DEFINING A RESILIENT NEXT GEN SUPPLY CHAIN MANAGEMENT TO DESIGN A SUSTAINABLE MODEL FOR MANUFACTURING INDUSTRIES

by

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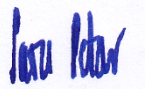

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DEDICATION

The research work is dedicated to billions of individuals who contribute day and night in shaping the manufacturing industries through their innovation, resilience and relentless hard work to drive transformational journey of progress and building the backbone of economics for any nation. It is through the dedication and excellence of today's inspirations that we envision a brighter tomorrow.

A salute to all the Engineers, Technicians, Operators and Visionaries, whose transformative ideas and dedication to their quality of work, efficiency and driving continuous improvement fuels modernization in the industries across generations.

Through this research, I hope it may contribute in a smaller way to support this transformative journey in shaping up the future of manufacturing.

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ABSTRACT

DEFINING A RESILIENT NEXT GEN SUPPLY CHAIN MANAGEMENT TO DESIGN A SUSTAINABLE MODEL FOR MANUFACTURING INDUSTRIES

Background

Recently manufacturing industries have seen an era of significant innovations driving rapid growth in technological advancements that revolutionized the overall business processes. As the global industry witnessed a range of disruptions, i.e. COVID 19, it is important that industry champions should continue to innovate methodologies to redesign the process value chains by enabling real-time monitoring to increase productivity and overcome critical challenges. Traditionally organizations depend on manual inspection processes or rule-based engines to understand the problem scenarios and provide solutions.

Lately, industries understand the need for intelligent processes that support proliferation into problem scenarios and provide simplified solutions. This led to the emergence of multiple technological platforms, one of which is Generative AI that has propelled advancements into every section of manufacturing processes offering a variety of intelligent solutions that has fastened the delivery of services to its end customers.

Methods

The study used a qualitative case method to identify multiple factors that cause disruptions in a regular logistical operation. The primary source of research method is to gather information from the available literature and secondary sources and understand the inter-relationship and cause of concerns prevailing in the industry.

As part of the analysis, data classifications on lead indicators of disruptions are grouped to define the possible use of case scenarios to guide improvement in the daily operations.

Results

Leading trend data were analyzed based on which classification methods have been defined to group disruptions and conducted risk assessment reflecting possible impacts and related key performance indicators. As part of this research, a Global Maturity model for adopting the journey of Generative AI is proposed to develop resilient supply chain operations and a culture of customer centric transformations.

Conclusion

The study's findings should be of most value to small, medium and large manufacturing organizations, that have embarked on a proactive journey to transform their business value chains and create a global network to overcome volatility and being customer value driven. Furthermore, it will help provide in-depth analysis and constant monitoring to bolster the organizations value chains with strength and flexibility required to withstand future market challenges and strengthen cross-collaboration to improve business efficiency.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

1.1 Introduction

The manufacturing industry has undergone significant transformations in the recent past largely driven by technological advancements, i.e. Artificial Intelligence (AI) and its applications. Advanced technologies like Generative AI is revolutionizing the end – to – end business value chains and changing the way organizations are operating (Veldhoven et al., 2022). It has emerged as one of the promising platforms to understand the business problems of customers, providing solutions to key business problems and improve key business performance indicators.

Research indicates that AI enabled implementations can significantly improve planning, production, reduce operational variability and enhance responsiveness to disruptions (Choi, Wallace and Wang, 2020).

Organizations are choosing proactive approaches to rewire with future proofing solutions to overcome the volatility associated with in flight transformations of value chains.

Key Megatrends (Ivanov and Dolgui, 2020) that are enabling the paradigm shift towards redefining the global operations for manufactures due to adoption of emerging technologies like Gen AI are of at most importance for all the stakeholders:

1) From "**Global" to "Globally Connected"** business value chain: Digital ecosystems and interconnected networks are becoming essential for supply chain visibility and collaboration.
2) Getting "**Digital" to "Being Digital"** across end-to-end value chain: Digital transformation is now embedded across entire value chains with AI and data analytics becoming core operational capabilities (Tortorella et al., 2020).
3) Being **"Cost-Driven"** to being **"Customer Value -Driven"**: Customer centricity is increasingly recognized as a strategic differentiator in supply design

4) **"Regulatory Compliance"** to **"Innovative Sustainability":** Sustainability and resilience have become strategic imperatives supported by digital technologies that enhance transparency and traceability.

Manufacturing firms are enabling such initiatives as medium to long-term goals for their day-to-day operations. The increase in complexity of manufacturing processes from small to large organizations due to the addition of new product lines to meet customer demands, there is an imperative need to introduce the latest technologies like Generative AI, a subset of intelligent neural network that has pushed automation at every stage of manufacturing lifecycle (Wamba et al., 2023). Generative AI can significantly boost productivity by avoiding redundant steps, improving decision-making processes and addressing upcoming challenges. Earlier research demonstrates that AI enabled manufacturing systems can improve operational performance, reduce downtime and enhance quality outcomes (Queiroz et.al. 2020).

The objective of this research is to highlight the pivotal role of Generative AI in enabling different stakeholders to enhance Productivity, Maintenance, Quality Control, Supply Chain Automation and Sustainability.

