A Strategic Framework for Automated Risk Modelling in Cybersecurity Enhancing Risk Quantification in Complex IT Infrastructures

Sneha Gogineni
USA
gsneha0828@gmail.com

Abstract

As cyber threats evolve in sophistication and frequency, the need for accurate and automated cyber risk quantification has become essential, particularly within complex IT infrastructures. This paper presents a strategic framework for automated risk modelling in cybersecurity, aiming to enhance cyber risk quantification across various industry sectors. By focusing on key challenges such as poor visibility, a dynamically changing threat landscape, and the shortage of resources, we highlight the critical elements necessary for successful risk quantification. Through an examination of the Factor Analysis of Information Risk (FAIR) model and the NIST 800-30 Risk Assessment Guide, we explore both quantitative and semi-quantitative approaches to assess the impact and frequency of potential cyber threats. Our proposed framework emphasizes the need for a standardized risk language to facilitate better decision-making and aligns with regulatory requirements. Using both a theoretical and practical approach, the framework encourages frequent updates, scenario-based planning, and thorough documentation to improve organizational resilience and stakeholder confidence. Ultimately, this paper underscores the value of cyber risk quantification as a tool for businesses to prioritize risks and allocate resources effectively, ensuring alignment with compliance mandates and growth goals.

Keywords: IT Infrastructures, Cyber risk, Cybersecurity

1. INTRODUCTION

The goal of cyber risk quantification is to determine the monetary and operational consequences of cyber risk for a company. To help their business executives and board members better understand the effect of cyber risk and how to minimise it, cyber leaders give data-driven metrics and context by quantifying risk in business terms [1]. You should conduct and include cyber risk quantification methodologies into your cybersecurity program due to the growing number of cyber events and cyber risk governance and legislation. With cyber risk

quantification (CRQ), you can get metrics backed by data that show how vulnerable you are to cyber threats. However, CRQ allows you to discuss risk in terms of its financial and business implications, rather than displaying these results in technical terms, like the conventional red-amber-green scorecards and heat maps.

For instance, with CRQ you can answer important questions such as:

- "What is the potential monetary loss if we fail to resolve a specific security program gap?"
- To what extent will various cyber incidents affect businesses?
  Which security projects should take precedence to improve risk stabilisation?
- "Where should we put our money to improve our security measures?"

How to select the right cyber risk quantification method

To quantify cyber risk, two main paradigms exist. I think it would be beneficial for your company if we compared the two.

1. Factor Analysis of Information Risk (FAIR)

Any organisation may comprehend, analyse, and quantify cyber risk using the FAIR approach. As per the FAIR Institute's findings:

- FAIR can assist with the financial quantification of cyber and operational threat.
- Unlike risk assessment frameworks, it focusses on quantitative weighted scales and qualitative colour charts as its output.
- It lays the groundwork for a strong information risk management strategy.

In-depth features of the FAIR model include a risk taxonomy and technological standards that are proprietary to the model [2]. Your company can use its probability-based methodology with any asset kind.

The FAIR method of CRQ is quite labour-intensive and laborious, despite its widespread use. Your digital environment (systems, assets, data flow) and vendors and providers (particularly those with direct access to your systems or data) must be thoroughly documented in order to conduct a FAIR assessment. The next step is to catalogue possible dangers, assess your safeguards, rank the severity of each risk (high, medium, low), and determine the possible consequences in different situations. The data collection process and the expertise needed to simulate different cyber threats in order to determine a risk exposure range make FAIR assessments complex, difficult to scale, and very impractical to repeat.

2. Turnkey cyber risk modeling

An alternate approach to FAIR is automated, turnkey cyber risk modeling. The Bitsight Financial Quantification for Enterprise Cyber Risk model is a solid illustration of this type of

approach.

Without adding staff or resources, Bitsight for CRQ can simplify the process of financially assessing your cyber risk. This solution integrates information regarding your digital assets and the systems upon which they depend, as well as data pertaining to your company, cyber insurance claims, and the likelihood of cyber scenarios [3]. A variety of business impact scenarios, such as ransomware, data breaches, denial of service attacks, third-party breaches, regulatory compliance concerns, and more, may be easily and swiftly simulated. With Bitsight, you can quickly and easily determine cyber risk without having to recruit extra staff or pay for outside advice. It's available whenever you need it.

You can more easily and rapidly identify the root causes of financial exposure with the help of the findings displayed in a graphical interface that allows you to drill down into examples of cyber events.

Why quantify cyber risk at all?

