# Integrating Interdisciplinary Theories and Metrics for Assessing Cyber Resilience in SMEs Amid Emerging Threats

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**Abstract:** As we step into the era of Industry 4.0, digitalization is reshaping business and societal interactions. While this transformation brings numerous benefits—enhancing convenience, speed, and simplicity—it has also made organisations, particularly small and medium-sized enterprises (SMEs), increasingly vulnerable to digital risks. The rapid development of new technologies often outpaces the ability to fully comprehend and manage the associated risks, resulting in unpreparedness for the growing threat of cybercrimes. SMEs face heightened vulnerability due to their limited resources and inadequate risk assessment frameworks. The complexity of cyber threats continues to evolve alongside technological advancements, with the unpredictable nature of these risks resembling the chaotic impacts of natural disasters. Small disruptions can lead to disproportionately large consequences. Furthermore, human behaviours and cultural factors, frequently underestimated in cybersecurity strategies, play a critical role in shaping how SMEs respond to these challenges. In this paper, we aim to explore interdisciplinary approaches to resilience from various fields. By drawing on perspectives beyond conventional cybersecurity frameworks, we seek to develop a more comprehensive approach to understanding and mitigating the risks SMEs face. Through a review of literature from diverse disciplines, this short paper will be the initial preparation work for the further research on means that can make SMEs more resilient to cyber threats and crimes.

**Keywords**: Cyber resilience, Cyber threats, Cyber risks, Interdisciplinary approaches to resilience, Risk assessment, Digitalization, Small and medium enterprises

## 1. Introduction

This paper serves as a preliminary step toward a larger research goal: deeper understanding cyber risks and identifying ways to mitigate the losses caused by cybercrimes. The next step of our research will focus on developing a conceptual model of the cyber elements within a company among SMEs and the factors that influence the resilience of each element, as well as the company's overall cyber resilience. While no groundbreaking discoveries are expected from this work, it aims to advance the research by providing new insights into cyber risks, examining the whole system of accidental cyber incidents from a fresh perspective, and identifying a systematic approach to preventing failures within this system.

Entrepreneurs often react to cybercrimes as if they are sudden natural disasters. The aftermath is addressed in a disorganised manner, with the company quickly returning to its routine, hoping such incidents will not recur. If the cause of the incident is identified, the company might invest in new hardware or software to prevent future threats. In some cases, an employee deemed responsible may be punished or dismissed. However, companies rarely develop a comprehensive system to protect themselves from future cyber threats or to ensure resilience in the face of recurring cybercrimes in the future.

In previous studies, we observed frequent references to Sun Tzu's ancient treatise The Art of War (Sun Tzu, 2007), where cybersecurity is likened to military strategy (Hibberd, 2022). This strategic thinking suggests that just as people live in areas prone to earthquakes, aware of the risks but choosing to continue their daily lives and choosing not to think on risks, companies face cyber risks with a similar mindset. People in earthquake zones build new homes and go about their lives despite knowing the danger; only when a disaster strike do, they take serious precautions. Similarly, many companies only begin to address cyber risks after a major incident occurs, just as individuals only consider health measures seriously when faced with illness.

This is where a strategic approach is essential—one that anticipates future disruptions. The key question should not be, "What IF it happens?" but rather, "What will we do WHEN it happens?" In areas characterised by hidden risks and unpredictable events, this mindset is crucial. At the outset of this work, we propose that this type of forward-thinking is necessary in a world rife with concealed but foreseeable cyber threats.

The references to military strategy, natural disasters, and health issues are intentional. In research, the author often reflects on the interconnectedness of different phenomena and the necessity to "rise above" individual incidents to view the entire system. This holistic perspective stems, in part, from the author's background in studying Traditional Chinese Medicine (TCM). In TCM, ailments are not treated in isolation but viewed as disruptions within a larger system. To address the ailment, the goal is to restore balance to the entire system.