1.2 Research Problem

Manufacturers ranging from small to large businesses are facing critical challenges in designing a modernized supply chain ecosystem. Lack of strategies, Inacurate forecasting, Demand uncertainty, Market dynamics make it difficult to predict the customer demand and behaviours (Rapaccini et al., 2020). Another key challenge is end-to-end visibility of operations involving all stakeholders as many organizations are still operating in a fragmented ways (Queiroz et.al., 2020) that restricts their ability to take informed decisions.

One of the other issue that was witnessed by all organizations especially during COVID - 19 Pandemic (Ivanov et al., 2020) was reliance on single source of supply that leads to supplier disruption and dependencies that creates risk across the supply chain oprations. Likewise, multiple studies from Fraunhofer et al. (2025) and Chandra Prakash et al. (2025) confirm that the pandemic caused unprecedented supply and demand disruptions resulting in widespread operational instability. The general issue in small and medium businesses are also around slow response time and inventory balances i.e. overstocking or stockout situations that is still remaining as a constant problem. Hence, it is required to bring innovative ideas that should lead a shift in the ways of working to improve performances of overall operations.

Lastly inefficient logistics and route plannings that lead to delivery delays and higher cost of transportation compel key stakeholders to design adaptive logistics strategies to improve the overall situation. Research suggests that AI-enabled supply chain models can significantly enhance visibility, improve collaboration and strengthen resilience across the value chain (Dolgui and Ivanov, 2021).

As organizations face immense pressure to meet customer requirements and sustainability goals, Digital Supply chain models powered with Gen AI framework should be evolved and they should work towards a common goal to change the organizational mindsets,stakeholders performance and end customer satisfaction levels. The impacts of such disruptive technologies will act as a technological lever to migrate and mature in an organizations journey from traditional to resilient supply chain models.

1.3 Purpose of Research

The purpose of this study is to explore the opportunities in supply chain operations that can enhance the performance and growth of manufacturing businesses to bring customer satisfaction and stakeholders' collaboration in the ecosystem. With the advent of leading technologies like Generative AI, it enables real-time monitoring, process optimization, improvement opportunities to increase productivity, product quality and end-consumer satisfaction index. Prior research demonstrates that AI driven systems can transform supply chain planning, risk management and operational execution by generating insights that traditional models cannot produce (Choi et al., 2021).

Organizations and many supply chain planners are keeping supply chain resilience a topic of greater importance than ever (Olivier Guyottot et al., 2022). Through this study it is important to bring out the factors that involve ensuring the effective operations of supply chain keeping a constant check on the disruption elements that will help recover quickly and deliver value to all the stakeholders.

Specific Aims

1. To define a classification method for grouping the cause of disruptions and its potential impacts.
2. To provide a method to conduct risk assessments on leading indicators of disruptions and suggests mitigation plans to overcome such scenarios.
3. To review industry best practices and factors for Generative AI adoption and its proposed implementation strategies.
4. To outline a conceptual Generative AI maturity model as a framework that should guide organizations to adopt and get benefits in measuring the Key performance indicators.

1.4 Significance of this Study

As expectations continue to rise for both manufacturers and the supplier community to remain competitive in an increasingly dynamic business environment, it becomes essential to continually identify methods that enhance understanding and deliver solutions that support business growth and stakeholder satisfaction (Weimu et al., 2022).

Through this study, valuable insights are brought with the help of leading technologies i.e. Generative AI in trasforming the ways of operations for all the key stakeholders i.e. suppliers,consumers, OEM and third party logistics providers. Manufacturers in today's world of operations need to be on top to adopt such latest technologies to compete and stay relevant in the market and overcome crisis situations.

Adoption of Generative AI requires inter-departmental alignment to understand the key operational goals and startegies to achieve them. Since the emergence of Gen AI is very recent, many organizations have already initiated improvement programs (Dubey et al., 2020) that should act as an platform to launch transformational programs to build a resilient supply chain operational ecosystem.

Industry experts estimate (Dolgui, 2020) that adopting Gen AI in manufacturing could enhance the overall productivity by 15-20% by early detection of problem areas, optimizations and error reduction. Further to this, Supply Chain Practioners (Belhadi et al., 2021) mention that applying Gen AI models in the areas of predictive warnings of errors could reduce the occurance of defects by 20-30% thus improving end consumer experiences.

Therefore, the outcomes of this study could be valuable for organizations of all sizes, from small enterprises to large corporations. They offer a framework and maturity model that help address gaps in understanding various business strategies and in designing implementation plans to achieve organizational goals.

Furthermore, Predictive AI models have demonstarted the ability to reduce defects, improve forecasting acuracy and strengthen resilience across manufacturing environments. The study outcome can also provide a way forward and recommend multiple short-term and long-term business capabilities to equip different departments with leading indicators of change i.e. opportunities to reduce logistics cost, improving downtime, predicting failures and optimizing processes.

Futhermore, it will help organizations to come up with customer order fulfillment strategies to increase long-term profitability and improve business efficiency.

1.5 Research Purpose and Questions

The purpose of this study is to explore and understand the mindset of key stakeholders i.e. suppliers, customers, logistics service providers and OEM leaderships in terms of developing strategies to build a resilient and state-of-art supply chain operations model. By integrating Generative AI into strategic planning and operational processes, organizations can enhance agility improve performance and strengthen customer satisfaction (Choi et al., 2021). The study aims to propose a conceptual framework powered with Generative AI technology and industry best practices that can assist the growth of small, medium and large businesses so that it can bring benefits to the overall operations and improving end customer satisfaction index.

