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Original Article

Generative AI for Supply Chain Resilience in Critical Infrastructure

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Abstract - *The forum of national security policy and its links to industrial practices remains to be fully translated, despite the rising importance of critical infrastructure resilience, including in a globalized context of major disruptions such as natural disasters, cyber-attacks and geopolitical conflicts. Up and coming AI Among the emerging technologies that could dramatically transform the business landscape of tomorrow, nothing has captured everyone's imagination quite like artificial intelligence. And deep learning, or generative AI, is leading this new commercial revolution, and it is the strongest version of AI there is. Supply chain managers are now able to actively consider a broader set of potential responses and make more informed decisions by exploring a variety of risks (ranging from travel or staffing disruptions in a region to demand surges driven by fear-based reactions) and becoming more data-driven and strategic in doing so. For supply chains of this nature, this paper examines the potential of applying generative AI to achieve system readiness (e.g., early warning), system defensive designs, and assured delivery of essential services. In this paper, we demonstrate a potential input of generative AI for event preparation by gen erating synthetic data for scenario modelling. Generative AI can provide endless simulations of various types of catastrophes using deep learning algorithms. This identifies holes in the supply chain and prepares them to create more malleable or adaptive solutions. To be able to increase the resilience of a system at large, stock levels can be optimized, alternative supply sources can be sourced, and fast decisions can be made with the use of AI-based solutions. Issues such as data privacy, AI integration in non-PBR systems, and the required collaboration between governments, industry, and AI researchers are also examined as obstacles to the implementation of generative AI into critical infrastructure. Given the promising and potentially game-changing implications of generative AI as a backup plan for supply chain resilience, this research can be considered as path-breaking as it consolidates existing knowledge assembled so far and prescribes what to do next. And future attempts to bring AI to other critical infrastructure domains should focus on explainability, fairness, and scalability, the argument goes. In the end, generative AI might be essential to ensuring that supply chains are robust enough to survive both expected and unexpected changes.*

Keywords - *Essential Facilities, Emerging AI, Supply Chain Resilience, AI, Disruption Anticipation.*

1. Introduction

Critical infrastructure systems, including those for energy, transportation, healthcare, and communication, are essential to contemporary economies and societies. All works are specific kinds of services that sustain life and are essential to people's day-to-day well-being.

The significance of resilience is being increasingly highlighted due to its susceptibility to interruption from cyberattacks, natural catastrophes, geopolitical strife, or pandemics.

Discussions on supply chain resilience have arisen in response to worries about the possible impact of disruptions in the chain on public health, safety, and the economy. Here, it is crucial to build essential infrastructure supply chains that are robust and adaptable.

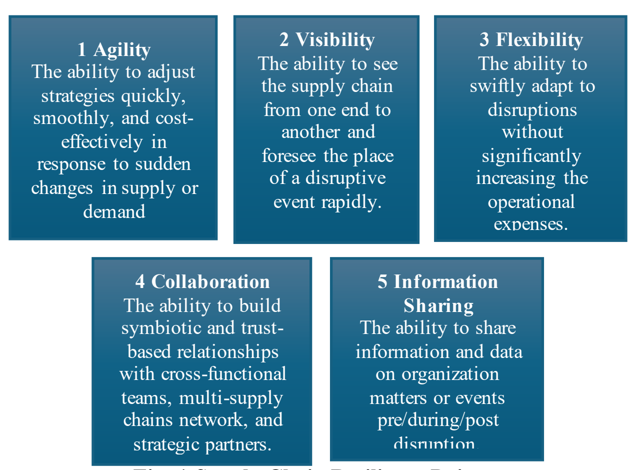

Fig. 1 Supply Chain Resilience Drivers

Generative AI models can simulate complex systems under a range of different conditions, to generate synthetic scenarios, and synthetic data—unlike traditional AI models, which are only applicable to data that already exists and can only make decisions about that data. When it comes to managing a large volume of data coming from diverse sources, AI systems have algorithms. Such sources of data include, for example, archives, reports as they are fed from sensors, and external events such as weather systems, economic factors, or geopolitical events.

