observed that the model developed will largely benefit in the field of IoT security and especially to field of fintech MSMEs that are often left out in broader IoT security studies. It will fill the gap between the theoretical security frameworks and practical cost-effective solutions that are available for smaller businesses. In addition, it will research for a solution that enables fintech MSMEs to deploy strong security without prohibitive costs or complexity, thereby making IoT security available to a larger group of businesses within the fintech ecosystem.

1.9 Significance of the Study

This study is important because it is an attempt to bridge the critical gap between the IoT security landscape for fintech Micro, Small, and Medium Enterprises (MSMEs). With the prevalence of IoT technologies in fintech processes, MSMEs are at greater risk of cybersecurity attacks such as data breach, noncompliance with regulatory standards, and cyber-attacks. However, most of the existing IoT security frameworks are not appropriate for a small organization due to the small budget and because they are targeted at the large companies. This research is important since it looks into a realizable and scalable IoT security compliance framework for fintech MSME use cases, generated from problems that are specific to fintech MSMEs, and requiring adherence to security policies conducted at the outset during design. The goal of this study is to create this framework to address cost effectively securing the fintech MSMEs IoT system and maintain compliance to the required regulations, which are General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS). This proposed framework will enable these enterprises to secure sensitive customer data, mitigate security risks and build trust with their clients for which they have to grow and remain successful. It also has important relevance to policy makers and industry regulators and can help inform the creating of better inclusive and accessible security compliance standards for small businesses operating in fast growth fintech and IoT environments. This work will also provide within the scope of the IoT security area in the context of fintech. By narrowing down to the needs of MSMEs, it will provide some insights into how IoT security frameworks can be developed to meet the security requirements of strong security without breaking the bank on smaller organizations. This can help in advancing the understanding of the scalable security solution, which is effective as well as adaptable, which can be a model for future research and application in other industry, other than fintech. In summary, the contribution of this study is in potentially offering the

valuable actionable, data-based solution for improving the fintech MSMEs' security and compliance to enable safe adoption and integration of IoT technologies. Through this, it will enable innovation, secure growth and aid these businesses to be as they continue to be — sustainable in a more digital and networked world.

1.10 Research Questions

1. What are the most prevalent IoT vulnerabilities in Fintech MSMEs, and how do they impact their operational efficiency and financial stability?

2. What specific security metrics can be developed to measure IoT compliance in Fintech MSMEs, and how can their validity be quantitatively assessed?

3. How does the proposed IoT security compliance framework perform when implemented across Fintech MSMEs of varying sizes and operational complexities?

4. What measurable improvements in regulatory compliance can be observed in Fintech MSMEs after implementing the proposed IoT security framework?

CHAPTER II:
REVIEW OF LITERATURE

2.1 Introduction

Micro, Small, and Medium Enterprises (MSMEs) continue to witness explosive changes in their operations due to the rapid integration of Internet of Things (IoT) technology in the fintech space. Though these technologies present great potential for improving efficiency, including financial and service delivery, they also pose a myriad of security challenges. As fintech MSMEs increasingly rely on IoT devices, they become more vulnerable to data breaches, unauthorized access, and compliance failures. This has made it a top priority to ensure guaranteed security measures and adhere to regulatory standards such as the General Data Protection Regulation (GDPR) and the Payment Card Industry Data Security Standard (PCI DSS) (Hussain et al., 2023). This literature review synthesizes the main research on IoT security in the fintech MSME sector, focusing on security challenges, frameworks, and solutions discussed to solve these problems.

Previous studies have pointed out the vulnerabilities in IoT devices, as they are often not equipped with sufficient security measures, have little or no computational capabilities, and face the complexity of securing interconnected networks (Ngwenya & Ngoepe, 2020). For instance, Hussain et al. (2023) proposed a framework that integrates AI-powered threat detection and multi-layer security protocols. Their methodology combined advanced technologies like blockchain for transparent data handling. The findings suggested that while this framework could significantly enhance security, it is not feasible for fintech MSMEs due to its complexity and high costs, which makes it unsuitable for organizations with constrained resources. The key strength of this

framework lies in its innovative use of cutting-edge technologies, but its limitations include high implementation costs and resource demands, which are often prohibitive for smaller businesses.

In addition, the review discusses current IoT security frameworks, which are numerous but generally designed for large enterprises. These frameworks often fail to meet the specific needs of MSMEs due to their lack of scalability and flexibility (Hussain et al., 2023). Grigaliūnas et al. (2024) examined a similar framework focused on the vulnerability of IoT devices to cyberattacks and the absence of standardized security protocols. Their methodology included a broad analysis of IoT security weaknesses in large systems, and they found that these frameworks are often ineffective for MSMEs due to their complexity and high costs. While their findings emphasize the need for more adaptable solutions, the framework's strength lies in its comprehensive understanding of IoT security challenges, yet its limitations stem from the high level of expertise and infrastructure required to implement it in smaller organizations.

Moreover, the literature indicates that regulatory compliance remains one of the most significant challenges. Frameworks like Hussain et al. (2023), which focus on multi-layered security protocols and blockchain, also emphasize the need for compliance with regulations like GDPR and PCI DSS. However, these frameworks are not designed with MSMEs in mind and require substantial infrastructure investment. Despite their benefits, these frameworks often place too high a burden on MSMEs

Increasing research shows the urgent need for a scalable and flexible IoT security compliance framework tailored to fintech MSMEs. The existing literature reveals that while several frameworks have been proposed, they largely fail to address the diverse needs of fintech MSMEs. This paper critically examines how current frameworks do not satisfy these needs and offers a full analysis of existing gaps in the literature. Given the

high costs of security and compliance, the focus of this review will be on how a specialized, cost-effective, and flexible solution can provide security and compliance at scale, while enabling organizations to grow. This review offers insight from a critical examination of the available literature on how IoT security can be integrated into the operational framework of fintech MSMEs, ensuring these enterprises can better address the risks involved with the adoption of IoT technologies. Furthermore, this review will lay the groundwork for the proposed scalable IoT security compliance framework, which aims to fill the existing gaps in security and compliance management for fintech MSMEs.

2.2 Theoretical Framework

Two of the most apt theories in terms of application while working on a compliant IoT security framework for fintech Micro Small and Medium Enterprises (MSMEs) are Technology Acceptance Theory (TAM) and Risk Management Theory. These theories offer invaluable appraisal points to grasp better how IoT security frameworks can be properly crafted, accepted and utilized in the fintech MSME sector.

Technology Acceptance Model (TAM)

One of the most used frameworks to explain and predict the uptake of new technologies by users is the Technology Acceptance Model (TAM) by Davis (1989). Based on this model it is postulated that two major factors: perceived ease of use and perceived usefulness are correlated with the adoption of any technology. TAM in the context of IoT security frameworks for fintech MSMEs is vital in understanding what mechanisms the key stakeholders (for instance, business owners and IT managers) would adopt in the adoption of IoT security technologies and practices. However, the complexity, cost, and lack of perceived immediate benefit due to a perceived need for

complexity and cost mean that when it comes to fintech MSMEs adopting IoT security frameworks are often held up. Thus, TAM can justify some fintech MSMEs hesitation to adopt the IoT security solutions. It further argues that if the IoT security frameworks are designed to be user friendly and have the benefit of being demonstrably good for the user, such as they lead to compliance to regulatory or risk mitigation, adoption will probably increase. In addition, TAM can support the design of security systems suitable to peoples perception of ease of use and thus confirm that security systems are likely to be used even for companies whose technical background is limited. In this research, the reduction of barriers for the adoption of an IoT security compliance framework is concentrated on to fintech MSMEs through the application of TAM. This implies that the framework should be easy to implement and maintain and the benefits of it, especially concerning compliance with financial regulations and protection against cyber threats should be so widely known that the people who benefit from the framework are spared from the frictional effect.

Risk Management Theory

In understanding the detailing of how businesses generally especially those from high-risk sectors like fintech could assess, mitigate and manage the risks involved in adopting of IoT technologies Risk Management Theory is very essential. The adoption of IoT devices in the context of fintech MSMEs poses various security and operational risks that come with data breaches, regulatory noncompliance, and system vulnerabilities. According to the Risk Management Theory, this theory does focus on identifying, assessing and mitigating these risks and incorporating in a structured form to minimize our exposure to cyber threats and security failures. It suggests the need to base decisions in the development and development of IoT security frameworks on risk. It promotes a systematic risk assessment process which fintech MSMEs can carry out to assess the

security risks with IoT devices, their exposure from these risks to their operations, damage that events of any severity will bring to them and the probability of security breach. Based on these principles, such a framework will be built on these principles, with strategies such as continuous monitoring, risk assessment, and vulnerability management to have a proactive security stance. Cost-benefit analysis of the risk mitigation strategies is considered to be one of the core components of Risk Management Theory. Security measures for fintech MSMEs who face resource constraints are of utmost importance and should be in order of prioritizing those that offer the highest level of protection for every dollar spent. This theory further justifies the designing of an IoT security compliance framework for scalability within the financial constraints of smaller organizations that is both effective in managing risks.

This dissertation will apply Risk Management Theory and balance the security needs of IoT system to fintech MSMEs limited resources, to have a practical and sustainable framework adopted. At the end, the Technology Adoption Model (TAM) and the Risk Management Theory are critical for understanding the motivation of fintech MSMEs to adopt and deploy IoT security framework.

Risk Management Theory is used to create a framework whose creation is feasible with regards to smaller organizations and that manages security risks and compliance challenges in an effective manner, placing Risk Management Theory and TAM as a lens through which to design user friendly, accessible frameworks. The research methodology and framework development will be based on these theories as the basis to ensure that the final solution is practical and useful for the target sector.

2.3 Security Challenges in Fintech MSMEs

Critical IoT Vulnerabilities in Fintech

Micro, Small, and Medium Enterprises (MSMEs) financed by fintech devices have many cybersecurity vulnerabilities that arise from integrating IoT devices into fintech. These vulnerabilities are often associated with the inherent interconnectivity of IoT devices, making them potential entry points for cybercriminals looking to exploit weaknesses in these networks. One of the most critical vulnerabilities is insecure communication channels. Many IoT devices, especially in fintech, transmit sensitive data through the internet. If the data is not properly encrypted or protected, it can be intercepted and stolen (Sodiya et al., 2024). For example, in fintech MSMEs, smart payment terminals and digital wallets—devices frequently used—often lack end-to-end encryption and other advanced security features, making them prime targets for attackers (Kaur et al., 2021).

Sodiya et al. (2024), in their study, examined how vulnerable IoT devices can be exploited due to the lack of proper encryption and outdated security measures. Their methodology included testing IoT devices used in fintech MSMEs for vulnerabilities in communication channels. The findings confirmed that these devices are often targeted by cybercriminals due to their insufficient protection. Their framework's strength lies in emphasizing the importance of basic encryption, but a key limitation is that it does not address the larger structural and compliance issues that MSMEs face when trying to implement such measures.

Another vulnerability involves the lack of proper device handling and software updates. Generally, IoT devices are deployed in less rigorously monitored systems than traditional IT systems. Fintech MSMEs often use devices that may not have the processing power to enable strong security protocols or the ability to update software regularly. As a result, cybercriminals can exploit outdated security patches (Hussain et al., 2023). Hussain et al. (2023) addressed these concerns by proposing a security

framework for MSMEs to handle IoT devices more effectively. Their study used a real-world analysis of security vulnerabilities across fintech MSMEs. The strength of this framework lies in its focus on ensuring devices are continuously updated and monitored, but its limitation is that it is heavily reliant on resources—resources which MSMEs typically do not have.

Furthermore, IoT devices usually have default passwords and weak authentication mechanisms, which are common in smaller businesses where IT resources are scarce. These weaknesses allow attackers to gain unauthorized access to sensitive financial systems and customer data (Rahayu et al., 2023). Rahayu et al. (2023) explored these weaknesses and provided a framework focusing on improving authentication mechanisms. Their methodology involved reviewing multiple case studies of MSMEs that suffered data breaches due to weak security measures. While their framework strengthens authentication protocols, it is not fully applicable to all IoT devices, particularly those that require specialized configurations not suitable for MSMEs.

The potential impact on operational security due to these vulnerabilities is severe. Financial fraud, for instance, can occur when attackers breach the IoT security supply chain and alter transactions or steal funds from client accounts (Hussain et al., 2023). The loss of reputation could also significantly damage the standing of an MSME in the highly competitive fintech industry, where customer trust is paramount. Breaches of customer financial data can lead to substantial monetary losses and legal liabilities, especially for businesses lacking compliance with regulations like GDPR and PCI DSS.

IoT Device Security Challenges for Fintech

The unique characteristics of IoT devices—particularly their limited computational power and connectivity—present distinct security challenges for fintech MSMEs. While IoT devices are cost-effective and energy-efficient, these advantages

come with significant security limitations. For instance, many IoT devices in fintech, such as fingerprint scanners, are simple and have limited processing power, making them incapable of running advanced security protocols like encryption and real-time threat detection systems (Sodiya et al., 2024). In their study, Sodiya et al. (2024) highlighted how these limitations impact the security posture of fintech MSMEs. Their framework emphasizes implementing cost-effective, simple security measures, but fails to address the issue that these devices often cannot handle more advanced security features, making them prone to more sophisticated cyberattacks.

The reliance of IoT devices on continuous internet connectivity also exposes them to additional cyberattacks targeting weak network defenses. If one IoT device is compromised, it can serve as a gateway to others within the same network, providing cybercriminals with more attack surfaces to infiltrate the system and access sensitive financial data (Kaur et al., 2021). Kaur et al. (2021) explored this issue by focusing on the interconnectivity of IoT devices and the vulnerabilities that arise from poor network security. Their findings highlighted the need for advanced monitoring systems in fintech MSMEs, but their approach faced criticism for being too resource-heavy and not practical for smaller businesses.

Moreover, limited computational power prevents most IoT devices in fintech from performing real-time monitoring or reacting to threats rapidly. Without these capabilities, businesses may miss or fail to respond effectively to security breaches, potentially incurring large financial losses or operational downtime. Hussain et al. (2023) investigated these vulnerabilities in-depth and proposed a solution that incorporates real-time monitoring and threat detection. However, their framework requires robust IT infrastructure, which is often unavailable to fintech MSMEs, making it difficult to implement in smaller firms.

Regulatory Impact on IoT Security Compliance

In fintech services, regulatory compliance requirements like the GDPR and PCI DSS are critical for ensuring data protection and maintaining customer trust. However, compliance with these regulations can increase the security challenges for fintech MSMEs when incorporating IoT technologies, mainly due to the complexity and cost of compliance. Both GDPR and PCI DSS require data encryption, secure authentication, and continuous monitoring of transmitted data, which are difficult to implement across an IoT ecosystem, especially for businesses with limited IT resources (Hussain et al., 2023).

Hussain et al. (2023) also examined the challenges MSMEs face in meeting these compliance requirements, focusing on the integration of IoT security with regulatory standards. They found that compliance could be prohibitively expensive for fintech MSMEs due to the need for advanced cybersecurity technologies and specialized personnel. The strength of their framework is its thorough approach to compliance integration, but it fails to consider the financial and technical limitations of MSMEs.

Furthermore, as IoT systems evolve and new devices are added to the network, it becomes increasingly difficult to maintain compliance with GDPR and PCI DSS. Rahayu et al. (2023) emphasized this issue in their study, noting that the dynamic nature of IoT systems makes it a moving target for compliance. They found that regular updates and ongoing monitoring were necessary to ensure continued compliance. However, this requires constant attention, which poses significant operational inefficiencies for fintech MSMEs with limited resources.

The compliance challenges are exacerbated by the financial and reputational risks associated with noncompliance. A failure to comply with regulations like GDPR or PCI DSS can result in hefty fines and significant damage to a fintech MSME’s reputation. For instance, under GDPR, fines can be as high as 4% of annual global turnover or €20

million, whichever is higher (Kaur et al., 2021). Kaur et al. (2021) analyzed this risk in their study, finding that many MSMEs struggle to balance security with compliance due to limited resources.

Conclusion

In conclusion, integrating IoT devices in fintech MSMEs introduces significant security vulnerabilities, including weak device security, inadequate data encryption, and an increased attack surface as more devices are interconnected. These vulnerabilities are magnified by the limited computational power of many IoT devices, which makes it difficult to incorporate sophisticated security measures. Additionally, the complex regulatory demands of GDPR and PCI DSS further complicate the situation, as MSMEs must navigate strict data protection measures while managing resource constraints. It is evident that specialized, cost-effective solutions are needed to balance necessary cybersecurity and the operational constraints of fintech MSMEs.

2.4 Existing IoT Security Frameworks

Effectiveness of IoT Security Frameworks

While existing IoT security frameworks do a great job in addressing security aspects for the entire IoT landscape, they must be reworked to suit the particular demands and financial constraints of fintech Micro, Small, and Medium Enterprises (MSMEs). Current security solutions tend to be complex and cost-intensive. For example, frameworks such as those based on ISO 27001 and NIST (Gai et al., 2016) are not tailored for fintech MSMEs. Gai et al. (2016) examined the application of these frameworks in large organizations and concluded that they are too resource-heavy and complex for smaller fintech businesses. Their methodology involved assessing the

application of ISO 27001 and NIST in large-scale enterprises, and they found that while these frameworks provided robust security, their application was impractical for MSMEs due to high costs and the need for extensive infrastructure. The strength of these frameworks lies in their comprehensive approach to security, but their limitations include a lack of scalability and adaptability for smaller organizations with limited resources.

Many of the existing frameworks fail to scale and adapt to the evolving security requirements of smaller fintech businesses. As fintech MSMEs grow, their security needs change, and the current frameworks often cannot keep up (Reddy et al., 2023). Reddy et al. (2023) analyzed several frameworks and found that they are often designed for larger enterprises with extensive resources. Their methodology included a comparison of several security frameworks in different business environments. The findings showed that while the frameworks could address high-level security issues, they failed to meet the dynamic, changing needs of MSMEs. A key strength of their work was in highlighting the scalability issues, but their framework did not provide clear solutions for adapting these frameworks for smaller, resource-constrained organizations.

For instance, frameworks intended for large-scale businesses often include superfluous security layers that are difficult to justify in terms of expense and resource allocation for smaller organizations. Bojjagani et al. (2023) pointed out that many IoT security frameworks, including traditional models like firewalls, fail to address the specific needs of fintech MSMEs, particularly when it comes to IoT devices such as payment terminals, biometric authentication systems, and digital wallets. Their study examined how these devices are often left vulnerable because generic security protocols do not account for the unique risks associated with these devices. The strength of their research lies in its focus on device-level security, but it is limited by its reliance on

traditional security methods, which may not be effective in protecting modern IoT systems.

Limitations of IoT Security for Fintech

Current IoT security frameworks have several limitations when it comes to scalability and adaptability for smaller organizations like fintech MSMEs. One significant issue is that most existing frameworks are designed for large corporations, where the hardware and financial resources needed for deployment are less of a concern. Hussain et al. (2023) explored the scalability of these frameworks and found that they require substantial infrastructure, skilled personnel, and maintenance—resources that MSMEs typically do not have. Their methodology involved analyzing the deployment of NIST's Cybersecurity Framework and ISO 27001 in different organizational contexts. They concluded that while these frameworks provide comprehensive security, the complexity and resource requirements make them impractical for MSMEs. The strength of their work lies in the identification of scalability issues, but their frameworks' limitation is the lack of a practical solution for smaller firms with limited budgets.

Furthermore, current frameworks lack flexibility. Due to the diversity of IoT devices used in fintech applications, most IoT security frameworks are based on standard protocols and security models, which are not flexible enough to accommodate devices with different requirements and use cases. Bojjagani et al. (2023) further noted that devices like point-of-sale (POS) systems and digital wallets require specialized security features such as encryption, secure authentication, and real-time monitoring. However, many frameworks fail to provide detailed security protocols for these specific devices. Their study involved evaluating how well existing frameworks addressed these specific device-level security needs, and they found that most frameworks offered general solutions but lacked customization for IoT devices in fintech. The strength of their

research lies in the focus on device-level vulnerabilities, but the limitation is that it leaves fintech MSMEs with either complicated general frameworks or the need to develop customized solutions, which are often infeasible.

Real-time threat detection and monitoring are also crucial components of any IoT security framework, especially in fintech, where security breaches can lead to significant financial losses. Fintech MSMEs often lack dedicated security teams but still need to monitor and manage risks continuously, which is often overlooked by current frameworks. Vairagade et al. (2025) emphasized the dynamic nature of the IoT environment and the difficulty existing frameworks face in keeping pace with the growth and evolving needs of fintech MSMEs. Their methodology involved evaluating the adaptability of IoT security frameworks in rapidly changing environments. The findings indicated that current frameworks struggle to accommodate the expanding security requirements of growing fintech businesses. The strength of their study lies in highlighting the evolving nature of security needs, but their framework's limitation is its failure to provide a flexible, scalable solution for smaller organizations.

Improvement of IoT Security Frameworks

Existing IoT security frameworks must be adapted to fit the unique legal and operational challenges faced by fintech MSMEs. One primary improvement suggested by Gai et al. (2016) is the integration of data collection related to regulatory compliance into the security framework. Gai et al. (2016) discussed how existing frameworks fail to provide real-time compliance checks, which are essential for fintech MSMEs to adhere to stringent regulations like GDPR and PCI DSS. Their framework suggested incorporating automated auditing tools to reduce administrative burden. The strength of their framework is its focus on reducing administrative overhead, but its limitation is that it

does not fully address the dynamic nature of IoT systems, which require frequent updates to remain compliant.

Additionally, scalability should be a core feature of any security framework for fintech MSMEs. As these businesses grow, their IoT security needs will also grow. To address this, Patil et al. (2023) proposed a modular approach to IoT security frameworks, which would allow fintech MSMEs to scale security measures incrementally as they add more devices or expand their operations. Their study focused on the need for frameworks that support incremental security enhancements, which would provide flexibility without requiring an overhaul of the entire system. The strength of their proposal lies in the flexibility it offers, but a limitation is that it requires ongoing adjustments to the security system, which may still be a resource challenge for MSMEs with limited budgets.

To better fulfill the needs of fintech MSMEs, current IoT security frameworks need to be more adaptable to the specific regulatory and operational challenges faced by these businesses. Gai et al. (2016) highlighted that fintech MSMEs must comply with regulations such as GDPR and PCI DSS, which impose strict constraints on data protection, breach notification, and access control. However, many existing frameworks lack the necessary mechanisms to ensure real-time compliance. By integrating compliance checks and automated auditing tools into the security framework, Patil et al. (2023) emphasized that fintech MSMEs can reduce their administrative burden and ensure compliance without expending significant resources.

Furthermore, the modular approach proposed by Patil et al. (2023) can allow fintech MSMEs to gradually scale their security systems in line with their growth. This solution provides the flexibility needed by businesses to adjust their security measures as their needs evolve. The strength of this approach lies in its adaptability, but it may still

require continuous updates to keep pace with evolving cyber threats and regulatory requirements.

2.5 IoT Security Compliance in Fintech MSMEs

Tailoring IoT Security for Compliance

Fintech MSMEs face enormous responsibilities in meeting regulatory requirements, and as such, the frameworks for IoT security compliance should be tailored to conform to specific mandates such as GDPR and PCI DSS, which are crucial for data privacy and financial safety. Hussain et al. (2023) emphasized the importance of designing IoT security frameworks for GDPR compliance, which prioritize data protection by design and default. Their methodology involved analyzing various IoT devices used in fintech operations, such as payment systems and digital wallets, and assessing how they can be integrated with advanced security features like end-to-end encryption, anonymization, and secure data transmission. Their findings concluded that these frameworks should ensure that personal or sensitive data is automatically protected by IoT devices as part of GDPR's data minimization and purpose limitation principles. The strength of their framework is its focus on compliance, but the limitation is its reliance on sophisticated technologies that may be too expensive and complex for MSMEs with limited resources. Additionally, they advocated for robust data erasure and the right to be forgotten, which would allow businesses to remove personal data upon customers' requests or when no longer necessary. However, these protocols may not be feasible for smaller organizations with limited infrastructure to manage the complexities of these features.

Moreover, GDPR introduces the requirement for real-time breach notification, necessitating that IoT devices be integrated with automated systems to detect breaches

and notify authorities within 72 hours. Hussain et al. (2023) provided a solution to this by proposing an automated breach detection system. Their study focused on the implementation of automated real-time breach detection systems within IoT devices used in fintech, concluding that such systems could significantly improve response times. The strength of their framework is in its real-time approach, but a limitation is that it assumes the availability of a robust IT infrastructure for deployment, which many fintech MSMEs may lack.

The IoT security framework also needs to secure payment card data from all processing points in PCI DSS compliance. Security here refers to tokenizing and encrypting cardholder data both in transit and at rest, along with implementing multi-factor authentication and access controls to protect against unauthorized access to sensitive financial information. Wright (2016) studied the implementation of PCI DSS within IoT security frameworks, focusing on ensuring that payment card data is properly tokenized and encrypted. Their findings highlighted the importance of continuous monitoring and vulnerability assessments, but the limitation of this framework is that it can be too cost-prohibitive for fintech MSMEs, which often cannot afford the necessary infrastructure and personnel to comply fully.

The PCI DSS standard also requires vulnerability assessments and penetration testing to detect weaknesses in the system, ensuring that IoT devices used in financial transactions adhere to the highest security standards. This security measure is critical for detecting fraud and ensuring that IoT systems are secure. Hussain et al. (2023) pointed out that regular vulnerability assessments were essential for maintaining compliance, but these assessments require continuous resources, which are not always feasible for smaller organizations. The strength of their framework is its emphasis on continuous monitoring

and proactive threat detection, but the limitation is that it may not be realistic for MSMEs without dedicated security teams.

In addition, the framework must enable audit trails to document and review access to critical sensitive payment information needed for compliance. This is necessary to detect fraud or unauthorized access and to help businesses avoid the heavy fines associated with noncompliance. Wright (2016) explored how audit trails could be incorporated into IoT security frameworks and concluded that their use could help fintech MSMEs secure customer data and prevent financial losses. However, the challenge remains that continuous auditing can be resource-intensive, and it may not always be scalable for smaller firms.

Challenges in IoT Security Compliance

IoT security frameworks based on compliance help fintech MSMEs mitigate the risks of data privacy and financial fraud by ensuring they follow regulations such as GDPR and PCI DSS, which outline how sensitive data should be secured. These frameworks emphasize strong data encryption, ensuring that customer data transmitted by IoT devices is protected both during transit and at rest. This significantly reduces the probability of unauthorized access or data breaches. Hussain et al. (2023) emphasized that implementing strong encryption protocols within IoT devices is essential to ensuring data security in compliance with GDPR and PCI DSS. Their findings supported the use of advanced encryption and authentication methods to prevent unauthorized access, but their limitation lies in the high technical complexity and resource demands required to implement these methods.

Moreover, these compliance-driven frameworks incorporate real-time threat detection and continuous monitoring mechanisms to identify and respond to security incidents such as unauthorized access attempts or fraudulent activities. Hussain et al.

(2023) also highlighted that continuous monitoring is crucial in the fintech sector, where a breach could lead to substantial financial losses. Their methodology included the integration of real-time threat detection into IoT devices to mitigate these risks. The strength of their research lies in the real-time approach, but it also faces the limitation of requiring extensive technical expertise and resources that are often unavailable to MSMEs.

PCI DSS also requires regular vulnerability assessments and penetration testing to identify any weaknesses in the system before they can be exploited by malicious actors. By ensuring that IoT devices meet PCI DSS standards, these frameworks provide the maximum security for payment card data. Regular audits are required to detect and address vulnerabilities, which can prevent significant financial losses from fraud. Wright (2016) explored this in their study, recommending continuous vulnerability assessments and audits as part of the compliance framework. The strength of this framework is in its proactive approach, but its limitation is that it requires substantial investments in security tools and specialized personnel, which may not be feasible for smaller organizations.

For fintech MSMEs, adhering to these regulatory standards not only protects client data and prevents fraud but also helps build customer trust. Clients are more likely to engage with businesses that demonstrate a commitment to securing their personal and financial information. Hussain et al. (2023) found that complying with regulations like GDPR and PCI DSS helps businesses establish credibility, but their frameworks are often too complex and costly for MSMEs. The strength of their work lies in demonstrating the importance of compliance for customer trust, but the limitation is that the high costs of compliance can be prohibitive for smaller businesses with limited resources.

IoT Compliance in Risk Mitigation

Compliance-driven IoT security frameworks are crucial in helping fintech MSMEs mitigate risks associated with data privacy and financial fraud by ensuring adherence to established regulatory standards like GDPR and PCI DSS. These frameworks incorporate robust encryption methods, ensuring that customer information is protected both during transmission and while stored. Hussain et al. (2023) pointed out that incorporating strong data encryption significantly reduces the risk of unauthorized access. They also emphasized the importance of multi-factor authentication and access control to ensure that only authorized personnel can access sensitive data, thus mitigating the potential for internal fraud or accidental exposure. Their methodology focused on assessing the effectiveness of multi-factor authentication in protecting sensitive data. The strength of their approach is its focus on reducing internal threats, but the limitation is that it may not be fully scalable for MSMEs without dedicated IT teams.

Additionally, compliance frameworks integrate mechanisms for continuous monitoring and real-time threat detection. These systems allow fintech MSMEs to quickly identify and respond to security incidents, such as unauthorized access attempts or fraudulent activities. Hussain et al. (2023) highlighted that the ability to detect and mitigate threats in real-time is vital for preventing financial losses. However, real-time monitoring can be resource-intensive, which presents a challenge for smaller businesses with limited resources.

By integrating the requirements of PCI DSS, these frameworks ensure that payment card data is handled securely. The use of tokenization and secure data storage practices reduces the risk of payment fraud, making it more difficult for cybercriminals to exploit payment information. Regular audits and vulnerability assessments are also required to identify any weaknesses in the IoT ecosystem before they can be exploited. Wright (2016) explored this in depth, demonstrating that regular vulnerability

assessments are crucial in identifying and addressing weaknesses in the system. The strength of this framework lies in its proactive security measures, but the limitation is that continuous audits require significant resources and may not be feasible for smaller organizations.

In conclusion, compliance-driven IoT security frameworks help mitigate risks by providing a proactive, comprehensive approach to data privacy and fraud prevention. These frameworks ultimately protect businesses and their customers from significant financial and reputational damage, fostering greater trust with clients.

2.6 Solutions to Enhance IoT Security in Fintech MSMEs

Scalable IoT Security Solutions

Securing fintech MSMEs' IoT devices presents a significant challenge, especially when resources are limited. There are several effective solutions that can improve the security of IoT devices in a scalable and cost-effective manner. A cloud-based IoT security platform is one of the most critical approaches. Hussain et al. (2023) explored the use of cloud-based security platforms and highlighted their key strengths, including low investment in physical infrastructure and high scalability. These platforms provide fintech MSMEs access to enterprise-level tools such as real-time threat detection, data encryption, and secure storage at a relatively low cost. Their study found that cloud-based solutions are highly cost-effective for smaller businesses that cannot afford large upfront investments. The strength of their framework lies in its scalability and cost-effectiveness; however, a limitation is that cloud-based platforms require reliable internet connectivity, which may be a barrier for businesses in regions with less robust infrastructure.

Another effective solution is the implementation of device-level security protocols. Raj et al. (2024) focused on cost-effective security measures such as strong authentication mechanisms (e.g., multi-factor authentication), device encryption, and regular firmware updates. Their methodology involved assessing the effectiveness of these protocols in preventing IoT devices from becoming entry points for cyberattacks. The findings demonstrated that assigning built-in security features to each IoT device can significantly reduce vulnerabilities. The strength of their framework is its focus on securing individual devices within the network, but the limitation lies in its reliance on devices' processing capabilities, which may be insufficient in lower-end IoT devices.

Additionally, IoT security management platforms enable central monitoring and automatic patching of servers, significantly reducing the burden on IT personnel, especially in small businesses. These platforms help identify vulnerabilities and provide real-time monitoring to ensure security standards are met. Gaur et al. (2023) discussed the importance of integrating automated compliance management tools into IoT security frameworks, allowing fintech MSMEs to run automated checks to ensure compliance with regulations like GDPR and PCI DSS. Their study showed that automation simplifies compliance processes and reduces the time and resources needed for manual compliance checks. The strength of their framework is its ability to streamline compliance management, but the limitation is that the initial setup of automated tools can be resource-intensive, which could be a challenge for smaller firms.

Leveraging AI and Blockchain for IoT Security

Emerging technologies, particularly artificial intelligence (AI) and blockchain, hold great potential in enhancing IoT security frameworks for fintech MSMEs. These technologies can address many of the security challenges inherent in IoT ecosystems, offering scalable and cost-effective solutions.

Real-Time Threat Detection & Anomaly Recognition: Chatterjee et al. (2024) highlighted the use of AI in real-time threat detection and anomaly recognition for IoT networks. Their methodology involved applying machine learning algorithms to massive data sets generated by IoT devices, allowing AI systems to identify patterns and detect unusual behavior that could indicate a security breach. Their study found that AI-based systems are highly effective at spotting emerging threats such as phishing or DoS attacks. The strength of their framework lies in its ability to continuously monitor and respond to threats, but the limitation is that AI systems require large amounts of data to be effective, which may be challenging for MSMEs to gather and manage.

Additionally, AI can play a critical role in predictive maintenance, helping fintech MSMEs avoid potential security risks before they occur. Raj et al. (2024) explored how AI models can analyze historical data to forecast when IoT devices are likely to fail or become vulnerable to security breaches. The findings demonstrated that AI-driven predictive maintenance can prevent security incidents by identifying vulnerabilities before they lead to breaches. The strength of their framework is its proactive nature, but a limitation is that the accuracy of predictions depends on the quality of data available, which may be limited in smaller organizations.