1) What are the leading factors of disruption in the current industry that affect business operations.
2) How to classify such disruptive factors and resolve with a new initiative and plans.
3) How to measure the impact of such disruptions in the operations and monitor their progress with the help of performance indicators.

4) How to overcome such disruptive scenarios with the involvement of Generative AI and other latest technological advancements.
5) How to introduce a methodical approach to adopt and conceptual framework to monitor the Gen AI maturity in the organization.

CHAPTER II: REVIEW OF LITERATURE

2.1 Introduction: Factors preventing designing a resilient supply chain ecosystem

Globally, supply chains suffer from unexpected events from time to time, disrupting overall operations and hindering the progress of organizational performance and long-term strategic goals (Rapaccini et al., 2020). Dynamic and complex scenarios always provided opportunities to come up with new solutions and modern approaches to address such disruptions. Recent studies highlight (Queiroz et al., 2020) that the most persistent challenge is the lack of end-to-end visibility across multi-ties supplier networks that limits the ability of firms to anticipate and respond to disruptions. Many organizations still rely on fragmented legacy systems and manual processes, creating information silos that hinder real-time decision-making and operational agility.

With lack of real-time data and digital infrastructure setup, many organizations often rely on manual processes and legacy systems that are vulnerable to scale-up the capabilities to meet the necessary demands (Tortorella et al., 2020).

In modern supply chain operations, it is of at most importance that organizations should focus on dynamic capabilities like scenario planning and simulations to take care of unexpected events rather than treating them as static ones or doing them one time (Choi et al., 2021). Many organizations that are operating in the current era of transformations often prefer lean operations and Just-in time Inventory which often includes the risk of supply shortage or missing of delivery timelines. Other factors such as change in trade regulations, sustainability pressures add complexities to the overall operations (Agrawal et al., 2024).

Rapaccini et al. (2020) says many small and medium scale organizations that contribute to larger operations have multiple challenges and roadblocks. Some of them are listed below:

- Lack of deep-tier supplier visibility
- Limited scenario planning for high-impact scenarios
- Complex and global supplier network

- Inconsistent traceability in developing regions leading to high exposure to risks of failure
- Lack of real time decision making tools.

Recent research highlights that resilience depends on dynamic capabilities, including scenario planning, rapid reconfiguration, and the use of digital collaboration tools (Dolgui and Ivanov 2021). However, many firms lack the analytical maturity and technological readiness to implement such capabilities effectively. These gaps tend to higlight the need for advanced technologies including AI, Generative AI and digital twins to enhance visibility, predict disruptions and support proactive decision making (World Economic Fourm, 2025). Another factor that adds to the current issue is move towards globalization of supply chain that results in complexities and creating vulnerable scenarios and disorders in the day-to-day operations (Ando et al., 2020).

Finally, resistance from within the organization, lack of cross-functional collaboration and limited focus on digital initiatives from senior leadership puts a hold on transformation initiatives for most of the organizations (Dubey et al., 2020). These factors constitute roadblocks in such a challenging environment where many companies are targeting to grow and build a future-proof resilient supply chain operational ecosystem.

Most small and medium businesses lack strategies to maintain a balance between the growing needs and operational excellence in meeting stakeholders expectations (Dolgui et al., 2020). They require inputs from globally diverse sources that enable participation in a system of enhanced productivity, quality and innovation. To ensure the resilience of critical global supply chains, a robust framework and methodology is required as a facilitator, integrator and collaborator of industry best practices and identification of opportunities for improvement.

As part of this research, numerous studies and materials from Marx et al. (2021), Ellstrom et al. (2022), McKinsey (2023), Saetra et al.(2023), Ivanaov et al. (2023) and Chandra Prakash et al. (2025) related to designing a reliable and resilient supply chain were reviewed. However, no existing research proposes a robust framework that enables step-by-step maturity in adopting the latest Generative AI technologies or offers an effective method to address growing customer demands and enhance collaboration with stakeholders.

To overcome such challenges many manufacturers and supply chain planners are looking towards latest technologies that can generate and synthesize the issues and bring out opportunities for improvements and aspects where opertaional improvements and customer expectations are met (Banh et al., 2023).

2.2 Theoretical Framework

In today's global business world, supply chain management forms the backbone of all kinds of operations, i.e. planning, procuring, manufacturing, delivery and distribution (Patel and Sambasivan 2022). One of the most significant contributors in revolutionizing operational efficiency, adaptability and intelligence across the entire value chain is through the introduction of Generative AI. As per Ellström et al. (2022), synthesize large volume of historical and real-time data for demand forecasting and anticipate disruptions to optimize inventory levels with greater precision than traditional models.

The key aspect is to ensure the right delivery to the respective destinations at the expected time frame and achieve customer satisfaction in a cost-effective manner. Over the years, manufacturers have noticed changes in the supply chain either due to technological advancements or situations like COVID 19 pandemic, which opened transformation avenues to keep less disruptions in the overall supply chain network (Olivier et al., 2022).

Through realistic simulations and scenarios, Generative AI allows organizations to identify the potential risk opportunities to enhance resilience and responsiveness.