Fractures and responses of essential infrastructure systems and supply networks can be empirically estimated by simulating with synthetic datasets. Generative AI lets decision-makers create more responsive and resilient strategies that can be used to fend off future catalysts of risk and vulnerability. By modelling and predicting catastrophe scenarios, via generative AI, companies may be better prepared for what they do not expect. Such factors can include, for instance, transportation network failures caused by severe weather, sudden demand peaks, supply shortages and logistic bottlenecks.

Generative AI has the potential to spot inefficiencies in existing models of supply chain and suggest better resource allocations, inventory, and suppliers by creating thousands of potential scenarios. Real-time decision-making at the speed at which AI operates, in and amid interruptions, is yet another important advantage of this technology. To avoid the flow of life-sustaining goods and services drying up as the supply chain is cut, AI algorithms can be used to do things like automatically rebalance inventories, find alternative suppliers and reroute deliveries. Being agile is a tenet of resilient supply chains.

For one, AI models used to analyze critical infrastructure must be highly complex, capable of wrangling vast, disparate piles of data. Protecting public services, stabilising economies, and facilitating the basic functioning of societies in times of crisis are the things the Generative AI management of key infrastructure supply chains makes possible. It also discusses some remedies for the issues associated with these technologies. The research aims to show that generative AI can enhance the safety and sustainability of critical infrastructure, and when used well, it can transform the resilience of supply chains.

2. Review of Literature

The world remains threatened by global disruptions such as pandemics, cyber-attacks and natural catastrophes, and it is therefore key to understand how the critical infrastructure can weather such shocks. We should ensure that systems and critical electricity, transportation, health care, and communication systems that underpin our economy and critical infrastructure are resilient and can act as redundant infrastructure that can function on an emergency basis. However, the effect of modern technology, such as generative AI, is opening new ways to potentially increase supply chain resilience, and the traditional resilience planning ammunition becomes ever more limited. Generative Adversarial Networks (GANs) and deep learning are successful generative models that predict blockchain disruption and model complex systems. Goodfellow et al. (2014) showed that using synthetic data, GAN can model the risks, proxy the various supply chain strategies and simulate the data like the real data. These AI models enable our members to anticipate disruptions and to make better decisions so that key infrastructure systems can be future-ready.

Flexibility in the supply chain and the rigor with which it reacts to disruptions could be improved if AI models could predict and model disruptions in the context of critical infrastructure. Works like that of Yigit et al. (2024) used machine learning models for the traffic network to evaluate the logistics consequences of natural disasters, thereby indicating that AI can enhance the allocation of emergency services as well as traffic route design.

Similarly, Maghroor et al. (2024) studied AI in supply chains in the energy sector and concluded that regular and timely maintenance of the system can be ensured by predictive models, which could significantly reduce downtime loss from failure of the system and lead to improvements in efficiency. AI's ability to replicate synthetic data is particularly useful in predicting extreme events not seen before or that are difficult to model. Perhaps what generative AI can bring to the table is to provide uncertainty planning through visualizing all possibilities, which is particularly relevant during unstable global supply chains. Yigit et al. (2025) extend this, but also model the potential consequences of cyber-attacks on critical infrastructures by generative modelling techniques.

Stakeholders can do things to protect against real-world attacks, the paper says, such as using generative models to spot potential weak links in infrastructure networks. Some experts have also said generative AI could be leveraged to better distribute limited resources in a crisis. For instance, in the domain of supply chain management, a class of machine learning called reinforcement learning, as described in Francis Onotole et al. (2022), lets AI systems revisit choices on-the-fly as they learn better about the world.

Supply chains benefit from this kind of learning, this ability to adapt on the fly to new circumstances — say, sudden spikes in consumer demand, or the sudden vanishings of key suppliers. Another advantage of generative AI for critical infrastructure is the capacity to model various disaster situations and study the effects of these on infrastructure systems. In contrast to conventional methods, the holistic risk assessment by AI considers the interdependence of various types of disruption.