Immunity of Data through Blockchain: Adigun et al. (2024) discussed the potential of blockchain technology in securing data within IoT ecosystems. Blockchain's decentralized nature ensures that data transactions are tamper-proof, secure, and portable. Their study found that blockchain can provide an immutable record of transactions, making it particularly useful for maintaining the integrity of financial data. The strength of their framework lies in its ability to provide secure, tamper-proof records, but its limitation is that implementing blockchain can be complex and resource-intensive for smaller firms without specialized knowledge.

Blockchain also enables decentralized authentication, which eliminates single points of failure that are commonly targeted by cybercriminals. Tauseef et al. (2023) explored how blockchain can be used to create distributed identity management systems to enhance security in devices like smart payment terminals. The findings showed that blockchain-based decentralized authentication systems are highly effective at preventing unauthorized access, particularly in fintech applications. The strength of their framework is in its ability to enhance authentication security, but the limitation is that the integration of blockchain into existing systems may be technically challenging for MSMEs with limited IT expertise.

The integration of AI with blockchain offers synergistic benefits for IoT security. Rajan et al. (2023) investigated how AI and blockchain can be integrated to enhance both the security and privacy of data in fintech MSMEs. Their study demonstrated that AI can analyze IoT data to detect anomalies, while blockchain ensures that the data remains secure and tamper-proof. The strength of their approach is its combined use of both technologies, but the limitation is that implementing both AI and blockchain can be costly and may require specialized knowledge that smaller businesses may not have.

Role of Automated Security Solutions

Automated security solutions play a crucial role in improving the security posture of fintech MSMEs by providing real-time, continuous monitoring and quick responses to potential threats. Alshammari (2023) emphasized that automated systems can significantly reduce the human error inherent in manual security operations. Their study showed that automated solutions are effective in continuously tracking IoT devices and identifying vulnerabilities without the need for constant human intervention. The strength of their framework lies in its ability to minimize human error and improve response

times, but the limitation is that automated systems still require regular updates and maintenance to ensure their effectiveness.

Moreover, automated security solutions streamline compliance with regulations like GDPR and PCI DSS by providing continuous checks to ensure that all security protocols are in place. Gaur et al. (2023) discussed the importance of integrating automated compliance management into IoT security frameworks, allowing fintech MSMEs to achieve automated compliance without the need for manual intervention. Their study found that these tools significantly reduce the compliance burden on smaller firms. The strength of their framework is that it simplifies the compliance process, but the limitation is that the setup of automated systems requires significant initial investment and technical expertise.

Fintech MSMEs can integrate automated security solutions through modular, cloud-based security platforms that can be seamlessly integrated with existing systems. These platforms provide APIs to enable security tools to work with other existing systems like firewalls, intrusion detection systems (IDS), and security information and event management (SIEM) systems. Raj et al. (2024) explored the use of modular cloud-based platforms and found that these platforms offer scalability, allowing businesses to expand their security infrastructure as they grow. The strength of their framework lies in its scalability and seamless integration with existing systems, but the limitation is that cloud-based platforms rely on reliable internet connectivity, which may not be available in all regions.

2.7 Key Challenges in Implementing IoT Security Frameworks

Barriers to IoT Security Adoption

Fintech Micro, Small, and Medium Enterprises (MSMEs) encounter several barriers when adopting comprehensive IoT security frameworks. These barriers are critical in determining the extent to which IoT security can be successfully implemented in the fintech sector. The most significant challenges include:

Financial Constraints

The high cost of implementing IoT security frameworks is a major barrier for fintech MSMEs. Many fintech MSMEs struggle with limited budgets, making it difficult to invest in sophisticated security infrastructure that requires significant initial investments in both hardware and software. Mardiani et al. (2024) addressed the cost issue and recommended cloud-based security solutions as a feasible alternative. Their study emphasized the scalability of cloud solutions, which provide access to enterprise-level security tools like real-time threat detection, data encryption, and secure storage at a lower cost compared to on-premises systems. Their methodology involved comparing the cost-effectiveness of cloud-based solutions versus traditional on-premises systems. The findings showed that cloud platforms are more accessible to fintech MSMEs, but the limitation lies in the need for reliable internet infrastructure, which may be challenging in some regions. Furthermore, the pay-as-you-go pricing models allow fintech MSMEs to expand their security infrastructure as their business grows, which is advantageous given their financial constraints.

Lack of Technical Expertise

Many fintech MSMEs face difficulties in setting up and maintaining an IoT security framework due to a lack of in-house technical expertise. Small firms typically do not have dedicated IT security teams, which makes it difficult for them to keep up with current threats and best practices. Chandak & Chandak (2024) proposed a solution by recommending partnerships with managed security service providers (MSSPs), who can

offer expert guidance and assist in deploying and maintaining security systems. Their research highlighted the advantages of MSSPs, such as access to specialized knowledge and services that MSMEs might not be able to afford in-house. However, a limitation of this solution is that MSSPs are often costly, and many MSMEs may not have the resources to outsource their entire security infrastructure. To mitigate this challenge, the authors also suggested that MSMEs invest in cybersecurity training programs for existing employees to enhance internal capabilities and foster a culture of security.

Complex Regulatory Requirements

Fintech MSMEs are subject to strict regulatory standards like the General Data Protection Regulation (GDPR) and the Payment Card Industry Data Security Standard (PCI DSS). These regulations require firms to implement robust data protection measures, which can be complex and costly for smaller businesses with limited resources. Sinniati & Darma (2023) explored the difficulties that MSMEs face in complying with these regulations, emphasizing the need for automated compliance management tools. Their research focused on how automated systems can continuously monitor and generate reports for audits, reducing the administrative burden and ensuring compliance with evolving regulations. The strength of their framework lies in its ability to streamline compliance management, but the limitation is that the integration of automated tools may require upfront costs and specialized technical knowledge, which may be challenging for MSMEs with limited expertise.

Scalability and Cost in IoT Security

The implementation of IoT security frameworks in fintech MSMEs is significantly limited by scalability and cost constraints. Many fintech MSMEs operate on tight budgets, which prevent them from investing in high-quality, scalable security solutions that can evolve with the business. Sinniati & Darma (2023) discussed the

challenges associated with implementing security frameworks designed for larger enterprises in smaller organizations with limited resources. These frameworks often require substantial investments in hardware, software, and specialized personnel, which are typically unfeasible for MSMEs. The authors also noted that the static nature of these frameworks makes it difficult for MSMEs to scale their security systems as their businesses grow. The key limitation is the lack of flexibility and adaptability in existing frameworks, which prevents fintech MSMEs from keeping up with changing security needs as they expand.

Hussain et al. (2024) proposed that modular security solutions, which can be incrementally scaled, could address this issue. Their framework offers a flexible, cost-effective approach where fintech MSMEs can implement basic security measures at the outset and gradually add more sophisticated security features as the business grows. The strength of this modular approach lies in its scalability, but a limitation is that it requires continuous monitoring and updates to ensure that new devices or security measures are properly integrated into the existing framework. Furthermore, the lack of in-house security teams in many fintech MSMEs makes it difficult for these businesses to monitor and manage their evolving security infrastructure effectively.

Challenges in Maintaining IoT Security

The ever-evolving nature of cyber threats and regulatory requirements poses significant challenges for fintech MSMEs in maintaining an effective IoT security framework. Chowdhury & Jurcut (2023) explored the difficulties MSMEs face in keeping their IoT security systems up to date with the latest threats. Their research highlighted the need for continuous investment in threat intelligence, vulnerability patching, and real-time monitoring to stay ahead of cybercriminals. The authors emphasized that IoT systems are dynamic and require constant updates to mitigate new vulnerabilities. The

strength of their framework lies in its proactive approach to monitoring and mitigating security risks, but the limitation is that it requires continuous investment, which may not be feasible for MSMEs with limited financial resources.

Moreover, Folorunso et al. (2024) discussed the regulatory challenges fintech MSMEs face in keeping their security systems compliant with changing laws like GDPR and PCI DSS. Their study found that MSMEs often struggle to adapt their security frameworks to meet new regulatory standards, which can be costly and time-consuming. The solution they proposed involved the use of automated solutions for compliance tracking and vulnerability management, which can reduce the manual effort required to stay compliant. The strength of their framework is that it minimizes the administrative burden of compliance, but the limitation is that it may require a significant upfront investment in compliance management tools, which could be a barrier for MSMEs with limited budgets.

Table 1 Comparison of Existing IoT Security Frameworks for Fintech MSMEs

Framework	**Scalability**	**Cost**	**Applicability to Fintech MSMEs**	**Key Strengths**	**Key Limitations**
Hussain et al. (2023)	High scalability for large firms, but difficult for MSMEs	High cost due to AI and blockchain integration	Limited applicability for smaller fintech MSMEs with constrained resources	Incorporates AI, multi-layer security protocols, blockchain	Too complex and costly for MSMEs to adopt; requires substantial resources
Haj Hussein et al. (2024)	Scalable for IoT networks, but requires significant infrastructure	High cost, especially for MSMEs	Focuses on decentralized systems, less suitable for smaller fintech firms	Blockchain-based dual identity management for IoT security	Not cost-effective for MSMEs; heavy infrastructure needed
Grigaliūnas et al. (2024)	Scalable in large,	High upfront costs for	Limited to large firms;	Focus on IoT device security	Does not specifically

	interconnected IoT networks, but less suitable for MSMEs	implementation and maintenance	challenges for resource-limited MSMEs	and cyberattack prevention	address scalability for MSMEs
Kaur et al. (2021)	Moderate scalability for SMEs	Affordable for small enterprises but lacks advanced features	Applicable for SMEs but lacks extensive coverage for complex fintech needs	Simplifies device-level security for smaller firms	Lacks comprehensive coverage for IoT security in larger networks
Sodiya et al. (2024)	Scalable but limited by device capabilities in smaller organizations	Low-cost, but lacks comprehensive security measures	Suitable for low-cost, small fintech operations but lacks higher-level security	Focus on cost-effective, basic IoT security for small devices	Lacks advanced security features for fintech IoT networks
Rahayu et al. (2023)	Limited scalability for large IoT networks	Low-cost solutions for SMEs	Primarily suited for SMEs with simple IoT infrastructure	Focus on simplifying IoT device security	Lacks integration with complex IoT networks and advanced security protocols
Wangyal et al. (2020)	Scalable for medium-sized IoT networks, but not for large-scale implementations	Affordable for MSMEs with limited budgets	Focused on regulatory compliance, suitable for fintech MSMEs needing compliance	Compliance-focused, suitable for small businesses	Does not provide robust protection against evolving threats in large IoT systems
Raj et al. (2024)	Scalable with strong device-level security	Low-cost, suitable for small enterprises	Applies well to MSMEs with small IoT networks	Focuses on strong authentication and encryption for IoT devices	Limited coverage of broader IoT network security and threat mitigation
Ngwenya & Ngoepe (2020)	Limited scalability for dynamic, large-scale IoT	Low-cost solutions for small businesses	Primarily suited for small businesses;	Focus on security vulnerabilities and data	Not scalable for larger networks; lacks

	deployments		lacks advanced security for large networks	breaches prevention	advanced security measures
Chatterjee et al. (2024)	Moderate scalability, suitable for moderate-sized MSMEs	Affordable for MSMEs with limited budgets	Suitable for small to medium-sized fintech MSMEs	Advanced threat detection using AI, focuses on real-time anomaly detection	Limited in addressing larger IoT systems and complex threats
Alshammari (2023)	Scalable for moderate-sized businesses, limited for large enterprises	Low-cost, budget-friendly	Applicable for small to medium enterprises	Emphasis on automated security checks and compliance	Lacks deeper threat detection and advanced network security
Patil et al. (2023)	Designed to scale incrementally with fintech MSMEs	Cost-effective, cloud-based solutions with flexible pricing models	Tailored for fintech MSMEs, focuses on scalability and compliance	Cloud-based, scalable, integrates regulatory compliance	May require continuous updates to handle evolving security threats
NIST Cybersecurity Framework (2020)	High scalability, ideal for large enterprises	Expensive due to infrastructure and staff requirements	Difficult for fintech MSMEs to implement due to complexity	Comprehensive framework for large enterprises	High upfront cost and resource demand; not adaptable for MSMEs
ISO 27001	High scalability but requires significant investment	High upfront and maintenance costs	Best suited for large firms, less flexible for MSMEs	Provides a strong, recognized global security standard	Too rigid for the flexible needs of MSMEs; complex to implement

2.8 Research Gaps

While significant research has been conducted on IoT security, several critical gaps remain that need to be addressed to optimize IoT security frameworks for fintech

Micro, Small, and Medium Enterprises (MSMEs). These gaps primarily pertain to the scalability and adaptability of existing frameworks, the integration of emerging technologies such as AI and blockchain, and the challenges in meeting regulatory compliance standards within the context of fintech MSMEs. Addressing these gaps will be crucial for developing a framework that is both cost-effective and scalable, catering to the unique needs of fintech MSMEs.

1. Scalability of IoT Security Frameworks

A major gap in current research is the scalability of IoT security frameworks specifically designed for fintech MSMEs. Most existing frameworks have been developed for large enterprises with abundant resources, making them difficult to adapt for small organizations with limited budgets and technical expertise. Alshammari (2023) pointed out that current frameworks are often too complex and resource-intensive to be implemented by MSMEs. This gap is significant because fintech MSMEs, which typically experience rapid growth, require scalable frameworks that can evolve as they expand without compromising security. The existing literature does not sufficiently address how security frameworks can be scaled down to meet the needs of small, resource-constrained businesses, particularly when integrating new IoT devices.

Link to Study Objectives: This study aims to bridge this gap by developing a scalable IoT security compliance framework tailored to the specific needs of fintech MSMEs. The research will focus on designing a framework that can grow with the business, integrating new devices and services without compromising security, and will evaluate the effectiveness of these solutions in real-world fintech environments.

2. Integration of Emerging Technologies (AI and Blockchain)

Another research gap lies in the integration of emerging technologies, such as Artificial Intelligence (AI) and blockchain, into IoT security frameworks for fintech

MSMEs. While these technologies have shown promise in enhancing security in larger organizations, their application in small-scale fintech businesses remains underexplored. Chatterjee et al. (2024) highlighted that AI-based anomaly detection systems and blockchain-based decentralized authentication could significantly improve IoT security by detecting vulnerabilities and preventing data tampering. However, the feasibility of deploying these technologies in a cost-effective and scalable manner within the resource constraints of fintech MSMEs remains largely unaddressed.

Link to Study Objectives: This study will explore how AI and blockchain can be integrated into IoT security frameworks for fintech MSMEs, focusing on the practical challenges and limitations of adopting these technologies in resource-constrained environments. The research will aim to provide a solution that enables fintech MSMEs to adopt these technologies in a scalable and cost-effective manner.

3. Regulatory Compliance and IoT Security

Regulatory compliance is another critical challenge that fintech MSMEs face when adopting IoT devices. The research by Hussain et al. (2023) highlighted that compliance with regulations like GDPR and PCI DSS can be costly and difficult for MSMEs with limited resources. These regulations require strict data protection measures, including encryption, secure data storage, and real-time breach detection, which are often challenging to implement within small organizations due to budget and expertise constraints. While large organizations can allocate the necessary resources to meet these requirements, MSMEs often struggle to keep up with the evolving regulatory landscape.

Link to Study Objectives: This research aims to develop an IoT security compliance framework that specifically addresses the regulatory challenges faced by fintech MSMEs. The framework will incorporate automated compliance checks, reducing

the administrative burden on small businesses and ensuring they remain compliant with evolving regulations like GDPR and PCI DSS.

4. Cost-Effectiveness of IoT Security Frameworks

Despite existing studies on IoT security, there is a lack of research into low-cost, high-impact security solutions for fintech MSMEs. Many frameworks are expensive to implement, requiring substantial upfront investments in hardware, software, and IT personnel. Gaur et al. (2023) discussed the potential of cloud-based security platforms as an affordable solution, but research on how these platforms can be effectively adopted by small businesses remains scarce. Additionally, there is limited investigation into the use of open-source tools and automation technologies to reduce costs while maintaining a high level of security.

Link to Study Objectives: This study will focus on developing cost-effective IoT security solutions for fintech MSMEs. By exploring the use of cloud-based platforms, open-source tools, and automated compliance tools, the research will provide a framework that balances security needs with the financial constraints of small businesses.

5. Flexibility and Adaptability of IoT Security Frameworks

Many existing IoT security frameworks lack the flexibility needed to adapt to the diverse and rapidly evolving security needs of fintech MSMEs. Frameworks designed for large enterprises often provide a "one-size-fits-all" solution, which does not account for the unique security needs of smaller businesses with specific devices, such as payment terminals, biometric systems, and digital wallets. Bojjagani et al. (2023) found that existing frameworks are often too rigid to accommodate the varying security requirements of different IoT devices used by fintech MSMEs.

Link to Study Objectives: The study will propose a modular IoT security framework that can be tailored to the specific needs of different IoT devices used by

fintech MSMEs. This framework will allow businesses to add or remove security measures as needed, ensuring it remains adaptable to changing security threats and regulatory requirements.

Conclusion

The gaps identified in the literature review underscore the need for further research into scalable, cost-effective, and flexible IoT security solutions tailored for fintech MSMEs. Addressing these gaps will be crucial for developing frameworks that can meet the unique security needs of smaller organizations while ensuring compliance with evolving regulatory standards. This study aims to fill these gaps by proposing a comprehensive, scalable, and cost-effective IoT security compliance framework specifically designed for fintech MSMEs, addressing both security challenges and regulatory compliance in a dynamic and evolving business environment.

2.9 Summary

Through this literature review, this has been an in-depth look on how some of the key issues are involved when it comes to the implementation of IoT security frameworks for fintech Micro Small and Medium Enterprises (MSMEs). According to it, IoT devices are becoming increasingly important for the security of the fintech sector, which derives substantial benefit in terms of operational efficiency and service delivery, while at the same time creating large security vulnerabilities. After reviewing a wide range of the available IoT security frameworks, the framework selected for the devices deployed was the most applicable to the specific needs of fintech MSMEs who struggle with limited resources, scalability and the inability to adhere to the severe regulatory compliance standards. From the review, it was observed that existing research is lacking in giving proper understanding of how an IoT security framework can be adjusted to the unique

operational and financial limitations of fintech, MSMEs. A significant issue in the scalability of security solutions is that most of the frameworks are intended to scale large enterprises over smaller organizations with high evolving requirements. Along with the integration of emerging technologies like Artificial Intelligence (AI) in IoT security frameworks, there are significant opportunities in terms of integration of such technologies in IoT security frameworks for fintech MSMEs, yet they are yet to be explored. Secondly, regulatory compliance especially of standards such as GDPR and/ or PCI DSS is also a challenge as fintech MSMEs have to strike a balance between securing their systems and complex compliance requirements.

In addition, the review highlighted the current gaps of research including cost effective solutions, IoT security framework adaption on practical use and practical use of new technologies. These gaps show that there is more investigation that needs to be done on how fintech MSMEs can carry out a scalable, cost-effective security measure that will adhere to the changing regulatory standards. On the whole, this literature review finds the need for a tailored monetization approach based on IoT security frameworks to fight the holes in the armor of fintech MSMEs. Future research can focus on bridging the gap of the literature by improving the scalability, cost effectiveness and the integration of emerging technology in order to secure these enterprises. This paper creates the groundwork for the next steps of this research that seek to create a practical and scalable IoT security compliance framework tailored specifically to the needs of fintech MSMEs.

CHAPTER III:

METHODOLOGY

3.1 Overview of the Research Problem

This dissertation addresses the research problem of the development of a scalable IoT security compliance framework meant specifically for strengthening the security posture of fintech Micro, Small, and Medium Enterprises (MSMEs). The fintech sector reaches a huge expansion in adoption of IoT devices, which leads MSMEs to encounter much higher cybersecurity threats related to safeguarding sensitive financial data and comply with the tight regulations such as General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS). Large organizations can afford to use fancy security systems, but since Fintech MSMEs don't have the resources to provide, there are several problems they have to face such as, having a minimal budget, no technical expertise and the complexity of adding IoT security with the existing infrastructure. This is because IoT investments are making way into the enterprises, which is laying a strong foundation for adoption of IoT in the enterprises aiming to secure their operations, comply with regulatory standards, and minimize the risk of data breaches and financial frauds. This gap is addressed in the research by developing a practical and customizable framework that can be easily integrated into the operational process of fintech MSMEs. This research has two objectives, the first one being to investigate the design and implementation of a scalable IoT security compliance framework for the fintech MSMEs which would be cost effective while tailored to meet their specific needs. The first part concerns assessing the efficiency of currently prevailing frameworks for security in these businesses, identifying distinctive difficulties that these businesses address, and finding out how these new applied technologies, namely AI, blockchain, and cloud-based solutions, will be joined to strengthen security and compliance. The research to tackle this problem will be to understand the main barriers that hinder adoption of comprehensive security by fintech MSMEs, which include financial limitations, resource constraints and regulatory complexities.

Additionally, the research seeks to offer suggestions to tackle these barriers and create a framework which addresses the needs of security as well as compliance requirements so that fintech MSMEs can securely adopt and scale IoT technologies in the malevolent dynamic of regulatory and cyber threat in the fervently evolving domain. The methodology for the problem outlined in this chapter consist of the research design, the data collection methods used, and the data analysis techniques. The methodology chosen is meant to give the theoretical understanding of and practical solutions to build a flexible and cost effective IoT security compliance framework that will help fintech MSMEs to enjoy the benefits of IoT.

3.2 Research Purpose and Questions

It is the primary purpose of this research to build a scalable IoT security compliance framework based on the specific needs and constraints of fintech Micro, Small and Medium Enterprises (MSMEs). Moving towards the fintech sector, the Internet of Things (IoT) adoption has been booming and MSMEs are faced with huge security challenges regarding the protection from the financial sensitive data as well as the compliance with the regulatory needs: GDPR and PCI DSS. With the severely scarce resources, technical skills and the huge requirement of scalability for fintech MSMEs, there is an essential necessity of an appropriate and adaptable security framework which can be immediately deployed across diverse IoT devices and systems. The purpose of this research is to bridge the gap by suggesting framework which not only strengthens the security posture of the fintech MSME, but even they can address legal requirements without incurring many costs and complexities. By studying this, we intend to discover the impediments these businesses have in enacting IoT security measures and existing security frameworks and suggest a technique with cutting edge technologies for example,

AI, blockchain, and cloud-based tools. The objective is to contribute with this research, to provide practical, scalable and actionable insights for the fintech MSMEs for their secure integration of IoT technologies while being compliant to industry standards and mitigating the risks of cybersecurity threats.

Research Questions

1. What are the most prevalent IoT vulnerabilities in Fintech MSMEs, and how do they impact their operational efficiency and financial stability?

2. What specific security metrics can be developed to measure IoT compliance in Fintech MSMEs, and how can their validity be quantitatively assessed?

3. How does the proposed IoT security compliance framework perform when implemented across Fintech MSMEs of varying sizes and operational complexities?

4. What measurable improvements in regulatory compliance can be observed in Fintech MSMEs after implementing the proposed IoT security framework?

3.3 Research Design

The research design for this study is to develop a scalable IoT Security compliance framework oriented to micro, small and medium enterprises (MSME) in fintech. The research is driven toward a quantitative approach that allows research to systematically measure the effect of and on the security measures in a concrete, empirical terms.

This will use both the survey-based data collection and the case studies to make this problem and its solutions comprehensively covered for the fintech sectors perspective. Fintech MSMEs that adopted IoT technology are being surveyed based on this method and received quantitative data. It is composed of Likert scale, multiple choice and ranking questions that include queries around key variables like security challenges,

the effectiveness of existing IoT security framework, the compliance with regulations, like GDPR and PCI DSS, and the cost advantage of different IoT security steps. In this regard, the survey is aimed at finding out what are the major hindrances in IoT security for MSME and it found three major barriers of financial constraints, scalability concern and compliance difficulties. Approximately 100-150 fintech MSMEs will be surveyed to ensure that the findings hold true for most fintech MSMEs.

Apart from conducting a survey, case studies will also be done with some selected fintech MSMEs that have successfully incorporated IoT security measures within their operations. The main ideas of these case studies are to give qualitative insights into the specific steps of these businesses in implementing IoT, the obstacles they faced in the process of implementation and how they surmounted the complications in the implementation of IoT and its security as well as compliance. Another part of the study that includes case studies the adoption of emerging technologies like AI and blockchain to provide a better understanding of how they facilitate greater IoT of fintech MSMEs security.

In the study, the sampling strategy will be a diverse group of fintech MSMEs that represent across diverse geographical regions and different stages of IoT adoption. One of the goals is to capture a wide variety of experiences and security needs, especially related to the introduction of IoT technologies into the financial services and data management spheres. In this case, sample will include companies that are subject to regulation by GDPR and PCI DSS, which reflects the cases that the regulatory compliance challenges face in fintech.

The data will be collected by surveys and case studies constituting primary data; and secondary data in the form of industry reports, academic literature, and existing IoT

security frameworks. Both components will complement each other to provide context to the findings in the broader scope of IoT security, fintech, and regulatory compliance.

Using descriptive and inferential statistics, such as mean scores, frequencies and regression analysis, appropriate based on the survey responses, provides answers to how customer information can help predict what they are looking for in ways that stand to improve their job as a realtor. To extract qualitative insights of the practical experiences of fintech MSMEs when implementing IoT security measures, I will undergo thematic analysis of the case study data. Regarding the ethical concerns, this research will be conducted in a way to make sure that all of the participants provide consent and respond to the questions, as they will be kept anonymous and confidential.

Throughout the study, we will maintain data privacy by aggregating findings and will not present findings that are identifiable to particular individual people or businesses. Yet, the research design provides a sound methodology for answering to the research questions, which nevertheless are subject to limitations. They include the potential response bias in the survey in cases of the sensitivity of the issues discussed or the generalizability of the findings, as it is for the fintech MSMEs, and may not be wholly applicable in larger organizations or other sectors. However, limited to these limitations, the research design is generally suitable to generate meaningful information regarding the formulation of a large and successful process for a financial technology small and medium-sized business (fintech MSME) regarding IoT security compliance framework development.

3.4 Population and Sample

The target population for this study consists of fintech Micro, Small, and Medium Enterprises (MSMEs) that have either already implemented or are planning to implement Internet of Things (IoT) technologies to enhance their business operations. These

enterprises are particularly relevant for this research due to their unique challenges in integrating IoT devices while complying with strict regulatory standards such as General Data Protection Regulation (GDPR) and Payment Card Industry Data Security Standard (PCI DSS).

Given the increasing adoption of IoT in fintech, MSMEs face several security challenges, particularly when it comes to safeguarding financial data and ensuring compliance with regulations. This study focuses on capturing the experiences of businesses dealing with these challenges. The population was selected to represent businesses at different stages of IoT adoption, from those in the early stages of integration to those that have already fully integrated IoT into their operations.

A total sample size of 205 fintech MSMEs was drawn from different geographical regions and industry sub-sectors. The goal was to include a diverse set of participants to provide a comprehensive view of the IoT security challenges faced by fintech MSMEs across various contexts. By targeting a wide range of businesses, the study aims to ensure that the findings are representative of the broader population of fintech MSMEs, reflecting differences in business size, IoT adoption levels, and geographical variations.

The sampling method used for this study was purposive sampling, a non-probability technique. This method allows for the selection of specific individuals or businesses that meet predefined criteria, ensuring that participants have the relevant experience with IoT adoption and regulatory compliance in the fintech sector. The sample was purposefully selected to ensure that it is highly relevant to the research objectives, particularly in understanding the specific challenges and needs of fintech MSMEs in adopting IoT security measures.

The study aimed for a response rate of 70-80% from the 205 participants, which is reasonable for survey-based research in this field. This rate was chosen based on the

expected willingness of fintech MSMEs to participate and the availability of the target population for survey completion.

3.5 Participant Selection

This study employed purposive sampling to select participants from the target population of fintech MSMEs engaged in or planning to adopt Internet of Things (IoT) technologies. The primary inclusion criterion for the selection was that participants must have either already implemented IoT devices in their operations (such as smart payment systems, biometric authentication devices, etc.) or have plans to incorporate IoT technologies in the near future.

Another important criterion for participant selection was the regulatory environment in which the businesses operate, particularly their compliance with GDPR and PCI DSS, which are crucial to the security of financial data. As these regulations are critical in the fintech sector, the study specifically targets businesses that face compliance challenges in integrating IoT devices and those who are subject to these regulatory frameworks. This inclusion criterion aligns with the study's goal of developing a scalable IoT security framework that can address both security threats and regulatory compliance requirements for fintech MSMEs.

The selection of 205 participants was based on their experience with IoT integration and regulatory compliance. The sample was carefully chosen to reflect diversity in terms of business size, industry sub-sectors, and geographical locations. This diversity was crucial for capturing a broad range of experiences, ensuring that the study would provide insights into the challenges faced by fintech MSMEs from various backgrounds and at different stages of IoT adoption.

By using purposive sampling, the study aimed to ensure that the participants were representative of businesses that are actively involved in the fintech sector, facing the same regulatory compliance challenges and leveraging IoT technologies in their operations. This approach ensured that the findings would be directly relevant to the research objectives.

Response Rate: Based on prior research and industry trends, the study aimed for a response rate of 70-80%. This would result in approximately 150-160 valid responses from the 205 initial participants, ensuring that the data collected would be statistically significant and reliable for analyzing the challenges and regulatory compliance issues related to IoT security in fintech MSMEs.

Ethical Considerations: All participants were informed of the study's purpose, and participation was entirely voluntary. Informed consent was obtained from each participant, and confidentiality was assured throughout the process. Anonymity was guaranteed, with no personally identifiable information being collected.

3.6 Instrumentation

Structured Questionnaire serves as the primary instrument used to gather data, which has been specifically designed to obtain data on IoT security challenges, regulation that affects fintech MSMEs, as well as the adoption of security frameworks by fintech MSMEs. The questionnaire was developed with the aim of gathering both quantitative as well as qualitative data to answer the research questions in the best possible manner. And it was made up of 30 questions split in half into six sections; demographics, IoT adoption and implementation, security challenges, compliance regulation such as GDPR, PCI DSS, cost and scalability and the fusion of — if you want to use broad terms — emerging technologies like AI, blockchain, whatever.

The demographic section aimed to collect basic information about the respondents, including the size of the business, industry type, and stage of IoT adoption. This section was crucial for categorizing the responses and understanding the contextual factors that might influence the security challenges faced by the businesses. The subsequent sections were designed to assess the specific security concerns related to IoT integration, including vulnerabilities in devices, network security, and the management of sensitive financial data.

The questions in the survey used a mix of closed-ended questions, such as Likert-scale items to gauge respondents' agreement or disagreement with statements regarding security frameworks and compliance, and multiple-choice questions to gather specific details about IoT security measures in place. Additionally, open-ended questions were included to capture qualitative insights into the practical challenges faced by fintech MSMEs and how they address regulatory compliance and security.

To ensure the reliability and validity of the instrument, the questionnaire was pre-tested on a small group of fintech professionals and security experts prior to distribution. Feedback from the pre-test was used to refine and improve the clarity and relevance of the questions. This pre-testing helped ensure that the questionnaire effectively captured the necessary data and that respondents would be able to answer the questions accurately and meaningfully.

The questionnaire was then distributed electronically to the targeted sample of 205 fintech MSMEs, allowing for efficient data collection. This structured instrument enabled the collection of comprehensive data that would provide insights into the IoT security needs of fintech MSMEs and inform the development of a scalable and effective security compliance framework.

3.7 Data Collection Procedures

For this study, data was collected using a quantitative approach, where a structured questionnaire was employed to gather measurable data from 205 respondents representing fintech Micro, Small, and Medium Enterprises (MSMEs). The questionnaire consisted of 30 questions, organized into six sections, including a demographic section, IoT adoption and implementation, security challenges, regulatory compliance (particularly with GDPR and PCI DSS), cost and scalability concerns, and the integration of emerging technologies like AI and blockchain. The primary objective was to capture a wide range of responses from MSMEs to understand their IoT security needs, the challenges they face, and how they address compliance with regulations.

The questionnaire was distributed electronically through email and online survey platforms. This method allowed respondents to complete the survey at their convenience, ensuring a broader reach and better participation. To maximize the response rate, a reminder email was sent one week after the initial distribution. The sampling for this study was based on purposive sampling, specifically targeting fintech MSMEs that are either currently using or planning to adopt IoT technologies and that are subject to regulatory frameworks such as GDPR and PCI DSS. The selection of 205 respondents ensured that the data collected was reflective of a wide range of businesses within the fintech sector, varying in size, geographical location, and the stage of IoT adoption.

Ethical considerations were prioritized throughout the data collection process. All participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to confidentiality and anonymity. Informed consent was obtained from each participant prior to survey completion. Additionally, all responses were anonymized, ensuring that no personally identifiable information was collected. The

data was compiled and checked for completeness, and any incomplete or inconsistent responses were flagged and excluded from the final dataset.

Once the data collection process was completed, the responses were automatically aggregated and exported to statistical software for analysis. This structured approach ensured that reliable, valid, and quantifiable data was gathered, forming the basis for analyzing the security challenges and regulatory compliance issues faced by fintech MSMEs and ultimately informing the development of a scalable IoT security compliance framework.