Analysing and applying data-driven metrics to previously recognised cyber dangers is called cyber risk quantification. To help company executives and board members make informed decisions on cybersecurity and financial priorities, cyber risk quantification aims to provide risk statistics in commercial terms. This helps business executives to better understand the different risk components, which in turn allows them to make more informed decisions and prioritise remediation efforts [4]. It turns the ethereal aspect of risk into quantifiable repercussions for the company. Cyber insurers often use key performance indicators (KPIs), security ratings, or modeling tools to quantify cyber risk and find their possible financial exposure.

With the correct approach to cyber risk quantification, businesses are able to:

• Monitor the monetary effects of both the obvious and less obvious consequences of risk.

• Make the organization's likely cyber vulnerability and its impact crystal clear.

• Acceptance, mitigation, or risk transfer through insurance should be the topic of well-informed conversations.

• Educate everyone in the company, not just the IT staff, on the need of cybersecurity.

• Invest more wisely to lessen overall cyber risk.

What is Cyber Risk Modeling?

Cyber risk conversations are now taking place at the highest levels of an organisation, from the C-suite to the boardroom, due to the proliferation of cyber security threats. Cybercrime is a major problem that needs to be addressed. In the United States, the typical price tag for a data breach has increased to almost $9.44 million so far this year. Claims pertaining to incidents

have skyrocketed by 486% since 2018, with the vast majority of these claims being associated with ransomware. These tendencies will persist, according to experts [5]. Board members and top executives must be able to estimate risk in a way that is not technical, because every company is different. That way, they can manage risks, lessen cyber risks, and transfer risks with confidence. Modeling cyber risk in a way that businesses can understand can simplify an otherwise daunting undertaking. Let's look at cyber security risk modeling, its uses, and the revolutionary insights it offers.

What is cyber security risk modeling?

The goal of cyber security risk modelling is to generate several possible risk scenarios, rank them in order of severity, and then quantify the possible consequences of each scenario - all in a language that your organisation can understand. Cyber threat modelling is different from cyber risk modelling. Frameworks for threat models aid in the detection of cyber risks and vulnerabilities, which in turn guide the prioritisation of countermeasures. Cyber risk modelling, in contrast, provides a reliable and repeatable way to estimate the probability of a cyberattack [6]. Your company can use this information to make informed decisions about where to put their money to get the best return on investment.

An example of cyber security risk modeling

Measuring cyber risk in monetary terms rather than business terms is a major example of cyber security risk modelling. If everyone in your company has the same idea of what cyber risk is, you can build a stronger cybersecurity program and have more fruitful discussions about how various cyber scenarios and investments will affect your company. Quantifying risk in a financial portfolio is quite similar to this analysis. To better understand and prepare for the potential effects of future events on performance, risk models are utilised by traders and portfolio managers, among others. Since this is known in advance, they can decide where to put their money without delay.

A data-driven approach to understand risk exposure

Any model will only be as accurate as the information and assumptions used to create it. All risks should be appropriately reflected in the data, which should be up-to-date. For any security staff, it's a daunting undertaking. An organization's attack surface and related dangers are

growing as digital ecosystems spread to the cloud and between different departments and affiliates. Finding all digital assets, assessing their risk vulnerability, and estimating the monetary consequences of a possible breach would demand a substantial investment of resources. There is no need to hire third-party consultants or go through tedious data collection procedures using Bitsight's cyber security risk modelling platform. With the tools at your disposal, your organisation can produce these insights. There's no need to engage external risk analysts or ask consumers for extensive data. Data used by Bitsight is sourced from actual cyber incidents. In order to measure monetary risk, we combine this data with details regarding the safety of your company's digital assets. When used together, these metrics provide a comprehensive picture of your company's cyber risk exposure across all divisions, affiliates, and potential acquisition targets. In addition, you may examine the monetary effect of each of hundreds of thousands of events—including ransomware, supply chain assaults, and more—during the threat modelling process, since no two risk scenarios are identical. You can also utilise these insights to identify the root weaknesses that affect financial exposure and determine the best actions to reduce cyber risk. The financial cyber risk quantification analysis can be accessed whenever you need it and is simple to replicate, allowing you to track your risk exposure over time, which is important because risk is always changing.

Establish a common language around cyber risk

By analysing various loss scenarios, Bitsight's cyber security financial quantification models connect the SOC with business leaders and shift the debate about cyber security at an organisational level. To facilitate conversations about cyber risk management, you must first translate the technical aspects of cyber security into common financial terms. Investments in new technology can be better prioritised and justified by your team. As a result of improved security posture, you can track the changes in your financial risk, determining the ROI of these investments becomes easier over time.