According to Das et al. (2022) the use of information should be effective for the operation if the users have visual access. With the introduction of digital technologies, the modern-day supply chain aims to maximize choices and streamline interdependencies via deeper knowledge of responsibilities performed by all stakeholders along the supply chain.

Moreover, Generative AI supports stakeholder collaborations by enabling real time data sharing to improve stakeholders' relationships thus reducing the lead time to completion (Marx et al., 2021). Eventually through Generative AI it empowers supply chain stakeholders to build more efficient, resilient and customer centric supply chains in a globally diversified environment.

The objective of this study is to understand and bring out key potential capabilities of Gen AI technology in supply chain optimization. Further to this it will list out the possible use cases that can be integrated and enabled in the existing operational methods to drive innovation and modernization in global business. In recent years supply chain operations have become critical and complex due to customer demands, ever changing business models and market volatility (Mohammad et al., 2023). This has caused the need for changes / agility in the overall operations.

Over the years supply chain visibility has become the key area of focus for many global organizations (Weimu et al., 2022). As several factors of disruption are erupting due to unlikely events, the supply chain experts are finding new ways to tighten up the overall operations by improving visibility and resilience. It is always practiced that access to the right quality of information that contributes to multiple factors of demand and supply should be accessible to the key stakeholders in the ecosystem (Ivanov et al., 2020). It must be accurate, timely and complete.

Although visibility is widely recognized as a foundational requirement for resilient supply chains, recent studies reveal that most organizations still lack multitier transparency, particularly beyond Tier1 suppliers. Ivanov et al. (2020) argues that disruptions such as COVID-19 exposed the fragility of global networks precisely because firms lacked real-time insight into upstream and downstream dependencies. This highlights the need for more integrated, intelligence driven visibility frameworks, a gap that Generative AI is uniquely positioned to address.

Ever since the world of business evolved, there are multiple scenarios of uncertainties that brought us to a point to think of an out-of-box solution to overcome (Das et al., 2021). The most recent example is COVID19, the global pandemic that disrupted the global supply chain operations in the worst possible way (Ando et al., 2022). After this, most of the organizations have decided to build a full proof solution / improvements to their existing supply chain networks that will bring resilience to the overall operations. It has become a strategic imperative at regulatory and corporate level in every industry. Several initiatives are introduced to build recovery capabilities to become resilient in the overall operations (Olivier et al., 2022). This must support and control the cost of doing business by continuously monitoring the expenses. Further it will enable organizations to study the nature, frequency and level of disruptions caused to the overall business.

To accommodate such scenarios, the following theories are considered to understand the levels of disruption and build a sustainable model for supply chain planners. These theories help guide strategic planning and assessment of risks to overcome potential issues effectively.

2.2.1 Dynamic Capabilities Theory

All major firms face a significant challenge due to rapid technological advancements and organizations fail to map their needs with such advancements. Every year manufacturers plan and strategize the context of digital transformations to keep them updated and achieve maximum benefits from such initiatives. In recent years, with the adoption of Generative AI many organizations are aiming to unlock new avenues for improving and enhancing their operations by leveraging such capabilities. Since Generative AI is still new to many organizations, a key challenge lies in evolving their internal capabilities quickly enough to adopt these technological advancements and drive effective digital transformation (Van Veldhoven and Vanthienem 2022).

40% of large organizations (Saetra, 2023) report that they are struggling to effectively implement AI Technologies, reflecting a gap in leveraging full potential to reshape business models (Ransbotham et al., 2019). As per the latest study and literature (Saetra, 2023) it has become evident that Generative AI offers a range of use cases for improving the operations and bringing competitive advantages. However the results realized from these initiatives remain uncertain. This brings us to the point when supply chain planners and other stakeholders need to recognize the relevance of dynamic capabilities and the overall strategic business value can be derived from its effective implementation.

Another point that came during the literature review is the gap between the rapid adoption of Gen AI in industry and the pace of academic research, determining a challenge in fully understanding and defining the capabilities of Gen AI for the benefits of organizations. Transformations in the supply chain operational models are a futuristic step by employing such disruptive technologies, i.e. Gen AI, to innovate and sustain new business models and enhance business value creation (Van Veldhoven, 2022).

Such transformation requires alignment of technologies with organizations objectives to improve performance (Ellstrom et al., 2022).

Dynamic capabilities and intricately linked to digital maturity and indicates and organizations journey in the adoptions of such digital technologies (Marx et. al., 2021). Studies show that organizations with high digital maturity are better positioned to leverage AI for predictive analytics, automation and strategic decision-making (Wamba et al., 2020).

The dynamic capabilities of the modern day supply chain allow manufacturers to integrate the state-of-the art digital technologies that enable them to redesign its business processes to achieve resilience. Based on this organizations can identify and adopt Generative AI technologies and achieve business transformations in their existing operating model (Dubey et al., 2020).

This will further enable manufacturing organizations to realize the capabilities of Generative AI to redesign its internal processes and improve digital maturity to ensure organizations remain competitive and adaptive in this digital era.