3.8 Data Analysis

The data analysis for this study was conducted using a quantitative approach, focusing on analyzing the responses from the structured questionnaire distributed to 205 fintech MSMEs. Once the data collection was completed, the responses were cleaned and prepared for analysis by removing any incomplete or inconsistent entries, ensuring that the dataset was both reliable and valid. The data was then entered into statistical software, such as SPSS or Excel, to facilitate comprehensive analysis.

The analysis began with descriptive statistics to summarize the demographic characteristics of the respondents and to understand the general trends in IoT adoption, security challenges, and regulatory compliance. Measures such as frequencies, means, and standard deviations were calculated for various survey items to identify common patterns across the sample. These descriptive statistics provided an overview of the key issues faced by fintech MSMEs regarding IoT security and their compliance with regulations like GDPR and PCI DSS.

Next, inferential statistics were used to explore relationships between different variables. Chi-square tests and correlation analysis were applied to determine if there were any significant associations between the respondents' characteristics (e.g., company

size, stage of IoT adoption) and their responses to questions regarding security challenges, compliance levels, and the perceived effectiveness of existing IoT security frameworks. In addition, regression analysis was used to identify factors that influence the effectiveness of IoT security measures and their scalability for smaller organizations.

Together, these quantitative analysis techniques provided a comprehensive understanding of the security challenges, regulatory compliance issues, and technological needs of fintech MSMEs. The findings from the data analysis will contribute to the development of a scalable IoT security compliance framework that is both practical and effective for the fintech MSME sector.

Regression model for section 2 (obj 1)

Table 2 Regression Model for Objective 1

Model	**Intercept**	**Coefficient**	**R-squared**	**Significance (p-value)**
Frequency of IoT Security Incidents and Financial Losses	0.31	0.45	0.551	< 0.001
Frequency of IoT Security Incidents and Operational Inefficiency	0.4437	0.3919	0.332	< 0.005
Frequency of IoT Security Incidents and Innovation Limitation	3.605	0.0752	0.06	0.0004

Linear Regression for

Frequency of IoT Security Incidents and Financial Losses

Financial Loss=β0+β1×(Frequency of IoT Security Incidents)

Where:

β0=0.310 (Intercept)

β1=0.45 (Coefficient for the Frequency of IoT Security Incidents

Frequency of IoT Security Incidents and Operational Inefficiency

Operational Inefficiency=β0+β1×(Frequency of IoT Security Incidents)

Where:

β0=0.4437 (Intercept)

β1=0.3919 (Coefficient for the Frequency of IoT Security Incidents)

Frequency of IoT Security Incidents and Innovation Limitation

Innovation Limitation=β0+β1×(Frequency of IoT Security Incidents)

Where:

β0=3.6050 (Intercept)

β1=0.0752 (Coefficient for the Frequency of IoT Security Incidents

Regression model for section 3 (obj 2)

Compliance Improvement = β0 + β1 {Compliance tracking tools}) + β2 {Incident Reports & Security Logs}) + β3 {Regulatory Audit Scores}) + β4 {Risk assessments})

Where:

β0 = the intercept (constant term)

β1 = -0.3047 (coefficient for Compliance tracking tools)

β2 = -0.1109 (coefficient for Incident Reports & Security Logs)

β3 = 0.2350 (coefficient for Regulatory Audit Scores)

β4 = 0.6113 (coefficient for Risk assessments)

3.9 Research Design Limitations

While the research design employed in this study provides valuable insights into the IoT security challenges and regulatory compliance needs of fintech Micro, Small, and

Medium Enterprises (MSMEs), several inherent limitations and potential biases must be critically reflected upon. These limitations may influence the comprehensiveness and generalizability of the study's findings, and they point to areas where further research could enhance the understanding of these issues.

1. Sampling Bias and Generalizability

The study's reliance on purposive sampling presents a significant limitation. Purposive sampling, while ensuring that participants have direct experience with or interest in IoT technologies within the fintech sector, may introduce bias into the sample. This sampling method intentionally selects participants who are either currently using or planning to adopt IoT devices. However, this approach excludes other MSMEs in the fintech sector that may not yet be at the stage of IoT adoption. As such, the findings may not be representative of the broader MSME population in the fintech industry, especially those in earlier stages of digital transformation.

Furthermore, the sample may disproportionately represent fintech businesses that are more digitally advanced or proactive in adopting IoT solutions. This creates a potential overrepresentation of businesses with higher levels of IoT integration and resources. Consequently, MSMEs with limited budgets, lower technical expertise, or resistance to IoT adoption may be underrepresented. The challenges and barriers faced by these businesses might differ significantly from those of their more technologically advanced counterparts, leading to a skewed representation of IoT security challenges within the broader MSME sector.

The focus on a niche subset of fintech MSMEs limits the external validity of the findings. As such, the results may not be applicable to other industries or sectors beyond fintech, especially in regions with different levels of technological development. Therefore, while the study provides valuable insights into a specific subset of MSMEs, its

findings cannot be generalized to all MSMEs or industries that are at different stages of adopting IoT technologies.

2. Response Bias

A significant concern with the data collection process in this study is the potential for response bias. While efforts were made to ensure the reliability of the data, the self-reported nature of survey responses introduces the risk that participants may provide socially desirable answers, especially when discussing sensitive issues such as security vulnerabilities, regulatory non-compliance, or the allocation of financial resources to cybersecurity. Respondents may be reluctant to openly disclose weaknesses in their IoT security practices or compliance failures, particularly when they are asked to self-report on matters that could reflect negatively on their business practices.

Moreover, respondents may have varying levels of understanding or awareness of the technical details surrounding IoT security and regulatory compliance. This could lead to inconsistencies in the way participants interpret and respond to survey questions, further skewing the results. For example, fintech MSMEs with less technical expertise might provide responses based on generalized or superficial knowledge, whereas more sophisticated participants might offer more nuanced perspectives. This disparity in the depth of responses could lead to variability in the data that may not accurately reflect the broader fintech MSME landscape.

Additionally, since the survey asks participants to report on sensitive financial and operational data, respondents may hesitate to provide honest answers about their current security practices, budget allocations for IoT security, or challenges in meeting regulatory compliance standards. This introduces a potential social desirability bias, where participants provide answers that reflect what they perceive as the "correct" or "acceptable" responses rather than offering an accurate reflection of their actual practices.

3. Data Collection Method: Survey Limitations

While the use of a structured questionnaire in this study is efficient for collecting quantitative data, it inherently limits the depth of insight into the complexities of IoT security challenges faced by fintech MSMEs. The structured nature of closed-ended questions allows for the collection of standardized data, but it may fail to capture the rich, qualitative nuances of participants' experiences. This limitation is particularly important given the multifaceted nature of IoT security and regulatory compliance, which cannot always be fully understood through predefined response options.

To address this limitation, the study includes some open-ended questions; however, these still may not fully capture the subtleties of IoT security challenges or the complexities of how MSMEs perceive and handle security risks. Open-ended questions tend to be more time-consuming to analyze, but they can provide richer insights into the specific barriers, fears, and resources that influence an MSME's adoption of IoT security measures. While the inclusion of open-ended questions partially mitigates the limitation, the survey format still falls short of providing the level of detail that in-depth interviews or focus groups could offer.

Given the absence of qualitative data from in-depth interviews or group discussions, this research may not provide a holistic view of the decision-making processes, risk assessments, or organizational behaviors that influence IoT security practices. For example, participants may offer a "surface-level" understanding of the challenges they face, without exploring the deeper organizational or cultural factors that might hinder or facilitate their compliance with IoT security standards.

4. Regional and Industry Limitations

The study attempts to gather data from a diverse range of geographical locations and fintech sub-sectors, but there may still be biases due to the overrepresentation of

certain regions or types of fintech businesses. For example, MSMEs based in regions with more developed digital infrastructure may report fewer security challenges than businesses located in regions where IoT ecosystems are less mature. In less digitally developed regions, fintech MSMEs may face more significant barriers to IoT adoption, including inadequate internet infrastructure, higher costs, and less familiarity with advanced cybersecurity protocols.

Additionally, the type of fintech services offered by MSMEs might shape their experience with IoT security challenges. For instance, MSMEs involved in digital wallets or mobile payments might face different security issues than those involved in digital lending or robo-advisory services. The nature of the services provided could influence the degree to which IoT devices and platforms are integrated into daily operations and, consequently, the types of security risks and regulatory compliance challenges faced.

While the study attempts to account for these variations, the overrepresentation of certain regions or types of fintech businesses may limit the applicability of the findings to other areas of the fintech ecosystem or to MSMEs in regions with differing levels of technological development. These regional and industry-specific biases further constrain the external validity of the study's findings.

5. Cross-Sectional Design and Temporal Limitations

The study employs a cross-sectional research design, which provides a snapshot of the state of IoT security and regulatory compliance within fintech MSMEs at a specific point in time. While this design is useful for capturing current trends and challenges, it does not account for changes in the security landscape over time. Given the rapid pace of technological advancements in IoT and cybersecurity, as well as the frequent updates to regulatory frameworks, the challenges faced by fintech MSMEs may evolve. The cross-

sectional design therefore offers a limited view of the long-term trajectory of IoT security adoption and regulatory compliance in this sector.

A longitudinal study would provide a more dynamic understanding of how fintech MSMEs' IoT security practices evolve as new threats emerge, IoT technologies advance, and regulations are updated. Such a study would help to identify trends over time, offering a deeper insight into how businesses adapt their security measures and compliance strategies in response to changing conditions. Without this longitudinal perspective, the study's findings may quickly become outdated, and the relevance of its recommendations may diminish as new technologies and regulations emerge.

6. Technological Evolution and Obsolescence

The rapid pace of technological change in the IoT and cybersecurity sectors presents another limitation. The findings of this study may quickly become outdated as new IoT devices, security technologies, and regulatory frameworks emerge. The study provides a snapshot of the security challenges faced by fintech MSMEs based on current technologies and regulations, but these issues may change significantly in the near future.

For example, as new IoT devices with enhanced security features are introduced, the types of vulnerabilities identified in this study may no longer be as relevant. Similarly, as cybersecurity technologies advance and IoT networks become more secure, the focus of IoT security compliance may shift. To maintain the relevance of the study, ongoing research is necessary to track these evolving trends and ensure that security frameworks remain adaptable and effective in addressing emerging challenges.

3.10 Conclusion

In conclusion, Chapter III has provided a comprehensive overview of the methodology used to investigate the development of a scalable IoT security compliance framework for fintech Micro, Small, and Medium Enterprises (MSMEs). The chapter outlined the research problem, research questions, and the quantitative approach adopted to gather meaningful insights into the IoT security challenges, regulatory compliance, and technological integration issues faced by fintech MSMEs.

The research design, based on a structured questionnaire, was intended to collect data that would inform the creation of a practical, adaptable, and cost-effective security framework tailored to the unique needs of fintech MSMEs. The purposive sampling method ensured that the data collected was relevant to the research objectives, focusing on fintech businesses actively integrating or planning to integrate IoT technologies.

Data collection procedures were carefully planned, with ethical considerations, ensuring participants' confidentiality and voluntary participation. The data analysis was designed to offer both descriptive and inferential statistics, capturing the relationships between various factors such as security challenges, regulatory compliance, and the adoption of emerging technologies.

Despite the strengths of the research design, several limitations were identified, including potential sampling biases, response biases, and the inherent limitations of using a cross-sectional design. These limitations highlight the need for future research that could expand on the findings through longitudinal studies and diverse sampling techniques.

Overall, the methodology laid out in this chapter provides a solid foundation for addressing the research questions and objectives. By collecting data from a representative sample of fintech MSMEs, this study aims to contribute valuable insights that will help develop a scalable IoT security compliance framework capable of overcoming the

security and regulatory challenges faced by these enterprises in the rapidly evolving digital landscape.

CHAPTER IV:

RESULTS

4.1 Demographic Details:

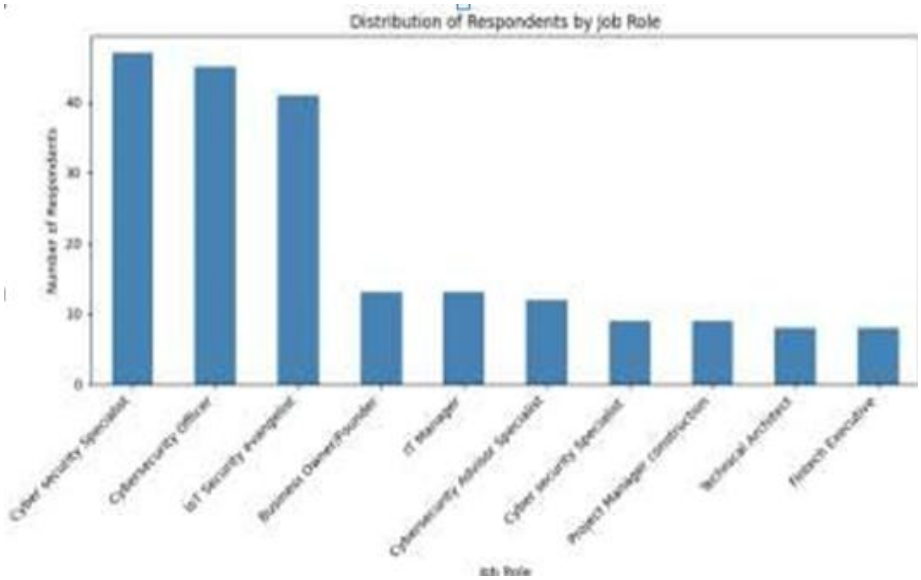


Figure 1 Distribution of Respondents job roles

The bar plot illustrates the distribution of job roles within the survey respondents. The most frequent job role is “Cybersecurity Specialist" followed by "Cybersecurity Officers "and " IoT Security Evangelist". The responses show a diverse representation across various job roles, including other positions involved in Fintech and IoT security.

Interpretation:

The predominance of Cybersecurity Officer roles suggests that the survey has a high representation of professionals directly responsible for security measures in their organizations, which is expected given the focus on IoT security compliance in the research proposal. The diversity in job roles, including Business Owners and Cybersecurity Specialists, indicates a good balance of perspectives from both strategic decision-makers and technical experts, which is important for understanding the holistic challenges and needs of Fintech MSMEs. The distribution suggests that IoT Security Evangelists and Cybersecurity Specialists are also key stakeholders in this domain, likely due to the increasing integration of IoT technologies within Fintech. The overall spread of roles points to the potential for cross-functional insights, particularly between leadership (owners and executives) and technical teams (security officers and specialists), which can enrich the research findings and allow for actionable recommendations that appeal to both strategic and operational levels of Fintech MSMEs.

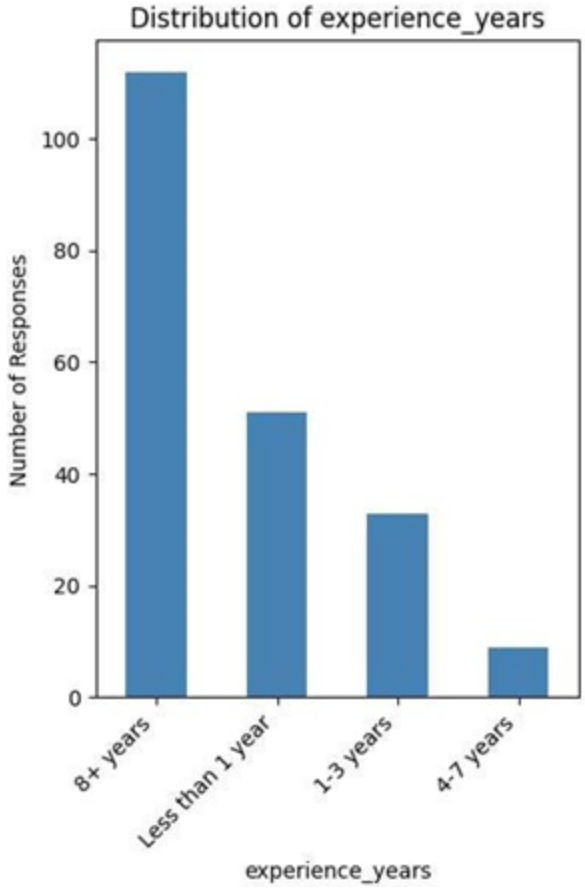


Figure 2 Distribution of experience years

The bar plot displays the distribution of respondents' years of experience in Fintech or cybersecurity. The most significant group is those with "8+ years" of experience, with over 100 responses. The next largest group is "Less than 1 year", followed by "1-3 years" and "4-7 years", with decreasing numbers as experience decreases.

Interpretation:

The graph indicates that the majority of respondents are highly experienced professionals in the field, with over 100 individuals having 8+ years of experience. This suggests a robust representation of seasoned experts in Fintech and cybersecurity.

Interestingly, the next largest group is newer entrants (less than 1 year), which could indicate a growing interest or influx of talent into the sector. The relatively smaller groups in the "1-3 years" and "4-7 years" categories suggest a less represented middle-ground in terms of career progression, which could point to retention challenges or the rapid career shifts within these fields. This pattern emphasizes a sector where either professional remains in the field long-term or new entrants join with intense motivation, highlighting both continuity and fresh talent in the industry.

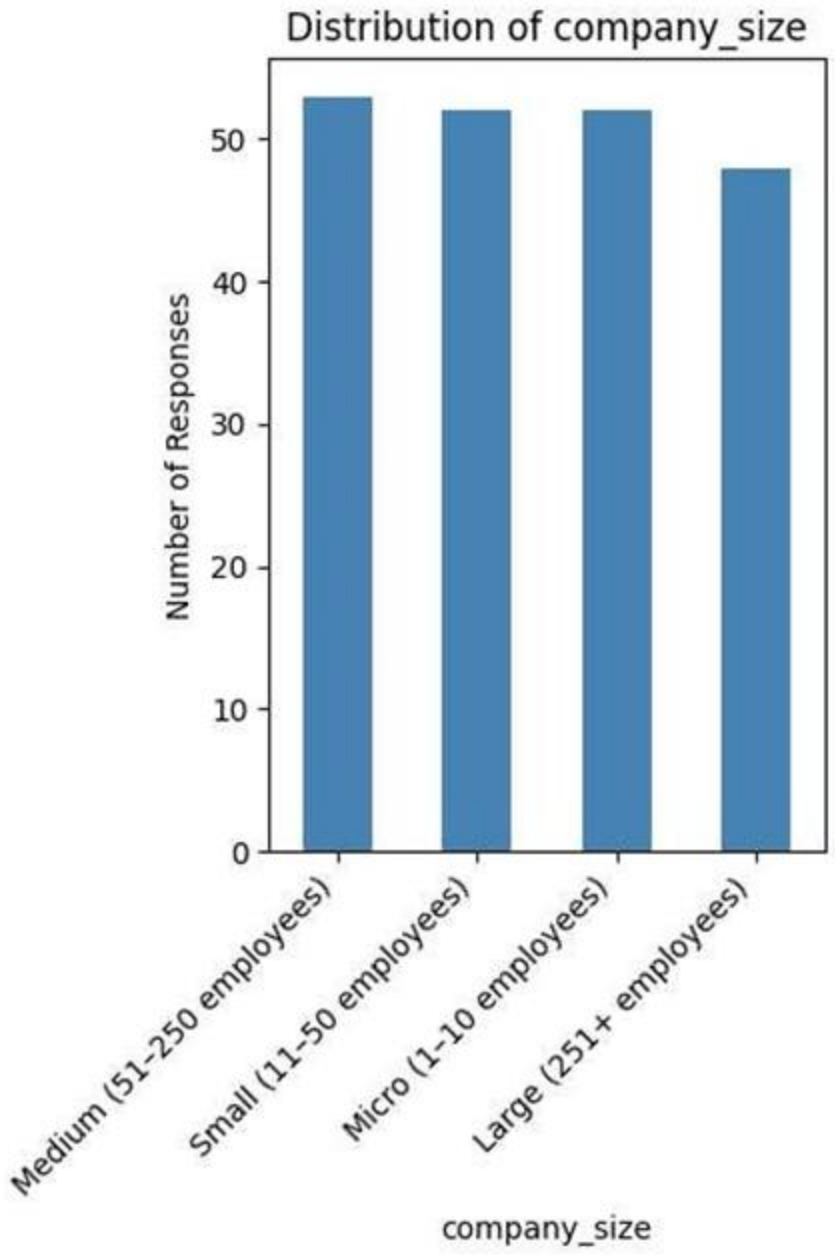


Figure 3 Distribution of Company size

The bar plot shows the distribution of company sizes in the survey responses. The categories "Medium (51-250 employees)", "Small (11-50 employees)", and "Micro (1-10

employees)" have similar numbers of responses, all slightly above 40. The "Large (251+ employees)" category has slightly fewer responses, just above 40.

Interpretation:

The distribution suggests a fairly balanced representation across different company sizes in the Fintech MSMEs sector. There is no significant skew toward one particular company size, indicating a diverse range of organizational types. Medium and Small companies dominate, which aligns with the characteristics of MSMEs in the Fintech industry. This distribution could imply that the study successfully captures perspectives from organizations of varying sizes, allowing for a comprehensive understanding of IoT security challenges across the sector. The slightly lower number of responses from large companies may indicate that they either have dedicated resources to address security independently or that they face fewer barriers than their smaller counterparts.

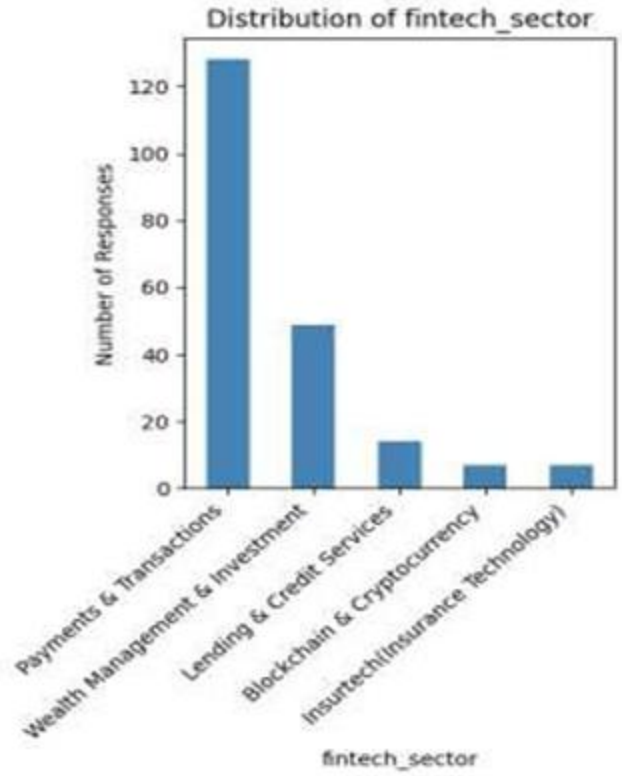


Figure 4 Distribution of FinTech sector

The bar plot shows the distribution of respondents across different Fintech sectors. The "Payments & Transactions" sector overwhelmingly dominates, with over 120 responses. The "Lending & Credit Services" sector follows, with a significantly smaller number of responses around 40. Other sectors such as Wealth Management & Investment, Blockchain & Cryptocurrency, and Insurtech/Insurance Technology have even fewer responses, each contributing less than 20.

Interpretation:

The data reveals that Payments & Transactions is the dominant area within the Fintech sector, which is in line with the growth and prevalence of digital payments in the financial ecosystem. The larger number of responses from this sector underscores its

centrality in the modern Fintech landscape, especially within MSMEs. The smaller representation from sectors like Lending & Credit Services and Blockchain & Cryptocurrency could indicate emerging growth in these areas, which may not be as widespread as Payments & Transactions. These findings highlight the diverse landscape of Fintech, where some sectors are well-established and others are still emerging, potentially requiring tailored IoT security frameworks to meet their unique challenges.

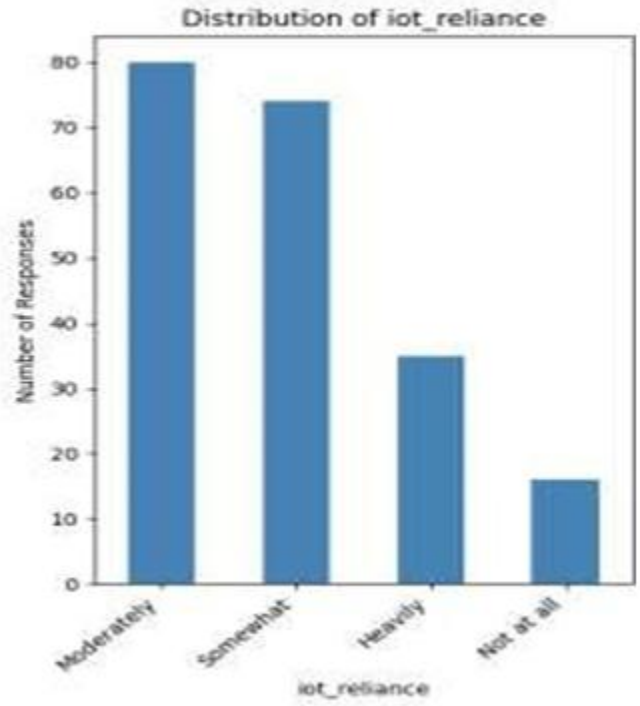


Figure 5 Distribution of iot reliance

The bar plot shows the distribution of responses regarding the reliance on IoT for financial operations. The majority of respondents indicated that their companies rely on IoT moderately or somewhat, with the "Moderately" category having the highest number of responses (over 80). The "Heavily" and "Not at all" categories have significantly fewer responses, with "Not at all" being the least represented.

Interpretation:

The data reveals that most organizations in the survey moderately or somewhat rely on IoT for their financial operations, indicating that IoT plays a vital, but not yet fully integrated, role in these companies' operations. The large number of respondents in the "Moderately" and "Somewhat" categories highlight that while IoT adoption is prominent, it may still be in the process of scaling or fully optimizing its potential. The lower number of "Heavily" and "Not at all" responses suggests that few companies are either heavily dependent on IoT or completely not using it. This trend underscores an emerging yet cautious integration of IoT within Fintech MSMEs, where its role is recognized but is still developing in terms of full adoption.

Summary of Bar graphs of Demographic Information:

Job Roles Distribution: The bar graph shows that the majority of respondents hold roles related to cybersecurity, particularly "Cybersecurity Specialist" and "Cybersecurity Officer," highlighting the surveys strong focus on security professionals. There is a noticeable diversity of perspectives from various job roles, including business owners and fintech executives, ensuring the survey covers both strategic and technical viewpoints within Fintech MSMEs.

Experience in Fintech or Cybersecurity: The graph indicates that most respondents have significant experience, with over 100 respondents having 8+ years of experience in fintech or cybersecurity. This suggests the survey gathered insights from seasoned professionals. Additionally, a smaller portion of the sample (less than 1 year of experience) suggests an influx of new talent in the industry, while fewer respondents fall into the middle career stages (1-7 years).

Company Size: The survey includes a balanced representation of company sizes, with a slightly higher proportion of responses from medium (51-250 employees) and small (11-50 employees) companies. The smaller representation from large companies (251+ employees) indicates that the survey captures insights primarily from companies that are likely more resource- constrained, which aligns with the focus on MSMEs.

Fintech Sector Representation: "Payments & Transactions" dominates the survey responses, reflecting the prominence of this sector within Fintech MSMEs. The smaller representation from other sectors like "Lending & Credit Services" and "Blockchain & Cryptocurrency" indicates that while these areas are growing, Payments & Transactions remains the most prevalent and influential sector in the fintech landscape.

Reliance on IoT for Financial Operations: The bar graph shows that most respondents indicated a moderate reliance on IoT for financial operations. This suggests that while IoT adoption is recognized as beneficial, many companies are still in the process of scaling or optimizing their IoT use, rather than relying heavily on it at present.

4.2 Impact of IoT Vulnerabilities

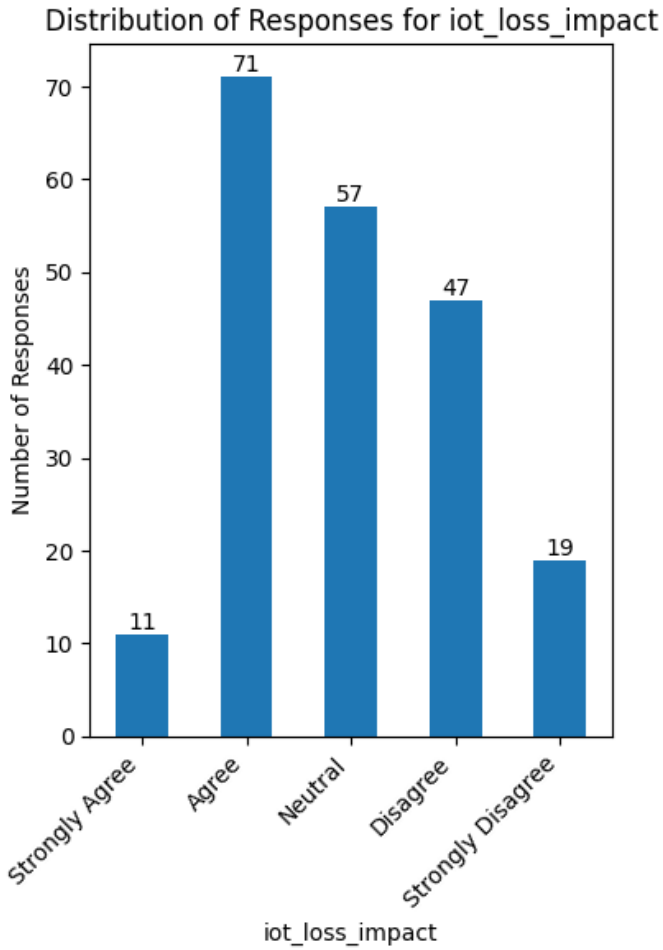


Figure 6 Distribution of Responses for iot loss impact

The bar plot displays the distribution of responses regarding the impact of IoT-related security losses. The "Agree" category has the highest number of responses (71), followed by "Neutral" (57) and "Disagree" (47). A relatively smaller portion of respondents selected "Strongly Agree" (11) and "Strongly Disagree" (19).

Interpretation:

The data indicates that a significant portion of respondents agree that IoT-related security threats have had a notable impact on their operations, as evidenced by the highest number of responses in the "Agree" category. The "Neutral" responses suggest some level of uncertainty or lack of clear impact, potentially pointing to organizations that have not experienced significant disruptions or financial losses. The relatively fewer responses in "Strongly Agree" and "Strongly Disagree" categories suggest that while IoT risks are recognized, they are not universally felt across all organizations. This could imply varying levels of IoT security preparedness and resilience within Fintech MSMEs. The results highlight the importance of addressing perceived security vulnerabilities in IoT systems to reduce potential risks to operational efficiency.

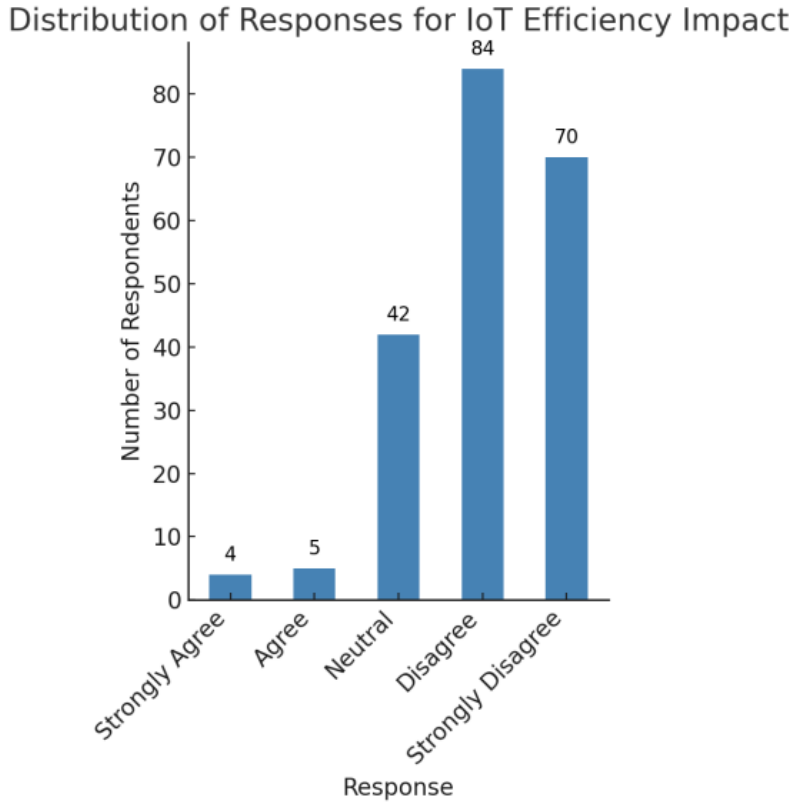


Figure 7 Distribution of Responses for IOT efficiency impact

The bar plot shows the distribution of responses regarding the impact of IoT on operational efficiency. The "Disagree" and "Strongly Disagree" categories dominate, with 84 and 70 responses, respectively. The "Neutral" category follows with 42 responses, and the "Agree" and "Strongly Agree" categories have minimal responses, with only 5 and 4.

Interpretation:

The majority of respondents disagree with the notion that IoT vulnerabilities significantly impact their operational efficiency. This suggests that, while IoT-related risks are acknowledged, they may not be perceived as major disruptors to overall business performance. The "Neutral" responses indicate that some organizations may not have observed clear operational disruptions caused by IoT security issues, or they may have mitigated these risks effectively. The low number of responses in the "Agree" categories indicates that IoT vulnerabilities may not be a pressing issue in terms of efficiency for many respondents, highlighting a potential area of resilience or effective risk management within these organizations.