2. LITERATURE REVIEW

Many products are moved by water, making the marine industry a vital part of international trade and business [7]. Financial and logistical ramifications can be substantial if a cyberattack were to interrupt normal operations. There is a critical cybersecurity issue in the maritime area due to the growing importance of digital technologies. There are new cybersecurity vulnerabilities due to the connectivity and automation of ship subsystems, which means that new cybersecurity solutions are needed alongside existing ones. Further, there are a number of

potential weak spots due to the variety and complexity of the technology utilised by contemporary ships, including as navigation, information communication, and operating systems. Ships are more vulnerable to cyberattacks and mishaps without enough preparation and awareness, which can lead to disruptions, liabilities, environmental issues, and even casualties. This is especially important to keep in mind while thinking about ports, since the rise of digital technologies in operations poses new risks and makes them more appealing targets for criminals. Ship operations may also be impacted by such circumstances. In the past few years, this domain has been the target of multiple attacks. One prominent example is the 2017 cyberattack that crippled Maersk's operations and cost the corporation millions of dollars [8]. This instance shows how cyberattacks can affect global supply chains and how inadequate maritime systems are in dealing with complex cyberattacks.

Automatic identification systems (AIS) are susceptible to cyber manipulation including spoofing, as is the case with other vulnerabilities in marine communication systems, as has been described in the literature. Collisions, piracy, and other threats to marine security can occur because of these weaknesses. Examples include the 2016 incident in which two naval boats became adrift in the Persian Gulf due to a cyberattack [9]. Cybercriminals also compromised the computer systems of a container ship owned by Germany in February 2017. As a result of the rapid appearance of hundreds of imposter ships near Elba Island, an Italian AIS base station also saw substantial interference. Therefore, the surveillance of maritime traffic in the region was interrupted. Another instance exists where Iranian tankers engaged in trade with Syria while disguising themselves as Tanzanian ships with the use of bogus AIS signals [10].

In the aftermath of these incidents, prominent maritime bodies like the IMO and BIMCO established standards and recommendations to enhance maritime cybersecurity. Operators and owners of ships are obligated to assess cybersecurity risks and safeguard their safety management systems in accordance with this integration's directives as of January 2021 [11]. As of July 2024, new classes of marine construction known as Unified Requirements E26 and E27 will be in place, thanks to the International Association of Classification Societies, with the goal of improving maritime cybersecurity. Integrity of third-party systems is the primary emphasis of E27, whereas E26 is aimed at protecting the integration of information and operational technologies as well as the continuing operations of marine networks [12]. Prior to their installation in vessels, it is crucial to secure user interfaces and establish standards for the design and development of new devices.

Challenges of cyber risk quantification

After assisting thousands of businesses with cyber risk management, we have identified the following as some of the most pressing issues:

1) Poor visibility: Security leaders are finding it harder and harder to obtain relevant insights based on risk level as the volumes of data processed within IT infrastructure continue to pile up. Companies attempting to manage their processes with manual or semi-automated systems and without proper cyber risk quantification tools will find this to be particularly true.

2) Changing threat landscape: The risk landscape is constantly evolving as malicious actors create and launch new, more sophisticated assaults. That being said, in few months from now, the findings of a risk assessment might not apply.

3) No starting point: Cyber risk awareness is a common challenge for startup and small company executives. They face difficulties in identifying where to begin due to a lack of knowledge or insight about their weaknesses.

4) The shift to quantitative approach: It is usual practice to employ qualitative methods. Due to their lack of transparency and the difficulties in determining the best course of action, stakeholders favour the quantitative method. Business operations are disrupted by this complex and unexpected change in processes.

5) Inadequate resources: Managing the life cycle of risk quantification requires a significant investment of time and resources. Prioritising the mitigation of security risks is often not given top priority by firms until something goes wrong, in order to satisfy regulatory requirements, or because of pressure from stakeholders. Allocating resources without halting critical processes becomes necessary in the face of unexpected changes.

Cyber Risk Quantification: Understanding Models & How to Address Key Challenges

Securely running a cloud-based company has never been more challenging. Where is the issue? Limited resources, overworked personnel, and an ever-increasing mountain of dangers [13]. However, the answer is right there in front of you: Quantifying cyber risk. By eliminating the need for educated guesswork, it enables you to identify the most pressing risks to your company, put a dollar amount on their possible impact, and set priorities appropriately.

Cyber risk quantification is the subject of this article, which investigates:

- Learn about it and how it functions.
- Models for assessing risk to kickstart your deployment.
- Important difficulties and ways to get past them.

Why is cyber risk quantification important?