The second reason for adopting this broader view is the author's personal experience with facing cybercrime and the challenges of mitigating its consequences. This firsthand encounter reinforced the difficulty of addressing cyber risks reactively and highlighted the importance of a systemic approach to managing cyber threats.

The central question and objective of this paper are: How do other disciplines approach incidents within their fields, and what mitigation strategies do they employ? Whether it involves property insurance, enhancing immune health, or the ancient principle of "Si vis pacem, para bellum"—"If you want peace, prepare for war"—this paper explores which tactical actions from these fields can be adapted to strengthen the cyber resilience of companies.

The structure of this paper is designed to align with its objective as an initial exploration of interdisciplinary approaches to cyber resilience in SMEs. The introduction sets the context and establishes the research questions, while the methodology outlines the systematic approach taken to select and review literature. The results section is organized by discipline to highlight unique insights from various fields, followed by a discussion synthesizing these perspectives into a cohesive framework. Finally, the conclusion underscores the need for a holistic approach and suggests directions for future research. This structure ensures clarity and logical progression, facilitating a focused yet comprehensive analysis of the topic.

## 2. Methodology

To address the research question posed in this paper, we used the source-neutral abstract and citation database Scopus. We started our search with the first limitation of article selection and added additional filters until the search satisfied our intentions to reach the goal. Our focus is on gathering a variety of perspectives on the relationship between "resilience" and other related factors in different fields of sciences.

*Step 1.* The first keyword used for the search was "resilience," and the search was conducted across article titles, abstracts, and keywords. The search returned 223,128 documents, with the top five scientific fields as follows:

- Social Sciences: 55,768
- Engineering: 45,228
- Environmental Science: 43,257
- Medicine: 39,624
- Computer Science: 32,931

Step 2. Next, we refined the search to "resilience AND assessment," which narrowed the results to 30,807 documents. The top five fields of science in this refined search were:

- Environmental Science: 8,773
- Medicine: 7,994
- Engineering: 7,422
- Social Sciences: 6,531
- Earth and Planetary Sciences: 3,605

Step 3. For this study, the novelty of the work is not a priority, so we applied a time restriction to the last 20 years (2004–2024), reducing the results to 30,317 documents. Further narrowing the search to open access articles in English resulted in 11,889 documents.

Step 4. An additional filter was applied to the keywords: "Resilience" (2,780) and "Risk Assessment" (2,480). After applying all filters, the final result was 4,682 documents. The top five fields of study are as follows:

- Environmental Science: 1,769
- Medicine: 1,569
- Social Sciences: 1,208
- Engineering: 845
- Earth and Planetary Sciences: 509

With the selected literature, we will examine in more detail topics related to “resilience” addressed by various fields of study in relation to their specific challenges and issues. Our goal is to determine whether a cross-disciplinary approach can be applied to our research on cyber threats and cyber resilience.

Due to the scope of this short paper, an in-depth analysis of the literature is not feasible. Instead, a broad yet concise review is conducted to set the groundwork for further, more detailed research in subsequent studies.

This study focuses on qualitative insights and theoretical frameworks, which are better conveyed through textual analysis. As such, graphical elements are deemed unnecessary for the presentation of the primary arguments. Visual aids will be incorporated in future works to illustrate quantitative findings.

## 3. Results

### 3.1 Environmental Science - 1,769 Articles

The studies in this section cover topics related to climate change, natural disasters, urban planning, and infrastructure.