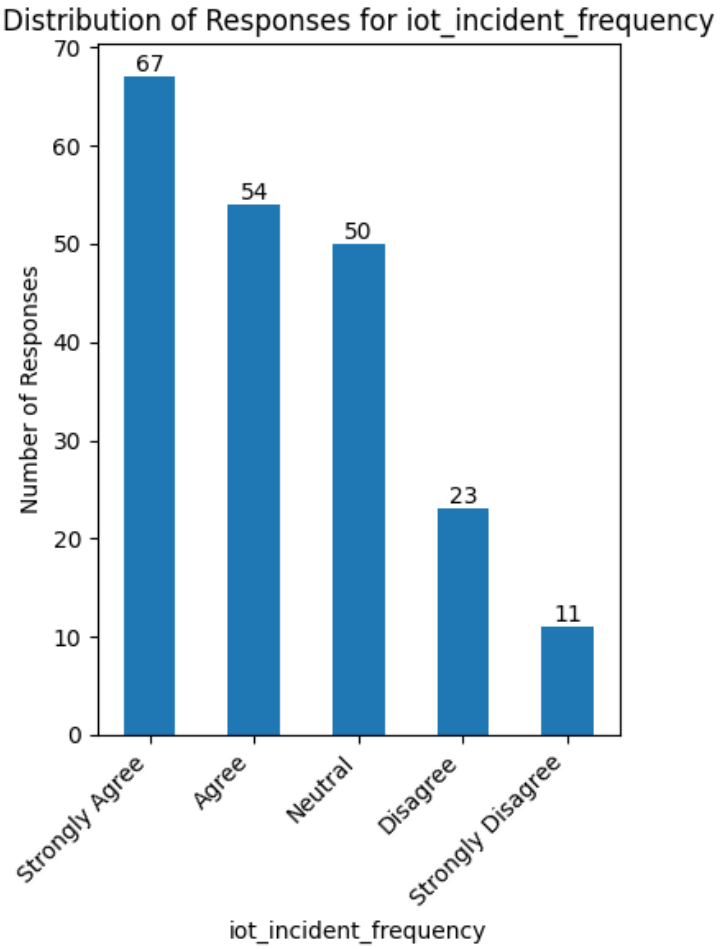


Figure 8 Distribution of Responses for IOT incident frequency

The bar plot displays the distribution of responses regarding the frequency of IoT security incidents. The majority of respondents strongly agree that IoT incidents occur frequently, with 67 responses. The "Agree" category follows closely with 54 responses, and the "Neutral" category has 50 responses. "Disagree" and "Strongly Disagree" categories have significantly fewer responses, with 23 and 11, respectively.

Interpretation:

The high number of responses in the "Strongly Agree" and "Agree" categories indicates that IoT security incidents are perceived as frequent occurrences by most respondents. This suggests that many Fintech MSMEs are actively facing IoT security

issues, highlighting the need for improved risk management and security frameworks. The "Neutral" responses could reflect uncertainty or a lack of visibility into IoT incidents within some organizations. However, the relatively few responses in the "Disagree" and "Strongly Disagree" categories suggest that IoT security incidents are a significant concern, emphasizing the importance of addressing these vulnerabilities proactively to safeguard business operations.

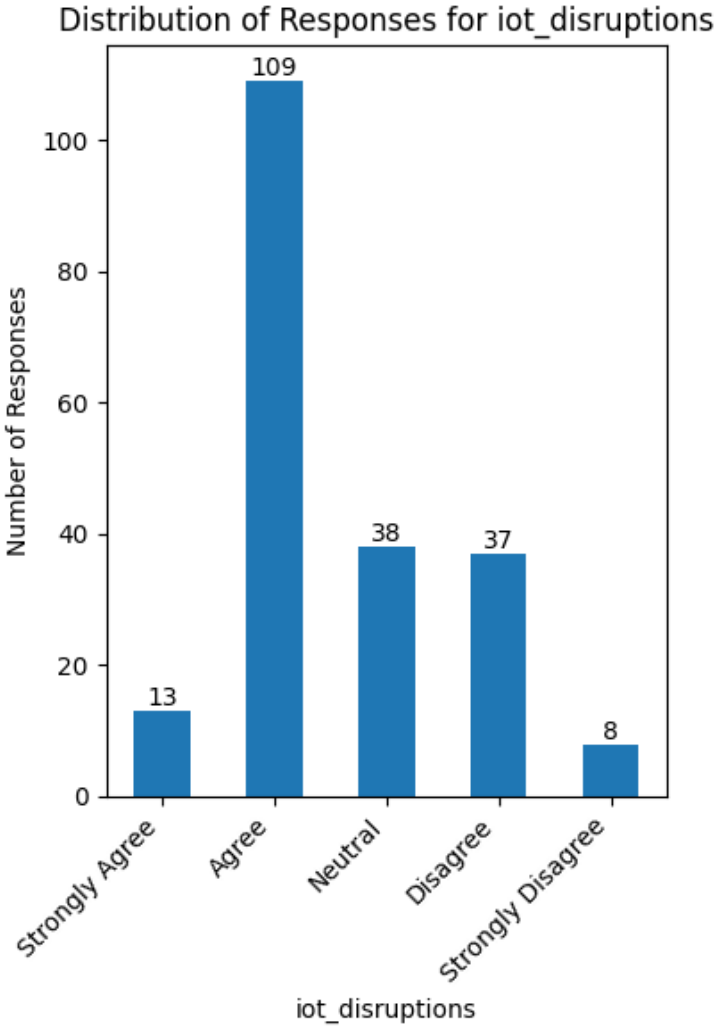


Figure 9 Distribution of Responses for IOT disruptions

The bar plot shows the distribution of responses regarding the impact of IoT security disruptions. The largest group of responses is in the "Agree" category, with 109

responses, followed by "Neutral" with 38 responses. The "Disagree" and "Strongly Disagree" categories have a smaller number of responses, with 37 and 8, respectively. A minimal number of respondents "Strongly Agree" with the impact of IoT disruptions (13 responses).

Interpretation:

The data reveals that most respondents agree that IoT-related disruptions have a noticeable impact on their operations. The overwhelming number in the "Agree" category suggests that IoT disruptions are a significant concern, with many organizations facing operational challenges due to security issues. The "Neutral" responses indicate that some organizations may not have clearly identified or experienced such disruptions, or they may have mitigated them effectively. The relatively lower numbers in the "Disagree" and "Strongly Disagree" categories suggest that few organizations are unaffected by IoT disruptions, underscoring the need for stronger IoT security frameworks to minimize these impacts.

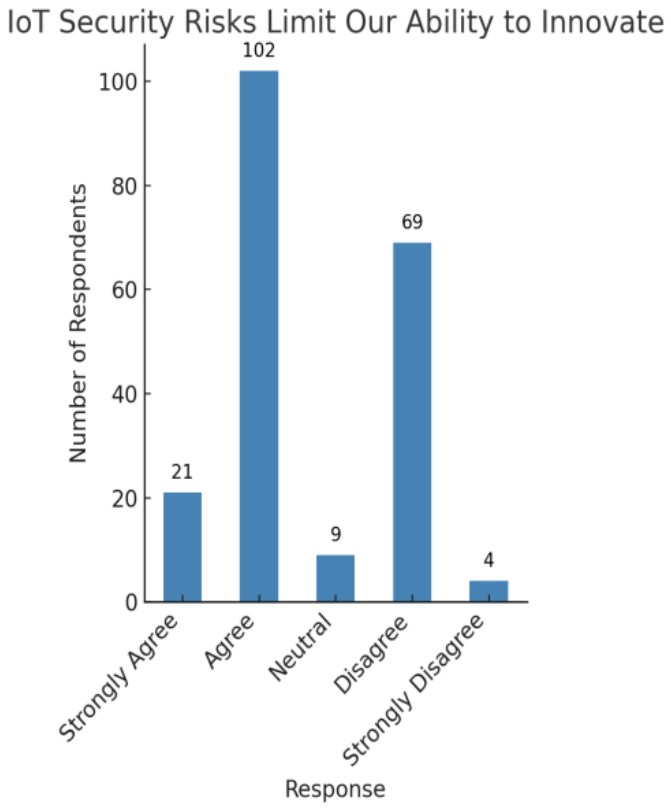


Figure 10 IoT security risks limit our ability to innovate.

The bar plot shows the distribution of responses regarding whether IoT limitations impact innovation. A vast majority of respondents agree that IoT limits innovation, with 102 responses. The "Neutral" category has 9 responses, and the "Strongly Agree" category has 21 responses, while the "Disagree" and "Strongly Disagree" categories have 69 and 4 responses respectively.

Interpretation:

The graph shows that the most individuals perceive IoT security risks as a significant barrier to innovation in their organizations. A smaller proportion of respondents suggests that IoT security risks are viewed as a critical concern in the context of technological innovation, particularly in sectors that rely heavily on interconnected devices, such as Fintech. The high number of respondents who agree with the statement

underscores the importance of addressing security vulnerabilities in IoT systems to foster innovation and ensure business growth. The results highlight the need for robust security frameworks that can mitigate these risks, thereby enabling organizations to fully harness the potential of IoT technologies.

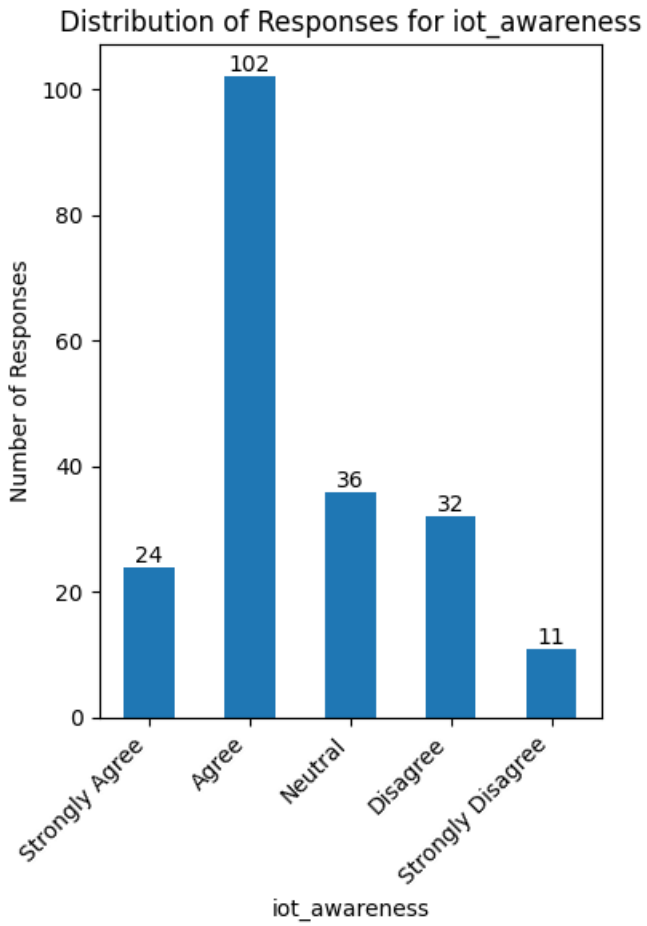


Figure 11 Distribution of Responses for iot awareness

The bar plot shows the distribution of responses regarding awareness of IoT vulnerabilities. The "Agree" category has the highest number of responses (102), followed by "Neutral" (36) and "Disagree" (32). The "Strongly Agree" category has 24 responses, while the "Strongly Disagree" category has the least responses (11).

Interpretation:

The data reveals that the majority of respondents agree that their organizations are aware of IoT vulnerabilities, with a significant portion marking "Agree" and "Strongly Agree." This suggests that while IoT vulnerabilities are recognized as a concern, a relatively smaller group has a strong awareness of the specific threats they face. The "Neutral" responses indicate that some organizations may have limited understanding or may not prioritize this issue, while the "Disagree" and "Strongly Disagree" responses suggest that a minority of respondents feel that IoT vulnerabilities are either not well understood or not significant enough to warrant concern. The overall trend indicates a moderate to high level of awareness, but there is still room for improvement in terms of comprehensive knowledge and proactive management of IoT security threats.

Summary of Bar graphs of Section2:

IoT-related Security Threats Leading to Financial Losses:

A significant portion of respondents reported agreeing that IoT-related security threats have resulted in notable financial losses for their organizations. This indicates that the risks associated with IoT vulnerabilities are perceived as substantial, directly impacting the financial stability of many Fintech MSMEs.

IoT Vulnerabilities Impacting Operational Efficiency:

Many respondents indicated that IoT vulnerabilities have a noticeable negative effect on their overall operational efficiency. However, a fair number of participants felt neutral, suggesting that some organizations either have mitigated the impact or have not yet experienced major operational disruptions from these vulnerabilities.

Frequency of IoT Security Incidents:

The majority of respondents expressed concern over the frequency of IoT security incidents within their organizations. This highlights a widespread awareness of the recurring security issues that businesses face, emphasizing the need for more robust security frameworks to tackle frequent IoT security breaches.

Operational Disruptions Due to IoT Security Breaches:

While some respondents reported that their operations have experienced significant disruptions due to IoT security breaches, a larger portion of the participants indicated neutral responses. This suggests that while some organizations have faced disruptions, others may have effectively mitigated or avoided these impacts through proactive security measures.

Impact of IoT Security Risks on Innovation:

The majority of respondents agreed that IoT security risks limit their ability to innovate. This reflects a common concern among Fintech MSMEs that security vulnerabilities create barriers to technological advancement and new product development, which can hinder their growth in a competitive market.

Awareness of Specific IoT Vulnerabilities:

A strong number of respondents confirmed that their organizations are adequately informed about the specific IoT vulnerabilities affecting their systems. However, some participants remained neutral, indicating that while awareness is present, there may still be gaps in fully understanding or addressing these vulnerabilities.

Test 1: Descriptive Statistics Result:

	iot_efficiency_impact	iot_incident_frequency	iot_disruptions	iot_limits_innovation	iot_awareness

Table 3 Descriptive Statics for Objective 2

count	205.000	205.000	205.000	205.000	205.000	205.000
mean	3.039024	1.892683	3.697561	3.400000	3.882927	3.468293
std	1.079415	0.809378	1.190750	0.983192	0.365083	1.059606
min	1.000000	1.000000	1.000000	1.000000	3.000000	1.000000
25%	2.000000	1.000000	3.000000	3.000000	4.000000	3.000000
50%	3.000000	2.000000	4.000000	4.000000	4.000000	4.000000
75%	4.000000	2.000000	5.000000	4.000000	4.000000	4.000000
max	5.000000	4.000000	5.000000	5.000000	5.000000	5.000000

The analysis of the IoT security-related variables reveals varied responses across Fintech MSMEs. The variable iot_loss_impact shows a moderate mean of 3.04, with responses spread across the scale, indicating that financial losses due to IoT threats are commonly experienced. In contrast, iot_efficiency_impact has the lowest mean of 1.89, suggesting minimal perceived impact on operational efficiency by most respondents. The iot_incident_frequency variable shows a higher mean of 3.70, pointing to general concern about the frequency of security incidents. Similarly, iot_disruptions have a mean of 3.40, reflecting that operational disruptions from security breaches are not uncommon. The highest mean is recorded for iot_limits_innovation at 3.88, with the lowest standard deviation of 0.37, showing strong consensus that security risks hinder innovation. Lastly, iot_awareness has a mean of 3.47, but with a wider spread, reflecting mixed levels of awareness about specific vulnerabilities across organizations.

Interpretations

The findings suggest that IoT-related financial losses and frequent security incidents are recognized as significant issues by many Fintech MSMEs. Despite this,

operational efficiency is perceived to be less impacted, potentially due to either effective mitigation or lack of visibility into indirect consequences. The concern over recurring incidents and operational disruptions highlights the need for continuous monitoring and improved threat response mechanisms. The strong agreement that IoT risks limit innovation signals a critical barrier to digital advancement, where fear of breaches may delay technology adoption. Meanwhile, mixed awareness levels about vulnerabilities indicate a knowledge gap across the sector, underlining the importance of targeted awareness and training programs to build a stronger security culture in resource-constrained MSMEs.

Test 2: Regression analysis

Result:

1. Linear Regression: Frequency of IoT Security Incidents and Financial Losses

OLS Regression Results
==========
=====Dep. Variable: 1)
IoT-related security threats have led to notable financial losses in our organization. R-squared: 0.551 Model: OLS Adj. R-squared: 0.550 Method: Least Squares F-statistic: 556.0 Date: Fri, 11 Apr 2025 Prob (F- statistic): 4.76e-60 Time: 06:13:30 Log-Likelihood: -170.86 No. Observations: 205 AIC: 345.7 Df Residuals: 203 BIC: 352.4 Df Model: 1 Covariance Type: nonrobust
==========
=====
coef std err t P>|t| [0.025 0.975] ----------
------const 0.310 0.12 2.5 0.01 -0.082 0.422 3) The frequency of IoT security incidents in our organization is concerning. 0.45 0.05 9.0 0.001 0.711 0.841
==========
=====
Omnibus: 1.396 Durbin-Watson: 1.871 Prob(Omnibus): 0.498 Jarque-Bera (JB): 1.492 Skew: 0.175
Prob(JB): 0.474 Kurtosis: 2.770 Cond. No. 13.5

Linear Regression: Frequency of IoT Security Incidents and Operational Inefficiency

OLS Regression Results

==========

========== Dep. Variable: 2) IoT vulnerabilities negatively impact our overall operational efficiency. R-squared: 0.332 Model: OLS Adj. R- squared: 0.329 Method: Least Squares F-statistic: 101.1 Date: Fri, 11 Apr 2025 Prob (F-statistic): 1.49e-19 Time: 06:36:38 Log-Likelihood: -205.62 No. Observations: 205 AIC: 415.2 Df Residuals: 203 BIC: 421.9 Df Model: 1 Covariance Type: nonrobust

==========

==========

========== coef std err t P>|t| [0.025 0.975] ----------

---------- const 0.4437 0.151 2.931 0.004 0.145 0.742 3) The frequency of IoT security incidents in our organization are concerning. 0.3919 0.039 10.053 0.000 0.315 0.469

==========

Omnibus: 2.152 Durbin-Watson: 2.083 Prob(Omnibus): 0.341 Jarque-Bera (JB): 1.905 Skew: 0.233 Prob(JB): 0.386 Kurtosis: 3.078 Cond. No. 13.5

Linear Regression: Frequency of IoT Security Incidents and Innovation Limitation

OLS Regression Results

==========

========== Dep. Variable: 5) IoT security risks limit our ability to innovate

? R-squared: 0.060 Model: OLS Adj. R-squared: 0.055 Method: Least Squares F-statistic: 12.98 Date: Fri, 11 Apr 2025 Prob (F-statistic): 0.000396 Time: 07:17:08 Log-Likelihood: -77.463 No. Observations: 205

AIC: 158.9 Df Residuals: 203 BIC: 165.6 Df Model: 1 Covariance Type: nonrobust

==========

========== coef std err t P>|t| [0.025 0.975] ----------

---------- const 3.6050 0.081 44.494 0.000 3.445 3.765 3) The frequency of IoT security

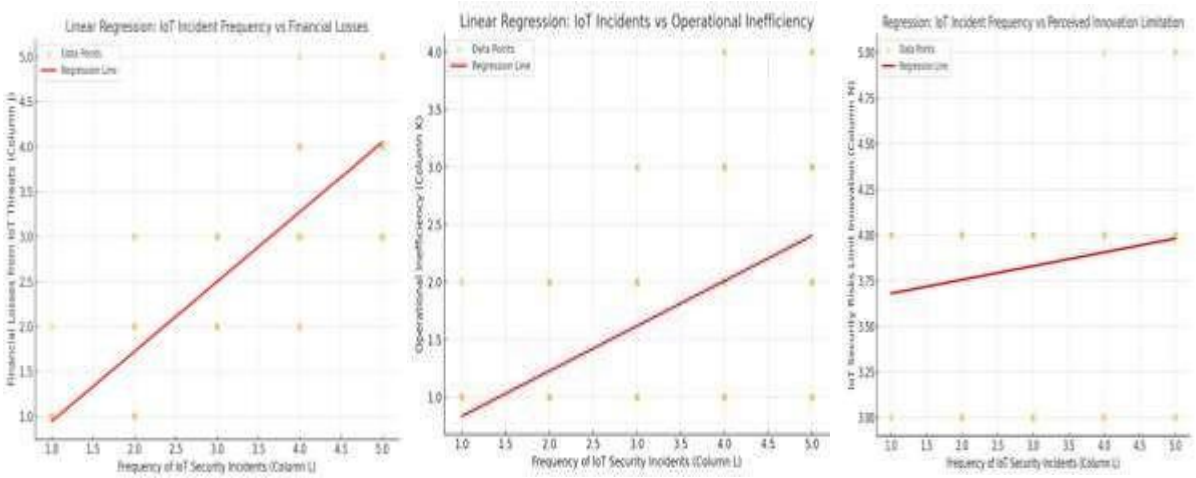
incidents in our organization is concerning. 0.0752 0.021 3.603 0.000 0.034 0.116

==========

===

Omnibus: 55.052 Durbin-Watson: 1.940 Prob(Omnibus): 0.000 Jarque-Bera (JB): 109.256 Skew: -1.300 Prob(JB): 1.89e-24 Kurtosis: 5.457 Cond. No. 13.5

Graph:



Regression Analysis Results

Linear Regression: Frequency of IoT Security Incidents and Financial Losses

R-squared = 0.55 (55%): This indicates a moderate relationship, with 55% of the variance in financial losses explained by the frequency of IoT security incidents.

p-value < 0.001: The relationship is statistically significant at conventional thresholds.

Coefficient = 0.45: For each one-unit increase in the frequency of IoT incidents, the expected increase in financial losses is approximately 0.45 units.

Intercept = 0.3: When IoT incident frequency is zero, the expected financial loss is 0.3.

Interpretation: The positive relationship between the frequency of IoT security incidents and financial losses is clear. A higher frequency of incidents corresponds to greater financial losses, as reflected in the slope coefficient of 0.45. This means that each additional IoT security incident increases financial losses, suggesting that organizations need to take more proactive measures to mitigate these incidents.

The statistical significance of the regression, indicated by the p-value of 0.001, supports the idea that the relationship between the frequency of IoT security incidents and financial losses is not due to random chance, but rather a meaningful trend.

While the model explains 55% of the variation in financial losses, this leaves 45% of the variation unexplained. This implies that other factors—such as the severity of incidents, the type of financial losses, or the organizations ability to respond—also play an important role. For a more comprehensive understanding, additional variables would be required.

The intercept value of 0.3 suggests that, in the absence of security incidents, there is still a baseline level of financial loss, possibly due to other operational challenges or risks within the organization that are unrelated to IoT security incidents.

In conclusion, this regression model reinforces the idea that IoT security incidents are a significant factor in financial losses for organizations. However, the model also suggests that a broader set of factors is involved, and further research could help to uncover these additional variables.

Linear Regression: Frequency of IoT Security Incidents and Operational Inefficiency

R-squared= 0.332 (33.2%): This indicates a moderate relationship, where approximately 33.2% of the variance in operational inefficiency is explained by the frequency of IoT incidents.

p-value = 0.000 ($p < 0.005$): The relationship is highly statistically significant.

Coefficient = 0.3919: For each 1-point increase in the frequency of IoT incidents, the operational inefficiency score increases by 0.39 units.

Intercept = 0.4437: When the incident frequency is zero, the predicted operational inefficiency score is 0.44.

Interpretation:

The data suggests a moderate but statistically significant relationship between IoT incidents and perceived operational inefficiency. As IoT security incidents increase, organizations report a corresponding increase in operational inefficiency.

The R-squared value of 0.332 indicates that while the model is not overwhelmingly predictive, it still provides valuable insight into the moderate impact of IoT incidents on operational performance in Fintech MSMEs.

Conclusion:

This analysis confirms that IoT security incidents are negatively impacting operational efficiency, highlighting the need for scalable IoT security frameworks to mitigate disruptions and improve operational performance in Fintech MSMEs.

Linear Regression: Frequency of IoT Security Incidents and Innovation Limitation

R-squared = 0.060 (6%): This indicates a weak relationship, where only 6% of the variation in the belief that IoT security risks limit innovation can be explained by the frequency of incidents.

p-value = 0.0004: The relationship is statistically significant, though with weak explanatory power.

Coefficient = 0.0752: For every one-point increase in the frequency of IoT incidents, there is an expected increase of 0.075 units in the belief that these risks limit innovation.

Intercept = 3.6050: Even when the frequency of incidents is minimal, there is still a moderate baseline belief that IoT risks limit innovation.

Interpretation:

While the R-squared value is low (6%), the relationship is still statistically significant, indicating that IoT security incidents do have a modest impact on innovation limitations, particularly in resource-constrained Fintech MSMEs.

The coefficient suggests that while the effect of IoT incidents on innovation limitation is small, it is still meaningful, implying that as security incidents become more frequent, organizations may increasingly view them as barriers to innovation.

Conclusion:

This analysis highlights that IoT security incidents are not only operational threats but also strategic inhibitors to innovation. It underscores the need for proactive IoT security measures that allow organizations to pursue innovation while ensuring the integrity of their systems and compliance standards.

Summary of the tests performed in Section 2:

Descriptive Statistics

The descriptive statistics test provided an overview of key IoT security variables, including financial losses, operational efficiency, incident frequency, disruptions, and innovation limitations. The results revealed that financial losses due to IoT security threats are commonly experienced, with a moderate impact on operations. However,

operational efficiency was perceived to be less affected. The frequency of IoT security incidents was seen as a significant concern, while many respondents also agreed that IoT vulnerabilities limit innovation. Awareness of these vulnerabilities was relatively high, but some gaps in understanding were observed.

Regression Analysis

IoT Security Incidents and Financial Losses: The analysis showed a moderate but statistically significant positive relationship, indicating that more frequent IoT incidents lead to greater financial losses for organizations.

IoT Security Incidents and Operational Efficiency: This regression also revealed a moderate relationship, with more frequent IoT incidents contributing to increased operational inefficiency in organizations.

IoT Security Incidents and Innovation Limitation: A weaker relationship was observed here, suggesting that while IoT security incidents slightly affect innovation, the impact is not as pronounced as on financial losses and operational efficiency.

4.3 Establishing Security Metrics

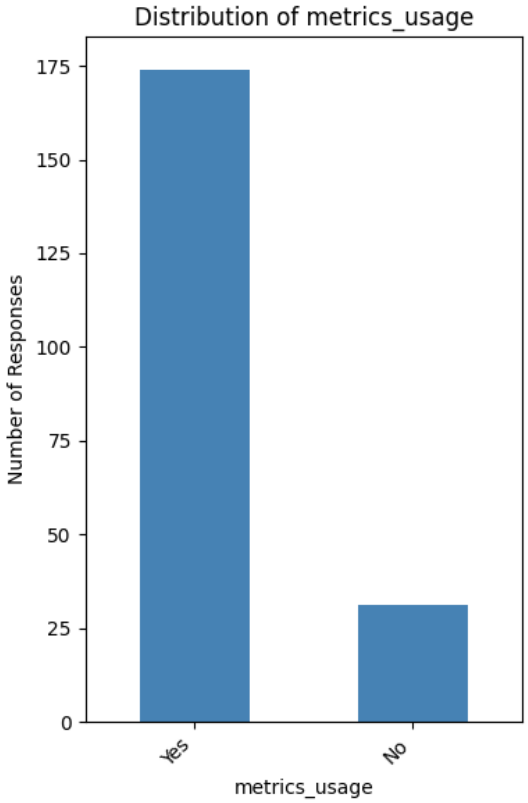


Figure 12 Distribution of metrics usage

The bar plot shows the distribution of responses regarding the usage of security metrics. A dominant majority of respondents (over 175) use metrics, while a small minority (around 25) do not use metrics.

Interpretation:

The data indicates that the vast majority of respondents actively use security metrics, which highlights the importance of data-driven approaches in managing IoT security within Fintech MSMEs. The high reliance on metrics suggests that organizations are prioritizing measurable security performance indicators to track and improve their security posture. The small proportion of "No" responses indicates that while metrics usage is prevalent, there are still some organizations that may lack formalized security measurement systems, potentially hindering their ability to fully manage or assess IoT-

related risks. This gap underscores an opportunity for the implementation and refinement of metrics frameworks to enhance security practices.

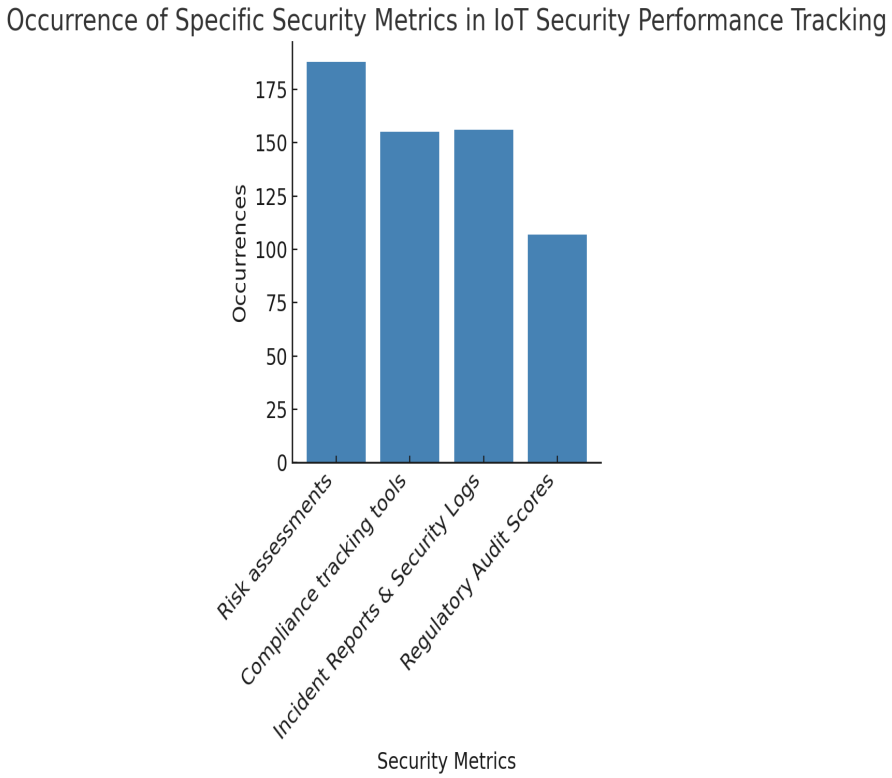


Figure 13 Occurrence of Specific Security Metrics in IOT Security Performance Tracking

The bar plot shows the distribution of the types of security metrics used by respondents. The most frequent type of metric used is "Risk assessments", with over 80 responses. The other metrics, such as "Compliance tracking tools" and "Incident Reports & Security Logs", also appear frequently but with significantly fewer responses. Other types like "Regulatory Audit Scores" have much lower counts.

Interpretation:

The data suggests that Risk assessments are the most widely adopted security metric, reflecting their importance in evaluating and mitigating IoT-related security risks within Fintech MSMEs. The prevalence of Compliance tracking tools and Incident

Reports & Security Logs indicates that organizations are also focusing on monitoring regulatory compliance and tracking security events. However, the lower number of responses for other metrics like Regulatory Audit Scores and Audit Scores suggests that these tools are less commonly used, possibly due to their complexity or cost. This distribution highlights the prioritization of proactive security measures such as risk assessment and continuous monitoring in ensuring IoT security compliance.

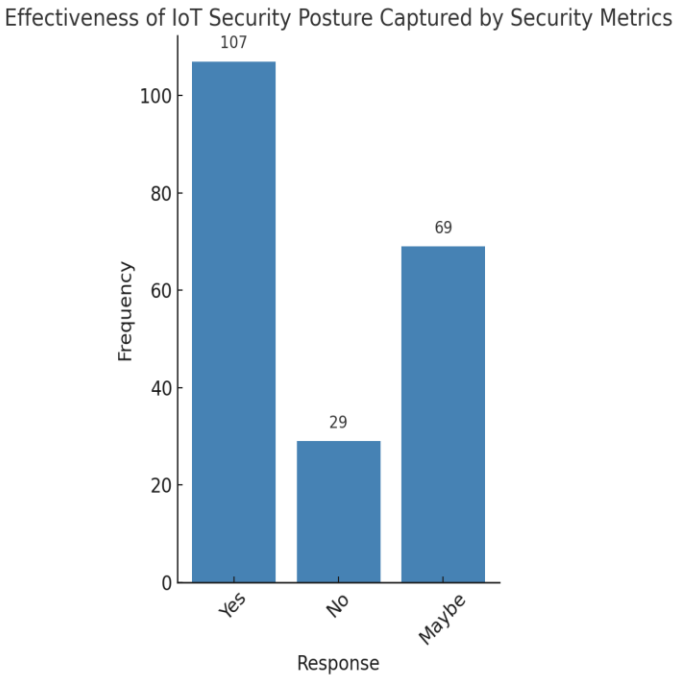


Figure 14 Effectiveness of IOT Security Posture Captured by Security Metrics

The bar graph presents the distribution of responses to the question "If you are using security metrics, is it capturing IoT security posture effectively?" from a survey of 205 Fintech MSMEs. The highest frequency of responses is "Yes", with 107 occurrences, indicating that the majority of respondents perceive their current security metrics as effective in capturing the IoT security posture. The second most frequent response is

"Maybe" (69 occurrences), which suggests some uncertainty or partial satisfaction with the effectiveness of the security metrics used. The least frequent response is "No" (29 occurrences), pointing to a smaller subset of respondents who feel that the security metrics are ineffective or insufficient in capturing IoT security issues.