Cyber risk quantification aids security professionals in prioritising vulnerabilities and threats and in calculating the monetary impact of possible cyber threats. Stakeholders, both technical and non-technical, will have an easier time understanding your efforts and expressing their concerns if you use objective risk language universally [14]. A cyber risk quantification system provides more precision in your procedure. Based on the location, technology, assets, and other components, you can receive insight into numerous risk variables. Gaining a detailed understanding of your business's strengths, weaknesses, opportunities, and threats allows you to create a personalised risk appetite. This data can be used by risk teams to safeguard assets that are vulnerable to attacks [15].

3. CYBER RISK QUANTIFICATION METHODS: MODELS AND FRAMEWORKS

To better understand and control potential threats in your specific setting, you can use a risk quantification model. Although there are several models and frameworks available, we will be covering two of the most well-known and extensively used ones today:

Factor Analysis of Information Risk (FAIR)

Organisations can gain insight into environmental concerns with the help of the FAIR risk model, a framework for quantitative risk analysis. It can help security and data scientists understand the interplay between all aspects of risk by decomposing complicated risk occurrences into quantifiable components. The FAIR model can predict monetary loss by mathematically dissecting the effect of various risk situations. Probability is its basis, not the high/medium/low model's predictive analysis. Put another way, you receive an unbiased assessment of risk. Quantifying the number of unauthorised access attempts, for instance, with a concrete figure like fifty, rather than depending on a subjective word like 'large number of incidents,' offers actionable data for risk analysis. Documenting the reasoning and assumptions behind the estimate is also encouraged by the framework. This allows you to examine the estimates and reasoning from a distance, which might help you resolve disagreements over the result.

The FAIR risk equation incorporates both the frequency of loss events and the size of losses. The framework takes a top-down approach, and each component has its own set of subcomponents. Separating these two components is the next step. The loss event frequency measures the likelihood of a danger event occurring during a specific timeframe. Two things are propelling it forward -

1. A threat actor's attempt to breach your infrastructure or access your assets is quantified by the frequency of threat events. But every effort does not result in a successful outcome. They could still do nothing with your assets even if they have access to them. Therefore, not all touch events lead to threat events. Likewise, not all threats lead to losses.
2. The likelihood that a threat event would lead to a loss is known as vulnerability. In this section, we evaluate the agent's threat capabilities in relation to the strength of your assets' resistance.

The likely amount of damage that will be caused by a loss is known as the loss magnitude.

1. A threat event's primary loss magnitude is the monetary impact felt by the most important stakeholder as a result of the danger. When calculating losses in the FAIR model, the main stakeholder's perspective is always considered.
2. When secondary stakeholders like as consumers, regulators, investors, etc., respond negatively to the primary stakeholder's loss, adding insult to injury, we say that secondary loss has occurred.

Using the FAIR method has the benefit of allowing you to skip layers that aren't essential to your study. For instance, it is unnecessary to get into secondary loss magnitude if you have enough information on loss magnitude. Having the data is the first requirement for implementing a control that impacts the magnitude of the secondary loss.

NIST Risk Quantification Model

In order to provide decision-makers with accurate information, NIST acknowledges the significance of risk rating. Given the limitations of the tools, the unreliability of the data, and the skill of the people involved, it warns users against relying on risk assessment results as an accurate metric. To help businesses calculate the chances of a threat happening and the damage it could do, NIST published the 800-30 Guide for Conducting Risk Assessments. Based on the capabilities, intent, and target of your opponent, it assigns a risk score using a mix of qualitative and semi-quantitative metrics.

Table 1: Risk scoring based on a mix of qualitative and semi-quantitative factors

Qualitative values	Semi quantitative values		Adversary capability	Adversary intent	Adversary target
Very high	96-100	10	Exhibits a high level of competence and possesses excellent resources. Able to carry out a number of simultaneous and effective assaults.	The objective is to make it so the entity can't accomplish its objectives by destroying or substantially impeding its essential infrastructure and operations.	Identifies and goes after particular companies, programs, projects, people, supply chains, and information systems that are vital to the company's operations.
High	96 – 100	8	Has a lot of resources and a good level of expertise as well. Equipped to carry out a number of well-coordinated assaults.	Planned to stay undetected by lingering inside the systems and infrastructure in order to weaken and delay vital business activities. In this approach, future attacks can be readily planned.	Selected businesses, organisations, mission-critical processes, and valuable data systems are the targets. People in critical roles that assist with these tasks are also their targets.