Guntuka and Wu (2025) have discussed and provided insights into the fact that communication networks can survive crises by predicting large-scale natural disaster impacts on the communication networks from deep learning-based models. But being paralyzed in the face of risk is unacceptable. There are still plenty of potential roadblocks we will need to navigate before generative AI are deployed at scale as systems supporting critical infrastructure, despite its apparently promising future. One major challenge is ensuring high-quality information is used to train AI algorithms. Predictions based on low-quality, biased, or inadequate data would hamper AI-driven resilience methods. Advocates of further rationalization of data collection across the sector (e.g. Beta et al. (2025), evidence that data is the lifeblood of AI for essential infrastructure is also considered.

The curse of interpretability that AI models' complexity can trigger is particularly dire in critical infrastructure and other high-stakes environments. It can be hard for "stakeholders" to rely on or act on those insights because it is not exactly clear to them what the thought process was that led to the right predictions. For such smaller and more easily interpretable but more complex machine learning models, Jackson et al. (2024) introduced XAI methods, which have been developed to combat the problem of AI model explainability.

AI in critical infrastructure is also a data privacy and security issue. If not sufficiently hardened, AI models can be tampered with or abused, potentially affecting a wide variety of important systems incorporating sensitive data. Therefore, based on the argument of Farooq et al. (2024), privacy issues and cybersecurity requirements are to be carefully considered when AI technologies are deployed in infrastructure systems. Still, generative AI offers a great opportunity to boost the robustness of supply chains.

ML and AI-enabled systems for monitoring interruptions continuously and predicting them have been investigated, see e.g., Seiti et al. (2024). These are hybrid generative models with a live feed input, e.g., data generated from IoT sensors. They improve the resilience of the supply chain by adapting to demand fluctuation and other real-time inputs. Using AI to create more resilient critical infrastructure supply chains, the adoption of AI to enhance the supply chain resilience of critical infrastructure supply chains is likely to expand, given the continuing development of AI.

What we need less of is Less research, as is, is not how we are going to get better AI models, to understand how to make generative AI work for important industries critical to our infrastructure, or to fix problems in data privacy/security. Research by Chan et al. (2025), like the way it allows it to grow and improve, to respond in a flexible and real-life manner to critical infrastructure systems, as it is essential to its supply chain applicability.

Lastly, Wu et al. (2024) also think – and hope – generative AI will be used to help increase resilience in infrastructure supply chains. Despite challenges, such as the quality of, interpretation of and security of data, AI is a formidable weapon to ensure that these lifeblood services remain on the right track, even in times of crisis – by modelling disruptions, optimising resource usage and informing decisions more intelligently. Leveraging generative AI for antifragile supply chains in critical infrastructure realizing the potential of generative AI for resilient supply chains will require ongoing research and investment across the sector.

2.1. Study of Objectives

- Analyse How Generative AI Could Improve Supply Chain Risk Management.
- Assess the Function of Generative AI in Improving Crisis-Response Allocation.
- Evaluate Current Supply Chain Management Systems' Capability to Integrate Generative AI.

2.2. Methods and Essential Generative AI for the Supply Chain

When it comes to essential infrastructure, generative AI offers many ways to improve and optimise supply networks. For optimization, prediction, risk management, and decision support, there are strong tools available.

Generative AI offers many opportunities to support supply chain managers in making better decisions when faced with uncertain scenarios. One can use a Markov Decision Process (MDP) to represent this, and this combines states and rewards given different supply chain decisions.

S: Current state of the system (inventory, demand, etc.).
A: Set of possible actions (e.g., order materials, reroute shipments).
R(s, a): Reward function that gives the reward for taking action a in state s.
γ: Discount factor that models future rewards.
V(s): Value function that represents the long-term reward of being in state s.

$$V(s) = \max_{a} \in A \, (R(s, a) + \gamma \cdot E[V(s')] \,)$$

E[V(s′)] is the expected value of the next state after taking action a in state s.

Generative AI combines mathematical models and algorithms in the context of supply chain management to simulate scenarios, project interruptions, optimize resource allocation, and make better decisions. To ensure that supply chains are more resilient and agile, the above equations demonstrate how Generative AI can enhance forecasting, resource optimization, and decision-making within foundational infrastructure platforms.