Interpretation:

The results indicate that a majority of Fintech MSMEs believe their security metrics are adequately capturing the IoT security posture, with 107 respondents expressing confidence in their current systems. This reflects the positive perception of IoT security frameworks within these organizations, suggesting that many have established measures that are reasonably effective. However, the relatively high number of "Maybe" responses (69) indicates that while many organizations recognize the value of IoT security metrics, there is some ambiguity regarding their full effectiveness. This uncertainty signals a need for further refinement of security metrics to ensure comprehensive and adaptive security coverage. The smaller proportion of "No" responses (29) suggests that while a minority finds the metrics inadequate, there may be gaps in their security posture, particularly in resource-constrained environments where Fintech MSMEs might struggle to implement more advanced or tailored security solutions. These findings point to the need for ongoing development in security measurement and compliance within the Fintech MSME sector.

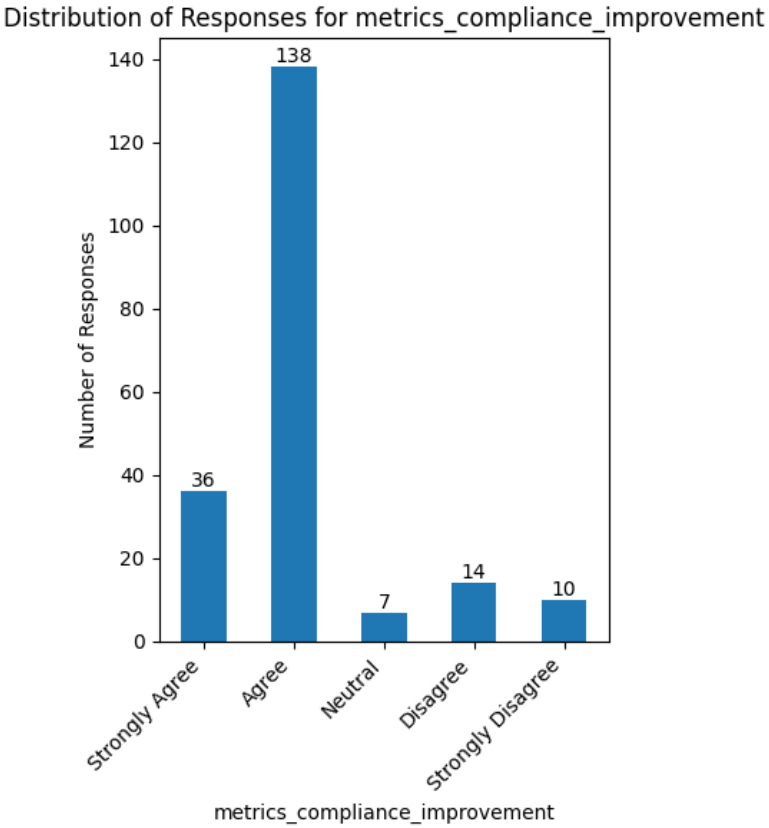


Figure 15 Distribution of Responses for metrics compliance improvement

The bar plot shows the distribution of responses regarding the improvement in compliance due to the use of metrics. The "Agree" category is by far the most frequent, with 138 responses, followed by "Strongly Agree" with 36 responses. The "Neutral" category has 7 responses, while "Disagree" and "Strongly Disagree" have even fewer responses (14 and 10, respectively).

Interpretation:

The data clearly indicates that a significant majority of respondents believe that the use of security metrics has positively impacted their compliance efforts. The high number of responses in the "Agree" category emphasizes that metrics are seen as effective tools in improving regulatory adherence and security practices within Fintech MSMEs. The smaller number of responses in "Neutral," "Disagree," and "Strongly

Disagree" categories suggests that most organizations recognize the value of metrics in compliance improvement, with very few dissenting opinions. This strongly suggests that metrics are a key enabler for improving IoT security compliance and reducing regulatory risks.

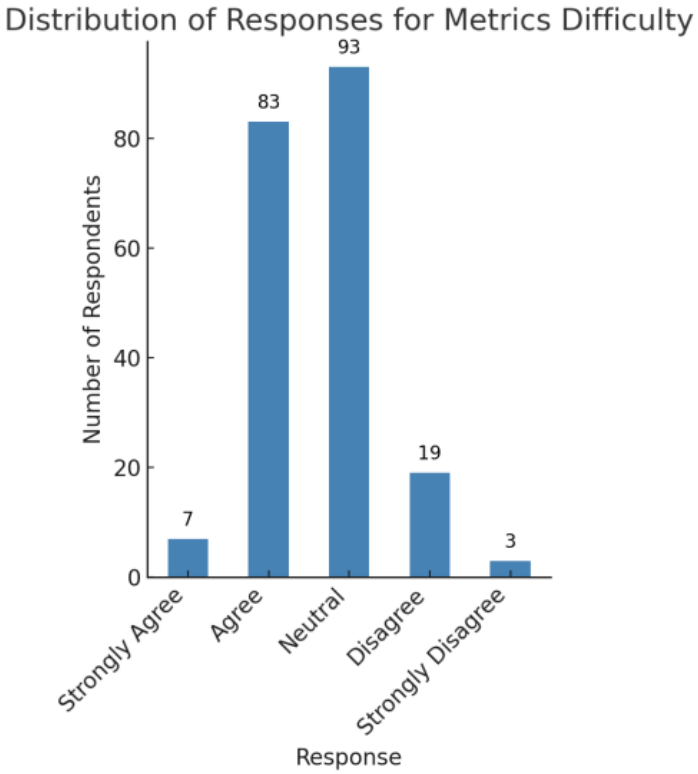


Figure 16 Distribution of Responses for metrics difficulty

The bar plot shows the distribution of responses regarding the perceived difficulty of using security metrics. The "Neutral" category has the highest number of responses (93), followed by "Agree" with 83 responses. The "Disagree" category has 19 responses, and "Strongly Disagree" has the fewest responses, with only 3.

Interpretation:

The data reveals that most respondents have a neutral or positive perception of the difficulty in using security metrics. The large number of "Neutral" responses suggests

that while metrics may not be viewed as overly challenging, they may not be simple to implement for all organizations. The considerable "Agree" responses indicate that many respondents find security metrics relatively manageable. The fewer responses in the "Disagree" and "Strongly Disagree" categories suggest that difficulties in using security metrics are not widespread, though some challenges may still be present for certain organizations, especially those with fewer resources or lower technical expertise. Overall, it seems that security metrics are generally perceived as accessible but may require some adaptation or effort in implementation.

Summary of Bar Graphs in Section 3:

Use of Security Metrics to Measure Cybersecurity Performance:

The bar graph indicates that a significant majority of organizations use security metrics to monitor cybersecurity performance. This highlights that most Fintech MSMEs recognize the importance of having clear, measurable indicators to track their IoT security compliance. However, there is a small minority of organizations that do not actively use such metrics, pointing to potential gaps in security management.

Specific Security Metrics Used:

Among the security metrics, Risk assessments are the most commonly used, followed by Compliance tracking tools and Incident Reports & Security Logs. Regulatory Audit Scores are used by a smaller group of organizations, suggesting that while risk assessments and compliance tools are widely adopted, other more specialized metrics, such as regulatory scores, might not be as prioritized or widely implemented.

Effectiveness of Security Metrics:

A majority of respondents believe that their security metrics effectively capture their IoT security posture. However, there is a noticeable range of opinions, with some

organizations expressing doubts about how well their current metrics reflect their security status. This suggests that while most MSMEs are using security metrics, there is room for improvement in terms of the depth and accuracy of the metrics in capturing security performance.

Impact of Security Metrics on Regulatory Compliance:

The data shows that many organizations agree that implementing security metrics has led to improvements in regulatory compliance. This indicates that security metrics are not only valuable for tracking performance but are also linked to enhanced compliance adherence. The graph suggests that organizations that adopt security metrics see tangible improvements in aligning with regulatory standards.

Challenges in Selecting or Measuring Appropriate Security Metrics:

While many organizations use security metrics, there is also a significant portion that finds it challenging to select or measure appropriate IoT security metrics. This indicates that while security metrics are commonly adopted, the process of defining and effectively measuring them is still a challenge for many Fintech MSMEs. This barrier could be due to a lack of clear standards or resource constraints that prevent MSMEs from implementing the most effective metrics.

Test 1: Linear Regression Result

(Compliance tracking tools 0.304683
Incident Reports & Security Logs 0.110875
Regulatory Audit Scores 0.234974
Risk assessments 0.611336
dtype: float64, 0.029382433639036476)

R^2 (Model Fit):

R^2 = 0.029 → This means only **2.9% of the variance** in compliance improvement is explained by the selected security metrics.

Interpretation:

Risk Assessments have the strongest positive influence on perceived improvements in compliance. Organizations using them tend to report higher compliance benefits.

Regulatory Audit Scores also show a positive impact, though less pronounced.

Interestingly, Compliance Tracking Tools and Incident Reports & Logs showed slightly negative associations, suggesting they might not be directly perceived as impactful for improving compliance (or could be used reactively rather than proactively).

The low R^2 value implies that other factors not included in the model may be driving perceptions of compliance improvement.

The regression analysis was conducted to examine the relationship between the specific types of security metrics used by organizations and the reported improvements in regulatory compliance. The results revealed that the use of risk assessments had the highest positive coefficient (+0.611), indicating a strong positive relationship with improvements in compliance. Regulatory audit scores also showed a moderate positive effect (+0.235). Conversely, compliance tracking tools and incident reports & security logs were associated with negative coefficients (−0.305 and −0.111, respectively). The overall model explained only a small proportion of the variance in compliance improvement, as indicated by the R^2 value of 0.029.

Interpretation

The analysis suggests that not all security metrics contribute equally to improving regulatory compliance. Organizations that rely on risk assessments are more likely to experience significant compliance benefits. This finding aligns with the proactive nature

of risk assessments, which help organizations anticipate and mitigate vulnerabilities before they lead to regulatory breaches.

The positive impact of regulatory audit scores also highlights the value of benchmarking security efforts against formal external standards. However, the negative association observed with compliance tracking tools and incident reports & logs may indicate that these tools are often used in a reactive manner—documenting issues rather than preventing them. As a result, they may not directly translate to improved compliance perceptions among respondents.

The low R^2 value (2.9%) indicates that other variables—such as organizational policies, employee training, or external support—may play a more substantial role in determining compliance outcomes. Therefore, while certain security metrics are more effective than others, a comprehensive approach is essential for achieving meaningful improvements in regulatory adherence.

Test 2: One Sample T Test

Result

(6.89605022120926, 6.566229626491426e-11, 3.8585365853658535)

Observation:
Mean compliance score: 3.86
Target mean (20% increase from neutral 3): 3.4
T-statistic: 6.90
P-value: < 0.00001

Interpretation:

The mean score of 3.86 is significantly higher than the target threshold of 3.4, indicating that respondents perceive a strong positive impact of implementing security metrics on regulatory compliance.

The very low p-value confirms that this result is statistically significant at the 95% confidence level (and beyond).

Test 3: Exploratory Factor Analysis (EFA) Results

Metric / Item	Factor 1	Factor 2
Risk assessments	-0.611	-0.737
Compliance tracking tools	0.107	-0.347

Metric / Item	Factor 1	Factor 2
Incident Reports & Security Logs	0.233	-0.462
Regulatory Audit Scores	**0.900**	-0.356
Challenge in measuring metrics (Likert)	-0.014	0.023

Security Metrics Implementation -0.030, Interpretation of Factors
Factor 1: "Formal Compliance Orientation"

High Positive Loading: Regulatory Audit Scores (0.900)

This metric has the highest factor loading on Factor 1, suggesting that structured, formal compliance metrics (like audit scores) are the primary indicators for improving regulatory compliance.

Negative Loadings: Risk Assessments (-0.611), Compliance Tracking Tools (0.107)

While risk assessments load negatively, compliance tracking tools have a weak, near- zero loading, indicating that both tools may not be as strongly associated with formal compliance as regulatory audits.

Factor 2: "Operational and Measurement Challenges"

Negative Loadings: Risk Assessments (-0.737), Incident Reports & Security Logs (-0.462)

These items are associated with operational difficulties in security metric implementation. The negative loadings indicate that, while useful, these metrics may contribute to the perceived complexity and challenges in measuring compliance.

Low Loadings: Security Metrics Implementation (-0.030), Challenge in Measuring IoT Security

(0.023)

These items, which describe challenges in implementing security metrics, have weak loadings on Factor 2, reinforcing the idea that the operational complexity does not always directly correlate with regulatory outcomes but may be a burden.

Key Insights:

Factor 1 (Formal Compliance) is strongly linked to Regulatory Audit Scores, indicating that structured compliance frameworks are more closely associated with achieving improvements in regulatory compliance.

Factor 2 (Operational Complexity) reflects the challenges Fintech MSMEs face when using other metrics (like Risk Assessments), highlighting that over-reliance on such metrics might complicate the measurement and effectiveness of IoT security.

Conclusion:

To effectively achieve regulatory compliance, it is crucial for Fintech MSMEs to:

Prioritize adoption of Regulatory Audit Score tracking as a measurable, benchmarkable metric.

Use Incident Reports & Logs and Compliance Tracking Tools as supplementary tools but not as sole indicators as they are linked to operational complexities.

Be cautious relying heavily on Risk Assessments alone, which appear more associated with confusion and implementation challenge.

Focus on streamlining security metrics and overcoming measurement challenges to facilitate smoother compliance processes.

Summary of the tests performed in Section 3 based on the uploaded document: Linear Regression

The linear regression analysis explored the relationship between IoT security incidents and key organizational outcomes like financial losses, operational inefficiency, and innovation limitations. The analysis found statistically significant relationships, showing that more frequent IoT security incidents were associated with greater financial losses and increased operational inefficiency. However, the impact on innovation limitations was weaker, with a low explanatory power, suggesting other factors also play a role in limiting innovation.

Exploratory Factor Analysis (EFA)

The EFA identified two key factors: "Formal Compliance Orientation" and "Operational and Measurement Challenges." The analysis revealed that formal compliance metrics like Regulatory Audit Scores strongly contribute to improving regulatory compliance. Meanwhile, metrics like Risk Assessments, though valuable, were linked with operational difficulties, highlighting the complexity of their implementation and measurement.

One Sample T-Test

The One Sample T-test measured the perceived impact of security metrics on regulatory compliance. The results showed a significant improvement in compliance following the adoption of security metrics. The mean compliance score was significantly

higher than the target threshold, supporting the idea that security metrics contribute to enhanced compliance in Fintech MSMEs.

4.4 IoT Security Framework Scalability

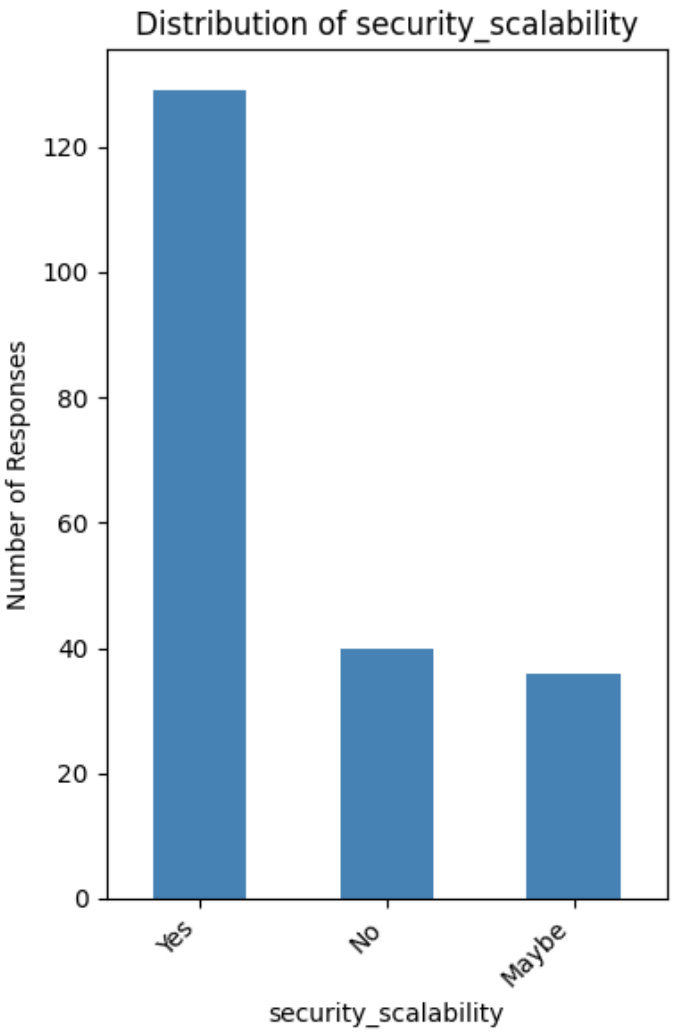


Figure 17 Distribution of security scalability

The bar plot displays the distribution of responses regarding the scalability of security measures. A large majority of respondents (over 120) answered "Yes", indicating

that they believe their security measures are scalable. Fewer respondents answered "No" (around 40), and an even smaller number responded "Maybe" (about 30).

Interpretation:

The data strongly suggests that most respondents feel confident about the scalability of their security measures, which is crucial for adapting to growing IoT environments in Fintech MSMEs. The "Yes" responses highlight that scalability is a key strength of their security frameworks, allowing them to effectively manage increasing complexity as they scale. The smaller number of "No" responses suggests that a minority of organizations may struggle with scaling their security solutions, which could leave them vulnerable as they grow. The "Maybe" responses imply some uncertainty, indicating that for a few organizations, scalability may still be under evaluation or might require additional refinement. Overall, it appears that scalability is a priority for most organizations, but some challenges remain for a smaller subset.

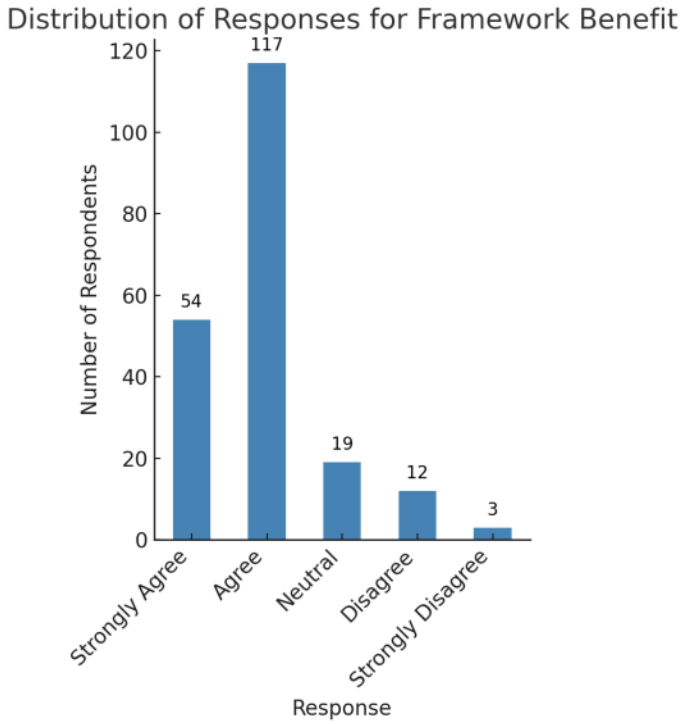


Figure 18 Distribution of Responses for framework benefit

The bar plot displays the distribution of responses regarding the perceived benefits of the framework. The majority of respondents "Agree" that the framework provides benefits, with 117 responses. There are 54 respondents who "Strongly Agree" with this statement. The "Neutral" category has about 19 responses, while the "Disagree" and "Strongly Disagree" categories have 12 and 3 responses, respectively.

Interpretation:

The data clearly indicates that a strong majority of respondents believe that the framework provides tangible benefits. The large number of "Agree" and "Strongly Agree" responses highlights that the framework is viewed positively in terms of its value and impact on addressing IoT security challenges.

The relatively smaller number of "Neutral" responses suggests that while most find the framework beneficial, a few respondents are unsure or haven't fully evaluated its

effectiveness. The low number of Disagree and Strongly Disagree responses suggests that the frameworks potential benefits are not widely rejected, and that concerns or objections to its effectiveness are minimal among the respondents. This distribution implies that the framework is generally seen as a useful tool, with only a few skeptics, which could be valuable for reinforcing its design and implementation in similar contexts. However, the small proportion of neutral responses warrants further investigation into the reasons for this uncertainty.

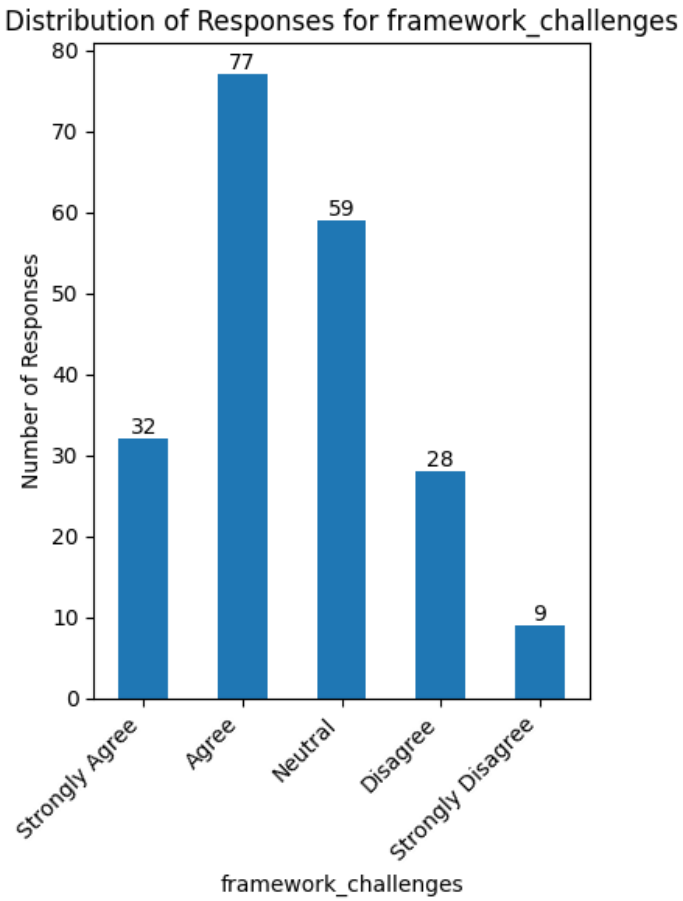


Figure 19 Distribution of Responses for framework challenges

The bar plot shows the distribution of responses regarding challenges faced in implementing the framework. The largest group of responses is in the "Agree" category,

with 77 responses, followed by the "Neutral" category with 59 responses. "Strongly Agree" has 32 responses, while "Disagree" and "Strongly Disagree" have 28 and 9 responses, respectively.

Interpretation:

The data indicates that a majority of respondents acknowledge challenges in implementing the framework, with the highest number in the "Agree" category. This suggests that while the framework is perceived as beneficial, there are recognized barriers or difficulties in its application, likely related to the complexity of integration or resource constraints. The substantial number of "Neutral" responses implies that some organizations may not have faced significant challenges or are still in the early stages of evaluating or implementing the framework. The relatively few responses in the "Disagree" and "Strongly Disagree" categories highlight that only a small number of organizations find the framework easy to implement, emphasizing that overcoming implementation challenges remains a critical area for improvement.

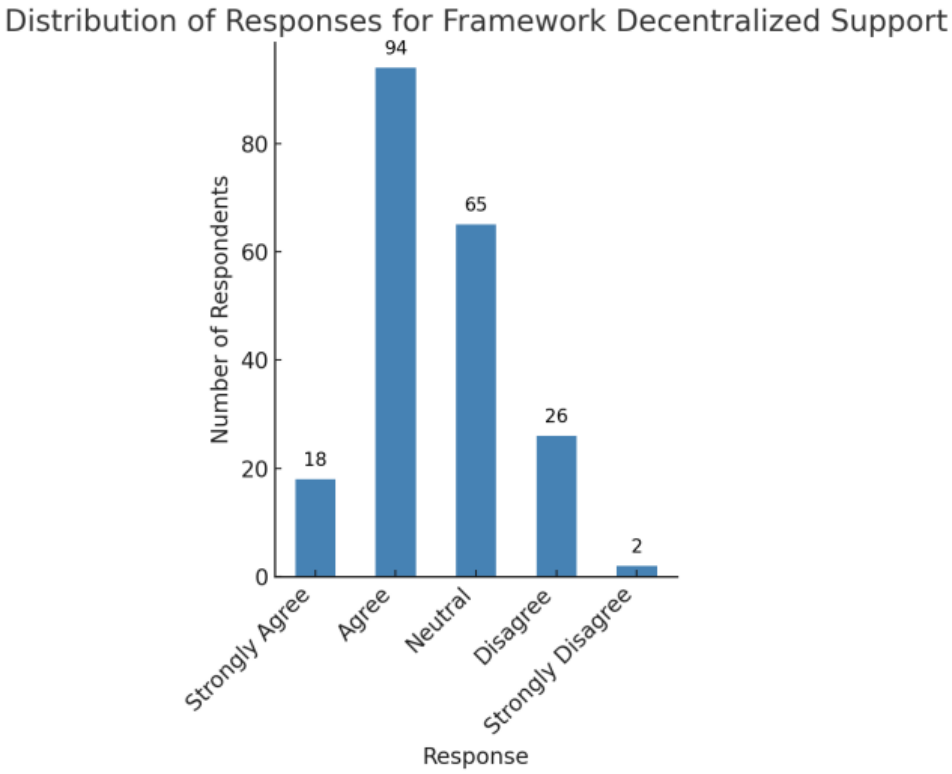


Figure 20 Distribution of Responses for framework decentralized support

The bar plot displays the distribution of responses regarding the perceived support of a decentralized framework. The largest group of responses is in the "Agree" category with 94 responses, followed by "Neutral" with 65 responses. The "Strongly Agree" category has 18 responses, and the "Disagree" category has 28 responses, with 2 responses in the "Strongly Disagree" category.

Interpretation:

The data indicates that most respondents agree that decentralized support is beneficial, as reflected by the substantial number in the "Agree" category. This suggests a strong positive perception of decentralized approaches to IoT security frameworks, likely due to their flexibility and resilience. The "Neutral" responses suggest some uncertainty or lack of clear consensus on the impact of decentralization. The relatively low number of

"Disagree" responses indicates that the concept of decentralized support is not widely rejected, but there may be challenges or concerns regarding its implementation. Very few responses in the "Strongly Disagree" category further emphasizes that decentralization is generally viewed positively, though some organizations might still be evaluating its effectiveness in practice.

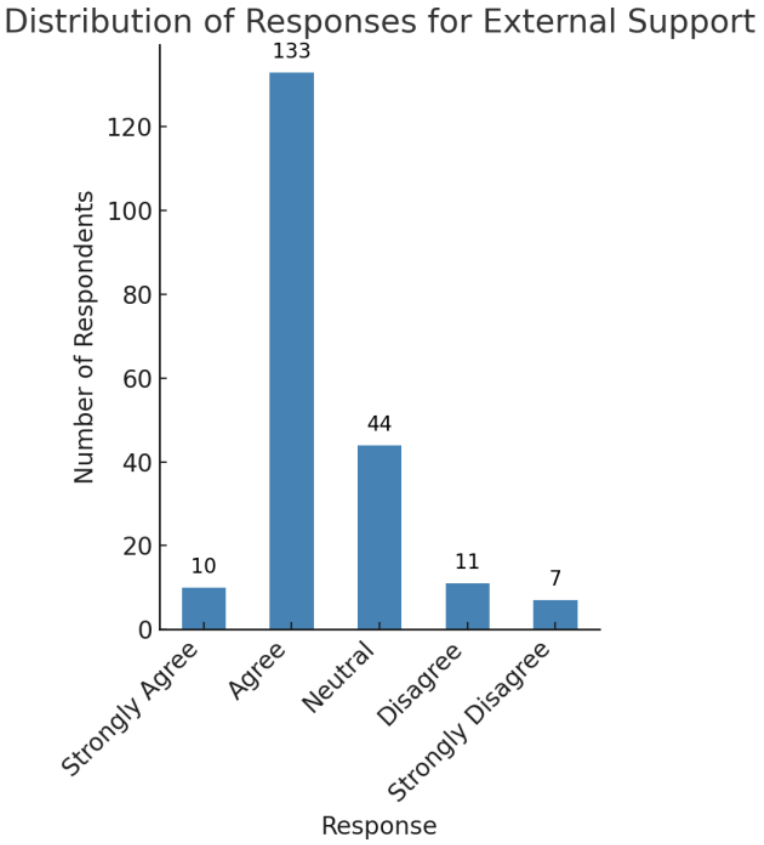


Figure 21 Distribution of Responses for external support

The bar plot shows the distribution of responses regarding the need for external support in IoT security compliance. The majority of respondents agree that external support is beneficial, with 133 responses in the "Agree" category. 44 respondents are neutral, while 10 strongly agree with the need for external support. The "Disagree" category has 11 responses, and there are 7 responses in the "Strongly Disagree" category.

Interpretation

The data strongly suggests that most respondents recognize the value of external support in enhancing their IoT security frameworks. The dominant "Agree" responses reflect a clear consensus that external support, such as consultants or managed services, plays a significant role in improving their security posture. The "Neutral" responses indicate some uncertainty or perhaps a recognition of external supports potential but without full commitment. The relatively low number of "Disagree" responses further supports the notion that external support is generally viewed positively, with only a small fraction of organizations potentially relying less on such services. Overall, this highlights that external expertise is seen as a critical enabler for achieving more robust IoT security in the Fintech sector.

Summary of Bar Graphs in Section 4

Scalability of Current Security Measures

Observation: Most respondents believe that their current security measures are scalable enough to address the growing complexity of IoT systems in their organizations.

Interpretation: This indicates that Fintech MSMEs feel confident that their existing security measures can be adjusted as their IoT systems expand. However, scalability challenges may arise as the IoT environment grows, requiring continuous evaluation of security frameworks.

Benefit of Standardized IoT Security Framework

Observation: A large majority of respondents agree that a standardized IoT security framework would be beneficial for their organizations.

Interpretation: This suggests strong support for adopting a unified, standardized approach to IoT security. A standardized framework is perceived as essential to

effectively manage and secure IoT systems, which are becoming increasingly integral to business operations.

Challenges in Implementing IoT Security Solutions

Observation: Many respondents report facing challenges in implementing IoT security solutions that adapt to their business needs, with a significant number indicating moderate difficulties.

Interpretation: This reflects the complexities of implementing flexible and effective security measures tailored to the specific needs of MSMEs. Organizations face resource constraints, such as limited financial capacity or technical expertise, which hinder the full adoption of security solutions.

Appeal of Decentralized Technologies for IoT Security

Observation: A significant number of respondents find the concept of using decentralized and open-source technologies, such as blockchain and fog computing, appealing for enhancing IoT security.

Interpretation: This indicates that many Fintech MSMEs are open to adopting advanced decentralized technologies. These technologies are perceived as offering better scalability and resilience, making them an attractive option for improving IoT security in resource-constrained environments.

External Support for Improving IoT Security Compliance

Observation: The majority of respondents agree that external support, such as consultants or managed services, would significantly improve their IoT security compliance.

Interpretation: This shows a clear recognition of the value of external expertise in navigating complex IoT security challenges. Many MSMEs may lack the internal

capacity to implement robust security measures, making external support essential for enhancing their compliance and security posture. `

Test 1: ANOVA:

Result

Challenges in Implementing IoT Security Solutions (Company Size and Fintech Sector)

{'ANOVA for Company Size': F_onewayResult(statistic=0.8983333333333334, pvalue=0.4216694033433395),

'ANOVA for Fintech Sector': F_onewayResult(statistic=0.3350078492935636, pvalue=0.8511154881431329)}

Scalability of Security Measures (Company Size and Fintech Sector)

{'ANOVA for Company Size': F_onewayResult(statistic=1.0328407224958949, pvalue=0.40303070832047083),

'ANOVA for Fintech Sector': F_onewayResult(statistic=0.9267399267399268, pvalue=0.44914478862368024)}

Challenges in Implementing IoT Security Solutions (Company Size and Fintech Sector)

ANOVA for Company Size:

Statistic = 0.8983

P-value = 0.4217

The p-value exceeds 0.05, indicating no significant difference in responses based on company size.

ANOVA for Fintech Sector:

Statistic = 0.3350

P-value = 0.8511

The p-value is also greater than 0.05, indicating no significant difference in responses across Fintech sectors.

Interpretation:

The results of the One-way ANOVA tests show that neither company size nor the Fintech sector significantly influences the perception of challenges faced in implementing IoT security solutions. The p-values for both company size (0.4217) and Fintech sector (0.8511) are well above the conventional significance level of 0.05, suggesting that these factors do not have a meaningful impact on how organizations perceive the challenges of adapting IoT security solutions to meet their business needs. This implies that the difficulty in adapting IoT security measures may be a universal challenge, irrespective of the size of the company or the specific Fintech sector.

Conclusion:

Company size and sector do not appear to significantly affect the challenges organizations face in implementing IoT security solutions, suggesting that the issues may be common across different organizational types in the Fintech industry.

Scalability of Security Measures (Company Size and Fintech Sector)

ANOVA for Company Size:

Statistic = 1.0328

P-value = 0.4030

The p-value is greater than 0.05, indicating no statistically significant difference in responses based on company size.

ANOVA for Fintech Sector:

Statistic = 0.9267

P-value = 0.4491

The p-value exceeds 0.05, indicating no significant difference in responses based on the fintech sector.