Moderate	80 – 95	5	Possesses a fair amount of available resources. Having the ability to go on numerous successful assaults.	Attempts to sneak up on or change certain parts of the system without anybody noticing. Attempts to gain access to the systems and is prepared to obstruct essential functions in order to accomplish their goals.	Identifies valuable companies, initiatives, information, or important positions (such as CISOs) by analysing publically available data.
Low	21 – 79	2	Has a low degree of competence. Is able to successfully launch many attacks with the minimal resources at their disposal.	Attempts to gain unauthorised access to sensitive data or to disable the system's cyber defences without raising suspicion.	Harnesses a set of high-level organisations or data that is already in the public domain to attack that group. Opportunities inside that data or organisation class are what they seek.
Very low	5 – 20	0	Very few opportunities, resources, and experts are available.	The goal is to covertly undermine or deface the cyber defences.	Could potentially go after any group or category of groups.

Once you know the opponent's scores, you may assess the possibility of a threat materialising into an event and the severity of the resulting incidents.

Table 2: A threat's potential for becoming an event and the severity of those events

Qualitative values	**Semi quantitative values**		**Likelihood/ rate of threat event occurrence**	**Impact if threat event is successful**
Very high	96 – 100	10	Almost certain to occur. Rate of occurrence is 100+ a year	Multiple/ severe/catastrophic adverse effects on operations and assets.
High	80 – 95	8	Highly likely to occur. The rate of occurrence is 10 – 100 times a year.	The consequences for operations and assets are extremely negative and disastrous. Major financial loss, severe asset damage, loss of life or life-threatening injuries, and the inability to continue business-critical operations are some of the outcomes.
Moderate	21 – 79	5	Somewhat likely to occur. Rate of occurrence is 1 – 10 times a year.	A negative impact on assets and operations that are vital to the company's success. Damage to assets, reduction in ability to continue critical operations, and serious but non-life-threatening injuries to people are all examples.
Low	5 – 20	2	Unlikely to occur. Rate of occurrence is less than 1 each year and more than 1 every 10 years.	The impact on operations and assets is minimally negative. The organisation can keep running essential operations, but with somewhat less capacity, a little hit to its assets, a little hit to its finances, and no real harm to people.

Very low	0 – 4	0	Highly unlikely to occur. Rate of occurrence is less than once a decade.	The impact on the company's operations, employees, and assets is minimal.

The final assessment scale is the risk matrix you get by combining the likelihood of threat occurrence and the level of impact.

Table 3: The final assessment scale

Impact level if threat event is successful	**Level of impact**				
	Very low	**Low**	**Moderate**	**High**	**Very high**
Very high	Very low	Low	Moderate	High	Very high
High	Very low	Low	Moderate	High	Very high
Moderate	Very low	Low	Moderate	Moderate	High
Low	Very low	Low	Low	Low	Moderate
Very high	Very low	Moderate	Very low	Low	Low

How to implement cyber risk quantification

In order to assist you in implementing cyber risk quantification techniques, we have compiled our learnings from assisting thousands of firms in proactively quantifying the effect of their infosec risks:

Get everyone on the same page: All parties involved, including risk teams, external stakeholders, and even high-value prospects, must work together to build a successful risk quantification program. Having a shared vocabulary for risk helps keep important decisions from causing rifts in the future and keeps everyone on the same page.

Update as and when needed: Environmental concerns will increase as your company grows or as you make significant changes to your technological stack. You may strengthen your risk program and lessen the likelihood of missing security threats by conducting periodic assessments and quantifying them.

Prepare for the worst: Consider the worst-case scenario when calculating the impact value when assessing the loss from a threat event. Both preparing for and recovering from an actual event can be aided by this.

Plan ahead: Many companies end up in a muck because they didn't prepare ahead, which seems trite and simple. Risk quantification is a massive task that will invariably cause modest interruptions to regular operations as well as other functions, processes, and workflows.

Document your efforts: Keep a record of your actions as you go along. In the event that something does not function as expected, documentation can serve as a reference for investigating problems, in addition to serving as a regulatory compliance checklist.

Benefits of cyber risk quantification

Cyber risk quantification assists with decision-making, regulatory compliance, and stakeholder satisfaction.

To make data-backed decisions

The attack surface grows daily as your organisation adds more processes, technology, and people to its infrastructure, which is inevitable given its rapid growth. Increases in both vulnerability and the likelihood of breaches are directly proportional to increases in attack surface.

From a monetary standpoint, it is realistically impossible to eliminate or significantly lessen all risks. Security and IT administrators can better decide which risks to accept, transfer, reduce, or eliminate when they assign a numerical value to each. It also provides executives and stakeholders with a shared vocabulary to use when deciding how to allocate resources.

To comply with regulations

Regulatory responsibilities to safeguard consumer data are common for businesses that handle sensitive information, such as those that offer services to enterprises hosted in the cloud. Organisations are obligated to undertake risk assessments in accordance with NIST 800 171 and 800 53, for instance. You need to use quantitative and qualitative values to classify the information systems according to the potential loss's effect on availability, confidentiality, and integrity if you want to meet these criteria.