2.2.2 Supply Chain Resilience Theory

Supply chain resilience has been advised in numerous fields as a progressive step to deal with unexpected situations (Norrman and Wieland, 2020).The main objective behind this is to identify, assess and monitor the different types of issues that can disrupt a given scenario. To avoid such situations it is important that organization should look upon adopting digital technologies that can improve the resilience by having real-time visibility and predictive insights. Aliahmahi et al. (2022) suggests that 70% of organizations experiences unexpected disruptions like delay in delivery, Material shortages or supplier discrepancies in the day to day operations and faces significant financial losses. Choi et al. (2021) point out that resilience becomes easier to build when organizations use

next-generation digital technologies that improve how clearly they can see what's happening and how well they can anticipate what comes next.

With this, it stresses the importance of having latest technologies like Generative AI to overcome such situations.

Through this study, the objective is to identify and bridge the critical gaps in the existing supply chain operations with the help of latest technologies to enable the manufacturing organizations overall operations. In order to achieve this, a structured approach is required with stable governance. With this combination it will help organizations to understand the key performance indicators and identify strategic initiatives to harness the complete potential of Generative AI and build adaptive supply chain operations network (Ergene et al., 2022). Generative AI use cases provide opportunities to enable scenario generation, risk classification and informed decision support.

This aligns with recent research emphasizing the need for data-driven strategies in the post COVID era of supply chain operations (Ivanov and Dolgui, 2020). Moreover, resilience literature (Saetra, 2023) has historically emphasized structural flexibility but paid less attention to cognitive and analytical capabilities required for rapid decision-making. Dubey et al. (2020) mentions the importance of digital intelligence, rather than physical redundancy, is becoming the primary driver of resilience.

By developing such frameworks, it supports in determining and guiding the organization to adopt measures or initiative to build resilience in a growing supply chain ecosystem. Further it will support and track the maturity of Gen AI adoption to support risk mitigations and keep everyone well informed about the uncertainties in supply chain management through real time monitoring and decision support systems.

2.2.3 Digital Twin Theory

In today's world of globalization, evolving market conditions and well-organized operations, effective supply chain operations are the key objectives of every manufacturer. According to Belhandi et al. (2024), most organizations face risks and volatility from dynamic advancements and technological modernization. Due to such variations in the market conditions most of the supply chain operations have become unpredictable (Agrawal et al., 2024). Manufacturers are changing their strategies frequently with policies to accommodate unexpected events and operate smoothly with materials and information flowing across different entities of the operations. Supply chain planners are now identifying opportunities to maintain seamless operations even during disruptive situations (Agrawal et al., 2024). Achieving a resilient supply chain coupled with proper strategies to make visible, agile and intelligent supply chain operations are needed of the hour coupled with digital twin theories and organizations are envisaging methodologies in this direction. Digital Twin technology enhances visibility and contingency planning, making them a comprehensive solution.

Digital Twin coupled with Gen AI powers organizations to transmit real-time data from Physical system and practically replicate them to generate predictive models and testing hypothetical scenarios, greatly improving proactive planning and transparency across supply chain (Huang et al., 2024). By incorporating Gen AI, Digital twin can accurately predict demand fluctuations and access disruptions and consequences using historical data and market conditions (Badakshan and Ball, 2024). Digital twins are increasingly recognized as a foundational technology for resilient supply chains, enabling firms to test disruptive scenarios, evaluate mitigations strategies and improve operational continuity (Lu et al., 2020).

With the above outcomes, it confirms that there is a need to develop the existing supply chain operations coupled with the latest technologies, i.e. Gen AI by exploring how it will

impact the future of supply chain operations and be a market leader. Numerous researchers have investigated the influence of Digital Twin on the overall performance, improving lead times, demand and service levels provide proactive approaches to overcome dynamic scenarios (Dolgui et al., 2021). Through this study, the proposal of enabling a framework powered with Gen AI solutions to understand the issues through early visualization and to adjust and reconfigure its existing capabilities in reaction to rapidly changing market conditions.

Despite growing interest in AI applications, Generative AI remains under leveraged in supply chain literature. Most existing studies focus on predictive analytics, machine learning, or optimization algorithms (Baryannis et al., 2020), while the generative capabilities such as scenario creation, automated problem solving and synthetic data generation are not much explored. Generative AI can augment human decision making by generating alternative supply chain scenarios, identifying hidden risks and proposing mitigation strategies. By integrating Generative AI into supply chain resilience, this study offers a novel contribution that extends beyond traditional AI applications to support the manufacturing organizations.

2.2.4 Transformational viewpoint on Gen AI Intervention

Globally manufacturers are under increasing pressure from volatility, disruption, and uncertainty. In the era of digital evolution where process efficiency and cost optimization are key factors, manufacturing organizations are also aligning and moving towards Next Gen technologies i.e. Generative AI to drive intelligence as core capabilities (Mckinsey 2023). Today's dynamic shifts in customer's demands (Ivanov 2025) acts as a stepping stone towards such transformational interventions.

Generative AI ensures identification potential risks, maps its potential mitigations and prepares adaptive strategies before the actual disruption occurs. This is achieved through proactive risk anticipation by synthesizing data from multiple sources (Mckinsey 2023).

Another important factor is Generative AI enhances better transparency and visibility across complex networks through integration of fragmented data streams and providing information transparency across all the layers of the organization. Through this approach, it will strengthen the decision-making process for all stakeholders. Generative AI can help in simulating alternative scenarios in sourcing and procurement, sales operations and warehouse management (Van Veldhoven et al., 2022) providing a range of options to identify the best-fit solution to overcome the complex situations.