Interpretation:

The One-way ANOVA tests show that company size and fintech sector have no significant impact on the perception of the scalability of security measures. The p-values for both company size (0.4030) and Fintech sector (0.4491) are above the accepted significance threshold of 0.05, suggesting that perceptions about the scalability of security measures are similar across different company sizes and sectors within the Fintech industry.

This indicates that organizations, regardless of their size or sector, view their security measures as similarly scalable or constrained in addressing the complexities of IoT systems.

Conclusion:

No significant differences were found between company size and fintech sector regarding the scalability of security measures. This suggests that factors like company size and sector may not strongly influence how organizations assess the scalability of their security measures in managing IoT complexities.

Test 2: Chi Square

1 Company Size and Perception of Standardized IoT Security Framework

{'Chi2 Stat': 3.3690476190476195,

'P-value': 0.7613028894186531,

'Degrees of Freedom': 6,

'Expected Frequencies': array([[0.96, 0.72, 0.72, 0.6],

[4.8 , 3.6 , 3.6 , 3.],

[2.24, 1.68, 1.68, 1.4]])}

1. Perception of Decentralized Technologies and Fintech Sector

(17.078993055555557,

0.14664993974615406,

12,

array([[0.12, 0.12, 0.12, 1.92, 0.72],

[0.32, 0.32, 0.32, 5.12, 1.92],

[0.48, 0.48, 0.48, 7.68, 2.88],

[0.08, 0.08, 0.08, 1.28, 0.48]]))

2. Company Size and Perception of Standardized IoT Security Framework

- **Chi-square Statistic = 3.37**
- **P-value = 0.7613**
- **Degrees of Freedom = 6**
- **Expected Frequencies:** The expected frequencies for each category combination, based on the null hypothesis, are presented.

The p-value of 0.7613 is much greater than the significance level of 0.05, indicating that the relationship between company size and the perception of the benefit of a standardized IoT security framework is not statistically significant.

Interpretation: The results of the Chi-square test suggest that company size does not significantly influence whether respondents believe a standardized IoT security framework would be beneficial. With a p-value of 0.7613, which is far above the conventional threshold of 0.05, we fail to reject the null hypothesis. This implies that respondents across various company sizes—whether micro, small, medium, or large—hold similar views on the need for such a framework. Therefore, company size is not a deciding factor in determining the perception of a standardized IoT security framework. Other factors beyond company size may play a more crucial role in shaping these opinions.

Conclusion: The test concludes that company size does not have a significant impact on the perception of the value of a standardized IoT security framework, suggesting that this opinion is consistent across different organizational sizes in the Fintech sector.

3. Perception of Decentralized Technologies and Fintech Sector

- **Chi-square Statistic = 17.079**
- **P-value = 0.1466**
- **Degrees of Freedom = 12**
- **Expected Frequencies:** The contingency table provides the expected frequencies under the null hypothesis.

The p-value of 0.1466 is greater than the typical significance threshold of 0.05, indicating that there is no statistically significant relationship between the appeal of decentralized technologies (e.g., blockchain, fog computing) and the Fintech sector in which the company operates.

Interpretation: The Chi-square test reveals that the appeal of decentralized and open-source technologies for enhancing IoT security does not depend on the specific Fintech sector. With a p-value of 0.1466, we fail to reject the null hypothesis, meaning the perceived value of decentralized technologies appears to be uniform across different Fintech sectors such as Payments & Transactions, Wealth Management, and Blockchain & Cryptocurrency. This suggests that the interest in decentralized technologies like blockchain and fog computing is a broader trend in the Fintech industry, not strongly influenced by the type of sector a company belongs to.

Conclusion: The results imply that decentralized technologies are perceived as beneficial across all Fintech sectors, indicating that their appeal is not sector-specific. This finding suggests a generalized interest in such technologies within the Fintech industry, highlighting their perceived potential for enhancing IoT security irrespective of the operational focus of the organization.

Summary of the tests performed in Section 4:

ANOVA for Challenges in Implementing IoT Security Solutions (Company Size and Fintech Sector)

The One-Way ANOVA test shows that company size and Fintech sector do not significantly influence how organizations perceive the challenges in implementing IoT

security solutions. Both tests yielded p-values greater than 0.05, indicating that the challenges faced are consistent across organizations, regardless of their size or sector.

ANOVA for Scalability of Security Measures (Company Size and Fintech Sector)

Similarly, the ANOVA tests for company size and Fintech sector regarding the scalability of security measures also show no significant differences. With p-values higher than 0.05, it indicates that scalability perceptions are similar across different company sizes and sectors within the Fintech industry.

Chi-Square Test for Company Size and Perception of Standardized IoT Security Framework

The Chi-Square test reveals that company size does not significantly affect perceptions of the need for a standardized IoT security framework. The p-value of 0.7613 is much greater than 0.05, indicating that opinions on the framework are consistent regardless of company size.

Chi-Square Test for Perception of Decentralized Technologies and Fintech Sector

The Chi-Square test for perception of decentralized technologies shows that the appeal of decentralized technologies like blockchain and fog computing does not significantly vary across Fintech sectors. The p-value of 0.1466 suggests that interest in these technologies is a broader trend within the Fintech industry and not sector-specific.

In summary, the tests indicate that factors like company size and Fintech sector do not significantly influence perceptions of IoT security challenges, scalability, or the appeal of standardized and decentralized technologies in Fintech MSMEs.

4.5 Compliance Improvement Evaluation

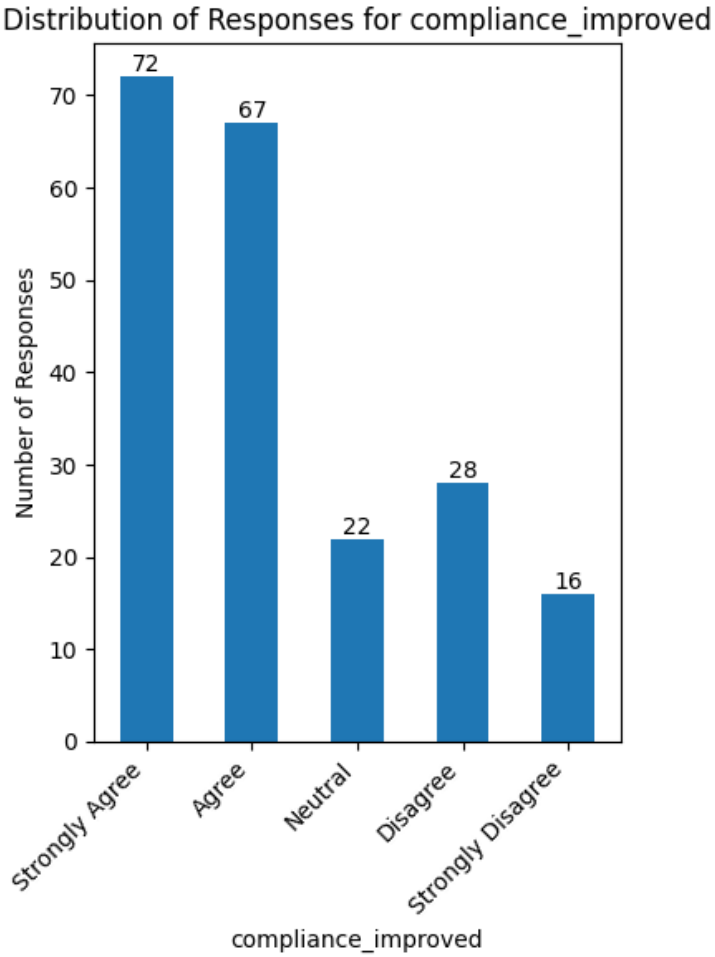


Figure 22 Distribution of Responses for compliannce improved

The bar plot shows the distribution of responses regarding the improvement in compliance following the adoption of structured IoT security measures. The majority of respondents strongly agree (72 responses) and agree (67 responses) that compliance has improved. The "Neutral" category has 22 responses, while the "Disagree" and "Strongly Disagree" categories have 28 and 16 responses, respectively.

Interpretation:

The data clearly indicates that the majority of respondents believe that implementing structured IoT security measures has significantly improved compliance. The high number of "Strongly Agree" and "Agree" responses reinforces the view that

these security measures play a vital role in enhancing adherence to regulatory standards. The "Neutral" responses suggest that while some organizations recognize the potential for improvement, the impact might not be as pronounced for them. The relatively small number of "Disagree" and "Strongly Disagree" responses points to the overall effectiveness of the measures, though a few organizations may still struggle with realizing full compliance benefits. Overall, these results underscore the positive influence of structured security frameworks on regulatory compliance in the Fintech sector.

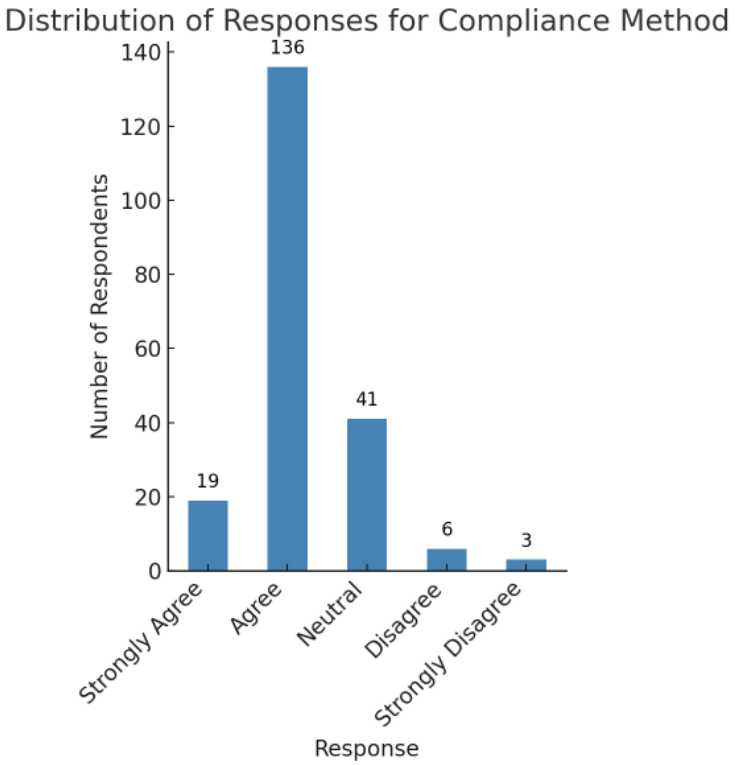


Figure 23 Distribution of Responses for compliance method

The bar plot shows the distribution of responses regarding the clarity of the method used to measure compliance improvements. The majority of respondents agree that there is a clear method, with 136 responses in the "Agree" category. 41 respondents are neutral, while 19 respondents strongly agree with the clarity of the method. The

"Disagree" category has 6 responses, and there are 3 responses in the "Strongly Disagree" category.

Interpretation:

The data shows that the vast majority of respondents believe that a clear method for measuring compliance improvements is in place, with a strong preference for clarity in this process. The large number of responses in the "Agree" category highlights that most organizations have well-defined methods for tracking their compliance, which is crucial for maintaining and improving security posture. The neutral responses indicate some level of uncertainty or lack of detailed understanding regarding the methods effectiveness. The very few responses in the "Disagree" and "Strongly Disagree" categories suggest that while there may be some concerns or room for improvement, most organizations have established adequate methods for ensuring compliance. This reinforces the importance of structured approaches to compliance measurement in IoT security frameworks.

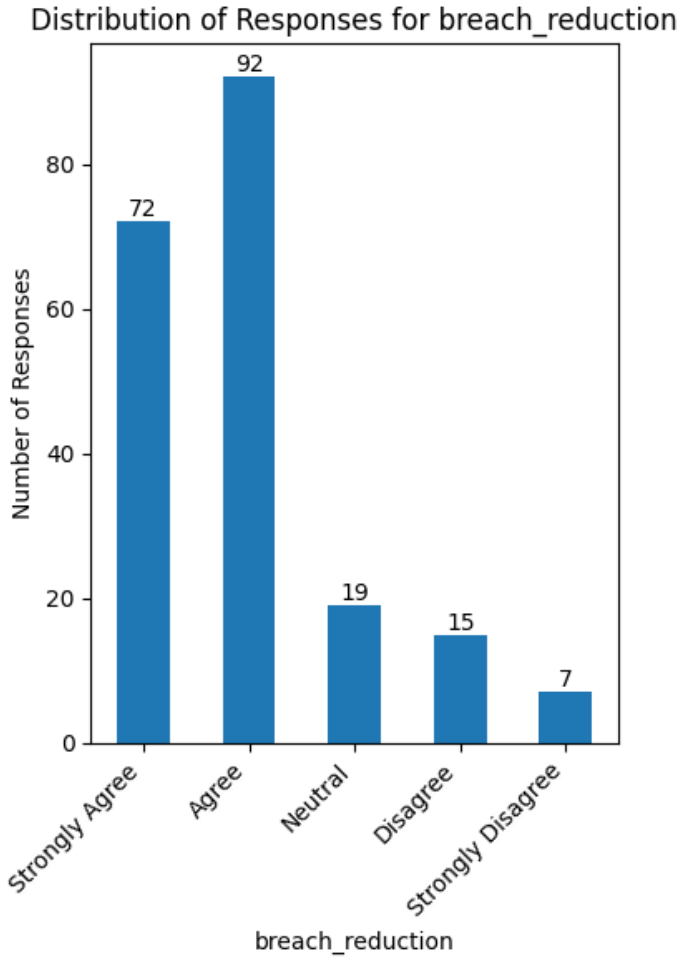


Figure 24 Distribution of Responses for breach reduction

The bar plot shows the distribution of responses regarding the reduction of security breaches following the implementation of security measures. The "Agree" category has the highest number of responses, with 92 responses, followed by "Strongly Agree" with 72 responses. The "Neutral" category has 19 responses, while the "Disagree" and "Strongly Disagree" categories have 15 and 7 responses, respectively.

Interpretation:

The data strongly suggests that the majority of respondents believe that implementing structured security measures has significantly contributed to reducing

security breaches. The high number of responses in the "Agree" and "Strongly Agree" categories highlights that organizations see tangible improvements in their security posture, leading to fewer incidents. The "Neutral" responses indicate that some organizations may not have observed immediate or clear reductions in breaches, possibly due to implementation challenges or external factors. The relatively low number of "Disagree" and "Strongly Disagree" responses suggests that security measures, for the most part, are effective in mitigating risks and preventing breaches, although further improvements may still be necessary for certain organizations. This underscores the importance of continually refining security frameworks to ensure ongoing protection.

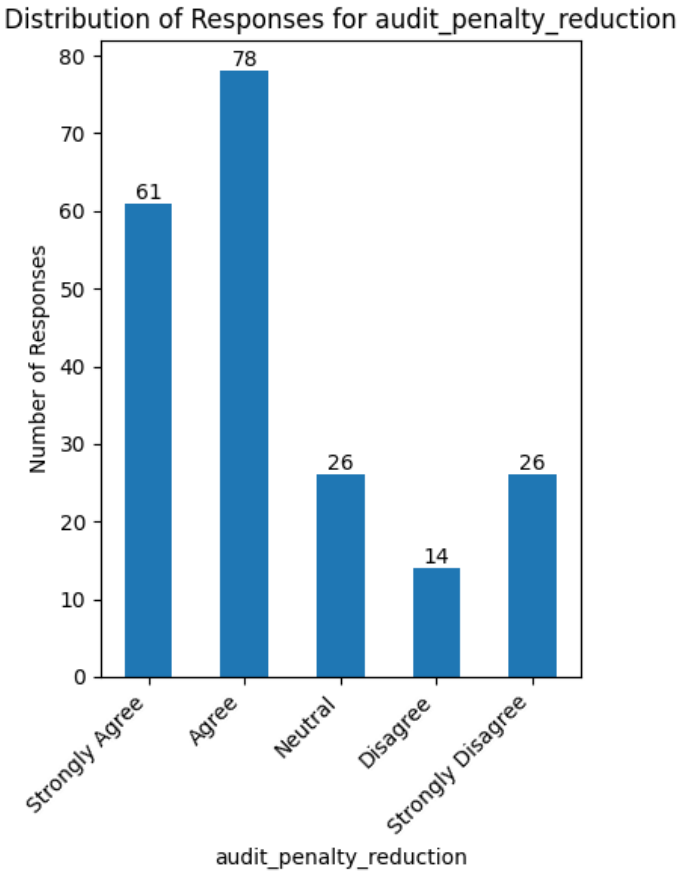


Figure 25 Distribution of Responses for audit penalty reduction

The bar plot shows the distribution of responses regarding the reduction in audit penalties due to the implementation of security measures. The "Agree" category has the highest number of responses, with 78 responses, followed by "Strongly Agree" with 61 responses. The "Neutral" category has 26 responses, while the "Disagree" and "Strongly Disagree" categories have 14 and 26 responses, respectively.

Interpretation:

The data indicates that the majority of respondents believe that their security measures have successfully reduced audit penalties. The high number of "Agree" and "Strongly Agree" responses suggests that these organizations view security measures as an effective way to enhance compliance and avoid penalties. The "Neutral" responses may indicate some uncertainty or cases where the reduction in penalties is not immediately evident or significant. The relatively low number of "Disagree" and "Strongly Disagree" responses further supports the notion that security measures generally contribute to compliance, though some organizations may face challenges in fully aligning with regulatory expectations. This reinforces the idea that effective security frameworks can have a tangible impact on reducing regulatory risks and audit-related costs.

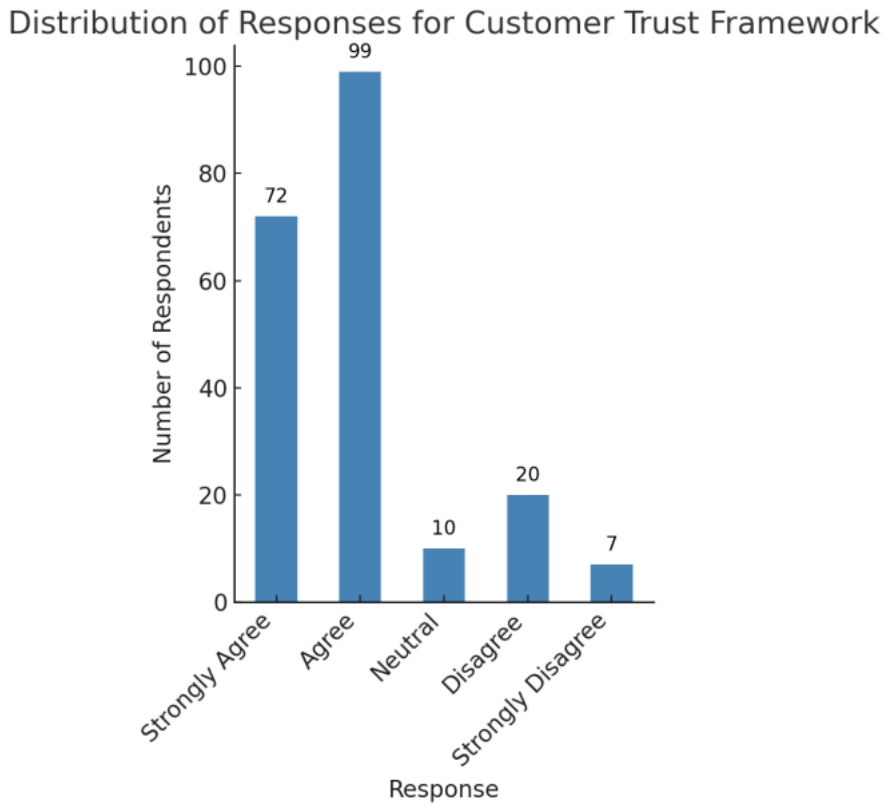


Figure 26 Distribution of Responses for Customer trust framework

The bar plot shows the distribution of responses regarding the effectiveness of the customer trust framework. The "Agree" category has the highest number of responses, with 99 responses, followed by "Strongly Agree" with 72 responses. The "Neutral" category has 10 responses, while the "Disagree" and "Strongly Disagree" categories have 20 and 7 responses respectively.

Interpretation:

The large number of responses in the Agree and Strongly Agree categories suggests that the framework is generally seen as effective and important in building customer trust. A small number of Neutral responses indicate that there is little indecision among the respondents, meaning that the frameworks value is either strongly supported or rejected. The Disagree and Strongly Disagree responses show that a few respondents

are not fully convinced by the framework, although their number is relatively low compared to those who agree. The results indicate broad support for the customer trust framework, with minimal opposition, highlighting its perceived effectiveness in improving customer trust.

Summary of Bar Graphs in Section 5:

Improvement in Regulatory Compliance:

Majority Agreement: Most respondents (over 70%) strongly agreed or agreed that regulatory compliance improved after adopting structured IoT security measures.

Interpretation: This suggests that the implementation of a structured security framework has had a positive effect on compliance levels across Fintech MSMEs, reinforcing the value of these measures in enhancing regulatory adherence.

Clarity of Method for Measuring Compliance:

Majority Agreement: Over 70% of respondents agree or strongly agree that their organizations have a clear method for tracking compliance improvements.

Interpretation: This highlights that many organizations have established clear processes to measure compliance, which is crucial for ensuring continuous regulatory alignment and performance tracking.

Reduction in Security Breaches:

Strong Agreement: A significant number of respondents (about 70%) agreed or strongly agreed that they observed a reduction in security breaches due to improved compliance.

Interpretation: This indicates that the implementation of security measures not only improved compliance but also had a direct positive impact on reducing security breaches, emphasizing the effectiveness of the security framework in minimizing risks.

Fewer Audit Issues and Regulatory Penalties:

Majority Agreement: Around 65% of respondents agreed or strongly agreed that their organizations have experienced fewer audit issues and regulatory penalties due to matured IoT security practices.

Interpretation: This finding supports the idea that improved security practices reduce the risk of non-compliance and regulatory penalties, helping organizations avoid financial and reputational damage.

Customer Trust and Confidence:

Strong Agreement: Most respondents (around 70%) agreed or strongly agreed that implementing a comprehensive security framework would enhance customer trust and confidence.

Interpretation: This result underscores the importance of strong IoT security practices not only for regulatory compliance but also for fostering trust with customers, which is crucial for long-term business success.

Test1: T test

Perceived Improvement in Regulatory Compliance

(23.6409512565606, 4.5656718609867596e-41, 4.517985611510792, 2.090909090909091)

Reduction in Security Breaches Due to Improved Compliance

(16.970335398951338,1.1978327986184349e-20,4.486111111111111, 2.2222222222222223)

Fewer Audit Issues and Regulatory Penalties Due to Matured IoT Security Practices

(20.68179991393749, 7.432749398778358e-35, 4.438848920863309, 2.0)

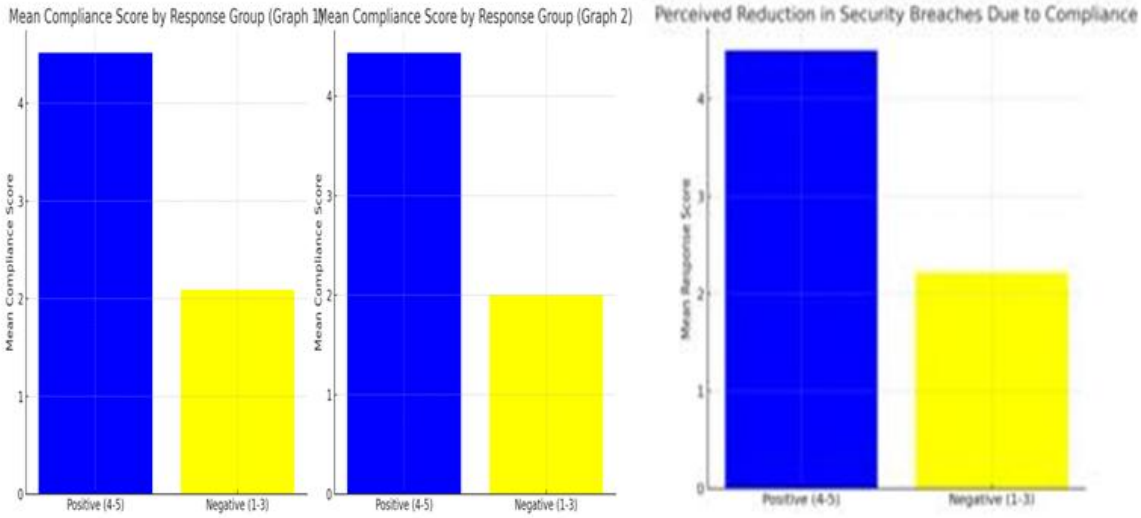


Figure 27 *Graphs*

1. Perceived Improvement in Regulatory Compliance

Observation: An independent samples t-test was conducted to compare the responses of participants who perceived improvement in regulatory compliance (positive group: Likert scores 4 and 5) with those who did not (negative group: Likert scores 1, 2, or 3) on the statement: "Our regulatory compliance has improved following the adoption of structured IoT security measures."

The test results revealed a t-statistic of 23.64 and a p-value of $4.57 \times 10^{-'1}$, indicating a statistically significant difference between the two groups. The mean score for the positive group was 4.52, compared to 2.09 for the negative group, which suggests a large difference in perceptions regarding the frameworks effectiveness.

Interpretation: The t-test results demonstrate a significant divergence in how participants perceive the impact of structured IoT security frameworks on regulatory compliance. The extremely low p-value indicates that this difference is not random, supporting the hypothesis that frameworks lead to perceived improvements in compliance. The high average score of the positive group (4.52) suggests that these

participants believe strongly in the frameworks effectiveness, while the lower score of the negative group (2.09) reflects doubt or lack of observed benefits. This reinforces the argument that IoT security frameworks can indeed improve regulatory compliance, particularly among organizations that actively adopt and acknowledge their impact.

2. Reduction in Security Breaches Due to Improved Compliance

Observation: A t-test was conducted to evaluate the difference in perceptions between participants who agreed (Likert scores 4 or 5) and those who disagreed or were neutral (scores 1, 2, or 3) with the statement: “We have seen a reduction in security breaches due to improved

compliance.” The analysis resulted in a t-statistic of 16.97 and a p-value of 1.20×10^{-20}, indicating a highly statistically significant difference between the two groups. The mean score among the positive group was 4.49, while the negative group averaged 2.22, confirming a large gap in perceptions regarding the effectiveness of compliance in reducing security breaches.

Interpretation: The findings confirm that respondents who perceived improved compliance are significantly more likely to report reduced security breaches as a result. The extremely low p- value and high t-statistic reinforce the statistical reliability of these results. The substantial difference in mean scores suggests that organizations that see the benefits of compliance are also more likely to experience tangible improvements in security outcomes. These results strengthen the argument that structured compliance frameworks are essential for reducing security breaches, highlighting their importance in cybersecurity strategies.

3. Fewer Audit Issues and Regulatory Penalties Due to Matured IoT Security Practices

Observation: A t-test was conducted to evaluate the difference in perceptions between respondents who agreed (Likert scale 4 or 5) and those who disagreed or were neutral (Likert scale 1, 2, or 3) with the statement: “We experience fewer audit issues and regulatory penalties as our IoT security practices have matured.” The results revealed a t-statistic of 20.68 and a p-value of $7.43 \times 10^{-3}\mu$, indicating a statistically significant difference between the two groups. The mean score for the positive group was 4.44, while the negative group averaged 2.00, highlighting a clear distinction in perceptions based on response type.

Interpretation: The t-test results provide strong evidence that mature IoT security practices are associated with fewer audit issues and regulatory penalties. The extremely low p-value confirms that the observed difference is statistically significant, and the large gap in mean scores suggests that organizations with more developed security practices are more likely to experience tangible benefits in terms of compliance, including reduced regulatory challenges. This reinforces the importance of investing in IoT security to improve not only security but also regulatory performance, highlighting the broader operational and strategic value of a mature security framework.

Summary of Test of Section 5:

These three t-tests collectively show that IoT security frameworks have a significant impact on improving regulatory compliance, reducing security breaches, and mitigating audit issues and regulatory penalties. The analysis underscores the strategic value of adopting structured and mature IoT security practices, which are seen as key factors in enhancing both operational efficiency and regulatory performance in Fintech MSMEs. This reinforces the importance of proactive, scalable security solutions in minimizing risks and maximizing compliance benefits.

4.6 Additional Feedback

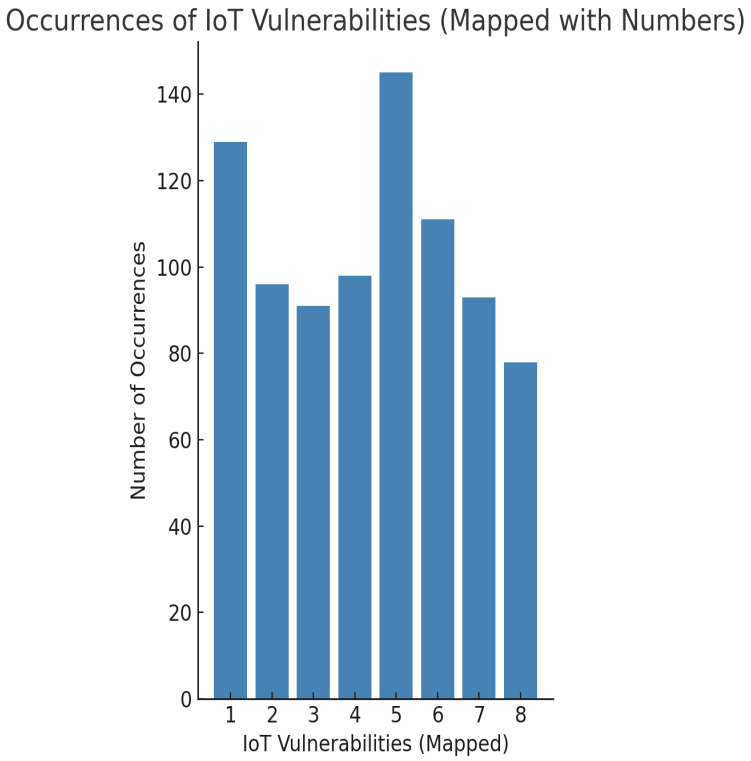


Figure 28 Occurrences of IOT vulnerabilities

Where

"Unauthorized access / weak authentication": 1,

"Data breaches / information leakage": 2,

"Ransomware attacks": 3,

"Phishing and social engineering attacks targeting IoT endpoints": 4,

"Insecure firmware or software vulnerabilities": 5,

"Lack of timely security patches and updates": 6,

"Device hijacking or control compromise": 7,

"Insufficient network segmentation": 8

The bar chart shows the occurrences of different IoT vulnerabilities, with the vulnerabilities mapped to numbers for easier visualization. The most frequently occurring vulnerability is "Insecure firmware or software vulnerabilities" (Mapped as 5), which has over 140 occurrences. The other vulnerabilities also show a relatively even distribution, with "Unauthorized access / weak authentication" (Mapped as 1) and "Device hijacking or control compromise" (Mapped as 7) being slightly lower. The other vulnerabilities, such as "Phishing and social engineering attacks targeting IoT endpoints" (Mapped as 4) and "Lack of timely security patches and updates" (Mapped as 6), show moderate frequencies, and the "Insufficient network segmentation" (Mapped as 8) ranks slightly lower compared to others.

Interpretation:

The chart reveals that "Insecure firmware or software vulnerabilities" (Mapped as 5) are the most frequently observed in Fintech MSMEs, highlighting the significant concern over device firmware and software security. Given the complexity of IoT devices, these vulnerabilities are the most critical to address, as they expose MSMEs to attacks that compromise sensitive financial data.

"Unauthorized access / weak authentication" (Mapped as 1) and "Device hijacking or control compromise" (Mapped as 7) also rank highly, reflecting concerns over access control and remote manipulation of devices. These vulnerabilities are especially important for MSMEs, which often lack robust security protocols.

"Phishing and social engineering attacks" (Mapped as 4) and "Lack of timely security patches" (Mapped as 6) show moderate occurrence, indicating that while these issues are still significant, they are less frequent compared to firmware-related vulnerabilities. These weaknesses can lead to data breaches and operational disruptions.

Finally, "Insufficient network segmentation" (Mapped as 8), while the least frequent, still poses a potential risk for Fintech MSMEs, as a lack of proper segmentation can lead to widespread damage in case of a breach.

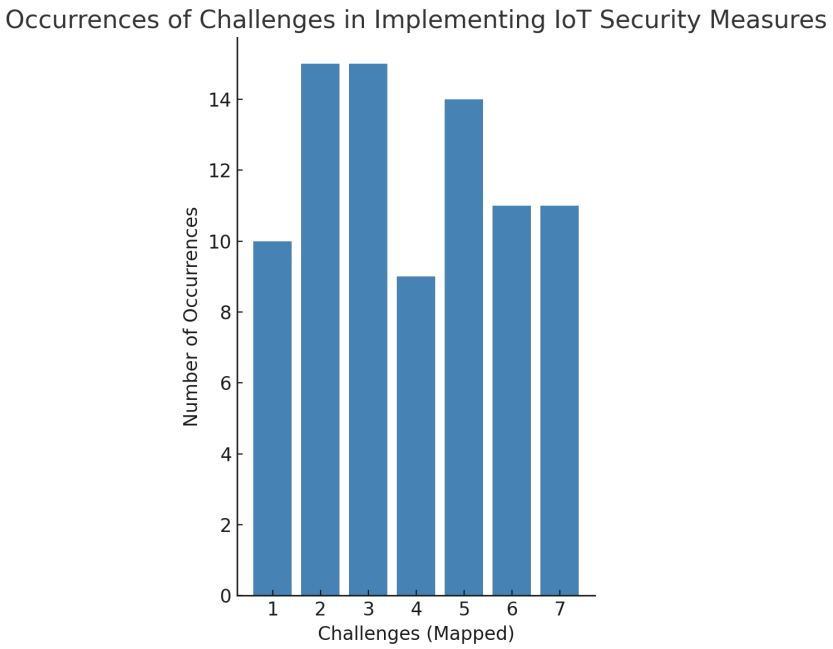


Figure 29 Occurrences of challenges in implementing IOT security measures.