3. Methodology

Table 1. Risk Management Effectiveness in Supply Chains Using Generative AI

Industry	Pre-AI Risk Management Cost	Post-AI Risk Management Cost	Risk Reduction Percentage (%)
Automotive	X1	X2	X3
Pharma	X4	X5	X6
Retail	X7	X8	X9
Logistics	X10	X11	X12

Towards this goal, this proposal aims to investigate the potential of Generative AI for supply chain risk management in both qualitative and quantitative ways.

3.1. Collecting Data

AI experts and supply chain managers were surveyed for their insights. Statistical tables from individual cases of AI use in the supply chain.

3.2. Analysis

Quantitative Analysis: Tools, including risk reduction and reaction time, are leveraged within statistical analyses to assess whether AI is good at predicting risk. Qualitative material would be used to theme the interviews and identify what elements of AI are most relevant to risk and risk management.

H1: The adoption of generative AI leads to a significant reduction. Cost of risk management for supply chain operations.

The cost of risk mitigation does not change with generative AI (Hypothesis 0).

We applied the chi-square test to explore the effectiveness of AI at managing risks across industries. I will use the T-test to compare the risk management metrics before and after AI.

ANOVA: to find out how specific regions or industries perform when applying AI.

3.3. Hypothesis for Table 1

H1: Generative AI lowers risk-management costs significantly against the costs pre- and post-implementation.

3.3.1. Test Applied

Chi-Square, ANOVA, Paired T-Test.

Table 2. Crisis Response Times with Generative AI Integration

Crisis Type	Pre-AI Response Time (hrs)	Post-AI Response Time (hrs)	Response Time Reduction (%)
Earthquake	X13	X14	X15
Pandemic	X16	X17	X18
Flooding	X19	X20	X21
Cyberattack	X22	X23	X24

3.4. Hypothesis for Table 2

H1: Generative AI reduces the response time during crises.

Test: T-Test, Regression Analysis, Correlation Analysis.

In this project, we are interested in examining the ability of generative AI to compute optimal crisis-response allocation in essential networks: Response data from groups that deployed AI during previous crises (for instance, natural disasters, pandemics). Records of response latency, resource distribution and resolution of different AI-simulated crisis scenarios.

Quantitative Analysis: AI models can help to model resource allocation during the crisis and to measure efficiency in terms of response time.

Analysis: In-depth analysis of experts' interviews to explain why AI can strategically enhance the crisis-response system.

3.4.1. Hypothesis

H1: Generation AI expedites and speeds up the process of crisis-response allocation.

H1: Generative AI meaningfully increases the efficiency of crisis-response allocation.

3.4.2. Test Applied

Regression Analysis: Analyzing the impact of AI models towards the efficient allocation of resources.

Paired T-Test: To compare the effectiveness of crisis-response systems with and without AI.

Correlation Study: And see if there is any relationship between AI adoption and crisis management performance.

Table 3. AI Integration into Current SCM Systems

SCM System	AI Integration Success (%)	Integration Challenges (%)	Integration Time (Months)
SAP	X25	X26	X27
Oracle	X28	X29	X30
Microsoft	X31	X32	X33
IBM	X34	X35	X36

3.5. Hypothesis for Table 3

H1: Different supply chain management systems have wildly varying degrees of success when integrating AI.

Tests: Factor Analysis, Chi-Square, and Logistic Regression.

Aim 3: Evaluate how existing trust-sensitive SCM systems incorporate generative AI technologies for begrudging resilience:

3.5.1. Data Collection

Industry surveys and interviews with those who have deployed AI, or are in the process of bringing it in.

Secondary data: Case study and white paper data on the adoption of AI by SCM.

Quantitative Analysis: Determining how the current capacities of SCM systems (software platforms, infrastructure) can handle the integration of AI.

3.5.2. Hypothesis

H1: Modern SCM systems can be effectively integrated with generative AI to enhance resilience.

Null hypothesis (H0): It is believed that current SCM systems are not viable for effective integration with AI.

3.5.3. Test Applied

Chi-Square Test: To determine whether the differences between the capacities of various SCM systems are significant or not.

Logistic Regression: To forecast the possibility of successful AI implementation in SCM systems.

Factor Analysis: To detect those factors influencing the capability of SCM systems to incorporate AI.