At last, Generative AI augments the human factor of supply chain operations that empowers the stakeholders with advanced analytics and predictive intelligence that foster collaboration across business processes and partners (BCG Henderson Institute 2022).

2.3 Summary

Achieving complete visibility and control in an organization's supply chain is a continuous process. Supply chain leaders often face issues due to emerging or unexpected situations that lead to temporary disruptions or irregularities. The lack of information leads to direct or indirect impact on various supply chain operations i.e. lead time to fulfill an order, Demand forecasting or customer satisfaction monitoring, so it becomes imperative that constant monitoring and continuous improvement with customer focus should be a key to the future of a resilient supply chain for all stakeholders.

The literature provides several situations in the supply chain operations that may lead to disruptions. However, situations like the global pandemic stressed the fact that it is important to introduce and implement technologies like Generative AI that can provide

huge support to overcome such scenarios. It is important to note that it a process and it does not contain one action but has multiple phases.

This research aims at bringing the mechanism to plough back the best practices in the supply chain operations through latest technologies based on the organization's needs and review it constantly through a maturity framework providing the best possible ways to grow and manage sudden eventualities in the global operations. Supply chain robustness is a key enabler to achieve, while there is a constant room to grow and mature in operations. Implementing proven practices and intelligent algorithms focused on specific business pain points is critical to success in all scenarios.

During the literature review, it is observed the adoption of Generative AI has been reviewed and debated by all the stakeholders as to how it can be more effective and resilient to overcome unforeseen issues in their daily operations (Mckinsey and Company 2023). However, the need is to have a structured framework to institutionalize the foundation of Generative AI principles in the existing supply chain operations and leverage Generative AI features for better control on effective communication with all the stakeholders. The objective of this research is to analyze and propose a comprehensive and structured framework to manage unexpected situations and mitigate. This framework will also include multiple leading performance indicators linked to each stage of the supply chain maturity through the adoption of generative AI technologies.

CHAPTER III: METHODOLOGY

3.1 Overview of the Research Problem

The importance of getting a better understanding of modern-day supply chain operations is increasing due to significant disruptions due to unexpected events, market fluctuations, inefficient demand and forecast predictions, outdated technologies sustainability issues and global pandemics (Das et al., 2021). Meanwhile evolving customer expectations and lack of transparent deliveries stress the importance for a shift in focus towards digital transformation leading to predictive decision making with informed data pointers leading to implement a robust supply chain model.

According to Duong and Chong (2020) the level of collaborative engagement among the members in the supply chain ecosystem generated a high-level of inter dependency that supports aligning with the strategic objective of the organizations. To manage and minimize the disruptions, the role of Generative AI brings a new imperative to establish and achieve strategic and tactical objectives to support constant evolution of supply chain models to adopt new market dynamics.

The complexity and unpredictability of modern supply chain environments require a methodological approach capable of capturing specific and multidimensional insights.

Since the research problem centers on identifying disruption factors, understanding their interrelationships and evaluating the role of Generative AI in strengthening resilience, a qualitative methodology is most appropriate. Furthermore, the reliance on secondary sources such as peer-reviewed literature and industry reports is justified given the study's objective to synthesize existing knowledge rather than collect primary data from human participants.

In the current competitive scenario, supply chain managers face unique challenges related to merging strategies between suppliers and corporate businesses (Chowdhury et al., 2021). As it is important to achieve process efficiencies on a large scale it is equally essential to optimize business operations by ensuring integration of both forward and reverse activities in the global supply chain operations. Another commonly noticed challenge is related to information sharing that leads to a potential gap between partners in the ecosystem (Javid Moosavi et al., 2022). As problems continue to arise and evolve with a solution in a time frame, there are scenarios that still require both process and technological focus.

3.2 Operationalization of Theoretical Constructs

The adoption of Artificial Intelligence is growing in manufacturing industries in recent years (Radhakrishna et al., 2022) due to the ability of improving efficiency, resolving business problems and ensuring a competitive advantage in today's market uncertainties and meeting customer demands. Today, most organizations lack a guiding factor for the AI implementation journey and continuous improvement to deal with unforeseen situations.

The proposed research has a long-term objective to suggest and develop an interconnected and multimodal supply chain that should get maturity based on managing day-to-day challenges and always keep a comprehensive view on industry trends and new technological implementation strategies. In the event of global disruption like COVID-19 and other natural disasters, Organizations and many supply chain planners are keeping supply chain resilience a topic of greater importance than ever (Olivier Guyottot et al., 2022). Through this research study it is important to bring out the factors that involve ensuring the effective operations of supply chain keeping a constant check on the disruption

elements through AI Models that will help recover quickly and deliver value to all the stakeholders.

In the present scenario, there are many research methodologies and techniques to evaluate and examine the problem scenarios better and propose a structured business framework to support organizations in their AI adoption journey and maturity assessment. In this study, qualitative research along with case study analysis approach has been leveraged. Through this approach the available AI assessment frameworks in the market are analyzed on strategic levels, i.e. Business process, Prescriptive AI Uses cases, Innovation and Transformation and end-to-end visibility.

3.3 Research Purpose and Questions

Historically organizations followed traditional scheduling and critical path methods to analyze such constraints that have their own limitations in modeling and suggesting resolutions to overcome the situations (Rameshwar Dubey et al., 2024).