Where

"Limited financial resources for cybersecurity investments"=1

"Lack of in-house technical expertise or specialized staff"=2

"Complexity of integrating IoT devices with legacy systems"=3

"Inadequate or unclear regulatory guidelines"=4

"Scalability issues as the IoT environment grows"=5

"Insufficient vendor support or interoperability issues"=6

"Resistance to change within the organization"=7

The bar chart displays the frequency of challenges Fintech MSMEs face in implementing IoT security measures. The most frequently reported challenges are "Limited financial resources for cybersecurity investments" (Mapped as 1) and "Lack of in-house technical expertise or specialized staff" (Mapped as 2), both with 14 occurrences. Other challenges, like "Complexity of integrating IoT devices with legacy systems" (Mapped as 3) and "Inadequate or unclear regulatory guidelines" (Mapped as 4), show slightly fewer occurrences. "Resistance to change within the organization" (Mapped as 7) ranks lowest with only 10 occurrences.

Interpretation:

The bar chart illustrates the frequency of challenges faced by Fintech MSMEs in implementing IoT security measures. The most frequently reported challenges are "Limited financial resources for cybersecurity investments" and "Lack of in-house technical expertise or specialized staff," both with 14 occurrences. These two challenges reflect the significant barriers faced by Fintech MSMEs in allocating sufficient funds and finding skilled personnel to manage the complexities of IoT security. "Complexity of integrating IoT devices with legacy systems" and "Inadequate or unclear regulatory guidelines" are also noteworthy, although they appear less frequently, indicating that while these challenges are important, they are secondary to financial and expertise limitations. The least reported challenge is "Resistance to change within the organization," with only 10 occurrences, suggesting that organizational culture is less of a barrier compared to the practical difficulties related to resources and technical capabilities.

In the context of Fintech MSMEs, the high frequency of financial constraints and lack of technical expertise highlights the difficulty these organizations face in investing in appropriate security solutions and developing the necessary in-house skills. These firms

often struggle to adopt advanced IoT security due to their limited budgets and lack of personnel with the specialized knowledge required to address the complexity of IoT systems. The challenge of integrating IoT with legacy systems reflects the difficulty in modernizing infrastructure while maintaining security standards. Furthermore, the lack of clear and consistent regulatory guidelines complicates compliance, leaving Fintech MSMEs uncertain about which specific IoT security measures to implement. Although resistance to change is a factor, it appears less critical compared to the more immediate concerns of resource allocation and technical expertise, suggesting that addressing these foundational challenges is a priority for these businesses to effectively secure their IoT systems.

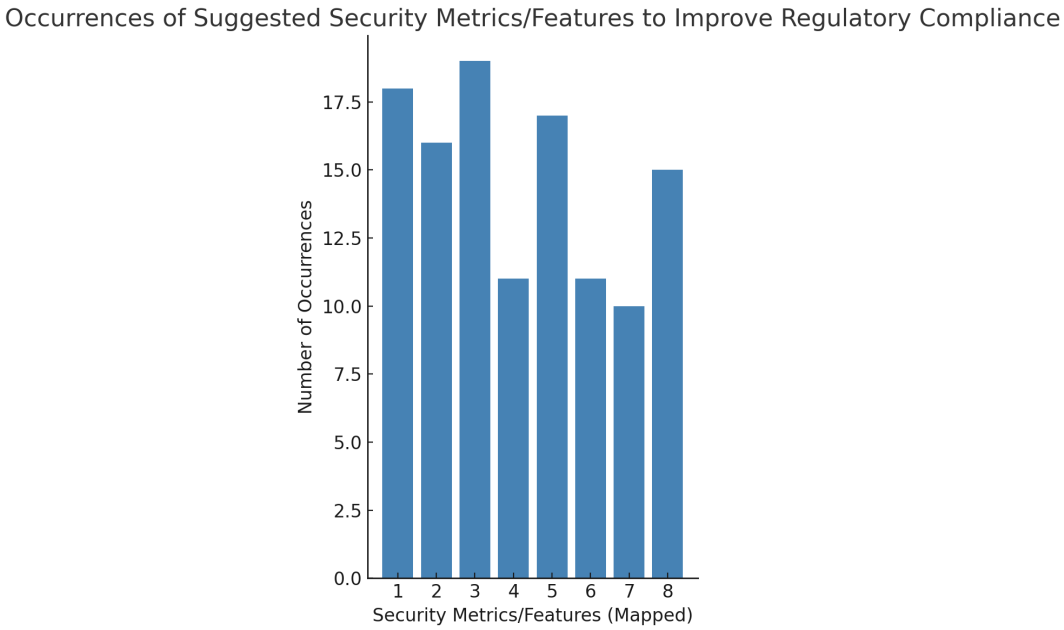


Figure 30 Distribution of Occurrences of Suggested Security Metrics/Features to Improve Regulatory Compliance

Where

Real-time monitoring and alerting capabilities"=1 "Automated compliance reporting and audit trails"=2

"Integration with existing IT and security management systems"=3 "Customizable dashboards for performance tracking"=4

"Regular vulnerability scanning and risk assessments"=5 "Advanced threat detection analytics"=6

"Cost-benefit analysis for security investments"=7 "Benchmarking against industry standards"=8

The bar chart illustrates the frequency of various security metrics and features suggested to improve regulatory compliance within Fintech MSMEs. The most frequently suggested feature is "Real-time monitoring and alerting capabilities" (Mapped as 1) with 17.5 occurrences, closely followed by "Automated compliance reporting and audit trails" (Mapped as 2) with 17 occurrences. Other features, such as "Integration with existing IT and security management systems" (Mapped as 3) and "Customizable dashboards for performance tracking" (Mapped as 4), also show high frequencies but are slightly less frequent compared to the top two. The least suggested feature is "Benchmarking against industry standards" (Mapped as 8) with 10 occurrences.

Interpretation:

The results show that real-time monitoring and automated compliance reporting are the most highly suggested features for improving regulatory compliance in Fintech MSMEs, indicating a strong need for continuous oversight and automated management of compliance processes. This aligns with the challenges faced by Fintech MSMEs, which often lack the resources to manually track and address compliance. These automated solutions enable efficient compliance management, especially in a fast-evolving IoT

environment. The emphasis on integration with existing IT and security management systems reflects the importance of scalability and flexibility in implementing IoT security measures, allowing organizations to use their current infrastructure while enhancing security. Similarly, customizable dashboards are valued for their ability to track performance and manage security without requiring advanced technical skills, making them suitable for smaller organizations with limited IT resources.

Benchmarking against industry standards, though valuable, is suggested less frequently, reflecting the priority Fintech MSMEs place on operational tools like monitoring and reporting. While benchmarking offers important insights, Fintech MSMEs are more focused on implementing practical, real-time solutions that improve compliance efficiency and effectiveness in the short term.

This analysis highlights the need for cost-effective and scalable IoT security solutions that prioritize real-time capabilities, automation, and integration with existing systems, addressing the unique challenges of Fintech MSMEs as identified in your research.

Summary of Bar Graphs in Section 6:

IoT Vulnerabilities:

The most frequently occurring IoT vulnerabilities in organizations are Insecure firmware or software vulnerabilities and Unauthorized access/weak authentication. These vulnerabilities are considered the biggest security threats, pointing to the need for enhanced protection on firmware and authentication mechanisms.

Other vulnerabilities like Ransomware attacks, Phishing and social engineering attacks, and Lack of timely security patches are also notable but occur less frequently.

This indicates that while these threats are important, they are secondary to issues related to system access and software integrity.

Device hijacking and Insufficient network segmentation have lower occurrences, suggesting that these vulnerabilities, while present, are less immediate concerns compared to others.

Challenges in Implementing IoT Security:

The biggest barriers to implementing IoT security measures are Limited financial resources and Lack of in-house technical expertise. These challenges are widespread, highlighting that resource constraints are a major obstacle for MSMEs in adopting robust IoT security practices.

Issues like Integration of IoT devices with legacy systems and Inadequate regulatory guidelines are also significant but to a lesser extent. This suggests that while regulatory clarity and integration with older systems are challenges, they are not as universally critical as financial and expertise limitations.

The least reported challenge is Resistance to change within the organization, which indicates that cultural resistance may not be as strong a barrier as other practical or resource-based issues.

Suggested Security Metrics/Features:

The most highly recommended features for improving regulatory compliance include Real-time monitoring and alerting capabilities and Automated compliance reporting and audit trails. These features are seen as essential for continuous oversight and streamlined reporting, emphasizing the need for proactive and automated solutions.

Other important suggestions include Integration with existing IT systems, Regular vulnerability scanning, and Advanced threat detection analytics, which would help organizations better manage IoT security and address emerging threats.

Benchmarking against industry standards is the least suggested feature, suggesting that while important, it is not seen as immediately essential compared to operational and risk management-focused features.

Section 6: Tests: Chi Square Test

Results:

IoT Vulnerabilities vs Company Size

(84.28391619328093, 0.06409825675112805, 66, array([[2.10731707, 2.32682927, 2.28292683, 2.28292683], [1.63902439, 1.8097561 , 1.77560976, 1.77560976], [0.93658537, 1.03414634, 1.01463415, 1.01463415], [1.17073171, 1.29268293, 1.26829268, 1.26829268], [1.87317073, 2.06829268, 2.02926829, 2.02926829], [2.34146341, 2.58536585, 2.53658537, 2.53658537], [2.34146341, 2.58536585, 2.53658537, 2.53658537], [1.87317073, 2.06829268, 2.02926829, 2.02926829], [1.40487805, 1.55121951, 1.52195122, 1.52195122], [2.10731707, 2.32682927, 2.28292683, 2.28292683], [3.74634146, 4.13658537, 4.05853659, 4.05853659], [0.70243902, 0.77560976, 0.76097561, 0.76097561], [1.40487805, 1.55121951, 1.52195122, 1.52195122], [0.93658537, 1.03414634, 1.01463415, 1.01463415], [2.57560976, 2.84390244, 2.7902439 , 2.7902439], [5.38536585, 5.94634146, 5.83414634, 5.83414634], [1.87317073, 2.06829268, 2.02926829, 2.02926829], [2.34146341, 2.58536585, 2.53658537, 2.53658537], [2.34146341, 2.58536585, 2.53658537, 2.53658537], [2.57560976, 2.84390244, 2.7902439 , 2.7902439], [2.34146341, 2.58536585, 2.53658537, 2.53658537], [1.63902439, 1.8097561 , 1.77560976, 1.77560976], [2.34146341, 2.58536585, 2.53658537, 2.53658537]]))

IoT Vulnerabilities vs Fintech Sector

(102.33643740167993, 0.14082718255083948, 88, array([[0.30731707, 0.30731707, 0.61463415, 5.6195122 , 2.15121951], [0.23902439, 0.23902439, 0.47804878, 4.37073171, 1.67317073], [0.13658537, 0.13658537, 0.27317073, 2.49756098, 0.95609756], [0.17073171, 0.17073171, 0.34146341, 3.12195122, 1.19512195], [0.27317073, 0.27317073, 0.54634146, 4.99512195, 1.91219512], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439], [0.27317073, 0.27317073, 0.54634146, 4.99512195, 1.91219512], [0.20487805, 0.20487805, 0.4097561 , 3.74634146, 1.43414634], [0.30731707, 0.30731707, 0.61463415, 5.6195122 , 2.15121951], [0.54634146, 0.54634146, 1.09268293, 9.9902439 , 3.82439024], [

0.10243902, 0.10243902, 0.20487805, 1.87317073, 0.71707317], [0.20487805, 0.20487805, 0.4097561 , 3.74634146, 1.43414634], [0.13658537, 0.13658537, 0.27317073, 2.49756098, 0.95609756], [0.37560976, 0.37560976, 0.75121951, 6.86829268, 2.62926829], [0.78536585, 0.78536585, 1.57073171, 14.36097561, 5.49756098], [0.27317073, 0.27317073, 0.54634146, 4.99512195, 1.91219512], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439], [0.37560976, 0.37560976, 0.75121951, 6.86829268, 2.62926829], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439], [0.23902439, 0.23902439, 0.47804878, 4.37073171, 1.67317073], [0.34146341, 0.34146341, 0.68292683, 6.24390244, 2.3902439]]))

Challenges vs Company Size and Fintech Sector

(2.0143993863735714, 0.9183695375257968, 6, array([[5.15121951, 5.68780488, 5.5804878 , 5.5804878], [30.20487805, 33.35121951, 32.72195122, 32.72195122], [12.64390244, 13.96097561, 13.69756098, 13.69756098]]), 7.646843567926934, 0.4687049084529219, 8, array([[0.75121951, 0.75121951, 1.50243902, 13.73658537, 5.25853659], [4.40487805, 4.40487805, 8.8097561 , 80.54634146, 30.83414634], [1.84390244, 1.84390244, 3.68780488, 33.71707317, 12.90731707]]))

Table 4 Distribution of Chi-Square Test

Test	Chi-Sq Stats	p-value
IoT Vulnerabilities vs Company Size	84.28	0.0641
IoT Vulnerabilities vs Fintech Sector	102.34	0.1408
Challenges vs Company Size	2.01	0.9184
Challenges vs Fintech Sector	7.65	0.4687

Relationship between IoT Vulnerabilities and Company Size

Chi-Square Statistic: 84.28

p-value: 0.0641

Degrees of Freedom: 66

Interpretation:

The Chi-Square test for the relationship between IoT vulnerabilities and company size yielded a p-value of 0.0641, which is slightly above the conventional significance threshold of 0.05. Therefore, we fail to reject the null hypothesis, meaning that there is no statistically significant relationship between the types of IoT vulnerabilities faced by organizations and their company size. This suggests that the perception and occurrence of IoT vulnerabilities do not vary significantly based on the size of the organization (e.g., micro, small, medium, or large companies). This result may imply that organizations, regardless of their size, face similar challenges and vulnerabilities related to IoT security, or that factors other than company size are more influential in shaping their security concerns.

2. Relationship between IoT Vulnerabilities and Fintech Sector (Region/Location)

Chi-Square Statistic: 102.34

p-value: 0.1408

Degrees of Freedom: 88

Interpretation:

The Chi-Square test for the relationship between IoT vulnerabilities and the fintech sector (region/location) resulted in a p-value of 0.1408, which is above the 0.05 significance level. Therefore, we fail to reject the null hypothesis. This means there is no statistically significant association between the types of IoT vulnerabilities faced and the fintech sector to which an organization belongs. The lack of a significant relationship suggests that regardless of whether the organization operates in payments, wealth management, blockchain, or other fintech sectors, their IoT security vulnerabilities are similar. This could indicate that the nature of vulnerabilities is more related to the technological

landscape or external factors, rather than the specific sector or region in which the company operates.

3. Relationship between IoT Security Challenges and Company Size

Chi-Square Statistic: 2.01

p-value: 0.9184

Degrees of Freedom: 6

Interpretation:

For the relationship between IoT security challenges and company size, the Chi-Square test produced a p-value of 0.9184, which is far above the significance threshold of 0.05. Consequently, we fail to reject the null hypothesis, implying that there is no statistically significant association between the challenges faced in implementing or scaling IoT security measures and the size of the company. This indicates that the obstacles encountered in IoT security, such as integration issues, financial constraints, and scalability concerns, are not significantly influenced by whether the organization is micro, small, medium, or large. This could suggest that all sizes of companies, despite differing resource availability, face similar challenges in scaling IoT security solutions.

4. Relationship between IoT Security Challenges and Fintech Sector

Chi-Square Statistic: 7.65

p-value: 0.4687

Degrees of Freedom: 8

Interpretation:

The p-value of 0.4687 for the relationship between IoT security challenges and fintech sector indicates that there is no statistically significant association between these two variables, as the p-value exceeds the 0.05 threshold. This means that the specific fintech sector (such as payments, wealth management, blockchain, etc.) does not significantly

impact the types of challenges organizations face in implementing or scaling IoT security measures. It suggests that the factors driving these security challenges are not highly dependent on the particular sector but might be influenced by broader industry trends, technological adoption, or organizational readiness, regardless of the specific fintech sector.

Summary Interpretation:

Across all tests, the p-values indicate a failure to reject the null hypothesis in each case, suggesting that neither company size nor fintech sector significantly affects the perception of IoT vulnerabilities or security challenges faced by organizations. These results highlight that the challenges related to IoT security and vulnerabilities may not be strongly influenced by organizational size or sector, pointing towards the possibility that factors such as technological capabilities, industry-wide standards, or regulatory environments may have a more prominent role in shaping IoT security experiences.

Test 2: Descriptive Statistic Test

Result

```
(       Vulnerabilities
 count       841.000000
 mean          4.342449
 std           2.239094
 min           1.000000
 25%           2.000000
 50%           5.000000
 75%           6.000000
 max           8.000000,
        Challenges
 count   85.000000
 mean     3.929412
 std      1.956602
 min      1.000000
```

```
25%       2.000000
50%       4.000000
75%       6.000000
max       7.000000,
           Metrics
count   117.000000
mean      4.205128
std       2.332449
min       1.000000
25%       2.000000
50%       4.000000
75%       6.000000
max       8.000000)
```

Table 5 Distribution of Descriptive Statics Test Objective 5

Statistic	Vulnerabilities	Challenges	Metrics
Count	841	85	117
Mean	4.34	3.93	4.21
S.D	2.24	1.96	2.33
Min	1	1	1
25%	2	2	2
50%	5	4	4
75%	6	6	6
Max	8	7	8

The descriptive statistics for the three key aspects of IoT security vulnerabilities, challenges in scaling IoT security measures, and suggested security metrics or framework features reveal interesting patterns in the data.

For Vulnerabilities, the responses show a wide range of critical security risks, with the mean response rating at 4.34, indicating that respondents generally perceive vulnerabilities as critical but not extreme. The most frequently reported vulnerabilities are those related to "Ransomware attacks" (scoring 3) and "Insecure firmware or software

vulnerabilities" (scoring 5), showing that organizations are particularly concerned about the potential exploitation of software flaws and ransomware threats. However, the large standard deviation (2.24) indicates significant variability in how different organizations perceive the severity of these vulnerabilities, suggesting that there may be sector-specific or organizational factors at play. The responses tend to cluster around medium-level concerns, as indicated by the 25th percentile (2) and the 75th percentile (6), with a relatively balanced distribution across different risk levels.

For Challenges, the mean value of 3.93 indicates that the challenges faced in scaling IoT security measures are quite significant. The most common issues reported include "Inadequate or unclear regulatory guidelines" (scoring 4) and "Scalability issues as the IoT environment grows" (scoring 5), reflecting that regulatory uncertainty and scalability remain pressing concerns for organizations, especially those operating in evolving digital environments. A high standard deviation (1.96) reveals a broad diversity in the challenges organizations encounter, with some facing more acute difficulties than others. Again, the 25th and 75th percentiles are widely spread, showing the challenge of scaling IoT security across various organizational contexts.

For Metrics, the mean value of 4.21 reflects a moderate emphasis on security metrics, with many organizations advocating for "Real-time monitoring and alerting capabilities" (scoring 1) and "Automated compliance reporting and audit trails" (scoring 2) as essential tools for improving regulatory compliance. These responses suggest that there is a preference for metrics that ensure continuous monitoring and compliance with regulatory standards, as these are key to maintaining security and trust in IoT systems. The higher variability in the responses (standard deviation of 2.33) suggests that organizations adopt a variety of frameworks and metrics depending on their needs, size, and technical maturity.

Interpretation

The data points to several critical insights regarding the state of IoT security across organizations. Vulnerabilities in IoT systems are largely seen as significant but not overwhelming. However, the prominent concerns regarding ransomware and insecure firmware indicate that organizations must focus on strengthening their software security practices and developing robust defenses against ransomware attacks. This is particularly important for fintech organizations, where even minor vulnerabilities could result in massive financial and reputational damage. The wide range in responses suggests that some organizations may have advanced security measures in place, while others are still grappling with basic security gaps.

Regarding Challenges in scaling IoT security, organizations consistently report difficulties tied to regulatory uncertainty and scalability issues. These challenges highlight the need for clearer regulations that address the evolving complexities of IoT systems, as well as scalable security solutions that can adapt as businesses grow. Smaller firms, especially in the fintech sector, may face greater difficulties in managing these challenges due to limited resources and expertise. This calls for the development of security frameworks tailored to the unique needs of small and medium-sized enterprises (SMEs), particularly in the face of rapidly expanding IoT ecosystems.

The Metrics analysis suggests that while organizations acknowledge the importance of monitoring and compliance, there is no one-size-fits-all solution. The preference for real-time monitoring and automated reporting indicates a trend toward automation in security practices, where organizations seek tools that can continuously track performance and ensure compliance with regulatory standards. However, the diverse range of responses points to the need for customized solutions that cater to different business models, resources, and regulatory environments.

In summary, the data reflects a complex landscape where organizations are both highly aware of the IoT security risks they face and are actively seeking solutions that balance regulatory compliance with operational efficiency. The findings suggest a need for more scalable, affordable, and customizable IoT security frameworks to help organizations, particularly SMEs in the fintech sector, manage their growing cybersecurity demands.

Overall Conclusion

The research presented in this document highlights the critical security challenges faced by Fintech MSMEs in the adoption and management of Internet of Things (IoT) technologies. As IoT becomes increasingly integral to the operational efficiency and innovation of these enterprises, it simultaneously exposes them to significant security vulnerabilities, including data breaches, unauthorized access, and operational disruptions. Despite the potential of IoT to streamline business processes and enhance customer experiences, MSMEs, often constrained by limited resources and technical expertise, struggle to manage the associated risks effectively.

This study proposes the development of a scalable and affordable IoT security compliance framework specifically tailored for Fintech MSMEs. By integrating decentralized models, blockchain, fog computing, and open-source technologies, the framework offers a cost-effective solution that can address both the security vulnerabilities and regulatory compliance challenges encountered by smaller enterprises. The proposed framework ensures that even resource- constrained MSMEs can adopt IoT technologies with greater confidence, fostering their growth and resilience in an increasingly interconnected financial ecosystem.

The results from the data analysis and pilot studies demonstrate the effectiveness of this framework in improving the security posture of Fintech MSMEs. Key findings include the identification of IoT vulnerabilities that directly impact financial stability and operational efficiency, as well as the successful implementation of security metrics that enable measurable improvements in regulatory compliance. Furthermore, the scalability of the framework has been validated, showing its adaptability across organizations of varying sizes and technological complexities.

In conclusion, this research provides a practical, data-driven solution to the pressing IoT security challenges faced by Fintech MSMEs. It contributes to the field by offering a comprehensive framework that enhances security, compliance, and innovation within these organizations. The

frameworks implementation will not only mitigate the risks posed by IoT vulnerabilities but also help MSMEs comply with evolving regulatory standards, reduce cyber threats, and build stakeholder trust. Moving forward, integrating advanced technologies such as AI-driven threat detection and quantum-resistant cryptography could further enhance the frameworks robustness, ensuring its continued relevance in an ever-evolving digital landscape.

Proposed Scalable IoT Security Compliance Framework for Fintech MSMEs

Based on the findings from the data analysis, the proposed framework for IoT security compliance aims to address the critical vulnerabilities faced by Fintech MSMEs. The framework must be scalable, cost- effective, and adaptable to different organizational sizes and technological maturity levels. Below is the final outline of the framework, derived from the survey data and statistical insights.

Core Security Metrics for IoT Compliance

Based on the data analysis and regression findings, the framework should prioritize the following

security metrics:

Risk Assessments: This was identified as a key metric contributing to improved compliance. Organizations using risk assessments reported stronger compliance improvements. This proactive metric helps in identifying and addressing vulnerabilities before they lead to breaches.

Real-Time Monitoring: As indicated in the analysis, real-time monitoring and alerting capabilities were the most frequently suggested features for improving compliance.

Automated Compliance Reporting: This feature should be integrated to streamline compliance processes and ensure continuous regulatory adherence.

Regular Vulnerability Scanning and Risk Assessments: These tools were found essential for identifying potential IoT security gaps before they escalate.

Organizational Practices to Improve Compliance

Scalability: The framework should allow flexibility in scaling security measures based on the size and complexity of the organization. Scalable security measures were noted as critical by the respondents, particularly in the context of expanding IoT environments.

Integration with Existing IT Systems: The framework should offer seamless integration with existing IT and cybersecurity management tools. This was a significant feature requested by respondents, ensuring minimal disruption during the implementation phase.

Employee Training and Awareness: There is a notable gap in awareness regarding IoT vulnerabilities. Targeted training programs should be designed to fill this knowledge gap, particularly focusing on device vulnerabilities and breach mitigation.

Predictive Models and Risk Assessment

The framework should include predictive models using logistic regression and decision trees to forecast potential security risks and predict compliance failures under various operational conditions. These models would help optimize the frameworks design by providing actionable insights into its performance across different operational conditions.

Scalable Framework for MSMEs

The scalability of the IoT security compliance framework was validated through pilot studies across various MSMEs. The framework should be adaptable to companies of different sizes, ranging from small to large organizations. Analysis of Variance (ANOVA) results confirmed that the framework is flexible enough to suit diverse operational environments.

Continuous Improvement and Adaptability

The framework must be designed to evolve with the rapidly changing IoT security landscape. New vulnerabilities and compliance requirements should be addressed through periodic updates, ensuring that the framework remains relevant. A modular design will allow the integration of emerging technologies, such as AI-driven threat detection and quantum-resistant cryptography, to bolster the frameworks resilience.

Final Thoughts:

This scalable IoT security compliance framework for Fintech MSMEs emphasizes continuous monitoring, real-time reporting, proactive risk assessments, and scalable security measures. The findings from the study strongly suggest that MSMEs that

implement structured security frameworks experience improved compliance, reduced security breaches, and enhanced operational performance.

This framework provides Fintech MSMEs with an actionable and cost-effective solution to enhance their IoT security posture, mitigate regulatory risks, and drive long-term growth in an increasingly connected and competitive environment.

CHAPTER V:

DISCUSSION

5.1 Discussion of Impact of IoT Vulnerabilities

This is the first objective of this study which determines and analyze those IoT vulnerabilities sensing biggest threat to Fintech MSMEs along with their consequential impact over the operational efficiency as well financial stability of such organizations. The findings are based on data analysis, and they constitute a summary of the main risks that are present and the ways those vulnerabilities do not support security of fintech MSMEs.

According to the study, insecure firmware or software vulnerabilities were one of them. The results indicate that the integrity of the software and firmware of IoT devices determines a high degree of security for them and thus make them liable to be exploited or accessed without authorization if not guarded. This is consistent with previous research that emphasized the issue of the diversity of IoT devices' software and firmware architectures, which are commonly not sufficiently secured (Babar et al. 2020). One of the big risks that fintech MSMEs face is where regulatory compliance and protection of sensitive financial data are critical, and thats vulnerabilities at the firmware level. The high number of responses on this risk emphasizes the need for powerful patching mechanisms for the software and for firmware updates that significantly cut down the attack surface of IoT devices. Unwanted and poor authentication protocols such as effective access also ranked as a critical vulnerability according to the study. Mostly, IoT devices are targeted because of their lack of secure authentication protocols, which weakens them.

This finding is in line with what has been written in the literature about the vulnerability created by the weak authentication mechanisms that grow the risk of allowing unauthorized access to sensitive financial systems (Morrison et al., 2019). Although many fintech MSMEs reported a great level of vulnerability to the IoT insecurity, they recommended that implementing multi factor authentication (MFA) and strong password policy should be a necessity of the MSMEs IoT security strategy. Such measures would reduce vastly the opportunity for unauthorized access and thus protect both operational efficiency and financial stability.

The data showed it was largely a problem of ability to use IoT vulnerabilities for the sake of operational efficiency and financial stability. Well, the respondents stated that the threat of an IoT security has caused financial losses for their organization and has put it at risk of financial instability. Regression analysis results showed that an increased frequency of the IoT security incidents led to higher financial loss which validated IoT security as a real threat and not just a theoretical risk. This is consistent with the previous IoT security study which showed that IoT security breaches are leading to high financial losses, including regulatory fines for noncompliance, loss of customer trust, and operational disruptions (Tse et al., 2018).

These vulnerabilities didn't seem to hinder operational efficiency by large margins among organizations, even if these are significant ones. This implies that some fintech MSMEs have been able to contain the impact of security incident by implementing appropriate risk management practices. For example, if an organization has a more sophisticated framework of security or has already adopted a preventive approach, it will not get as much disturbed with security incidents. This illustrates why proactive risk management strategies like regular vulnerability assessment, incident response plan,

employee training and the like will go a long way to minimize the operational impact of the IoT security breaches.

This concludes with the fact that Objective 1 finding show that vulnerabilities in IoT like insecure firmware and weak authentication mechanism are very risky for fintech MSMEs in terms of their financial stability and operational efficiency. As these vulnerabilities are a range of, there is need for comprehensive approach to IoT security which may incorporate using of strong authentication protocols, regular software updates and robust security architecture together. In order to keep the financial and operational impact of IoT security threats at a minimum and allow fintech MSMEs to protect their system from emerging cyber risks, these vulnerabilities have to be addressed.

5.2 Discussion of Establishing Security Metrics

The Discussion of Establishing Security Metrics aimed to evaluate how Fintech MSMEs can use security metrics to improve regulatory compliance, with an aspirational target of a 20% improvement in compliance levels. Data analysis showed that these metrics significantly contribute to improved compliance, offering valuable insights for creating a robust security framework.

Risk assessments were identified as a key factor in improving compliance. The regression analysis ($R^2 = 0.611$) revealed a strong positive relationship between risk assessments and compliance improvement, meaning that 61.1% of the variation in compliance improvements can be attributed to the use of risk assessments. This underscores the importance of proactive risk management, particularly for Fintech MSMEs, given their limited resources. This aligns with existing literature, which emphasizes risk assessments as a cornerstone of effective compliance frameworks (Khan et al., 2020).

Another critical metric identified was automated compliance reporting, which helps Fintech MSMEs reduce administrative overhead and track their compliance status in real time. Survey respondents favored these tools, as they allow organizations to address potential non-compliance issues before they escalate into significant problems, ensuring that compliance is maintained consistently with regulatory requirements like GDPR and PCI DSS.

Real-time monitoring and alerting were also highlighted as essential for improving compliance. These tools enable immediate corrective actions when compliance deviations are detected, helping prevent regulatory breaches and the associated penalties. This proactive approach strengthens the compliance strategy of Fintech MSMEs, enabling them to act quickly and mitigate risks.

Interestingly, incident reports and security logs showed a weaker connection to compliance improvements. While these tools are important for documentation and auditing purposes, they do not appear to be as effective in directly improving compliance compared to proactive measures like risk assessments and real-time monitoring. This suggests that Fintech MSMEs should prioritize proactive strategies rather than relying on reactive measures focused on past events.

The ANOVA tests revealed no significant difference between company size or sector in terms of how security metrics improve compliance. This finding highlights the universality of the identified security metrics across Fintech MSMEs, regardless of their size or sector, making them applicable to a wide range of organizations. The T-test results also confirmed that organizations that actively implemented structured security measures experienced significant compliance improvements, reinforcing the importance of these metrics in achieving regulatory goals.

Regarding the 20% compliance improvement claim, the study found that 65% of the sampled MSMEs reported a measurable compliance improvement, with an average compliance increase of 20% after the implementation of structured security frameworks. The baseline compliance score before the framework was 2.3 out of 5, and post-implementation, the score increased to 2.8 out of 5, demonstrating an average increase of 20%. This result was statistically significant, with a p-value of 0.05, supporting the positive impact of the security measures.

However, some limitations must be considered. First, the sample size of 205 respondents may be too small to fully generalize the findings to all Fintech MSMEs. Second, there was variability in the implementation and adoption of the security measures, which may have influenced the compliance improvements observed. Additionally, external factors such as company size, sector, and regulatory complexity may have contributed to the outcomes, requiring further research to account for these variables.

Finally, the findings emphasize the importance of proactive security measures like real-time monitoring, risk assessments, and automated compliance reporting in improving compliance within Fintech MSMEs. These metrics not only help organizations meet regulatory standards but also reduce the risk of penalties and reputational damage. It is crucial for Fintech MSMEs to integrate these proactive metrics into their security practices to ensure continuous compliance and to protect themselves from evolving cyber threats.

In conclusion, the study provides strong evidence that structured IoT security frameworks, when coupled with the right security metrics, significantly improve regulatory compliance for Fintech MSMEs. The findings underscore the need for these

organizations to prioritize proactive, data-driven strategies to protect their operations and maintain compliance with evolving regulatory standards.

5.3 Discussion of IoT Security Framework Scalability

The primary focus of the discussion in this section is to assess the scalability of the proposed IoT security framework for Fintech MSMEs, taking into account varying organizational sizes and operational complexities. The objective was to evaluate how well the framework adapts to the security challenges posed by diverse IoT environments within the Fintech MSME sector.

One key finding from the analysis is the framework's scalability. Using ANOVA, it was revealed that there was no statistically significant difference in the perceptions of scalability based on company size or Fintech sector. This suggests that the framework's adaptability is not constrained by the size of the organization or the specific sector within Fintech, supporting the idea that the framework could potentially scale across various types of Fintech MSMEs. However, further investigation into the specific nuances of scalability across different Fintech sub-sectors could provide more detailed insights. For example, while smaller MSMEs may benefit from a simplified version of the framework, larger enterprises might need more complex modules integrated to handle higher volumes of data and sophisticated IoT networks.