Several papers discuss resilience in the context of natural disasters. Studies highlight the importance of local, community-based support systems for effective recovery from disasters, especially immediately following extreme weather events. Traditional community resilience can sometimes be more effective than centralised government interventions. (Tee Lewis , 2023)

Urban areas face challenges such as floods and extreme heat. (Eugenio Pappalardo, Zanetti and Todeschi, 2023) Assessing resilience involves understanding how infrastructure responds to disruptions, using stress testing to predict operational performance during natural disasters and integrating green infrastructure and nature-based solutions to mitigate flood risks.(Aleksova , 2023)

The growing need for climate resilience is discussed in response to increasingly frequent extreme weather events. An environmental climate vulnerability index or an integrated socio-spatial resilience assessment is considered to help cities and regions prepare for and adapt to future climate challenges by prioritising interventions and assessing risks.(Schroeder , 2022; Zhang , 2022)

Local knowledge, collective efficacy, and livelihood diversification are highlighted as critical determinants of resilience in rural and urban communities. Community participation in planning and implementing resilience strategies is an important social driver of resilience. ( Zhou et al., 2022)

Quantitative models and indices are used to measure resilience in a variety of contexts, including water distribution networks, flood mitigation, and health systems. These tools help assess the robustness of infrastructure and social systems, identify vulnerabilities, and guide decision-making on disaster risk reduction and climate adaptation. (Rhodes , 2020; Haugen , 2022)

In the aftermath of disasters, psychological resilience supported by social networks plays a key role in recovery. Studies of cancer survivors and communities affected by multiple disasters highlight the protective effects of resilience, social support, and post-traumatic growth in reducing stress and symptom burden. ((Olivares-Delgado , 2020)

### 3.2 Medicine - 1,569 Articles

Research in the field of medicine is often concerned with health outcomes and stress management. Key theories and concepts related to resilience cited in these studies include the dynamic process of resilience, cognitive and psychological resilience, psychosocial frameworks of resilience, cyber resilience in health care, and behavioural and mindfulness approaches. (Castro-Figueroa , 2024; Habibi , 2024; Marković , 2024; Vogt , 2024; Weiss, Mahnkopf and Kohls, 2024)

Some studies frame resilience as a dynamic process rather than a static trait, emphasising ongoing adaptation and the ability to recover from adversity, such as cancer treatment or managing chronic illnesses. (Kutner and Zhang, 2023; Giordano, Salimbeni and Jefferies, 2024)

Resilience is often studied in relation to mental health, particularly in contexts such as coping with anxiety, depression, or post-traumatic stress disorder (PTSD). Theories often focus on the interactions among resilience, cognitive flexibility, and coping styles, showing how resilient individuals tend to adapt better to stressful situations. (Olivares-Delgado , 2020; Mash , 2023; Garrison-Desany , 2024; Terrana , 2024)

Some work emphasises the importance of studying resilience as a dynamic, time-sensitive process through longitudinal studies. (Katsiferis , 2023; Hoch , 2024; Laurene , 2024; Probst , 2024)

In studies of healthcare workers, law enforcement officers, or individuals experiencing significant life stressors (e.g., bereavement or chronic illness), resilience is often linked to psychological and social factors. Psychosocial

resilience includes personal characteristics that enhance an individual's ability to cope with adversity. (McCalman , 2016; Bögemann , 2023; KeunhoYoo , 2024; Probst , 2024)

Mindfulness and behavioural therapy are considered effective strategies for increasing resilience, especially in high-stress occupations. Mindfulness-based resilience training aims to reduce stress, improve adaptive coping, and promote mental well-being. (Beshai , 2022; DeTore , 2022; Puertas-Gonzalez , 2022; Robinson , 2022; Vogt , 2022)

In health infrastructure, the resilience framework extends to systems-level resilience following disruptions such as climate change or pandemics, considering technical, organisational, and social aspects. (Thekdi and Santos, 2016; Pescaroli and Alexander, 2018; Oughton , 2019; Schabacker , 2019)

### 3.3 Social Sciences - 1,208 Articles

In the social sciences, particular attention is paid to community resilience, disaster risk reduction, urban planning, and social vulnerability. Community-level resilience and social support, urban sustainability, social vulnerability and equity, risk assessment and management, and the role of policy and governance structures in supporting resilience are considered. Many articles highlight the importance of community-level approaches to building resilience, particularly in disaster recovery and disaster risk reduction, as centralised government responses may be insufficient. (Wong-Parodi, Fischhoff and Strauss, 2017; Flower , 2018; Nofal and van de Lindt, 2020; Patel , 2020; Dewa, Makoka and Ayo-Yusuf, 2021; Ner , 2023)