To meet stakeholder expectations

While regulatory frameworks are necessary in certain contexts, they also provide as an opportunity for expansion for many businesses. A growing number of cloud-hosted software as a service (SaaS) providers are proving their ability to safely manage sensitive data by implementing security frameworks such as SOC 2 or ISO 27001. Instead of being a costly hindrance, security compliance can be turned into a development driver in this manner. Resolving gaps and doing risk assessments are essential components of these frameworks. The first step is to catalogue all the important possessions and then assess the danger level, typically using a scale from low to high. Management is better able to reach consensus with stakeholders and take appropriate action in response to quantified risk.

4. RESULTS AND DISCUSSION

Impact vs. Likelihood Matrix: A heatmap showing the relationship between impact level and likelihood of threat occurrence, with risk levels increasing as you move to higher likelihood and impact combinations.

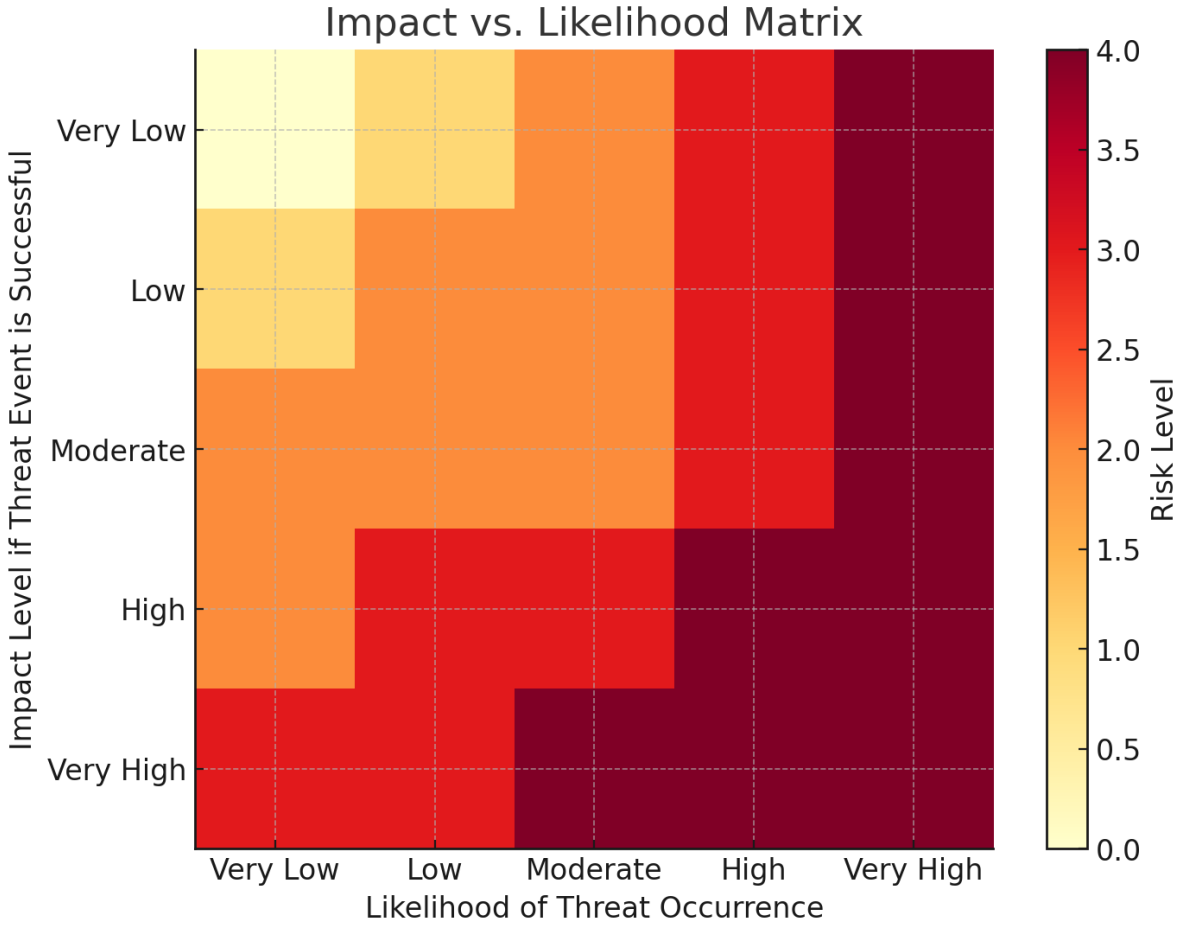

Fig 1: Impact vs. Likelihood Matrix

FAIR Model Breakdown: A pie chart representing the contributions of various components within the FAIR model, including Threat Event Frequency, Vulnerability, Primary Loss, and Secondary Loss.