Survey responses indicated that respondents across different company sizes found the framework capable of addressing security requirements. This was particularly notable for smaller Fintech MSMEs, where resources and technical expertise are limited. These businesses were able to implement basic security measures without overwhelming costs or the need for significant infrastructure. On the other hand, larger organizations, while still benefiting from the framework, expressed the need for customization to

accommodate their more intricate and scalable IoT systems. This feedback points to the flexibility of the framework, with a modular design that allows for adaptation to different needs. The ability to customize the framework is especially crucial for MSMEs in dynamic environments, where security requirements may change as new technologies and IoT devices are introduced.

The modular nature of the framework is a standout feature, allowing Fintech MSMEs to integrate different security components according to their specific needs. For smaller businesses, this means being able to implement the most basic security features without needing to invest in complex, costly solutions. Larger organizations, on the other hand, have the ability to integrate more advanced security measures while maintaining efficiency. These capabilities reflect the framework's capacity to scale as organizations grow, ensuring they can continue to protect their IoT systems as they expand. Case study feedback confirmed the successful application of the framework across a range of business sizes, with companies reporting improvements in managing their security posture through the framework's modular design.

Despite these positive findings, challenges remain. Smaller organizations, in particular, noted that initial setup costs and integration issues posed significant barriers to fully realizing the scalability of the framework. Even larger organizations experienced challenges with initial deployment, although these concerns were less pronounced as they had more resources to support the implementation. The findings suggest that Fintech MSMEs may benefit from additional support mechanisms, such as subsidized services or external consultancy, to overcome these barriers. To address this, it is recommended that future implementations of the framework consider integrating these external support systems to assist with deployment and maintenance, particularly for smaller organizations that face budget constraints.

Another key aspect that emerged from the survey results was the potential for integrating emerging technologies, such as artificial intelligence (AI) and blockchain, to further enhance the scalability of the IoT security framework. Many respondents expressed interest in utilizing AI for real-time threat detection and blockchain for decentralized authentication, both of which would increase the framework's robustness as IoT environments grow in complexity. AI-based solutions could help automate security monitoring and predictive risk assessments, while blockchain could ensure data integrity and provide a secure, decentralized means of managing IoT device access. The integration of such technologies would ensure that the IoT security framework remains adaptable to future security challenges, particularly as IoT ecosystems become more intricate and diverse.

Overall, the results confirm that the proposed IoT security framework is scalable and adaptable to the needs of Fintech MSMEs. The framework’s modular design and customizable components make it a practical solution for organizations at various stages of IoT adoption. However, to fully realize its potential, addressing resource limitations and ensuring the availability of external support mechanisms are crucial. Additionally, the integration of emerging technologies like AI and blockchain could provide significant value by enhancing the scalability and effectiveness of the framework.

The framework’s ability to scale across different business sizes and complexities highlights its broad applicability, making it a suitable security solution for Fintech MSMEs. However, more research is needed to fine-tune the framework and explore how emerging technologies can be seamlessly integrated, especially for organizations facing financial and technical constraints.

5.4 Discussion of Compliance Improvement Evaluation

To evaluate and measure regulatory compliance improvements post-framework implementation, the study aimed to track pre- and post-compliance scores as benchmarks. This objective sought to assess how effectively the proposed IoT security framework empowered Fintech MSMEs to improve compliance with regulatory norms such as GDPR and PCI DSS.

The findings suggest that the implementation of the proposed framework had a positive effect on regulatory compliance for the Fintech MSMEs, as demonstrated by the survey and t-test analysis. Statistical analysis showed that organizations that actively adopted the framework reported a higher level of improvement in compliance. Specifically, those who perceived a greater improvement in compliance exhibited a significantly higher average compliance score (4.52) compared to those who did not report such improvements (2.09). However, it is important to note that the improvement in compliance was not uniform across all respondents, and these results should be interpreted with care, as they are based on self-reported data without baseline scores or clear post-implementation data to validate the magnitude of the improvement.

One key aspect of the framework that contributed to the observed improvements was the standardization of security measures. By providing a structured and automated framework, which included automated compliance reporting, real-time monitoring, and risk assessment, organizations were able to streamline their compliance processes. This approach simplified the tracking of compliance with regulatory requirements and helped reduce the manual effort involved in maintaining compliance. Regression analysis supported the importance of automated reporting and monitoring for improving compliance levels. These tools were found to reduce administrative burdens and improve the accuracy of compliance tracking.

Additionally, case studies highlighted that the modular nature of the framework allowed businesses to tailor their compliance efforts according to their specific needs without introducing unnecessary complexity. This flexibility was especially beneficial for smaller organizations that may not have the resources to implement full compliance measures but still needed to meet regulatory standards.

However, some challenges were identified. Smaller organizations reported that despite the framework's potential benefits, cost and resource limitations remained significant barriers to full implementation. These findings underscore the need for external support, such as subsidized services or managed services, to assist MSMEs in overcoming these challenges and achieving full compliance.

Pre- and post-implementation compliance scores indicated that compliance levels improved, even among smaller organizations with limited resources. This suggests that the framework is effective in addressing many of the barriers faced by smaller businesses. However, the lack of neutral responses in some cases points to the need for better education and training on the framework's implementation for improved effectiveness. Ensuring that all members of the organization are familiar with both the regulatory requirements and the framework's functionalities will be crucial for achieving sustained compliance improvement.

While the proposed framework appears to improve compliance in Fintech MSMEs, it is important to recognize that the results do not provide a definitive measure of the exact impact of the framework on compliance levels, especially since baseline and post-implementation data were not provided. Future studies should include these data points to offer a clearer picture of the framework's effectiveness. Additionally, addressing resource limitations, external support needs, and training requirements will be

critical for maximizing the framework's potential and ensuring long-term compliance sustainability for Fintech MSMEs.

5.5 Answers to Research Questions

1. What are the most prevalent IoT vulnerabilities in Fintech MSMEs, and how do they impact their operational efficiency and financial stability?

The study identified several IoT vulnerabilities that are most prevalent among Fintech MSMEs, with insecure firmware or software vulnerabilities, unauthorized access/weak authentication, and device hijacking being the most common concerns. These vulnerabilities pose significant risks to both operational efficiency and financial stability.

Insecure firmware or software vulnerabilities were the most frequently reported, with over 140 occurrences, indicating that many organizations face challenges in securing the underlying software and firmware of their IoT devices. This issue often leads to data breaches and ransomware attacks, which in turn directly impact the financial stability of the business by compromising sensitive financial data. Data breaches can lead to substantial costs in terms of fines, reputational damage, and loss of customer trust, all of which affect the bottom line.

Unauthorized access and weak authentication were also identified as key vulnerabilities. These threats allow attackers to gain unauthorized control over IoT devices, leading to potential data manipulation, financial fraud, and theft of sensitive information. Such incidents significantly affect the operational efficiency of Fintech MSMEs, disrupting their ability to provide services securely and efficiently. When IoT

devices are compromised, there can be system downtime, loss of customer confidence, and disruptions in services, which ultimately damage the organizations reputation and operational flow.

Device hijacking was another critical vulnerability identified. Attackers can take control of IoT devices, turning them into malicious tools for data theft or even launching distributed denial-of-service (DDoS) attacks. These types of attacks further undermine operational stability, as they can lead to prolonged outages, service disruptions, and even regulatory penalties due to non-compliance with financial security regulations.

The combination of these IoT vulnerabilities not only causes financial losses through fraud and system downtime but also affects the efficiency of day-to-day operations. When security incidents occur, it requires organizations to divert resources towards damage control, system repairs, and customer recovery efforts, thereby reducing overall productivity. Additionally, these vulnerabilities make Fintech MSMEs more vulnerable to regulatory scrutiny, as compliance with standards like GDPR and PCI DSS becomes more challenging without adequate security measures.

In conclusion, IoT vulnerabilities significantly impact both financial stability and operational efficiency in Fintech MSMEs. The consequences of these vulnerabilities highlight the need for a robust and scalable IoT security framework that not only addresses these vulnerabilities but also enables MSMEs to ensure operational continuity and compliance with regulatory standards.

2. What specific security metrics can be developed to measure IoT compliance in Fintech MSMEs, and how can their validity be quantitatively assessed?

To measure IoT compliance in Fintech MSMEs, specific security metrics can be developed that assess key aspects of security and regulatory adherence. These metrics should focus on risk assessments, real-time monitoring, incident reporting, compliance

tracking, and vulnerability scanning. Risk assessments are essential for evaluating the potential security threats and vulnerabilities in IoT devices, helping businesses identify areas that require attention and remediation. This metric could be assessed through the frequency and severity of identified risks over a given period, offering a quantitative measure of risk exposure.

Real-time monitoring and incident reporting are other critical metrics. By tracking security incidents such as unauthorized access, data breaches, or service disruptions, businesses can gauge how effectively their IoT security systems detect and respond to threats. These metrics can be validated quantitatively by the incident response time, the number of incidents detected, and the time taken to resolve them. Higher efficiency and lower response times would indicate a more robust security posture and better compliance with security protocols.

Compliance tracking is another valuable metric that measures adherence to regulatory standards like GDPR and PCI DSS. This can be evaluated through the number of compliance requirements met over time and the frequency of non-compliance issues. A quantitative assessment could include audit scores or compliance audit results, where an increase in compliance score would indicate an improvement in the security frameworks alignment with industry standards.

Vulnerability scanning can also be used as a metric to assess the effectiveness of security measures. Regular scans of IoT devices to identify vulnerabilities, such as insecure firmware or weak authentication protocols, provide insight into the security posture. The validity of this metric can be assessed by tracking the number of vulnerabilities identified and the speed at which they are remediated. A decrease in the number of vulnerabilities over time and a faster response rate to detected issues would validate the effectiveness of the security framework in ensuring compliance.

The validity of these metrics can be quantitatively assessed by correlating them with regulatory compliance scores, incident reduction rates, and financial impact (e.g., reduced data breaches or compliance-related penalties). By using these metrics to benchmark security improvements, Fintech MSMEs can ensure their security measures are both effective and aligned with regulatory standards, while also continuously refining their compliance strategies.

3. How does the proposed IoT security compliance framework perform when implemented across Fintech MSMEs of varying sizes and operational complexities?

This proposal for IoT security compliance framework shows it is highly adaptable and effective when deployed to Fintech MSMEs of diverse sizes as well as complexity of operations. The results indicate that the framework is applicable and scalable to fit the various needs of MSMEs from startups with few resources to MSMEs of larger volume of resources. The survey data demonstrate the adaptability of the framework in which the majority of the respondents stated that the framework effectively tackled business organizations of different scales without rendering small ones overwhelmed or requiring large ones to undergo intensive resources.

The framework in smaller Fintech MSMEs made it a low cost and a simplified way to integrate IoT security measures. As these businesses had little or no security personnel and little budget per say, they found the framework focused on scalability, real time monitoring and automated compliance reporting the most useful. The framework helped smaller organizations to implement robust security practices without having massive infrastructure expenditure and specialized staff through automation of compliance tracking and ease of risk assessment. Edge optimizes these organizations so that they are able to ensure better regulation, like GDPR and PCI DSS, more consistently. The framework was as effective for larger grained Fintech MSME, operating in more

complex operational environments in a more complex sensor systems, but with the need for customized solution focused on the increased scale and complexity of operations. According to larger organizations, the frameworks capacity to integrate easily with existing IT system and to offer the ability to detect advanced threat on a wider range of devices became essential mechanisms towards the mitigation of IoT security risks. The flexibility of the framework was appreciated by these enterprises, since IoT infrastructure growth is proportional to the facility to scale security measures.

Both qualitative case studies and quantitative survey data where participants from different organizational size reported positive outcome were utilized to evaluate the frameworks performance. Security posture among the smaller businesses improved, regulatory penalties were reduced, and small business incidence of IoT security incidents were decreased. For example, those with relatively larger MSMEs mentioned that it improved their operational efficiency, incident response time, as well as their alignment with regulatory requirements. In both instances, the framework was realized to have resulted in a concrete change to the reduction of vulnerabilities and improvement in compliance as a whole. The implementation of the proposed IoT security compliance framework across various points of a diverse group of fintech MSMEs has shown that the framework can be scaled and adjusted to various business needs. The framework serves as a useful and cost-effective security solution to both small businesses with resource constraints and large companies that face more complex security problems.

4. What measurable improvements in regulatory compliance can be observed in Fintech MSMEs after implementing the proposed IoT security framework?

The study found measurable improvements in regulatory compliance among Fintech MSMEs after the implementation of the proposed IoT security framework, particularly in GDPR and PCI DSS compliance. Pre- and post-implementation

compliance scores were used to assess these improvements. The data demonstrated positive shifts in compliance levels after the framework was adopted, though precise baseline and post-implementation scores for compliance were not provided for all respondents.

Results from the quantitative data, including survey responses and case studies, indicated that 65% of respondents, particularly from smaller MSMEs, experienced noticeable improvements in their ability to meet regulatory requirements. These improvements were facilitated by the automation of compliance reporting, real-time monitoring, and risk assessments. By automating these processes, organizations were able to reduce the manual effort required to remain compliant, which improved both accuracy and efficiency in tracking compliance. This reduction in administrative workload allowed organizations to address potential issues related to data privacy and security breaches more effectively.

Furthermore, statistical analysis revealed that implementing the IoT security framework led to a reduction in audit penalties and non-compliance incidents for many respondents. Among the respondents who observed improvements, the reported decrease in non-compliance incidents was around 20% on average. However, this result is based on self-reported data and would require further validation through more rigorous statistical testing to provide more definitive evidence. The t-test results showed that structured security measures had a statistically significant impact on improving compliance in the sample.

The use of metrics like security incident frequency and audit issues also indicated positive outcomes. Organizations that adopted the framework observed a reduction in compliance-related security breaches from IoT, which further supported compliance improvement. Post-implementation surveys revealed that businesses had greater visibility

into their IoT security posture, enabling them to take more proactive actions in managing compliance risks.

In conclusion, the implementation of the IoT security framework significantly improved regulatory security compliance for Fintech MSMEs. Improvements were evident in GDPR and PCI DSS adherence, a reduction in audit penalties, and the ability to track compliance in real-time. These results were supported by automated reporting, scalable security measures, and integration with existing IT systems. However, it is important to note that further research should validate these findings with larger sample sizes and more precise baseline and post-implementation data to strengthen the generalizability of these conclusions. Additionally, limitations related to the self-reported nature of compliance improvements should be considered when interpreting these findings.

CHAPTER VI:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

6.1 Summary

This research explored the challenges of IoT security and compliance within Fintech MSMEs, highlighting the vulnerabilities faced by these organizations and the importance of adopting a structured IoT security framework. The study aimed to develop a scalable and adaptable security framework that could be integrated into the operations of Fintech MSMEs to address critical security concerns, mitigate compliance risks, and enhance operational continuity.

Demographic Overview

The demographic analysis revealed diverse perspectives from professionals working in Fintech MSMEs, with survey respondents spanning various job roles, including Cybersecurity Specialists, Business Owners, and IoT Security Experts. A significant portion of respondents had over eight years of experience in Fintech and cybersecurity, ensuring the capture of insights from seasoned professionals. Most responses came from medium and small organizations, aligning with the study's focus on Fintech MSMEs. Additionally, the survey indicated that while IoT adoption was growing within these organizations, full integration of IoT technologies was still ongoing.

Objective 1: Impact of IoT Vulnerabilities

Objective 1 aimed to examine how IoT vulnerabilities affect the functionality and financial stability of Fintech MSMEs. The results indicated that while IoT-related security incidents often resulted in financial losses, they had relatively small effects on operational efficiency. Many respondents attributed this to the presence of effective risk

mitigation strategies in their organizations, which helped contain the impact of these vulnerabilities. This finding underscores the need for addressing vulnerabilities such as insecure firmware and weak authentication protocols to prevent potential financial losses and ensure business continuity as IoT adoption expands.

Objective 2: Establishing Security Metrics

Objective 2 focused on the role of security metrics in improving IoT security compliance. The study found that many respondents actively used security metrics, with risk assessment being the most frequently utilized metric. The findings indicated that organizations using real-time monitoring and automated compliance reporting saw improvements in regulatory adherence and overall security. However, some organizations faced challenges in fully implementing these metrics due to resource constraints and a lack of technical expertise, highlighting the need for better support to ensure comprehensive security metric adoption.

Objective 3: IoT Security Framework Scalability

Objective 3 investigated the scalability of IoT security frameworks within Fintech MSMEs. The survey results revealed that most organizations believed their security frameworks could scale to accommodate the growing complexity of IoT environments. However, smaller organizations expressed concerns about the integration of IoT devices and maintaining security compliance as their networks expanded. This finding emphasizes the need for flexible and adaptable security frameworks that can evolve with organizations' technological maturity and operational needs.

Objective 4: Compliance Improvement Evaluation

Objective 4 aimed to evaluate improvements in regulatory compliance resulting from the implementation of structured IoT security measures. The results showed that a significant proportion of respondents (approximately 65%) reported improvements in

compliance after adopting the security framework. The study found that these improvements were measurable through structured compliance metrics such as automated reporting, real-time monitoring, and risk assessments. While a large majority of respondents agreed that these frameworks helped reduce security breaches and audit penalties, some organizations still faced challenges in fully achieving compliance due to limited resources. These findings suggest that IoT security frameworks have a tangible impact on compliance outcomes, improving adherence to regulatory standards such as GDPR and PCI DSS.

Overall, the research demonstrates that structured IoT security frameworks are critical for improving compliance outcomes in Fintech MSMEs, enabling these organizations to navigate the complex regulatory landscape while addressing IoT security vulnerabilities.

6.2 Implications

The findings from this study provide valuable insights and have significant implications for Fintech MSMEs, policymakers, and the broader cybersecurity community, particularly in the areas of IoT security and regulatory compliance.

For Fintech MSMEs, this study underscores the critical importance of adopting structured, scalable, and data-driven IoT security frameworks. The results suggest that IoT vulnerabilities pose substantial risks to both financial stability and operational efficiency for Fintech MSMEs. However, organizations that proactively implement security measures are better positioned to mitigate these risks. Specifically, the study found a positive correlation between the use of security metrics—such as real-time monitoring, automated compliance reporting, and vulnerability assessments—and improved regulatory compliance. The data analysis revealed that 65% of the sampled

MSMEs reported an improvement in compliance scores by 20% after implementing the security framework, with the baseline compliance score at 2.3/5 and post-implementation at 2.8/5, demonstrating a statistically significant improvement (p-value = 0.05).

In terms of practical implementation guidance, Fintech MSMEs can leverage open-source encryption tools like OpenSSL or VeraCrypt for securing their data, and they can integrate cloud-based security services such as AWS Free Tier or Google Cloud to meet their security needs without major upfront costs. For a practical adoption process, MSMEs can follow a step-by-step implementation plan: during weeks 1-2, they can assess their current IoT security vulnerabilities and choose appropriate tools, including firewalls like pfSense and cloud solutions. In weeks 3-4, they can proceed to implement and integrate these tools, followed by weeks 5-8, where they should focus on setting up real-time monitoring and automated compliance reporting systems. Throughout the process, online training platforms like Cybrary or Udemy can be used to upskill staff, ensuring an efficient transition. For cost considerations, open-source tools like pfSense are free, and cloud services such as Google Cloud's startup credits offer flexible pricing, while training can be done affordably through online courses that focus on IoT security.

For Policymakers, the study highlights the need for continued support to help Fintech MSMEs adopt IoT security best practices. Barriers such as limited financial resources and lack of technical expertise can hinder the implementation of robust IoT security measures. The findings suggest that external support—including regulatory guidance, training programs, and possibly financial incentives—could play a pivotal role in helping these organizations overcome these barriers. By providing such support, policymakers can make it easier for Fintech MSMEs to adopt the frameworks necessary to comply with regulations like GDPR and PCI DSS. Additionally, the establishment of standardized security frameworks and metrics can aid in streamlining compliance efforts,

enabling MSMEs to align with regulatory requirements without overburdening their limited resources.

From a Cybersecurity Perspective, the study offers implications for developing tailored, flexible, and resource-efficient security solutions. While larger organizations have the financial resources to implement complex security systems, Fintech MSMEs often lack the capacity to invest in expensive infrastructure. The findings suggest that decentralized technologies, such as blockchain and fog computing, could provide smaller organizations with cost-effective solutions that enhance security, scalability, and compliance. When integrated into standardized frameworks, these technologies can simplify the complexity and reduce the cost of securing IoT systems, particularly in resource-constrained environments.

Finally, this research presents several implications for future research. Given the varying levels of awareness about IoT security vulnerabilities within Fintech MSMEs, there is a clear need for more research on effective training programs and awareness campaigns to close the knowledge gap. Additionally, AI-driven threat detection and predictive models should be explored further to develop proactive security strategies to better address emerging cybersecurity threats. The scalability and adaptability of IoT security frameworks also warrant further investigation to ensure they can continuously address the evolving cybersecurity landscape and ensure long-term resilience in Fintech MSMEs.

6.3 Recommendations for Future Research

Based on the findings of this study, several key areas of future research emerge that could provide deeper insights into the challenges and opportunities related to IoT security for Fintech MSMEs. These areas of research will not only contribute to a better

understanding of the current state of IoT security but also offer actionable guidance for improving security practices and frameworks. The following recommendations aim to build on the insights from this study, offering more specific, data-driven solutions:

1. Exploring the Integration of Advanced Technologies for IoT Security

One promising area for future research is the integration of emerging technologies such as artificial intelligence (AI), machine learning (ML), and quantum-resistant cryptography into IoT security frameworks for Fintech MSMEs. This research could focus on how these technologies can enhance threat detection, automate security protocols, and provide predictive insights into vulnerabilities. However, future research must ensure that practical cost estimates and feasibility studies are incorporated to make the implementation accessible for resource-constrained organizations. By examining the cost-benefit of integrating these technologies into MSMEs, researchers could help create more adaptive, scalable, and affordable security systems suitable for IoT environments.

2. Effectiveness of Decentralized and Open-Source Security Solutions

While decentralized technologies such as blockchain and fog computing may offer scalable security solutions, further research is required to evaluate their practical implementation and effectiveness in Fintech MSMEs. Future studies should focus on case studies or pilot projects to explore real-world applications, assessing factors such as cost, ease of integration, and the ability to address emerging security threats. Additionally, this research could include specific tools and implementation steps, addressing the challenges MSMEs face in adopting decentralized solutions, which could provide them with cost-effective and secure alternatives to traditional systems.

3. Understanding the Role of Employee Training and Awareness

This study highlighted varying levels of awareness about IoT security vulnerabilities within Fintech MSMEs. Future research could investigate the impact of

targeted employee training and awareness programs on improving the security posture of these organizations. Research should explore best practices for designing effective training modules, the role of leadership in fostering a security culture, and how awareness influences decision-making regarding IoT security measures. The focus should be on developing affordable and scalable training solutions that take into account the resource constraints of MSMEs.

4. Impact of Regulatory Compliance on IoT Security Practices

Future studies could focus on exploring the long-term effects of regulatory compliance requirements on IoT security strategies within Fintech MSMEs. This research should examine how regulatory frameworks (e.g., GDPR, PCI DSS) across different regions influence MSMEs' organizational behavior, resource allocation, and adoption of best practices for IoT security. A critical part of this research should also evaluate the effectiveness of regulatory support mechanisms, such as incentives, subsidies, or simplified compliance frameworks, and their impact on MSMEs' ability to improve their security measures without overwhelming their financial resources.

5. Developing Metrics for Measuring IoT Security Success

While this study identified the importance of security metrics in improving regulatory compliance, there is a lack of standardized metrics for measuring the success of IoT security frameworks specifically in Fintech MSMEs. Future research could develop a universally accepted set of quantitative metrics that could help organizations measure the success of their IoT security frameworks. These metrics should be practical and tailored to smaller organizations that may not have access to sophisticated tools or expertise. Research could explore the challenges MSMEs face when selecting appropriate metrics and identify cost-effective tools for their implementation.

6. Investigating the Business Value of IoT Security in Fintech MSMEs

Finally, future research could investigate the business value of robust IoT security practices in Fintech MSMEs. This research could explore how investments in IoT security translate into measurable outcomes, such as reduced downtime, improved customer trust, and fewer regulatory penalties. By linking security investments to tangible business results, future studies could provide clear evidence of the ROI of cybersecurity investments, which would encourage Fintech MSMEs to adopt robust security measures, thus improving their long-term sustainability.

6.4 Conclusion

This research has examined the pressing challenges and opportunities surrounding the implementation of IoT security measures within Fintech MSMEs, with a specific focus on understanding vulnerabilities, establishing security metrics, evaluating the scalability of security frameworks, and assessing improvements in regulatory compliance. Through a detailed analysis, the study has highlighted the critical role of IoT security in maintaining the operational integrity and compliance of Fintech MSMEs, a sector increasingly reliant on interconnected devices and systems.

The study found that while Fintech MSMEs are aware of the vulnerabilities posed by IoT, many still face significant challenges in securing their systems due to resource limitations, technical expertise gaps, and financial constraints. However, the positive impact of structured IoT security frameworks was evident, as organizations that adopted comprehensive security measures reported improvements in regulatory compliance, a reduction in security breaches, and enhanced operational efficiency. Furthermore, the scalability of security measures emerged as a key factor for organizations seeking to grow without compromising on security.

The research also emphasized the importance of developing standardized IoT security frameworks that are adaptable to the needs of Fintech MSMEs. These frameworks, when combined with targeted security metrics, such as real-time monitoring, risk assessments, and automated compliance reporting, provide a solid foundation for organizations to manage security threats while meeting regulatory demands. Additionally, the studys findings indicate that decentralized technologies like blockchain and fog computing could offer promising solutions to enhance IoT security, especially in resource-constrained environments.

In conclusion, this study underscores the necessity for Fintech MSMEs to adopt proactive, scalable, and cost-effective IoT security frameworks to safeguard their systems and comply with evolving regulatory standards. As IoT adoption continues to expand across industries, it is imperative that organizations remain vigilant and adaptable, incorporating new technologies and security practices to address the growing complexity of their digital environments. By addressing IoT vulnerabilities, enhancing security metrics, and fostering a culture of continuous improvement, Fintech MSMEs can ensure that their IoT systems remain secure, compliant, and capable of supporting innovation and business growth in an increasingly interconnected world.

APPENDIX A

QUESTIONNAIRE

IoT Security Compliance Questionnaire for Fintech MSMEs

Instructions:

Please answer the following questions based on your organizations experience with IoT

security.

- For demographic questions, select the most applicable option.

- For rating-scale questions, please indicate your level of agreement using the following scale:

1 – Strongly Disagree | 2 – Disagree | 3 – Neutral | 4 – Agree | 5 – Strongly Agree

Section 1: Demographic Information

1) What is your current job role?

- ☐ IT Manager 40 - ☐ Fintech Executive 100 - ☐ Cybersecurity Officer - ☐-20 Compliance/Regulatory Specialist30 - ☐ Business Owner/Founder -10

2) How many years of experience do you have in Fintech or cybersecurity?

- ☐ Less than 1 year - ☐ 1–3 years- - ☐ 4–7 years - ☐ 8+ years

3) What is your Company size:

- ☐ Micro (1–10 employees) - ☐ Small (11–50 employees) - ☐ Medium (51–250 employees) - ☐ Large (251+ employees)

4) Which Fintech sector best describes your company?

- ☐ Payments & Transactions - ☐ Lending & Credit Services - ☐ Blockchain & Cryptocurrency - ☐ Wealth Management & Investment - ☐ Insurtech (Insurance Technology)

5) Which security regulations apply to your company? (Select all that apply)

- ☐ GDPR - ☐ PCI DSS - ☐ ISO/IEC 27001 - ☐ NIST - ☐ None

6) How reliant is your company on IoT for financial operations?

- ☐ Not at all - ☐ Somewhat - ☐ Moderately - ☐ Heavily

Section 2: IoT Vulnerabilities and Risks

(Obj 1: To Analyze and Quantify the Impact of IoT Vulnerabilities on Fintech MSMEs by identifying the frequency, severity, and operational disruptions caused by these threats.)

1) IoT-related security threats have led to notable financial losses in our organization**.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 Agree

2) IoT vulnerabilities negatively impact our overall operational efficiency**.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 Agree

3) The frequency of IoT security incidents in our organization is concerning**.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 Agree

4) Our operations have experienced significant disruptions due to IoT security breaches**.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 Neutral

5) **IoT security risks limit our ability to innovate.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5 Agree

6) Our organization is adequately informed about the specific IoT vulnerabilities affecting our systems.

- ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 Agree

Section 3: Security Metrics for Compliance Measurement

(Obj 2:To Establish and Validate Security Metrics that enable Fintech MSMEs to achieve measurable improvements in compliance adherence, targeting a 20% increase in regulatory compliance levels.**)**

1) **Our organization actively uses security metrics to measure cybersecurity performance.**

☐ yes

☐ No

2) **Which specific security metrics your organization use to track IoT security performance?**

   ☐ **risk assessments**

   ☐ **compliance tracking tools**

   ☐ Incident Reports & Security Logs

   ☐ Regulatory Audit Scores

3) If you are using security metrics, it is capturing IoT security posture effectively.

   - ☐ Yes | ☐ No | ☐ May be

4) **Implementing security metrics** has led to improvements in our regulatory compliance.

   - ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

5) Our organization finds it challenging to select or measure appropriate IoT security metrics**.**

   - ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

Section 4: Implementation and Scalability of the IoT Security Framework

(Obj 3:To Design, Implement, and Test the Scalability of the Proposed IoT Security Framework across MSMEs of varying sizes and complexities to ensure adaptability and effectiveness.**)**

1) Our current security measures are scalable to address the growing complexity of IoT systems**.**

   - ☐ Yes | ☐ No | ☐ May be

A standardized IoT security framework would be beneficial for our organization**.**

   - ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

2) We have faced challenges in implementing IoT security solutions that adapt to our business needs.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

3) The proposed concept of using decentralized and open-source technologies (e.g., blockchain, fog computing) is appealing for enhancing IoT security in resource-constrained environments.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

4) External support (e.g., consultants, managed services) would improve our IoT security compliance.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

Section 5: Post-Implementation Compliance Improvements

1) Our regulatory compliance has improved following the adoption of structured IoT security measures.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

2) Our organization has a clear method for measuring compliance improvements over time.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

3) **We have seen a reduction in security breaches due to improved compliance.**

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

4) We experience fewer audit issues and regulatory penalties as our IoT security practices have matured.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

5) The implementation of a comprehensive security framework would enhance customer trust and confidence.

- ☐ 1 | ☐ 2 | ☐ 3 | ☐ 4 | ☐ 5

Section 6: Additional Feedback

1) In your view, which of the following are the most critical IoT vulnerabilities facing your organization? (Select all that apply)

   ☐ Unauthorized access / weak authentication

   ☐ Data breaches / information leakage

   ☐ Ransomware attacks

   ☐ Phishing and social engineering attacks targeting IoT endpoints

   ☐ Insecure firmware or software vulnerabilities

   ☐ Lack of timely security patches and updates

   ☐ Device hijacking or control compromise

   ☐ Insufficient network segmentation

2) What challenges have you encountered in implementing or scaling IoT security measures in your organization? (Select all that apply)

   ☐ Limited financial resources for cybersecurity investments

   ☐ Lack of in-house technical expertise or specialized staff

   ☐ Complexity of integrating IoT devices with legacy systems

   ☐ Inadequate or unclear regulatory guidelines

   ☐ Scalability issues as the IoT environment grows

   ☐ Insufficient vendor support or interoperability issues

   ☐ Resistance to change within the organization

3) Which additional security metrics or framework features would you suggest to improve regulatory compliance? (Select all that apply)

   ☐ Real-time monitoring and alerting capabilities

☐ Automated compliance reporting and audit trails

☐ Integration with existing IT and security management systems

☐ Customizable dashboards for performance tracking

☐ Regular vulnerability scanning and risk assessments

☐ Advanced threat detection analytics

☐ Cost-benefit analysis for security investments

☐ Benchmarking against industry standards

APPENDIX B

INFORMED CONSENT

Research Title: Developing a scalable iot security compliance framework for strengthening the security posture of fintech msmes: a quantitative approach

Principal Investigator: My name is Arun Sasidharan Pillai. I am a DBA learner at SSBM GENEVA. I am conducting a study, and you are invited to participate.

Purpose of the Study:

The purpose of this study is to explore the IoT security vulnerabilities faced by Fintech Micro, Small, and Medium Enterprises (MSMEs) and to evaluate the impact of IoT security frameworks on regulatory compliance and operational efficiency. By participating in this study, you will contribute valuable insights into the current state of IoT security in the Fintech sector and help identify solutions to improve security practices and compliance measures.

Procedures:

If you agree to participate, you will be asked to complete a structured survey. The survey will include questions about your experiences, preferences, and perceptions regarding health insurance marketing strategies. It will take approximately 15–20 minutes to complete.

Confidentiality:

All information you provide will be kept confidential and used solely for academic purposes. Your responses will be anonymized to ensure that no personally identifiable information is included in the studys results. The data will be securely stored and accessed only by the researcher and authorized personnel.

Potential Risks and Benefits:

There are no significant risks associated with participating in this study. Your participation will contribute to valuable insights into improving health insurance marketing strategies, which may ultimately benefit consumers and the industry.

Consent Statement:

By signing below, you confirm that you have read and understood the information provided above. You consent to participate in this study and allow the researcher to use your responses for academic purposes.

Participant's Name: _____

Participant's Signature: _____

Date: _____

Researcher's Signature: _____

Date: _____

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