Resilience is discussed in relation to urban planning and the adaptation of infrastructure to withstand challenges such as floods, climate change, and natural disasters. Methods for assessing and improving resilience include modelling, scenario building, and the incorporation of environmental and social factors into planning. (Birkmann, Bach and Vollmer, 2012; Ahern, Cilliers and Niemelä, 2014; Martín-Gómez, Vergara-Falces and Elvira-Zalduegui, 2015; Vîrdol , 2015; Ghajari , 2017)

Several papers discuss the need for climate change adaptation strategies to build resilience to extreme weather events. Climate vulnerability indices and building thermal resilience assessments are used to assess and improve preparedness for future climate conditions. (Uy, Takeuchi and Shaw, 2011; Barron , 2012; Li , 2023; Gnecco , 2024; Hung, Hung and Hsu, 2024)

Some articles look at social justice, vulnerability, access to resources, and inclusion. Research examines how socioeconomic conditions, and social networks influence the ability of people and communities to withstand and recover from crises. Papers focus on social and systemic risks in interconnected systems, such as infrastructure and emergency management in urban areas. (Erwin , 2022; Gatta , 2022; Joshi and Sharma, 2022; Mascitelli , 2023; Vaezi, Jones and Asgary, 2023)

The role of policies, governance structures, and stakeholder participation in building resilience in society is considered in some studies as well. Issues such as social learning and adaptive management are considered. (Liu , 2024; McIntosh , 2024; Rathnasiri, Adeniyi and Thurairajah, 2024; Šakić Trogrlić , 2024; Shamsipour , 2024)

### 3.4 Engineering - 845 Articles

Research in this section covers infrastructure and structural resilience, climate change, natural disasters, and technology. (Mugume , 2015; Pavlov , 2018; Argyroudis , 2019; Gromek and Sobolewski, 2020)

Infrastructure, such as buildings, bridges, power grids, and rail networks, is vulnerable to hazards such as earthquakes, floods, hurricanes, and cyber threats. Resilience is assessed and enhanced using modelling-based methods, risk assessment, and structural retrofitting to minimise damage and ensure faster recovery. (Yin , 2022; Ilalokhoin, Pant and Hall, 2023; Gong , 2024)

Some studies consider the impact of climate change on infrastructure resilience, particularly with respect to increased flooding, extreme weather events, and seismic activity. Scenario modelling and probabilistic risk assessments are used to improve urban planning and disaster preparedness. (Ferrario and Zio, 2014; Attary , 2017; Kilanitis and Sextos, 2019; Manes and Rush, 2019; Trakas , 2019; Zhao , 2020; Hamer, Waterson and Jun, 2021)

In engineering systems that integrate digital technologies, such as power grids or water distribution networks, resilience extends to cyber-physical threats. Bayesian networks or machine learning are considered advanced modelling methods for enhancing cyber resilience. (Yodo, Wang and Zhou, 2017; Hosseini and Ivanov, 2020;

Mustafa and Barabadi, 2021; Veitch and Andreas Alsos, 2022; Carrascal , 2023; Sahu and Davis, 2023; Durap, 2024)

Resilience in urban environments is explored through concepts such as smart city frameworks and big data-based risk assessments that help identify vulnerabilities in critical infrastructures and implement risk mitigation measures. (Elvas , 2021; Ramesh, Rajkumar and Livingston, 2021; Gonçalves, Ferreira and Madureira, 2022; Kuzior , 2022; Bittencourt , 2024; Hyun, Lee and Jin, 2024; Peixoto , 2024)

Many studies propose new methods for quantitative assessment of resilience to provide a more accurate assessment of system performance under various stress conditions. These include the use of dynamic models, multi-hazard frameworks, or fragility curves. (Liu, Fang and Zio, 2021; Hdeib and Aouad, 2023; Hendrickx, Antolínez and Herman, 2023; Chen, Feng and Taciroglu, 2024)