As problems continue to evolve, so is the need for bringing new operating models empowered by the latest technologies to ensure constraint free execution.

In summary, there is a need to study evolving issues that act as a contributor to disruption and hurdles organizations to achieve year-on-year objectives, more specifically to understand and address the following questions:

1) What are the leading factors of disruption in the current industry that affect business operations
2) How to classify such disruptive factors and resolve with a new initiative and plans
3) How to measure the impact of such disruptions in the operations and monitor their progress with the help of performance indicators

4) How to overcome such disruptive scenarios with the involvement of Generative AI and other latest technological advancements
5) How to introduce a methodical approach to adopt and conceptual framework to monitor the Gen AI maturity in the organization

Each Research Question (RQ) is addressed through a specific methodological pathway to ensure coherence between the study's purpose and its analytical procedures.

RQ1 - Seeks to identify leading disruption factors and addressed through thematic analysis of academic and industry literature.

RQ2 – Focuses on classifying disruptions supported by coding and categorization techniques that group similar patterns into meaningful clusters.

RQ3 – Examines the impact of disruptions and addressed through comparative analysis of performance indicators reported across multiple sources.

RQ4 – Explores the role of Generative AI is examined through document analysis of AI-enabled use cases.

RQ5 - Introduce a methodical approach to adopt a conceptual framework to monitor the Gen AI maturity in the organization and define an Implementation roadmap.

Through this approach, it ensures that each of the respective questions will be analyzed methodically and thoroughly.

3.4 Research Design

In this research a Qualitative Document Analysis (QDA) approach is considered for research design, that is well-suited for synthesizing insights from diverse textual sources (Morgan, 2023). It enables systematic examination of written materials including academic publications, consulting frameworks and industry whitepapers to identify patterns and conceptual relationships relevant to supply chain resilience and AI adoption. This design

is appropriate because the research does not involve human participants but instead relies on existing knowledge to construct a conceptual model.

The design is further supported by Comparative Framework Analysis, which allows evaluation of multiple AI maturity models to identify strengths, gaps and areas of convergence (Mettler and Pinto 2021).

In order to analyse and find out the key pointers from the existing literature and frameworks,this study shall use a qualitative research design to explore and identify the applicability, key strengths and limitations of existing AI adoption and assessment frameworks in context to manufacturing supply chain operations.

The objective of this research is to identify various factors that lead to disrupt the operations in a regular logistical flow. Through this section, it is outlined that the primary source of research method is to study the literature available through multiple sources and references and understand how they are interrelated. The study will first collate different data points as part of information collection and then perform conceptual modeling to classify and identify different agents that cause disruption in the supply chain ecosystem.

In the first stage, as part of the analysis, data categories will be classified to identify the lead agents of disruptions in the supply chain operations. The second stage would be a comprehensive study of related literature based on best practices in the current industry and research materials. Finally, once a classification method is identified, a conceptual maturity model adopted with the generative AI principles will be defined that will act as a business accelerator to guide steps to improve the day-to-day operations.

The framework will act as a lever to guide the operative agents to identify different initiatives through the adoption of Gen AI technologies to improve and grow to the next level on the maturity ladder to withstand the ever-changing logistics operations business.

Descriptive statistics in the form of percentage will be included to reflect the adoption of Generative AI technology that will form the basis of development of such maturity models. The maturity framework will act as a living model that should be adopted and ploughed back the best practices gained at every step of operations into the maturity model to keep it up to date and ready for any unexpected scenarios beforehand, so that it can identify, analyze and suggest innovative initiatives along with an implementation strategy to overcome such scenarios and become resilient.

3.5 Population and Sample – Section of Analytical Sources

As part of this research, around 50+ related and referencable contents are identified based on the credibility and relevence to this topic. It includes industry research reports, consulting frameworks, research journals and referancable case studies. These contents ensures that the analysis and outcomes reflects the most current developments in Generative AI and Supply chain resilience and represents a robust and diverse body of knowledge required for this study. Inclusion criteria required that documents explicitly address supply chain disruptions, AI-enabled capabilities or maturity framworks. Exclusion criteria eliminated sources lacking methodological transparency or those unrelated to manufacturing contexts.

A purposive sampling strategy was used to select the following AI maturity model that are prominent and industry relevant.

a) NIST AI Risk Management Framework
b) Gartner AI Maturity Model
c) ISO/IEC 42001
d) BCG/WEF AI Maturity Map
e) IBM AI ladder