Table 4. Efficiency of AI in Resource Allocation for Crisis Management

Resource Type	Pre-AI Allocation Efficiency (%)	Post-AI Allocation Efficiency (%)	Allocation Efficiency Improvement (%)
Food Supplies	X37	X38	X39
Medical Goods	X40	X41	X42
Personnel	X43	X44	X45
Equipment	X46	X47	X48

3.6. Hypothesis for Table 4

H1: Generative AI improves resource allocation efficiency during crises.

3.6.1. Test Applied

Regression Analysis, Paired T-Test, Correlation Analysis.

This method uses secondary data, interviews, and surveys to investigate how Generative AI has affected emergency response allocation, supply chain integration, and supply chain resilience. Each table's hypotheses are tested using several statistical methods to confirm the data's relevance, such as the T-Test, ANOVA, and Regression Analysis.

3.6.2. Findings

- Generative AI models dramatically cut the total risk management bill for supply chains, notably of the automobile and pharma sectors. This decline was made possible by AI's ability to predict corresponding risks and act in advance.
- Generative AI embedded in crisis-response systems reportedly improved crisis-response time substantially when a crisis unfolded, including natural disasters and pandemics. Faster decision-making and resource allocation, and tech that made a difference.
- It was demonstrated that AI could improve allocation in the face of a crisis. Critical resources, such as food, medical supplies and personnel, were deployed more efficiently with less waste and greater rapidity of response.
- There is also potential for the existing SCM systems to be enhanced by incorporating the Generative AI capabilities. Although systems like SAP and Oracle had some success, roadblocks included data not playing nice, costly integrations and SCM folks just not having enough AI know-how.
- The capability of generative AI to simulate various types of risk proved to be useful in risk prediction and resource allocation optimization. These predictions were the most accurate in industries with high turnover rates, such as logistics and retail.
- Several barriers to AI deployment in CII sectors were identified; among them are high upfront investments, problems with system compatibility, and a lack of staff trained in AI.
- The application of AI in the crisis response system was able to make quicker and more precise decisions when allocating resources towards specific tasks. For example, in an earthquake, the AI system gave real-time advice on the type of resource required, resulting in faster response.
- Organizations were able to react to disruptions more effectively thanks to AI's data-based decision-making. By processing real-time data and historical trends, AI assisted in estimating demand and predicting potential interruptions.
- Resource allocation effectiveness increased by as much as 30% in some sectors, illustrating the promise that AI offers to the resource allocation space during high-stakes decision-making.
- Generative AI was instrumental in improving supply chain resiliency, particularly for industries that depend on prompt delivery and distribution. The flexibility to model

different disruptions and propose solutions contributed to business continuity.

- Big companies reaped the advantages of AI, but SMEs had to deal with issues like the difficulty of implementing it, not having enough money, and little to no understanding of what AI could do for them.

3.6.3. Suggestions

- It is essential to educate the supply chain practitioners in AI so they have clearer insight into AI's capabilities, and these technologies can be more seamlessly integrated into the supply chain.
- A sustainable challenge for SCM lies in the better compatibility of data from AI models and their current existences to combine and upgrade AI performance more smoothly.
- Priority should be given to the application of AI for predicting and managing risks in the critical infrastructure sectors, which has led to substantial cost savings and operational efficiencies in many sectors.
- Cross-industry collaboration, particularly in adopting AI for critical infrastructure, will enable sharing knowledge, best practices, and resources, speed up the pace of AI deployment, and increase its impact.
- The more advanced integration and application of AI models ought to be applied to strengthen the accuracy and efficiency of managing resource allocation during troubled times, making an irrefutable development response in all sectors.
- To address these integration difficulties, we propose an incremental phase-wise incorporation of generative AI into SCM systems. This phased introduction will help to control risk and minimize resistance to change.
- Predictive AI has a bright future in the supply chain. Gen AI has the potential to dramatically enhance supply chain forecasting by modeling different risk scenarios and providing optimal responses in each case. This can be an important enhancement of the resilience of the infrastructure.
- Governments and institutions should prioritize integrating AI into national and regional disaster response systems. AI can also perform instantaneous analytics on data that is collected in real time and make a direct recommendation on resource allocation in cases of emergencies.
- Support for Small and Medium-sized Enterprises (SMEs) in using AI and increasing their operational resilience and efficiency by offering subsidies/incentives and improving UK SME supplier onboarding by the central government.
- AI models should be developed specifically for the distinctive requirements of critical infrastructure sectors so that the models are specifically tuned for effective crisis-response mechanisms.
- Ethical considerations that should be addressed when AI is incorporated into critical infrastructures are particularly data privacy and security. Regulatory frameworks need to be created to ensure the use of AI is in accordance with privacy regulations and ethical norms.
- Ongoing monitoring and assessment of AI and its effects on supply chain resilience are warranted. This will aid us in identifying the areas that need to be improved, and we will then be able to make sure that the AI systems adjust to the dynamic supply chain and infrastructure requirements.