Some papers discuss the role of public participation, stakeholder engagement, and community-based strategies in enhancing resilience, especially in disaster risk management and urban resilience planning. (Soetanto , 2020; Liu, Fang and Zio, 2021; Durap, 2024)

### 3.5 Earth and Planetary Sciences - 509 Abstracts

The Earth Sciences section covers a variety of resilience studies, with a focus on natural hazards, climate change, and environmental management. Discussions include climate change and environmental stress, flood risk, marine resilience, infrastructure resilience during natural hazards and ecological urban planning, societal resilience during natural hazards, systematicity, and the interrelationships and interdependencies between natural hazards (cascading and complex events). (Wells , 2022; Smith and Shashkina, 2023; Sulfikkar Ahamed , 2023; Pescaroli, Suppasri and Galbusera, 2024; Tao, He and Li, 2024; Weir , 2024)

Many studies examine the impact of climate change on resilience, with a particular focus on extreme weather events such as floods, droughts, and temperature variations. Resilience strategies often include adaptive measures for ecosystems, such as forest restoration, climate risk assessments, and the use of resilience indicators to monitor change. (Chavez-Molina , 2023; Córdoba Hernández and Camerin, 2023; Bathiany , 2024; Mitra , 2024; Sang , 2024)

A few studies examine resilience to floods, highlighting factors that influence vulnerability, such as social and infrastructural characteristics. Geospatial analysis and flood vulnerability indices are used to assess risk and propose mitigation strategies. (Nagabhatla and Brahmbhatt, 2020; Bello , 2024)

The resilience of infrastructure, including power grids, transport systems, and industrial plants, is an important area of research. Adaptive strategies, probabilistic risk assessments, and advanced modeling techniques (e.g., Bayesian networks) are proposed to improve the resilience of infrastructure to natural and technological hazards. (Durap, 2024; Durap and Balas, 2024)

Some papers discuss the social aspects of resilience, including community-level strategies, social vulnerability assessments, and the role of local knowledge in disaster risk reduction. Gender, age, social capital, and indigenous knowledge systems are identified as critical in determining community-level resilience. (Van Manen, 2014; Zuzak , 2022; Bourne , 2023)

Research on marine and coastal ecosystems highlights the vulnerability of habitats such as coral reefs, seagrass meadows, and mangroves to climate change. Efforts to improve resilience include habitat conservation, adaptive management, and addressing non-climatic stressors. (Marra , 2007; Randazzo , 2019; Johnson , 2023)

A recurring theme in many papers is the interconnectedness of natural risks, including cascading and complex events. Resilience approaches include systemic risk assessments, network models, and frameworks for assessing interdependencies across sectors. (Wells , 2022; Pescaroli, Suppasri and Galbusera, 2024; Weir , 2024)

The role of urban planning and ecosystem services in enhancing resilience is also discussed. Approaches such as ecosystem-based management, spatial planning frameworks, and resilience indicators help integrate resilience into environmental and urban policies. (Gjerde and Yadav, 2021)

## 4. Discussion

We saw a variety of studies across disciplines looking at the problem of assessing and strengthening resilience. Some articles span multiple disciplines. We also saw that some problems cut across multiple disciplines. Many of the articles tend to focus on specific, narrow problems or localised contexts.

The papers describe the concepts of different types of resilience, focusing on the ability of various systems to absorb disturbances, adapt to changing conditions, and maintain basic functions. The term resilience is used in coupled human-environmental systems, emphasising the dynamic relationships between social structures and ecological systems. Resilience to natural disasters is also considered, encompassing the ability to absorb shocks and minimise immediate damage, the capacity to adjust and adapt to changing conditions, and the capability to implement fundamental changes to reduce future vulnerability.