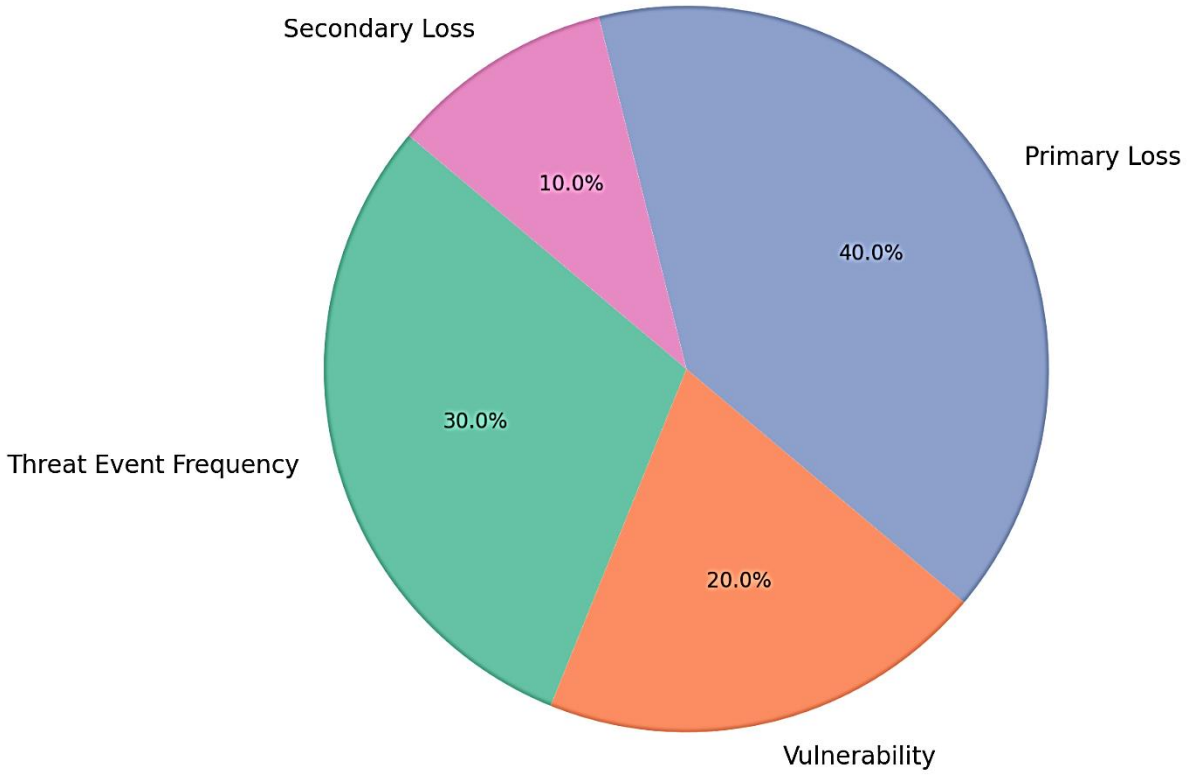

Fig 2: FAIR Model Breakdown Risk Component Contributions

Cyber Risk Quantification Over Time: A line graph showing how risk scores fluctuate over a 12-month period, reflecting how risk levels can change over time due to evolving threats and infrastructure changes.