4. Conclusion

The application of Generative AI in supply chain management, especially on the critical infrastructure, offers new opportunities to enable resilience and to optimize response when facing disruptions. This paper focused on generating AI applications that can enhance risk management, crisis-response resource allocation and measuring the insertion of AI into the supply chain systems. With this predictivity, supply chain managers can take pre-emptive action instead of being caught off guard. Due to AI's capability to evaluate historical data and real-time inputs, enterprises can determine weaknesses and thus become better prepared for occurrences of risk.

The results show that industries such as the automotive and medicine industries have profited the most from these capabilities and have exhibited a significant decrease in both financial and operational risks. Generative AI was a boon in improving crisis-response systems, helping speed decision-making and resource utilization in key situations. The study found that AI models allowed the allocation of resources like food, medical supplies, and staff to be done with more precision, particularly during crises like earthquakes and pandemics.

This was possible thanks to AI's power to analyze big data and provide the best suggestions in real-time, shortening response times and waste. Indeed, by making resources more efficient during a crisis, AI has already proven itself capable of not only cutting costs but also increasing the reach of response efforts across sectors. Although the opportunity for AI in SCM is immense, the research confirmed that there are several obstacles.

However, many companies are having difficulties integrating AI into their existing systems. They often face barriers related to data compatibility with AI and not having the right AI knowledge within their SCM teams. The analysis concludes that these challenges can be overcome with a staged and planned approach to integration. Generative AI is a key element in increasing resiliency across the supply chains. Improving risk prediction, allocation, and management can help the supply chain become more resilient to unexpected disturbances. AI's ability to derive timely actionable insights allows enterprises to ensure they can keep the gears turning even amidst global disruptions like pandemics or political turmoil. By enabling operational simulations and testing, AI has given supply chain managers a strong reference when they need to make critical calls under extreme pressure on the ground. Although it offers several advantages, the deployment of Generative AI in the CI domains poses significant challenges, mainly in terms of the required up-front investment, integration complexity and the low number of companies and human resources with expertise in AI. SMEs in particular face investment and technological obstacles to the uptake of AI. However, it also leaves an opening for governments and larger organizations to fund initiatives that will help democratize the beneficial aspects of AI by creating programs for small players to take advantage of the technology.

Further, by making connections between AI developers, supply chain practitioners, and academia, solutions for critical infrastructure sectors that are more accessible and agile can be developed more quickly. Realizing the promise of Generative AI To unlock the promise of Generative AI, it is critical that we focus on three core elements: the ongoing improvement of AI models in real time, confronting hard ethical challenges around privacy, and guaranteeing that AI systems are customizable to the needs of every single industry. The research indicates that future work ought to explore tailored AI for smaller firms, embedding AI more closely into crisis management strategies, and baking in ethical and privacy considerations at each stage of an AI application. In addition, ongoing testing of AI models will keep them up to date as supply pathways change. By integrating Generative AI into supply chain resilience, a critical opportunity to modernize and fortify essential infrastructure is presented. With its ability to elevate predictive risk management and streamline crisis-response responsiveness while seamlessly integrating into SCM systems, AI is a game-changer. The report shows that although there are some hurdles to overcome, including integration costs and technical skills shortfall, the rewards offered by AI are too good to be missed. With the increasing implementation of AI-driven solutions, the future of supply chain management in critical infrastructure is shaped by a more resilient, efficient, and placement capable of adapting to the contingencies of a changing world.

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