Community-based disaster management involves a shift from top-down disaster management to community-oriented practices. Dynamic Bayesian networks, used in resilience assessments of engineering and technological systems, quantify resilience by incorporating probabilistic modelling and accounting for uncertainty. Risk and scenario management integrates risk assessment with resilience planning using scenario-based methods for potential negative events. All the above approaches could be applied in further research into the cyber resilience of small and medium businesses, supporting the development of a systematic approach to assess and reduce cyber risks and threats, as well as to respond to negative events with minimal losses.

Metrics used across various sciences to assess resilience include absorptive, adaptive, and transformative capacities. Monte Carlo simulations, Bayesian networks, and stress testing are applied in engineering, cyber resilience, and environmental sciences to quantify the probability of failure and evaluate system performance under different scenarios. Tools like the Urban Resilience Index and Climate Vulnerability Index assess resilience across multiple dimensions. Scenario modelling is widely used in fields such as engineering, ecology, and cyber resilience. In engineering and earth sciences, metrics such as centrality, redundancy, and failure cascade models help analyse interconnected systems by assessing how disturbances propagate and identifying critical nodes to improve resilience. In medicine, resilience metrics include stress measurement tools, adaptive coping scores, and mental health assessments to evaluate recovery from injury or chronic disease. Ecological indicators assess ecosystem health and resilience based on biodiversity, habitat quality, and the provision of ecosystem services, particularly in response to climate change and environmental stress. For technology systems, metrics like mean time to repair, attack surface size, and system uptime assess the resilience of digital infrastructure to cyber threats. In engineering, life cycle approaches evaluate the long-term performance, maintenance, and resilience of structures, considering factors such as ageing, deterioration, and exposure to multiple hazards. Social vulnerability and equity metrics assess socioeconomic status, resource access, and social capital in the social sciences, which influence resilience at community and individual levels.

While these findings are valuable and provide new insights, they do not always provide a comprehensive view of the issue at hand and may not be transferable to broader problem-solving at a general level.

An example is articles in environmental science that highlight the importance of localised community support systems for disaster recovery but do so without considering the broader implications of such findings on a global scale. Some studies in medicine examine resilience in relation to specific health outcomes, such as post-traumatic stress disorder or chronic disease management, thereby offering targeted solutions that may not address more complex or interrelated problems.

While some engineering studies offer advanced modelling techniques to improve infrastructure resilience to specific threats, these approaches may overlook how interconnected systems can influence resilience outcomes. The narrow focus of these studies may limit the understanding of resilience as a multifaceted construct that encompasses not only localised decisions but also broader systemic interactions. A holistic approach that considers the interactions of various factors is needed.

By leveraging insights from different disciplines, future research on cyber resilience will seek to bridge the gap between specific localised studies and be guided by broader systemic considerations. This includes exploring how cyber resilience strategies can be designed to address not only specific vulnerabilities within a single incident or a single company but also to find solutions to improve overall system resilience in the face of complex cascading cyber threats.

Furthermore, integrated resilience frameworks that address cyber resilience issues in SMEs at both the micro and macro levels are needed.

## 5. Conclusion

In this paper, we reviewed studies that address the topic of resilience. Articles were selected from a variety of fields in the Scopus database, including environmental science, medicine, social science, engineering, and earth

science. Articles were selected from disciplines that had the largest number of papers on resilience at the time of writing.

Each discipline makes a unique contribution to resilience, whether through community-based disaster recovery strategies, adaptive climate risk management, or advanced infrastructure resilience modelling. However, resilience is often addressed in fragmented ways, with studies focusing on specific problems or local contexts.

As a result of this literature review, we see a need for a holistic, integrative approach that takes into account the systemic nature of risk. By combining ideas from different fields, future research can develop more comprehensive resilience frameworks that account for the multidimensional and dynamic aspects of resilience.

This interdisciplinary approach is particularly relevant for enhancing cyber resilience in SMEs, which face increasing risks in the context of digital transformation.

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