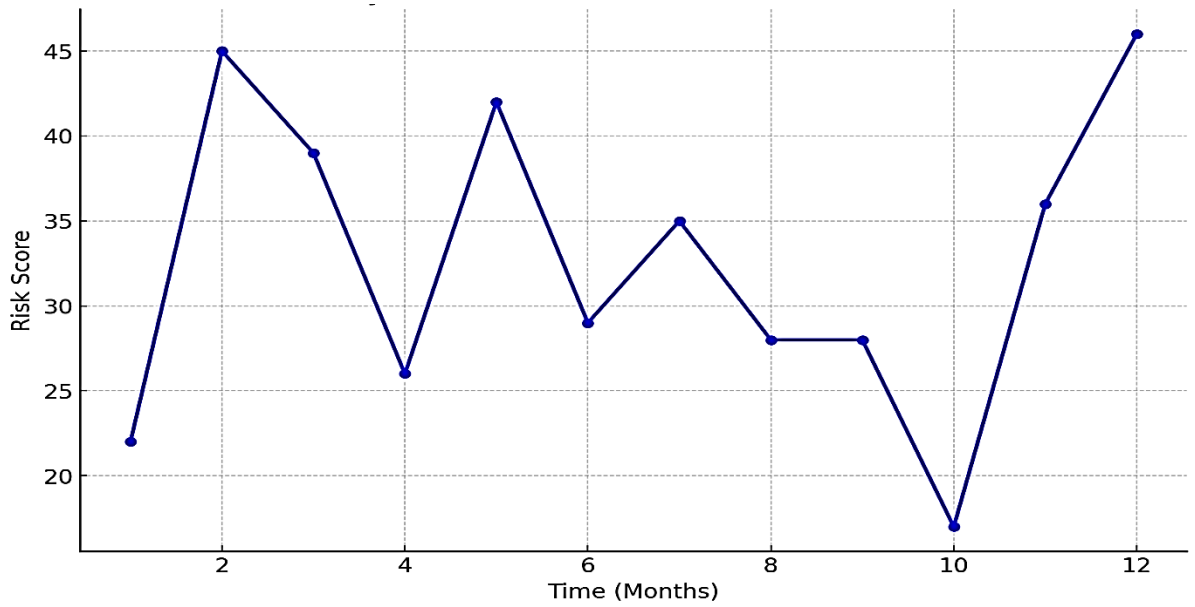

Fig 3: Cyber Risk Quantification Over Time

Resource Allocation for Risk Reduction: A horizontal bar chart indicating the allocation of resources across various risk reduction strategies, such as mitigation, transfer, acceptance, and incident response.

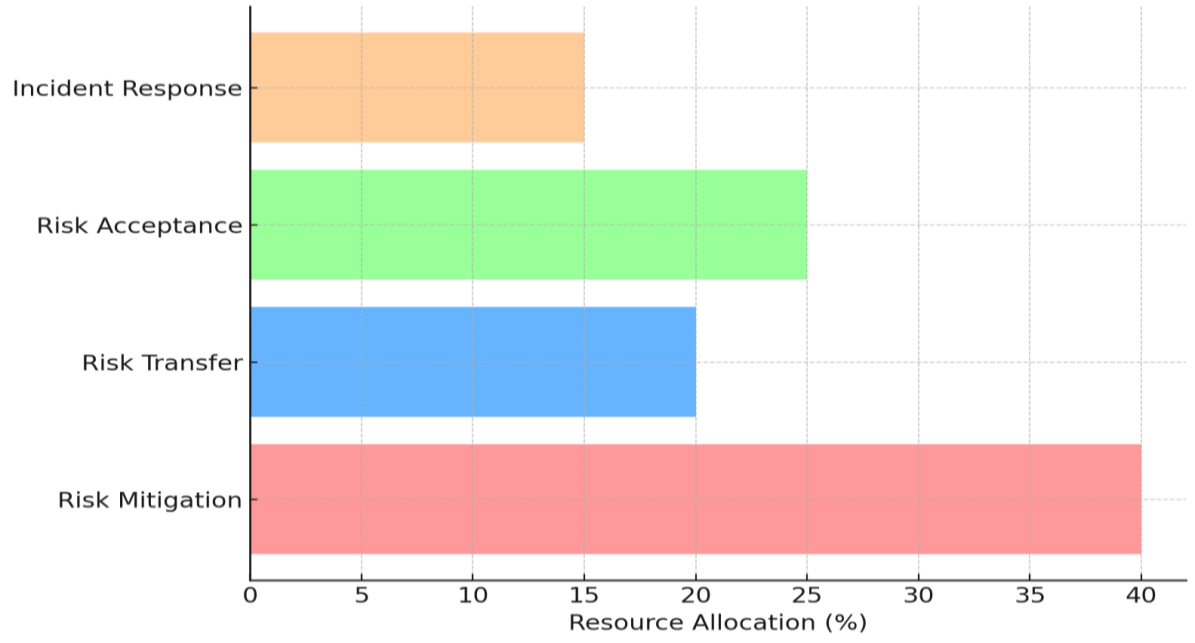

Fig 4: Resource Allocation for Risk Reduction

These visualizations provide insights into key elements of automated risk modeling and help in prioritizing resources and strategies effectively.

CONCLUSION

Automated risk quantification provides a significant advantage for organizations operating within complex IT ecosystems. By using a structured and quantitative approach, organizations can address and prioritize cyber risks effectively, minimizing the likelihood of costly breaches and meeting regulatory and stakeholder expectations. Adoption of frameworks like FAIR and NIST equips organizations to handle evolving threats with a proactive, data-driven methodology. Through this framework, cyber risk quantification not only fosters enhanced protection of critical assets but also aligns cybersecurity initiatives with business continuity and growth strategies, thereby reinforcing cybersecurity as a cornerstone of modern IT infrastructure management.

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