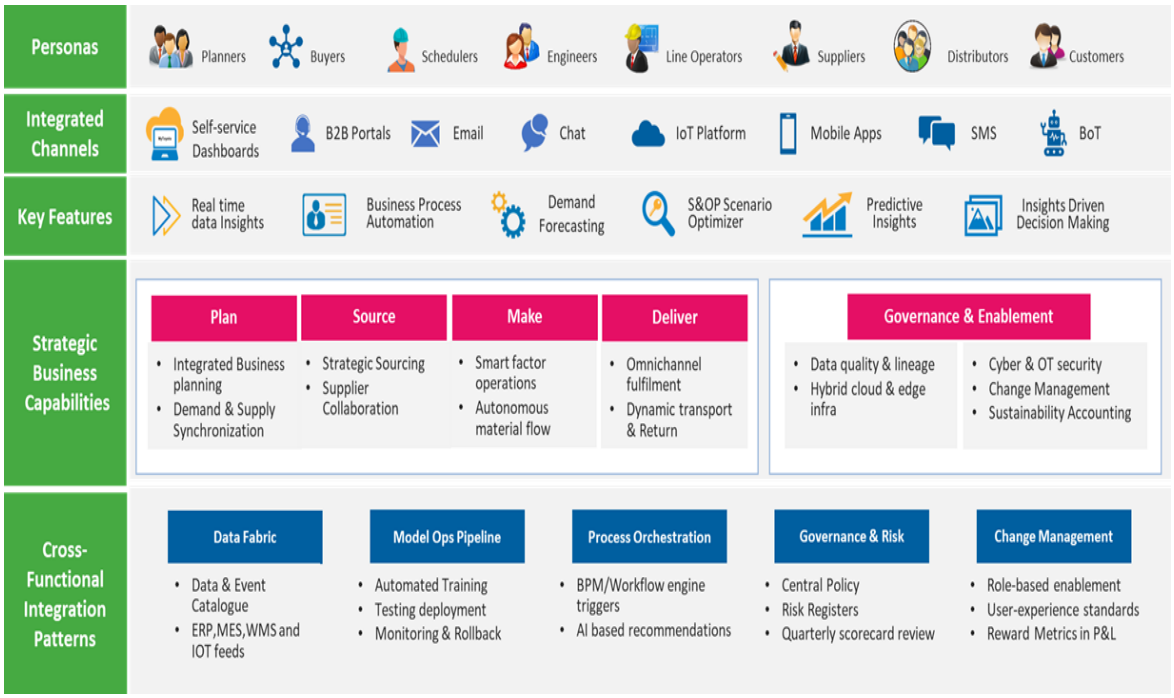
f) AIMAA Model

Each model was evaluated under ten critical success factors to understand the reflection of core business capabilities,governance needs and key enablers for a successful adoption of AI in an manufacturing supply chain organization. These criterias were derived from industry benchmarking standards i.e. SCOR model and recent literature on responsible AI and digital supply chain transformation. A comparative analysis is conducted to understand the key gaps ,overlaps and limitations in the current models and how this can be fulfilled in a new comprehensive framework for an agile tracking to achieve traceability of judgement.

As part of this study and detailing of the research problems multiple factors are considered to understand the alignment of such frameworks on real-world supply chain objectives i.e. forecasting accuracy, inventory turnover or lead time. Further it evaluates such insights into a business framework model including the key stakeholders, digital channels and AI capabilities along with cross-functional touchpoints for a scalable AI adoption in the organizations.

Below is a indicative version of the conceptual business architecture for an organization that foresees an AI implementation journey.

Figure 1 - Proposed Business Architecture with Strategic Capabilities



The business architecture represents an integrated framework for a collaborated supply chain ecosystem representing the cross-functional layers of operations between People, Process and Technology to drive operational excellence and strategic agility.

- **Identified Personas -** diverse set of stakeholders:
    - **Planners, Buyers and Schedulers**: Focused on forecasting, supplier collaboration and procurement planning.
    - **Engineers, Line Operators**: Engaged in design, manufacturing and real-time operations.
    - **Suppliers, Distributors and Customers**: Preferred partners and end-users that interact through digital communication channels.
- **Integrated Channels for communication -** To ensure seamless collaboration and responsiveness:

- **B2B Portals and Dashboards:** Enables users with real-time visibility and control.
- **Email, Chat, SMS and Mobile Apps:** For effective communication.
- **IoT Platforms:** Enables machine-to-machine information exchange and automation.

- **Key Functional Features**

  The platform delivers advanced capabilities to enhance decision-making and efficiency:

  - **Real-time Data Insights:** For visibility into process operations and KPI performances.
  - **Business Process Automation:** Streamlined workflows and less manual interventions.
  - **Demand Forecasting and SandOP Scenario Optimization:** For simulation, planning and scenario analysis.
  - **Predictive Insights and Decision Support:** AI-driven recommendations for strategic initiatives and improvements.

- **Strategic Business Capabilities**
  - **Plan**: Integrated Business Planning, Demand-Supply Synchronization.
  - **Source**: Strategic Sourcing, Supplier Collaboration.
  - **Make**: Smart Factory Operations, Autonomous Material Flow.
  - **Deliver**: Omni channel Fulfillment, Dynamic Transport and Returns.
  - **Governance and Enablement**: Data Quality, Hybrid Infrastructure, Cyber security, Change Management and Sustainability Accounting.

- **Cross-Functional Integration Patterns**

These patterns ensure cohesion across systems and processes:

- **Data Fabric**: Unified data architecture integrating ERP, MES, WMS and IoT feeds.
- **Model Ops Pipeline**: Automated model lifecycle management including training, deployment and monitoring.
- **Process Orchestration**: AI-enhanced workflows and business process triggers.
- **Governance and Risk**: Centralized policy management, risk tracking and performance reviews.
- **Change Management**: Role-based enablement, user experience standards and performance-linked incentives.

This architecture describes how digital transformation adoption in supply chain management is not restricted to technology, but rather about synchronizing people and processes to achieve resilience, agility and sustainability.

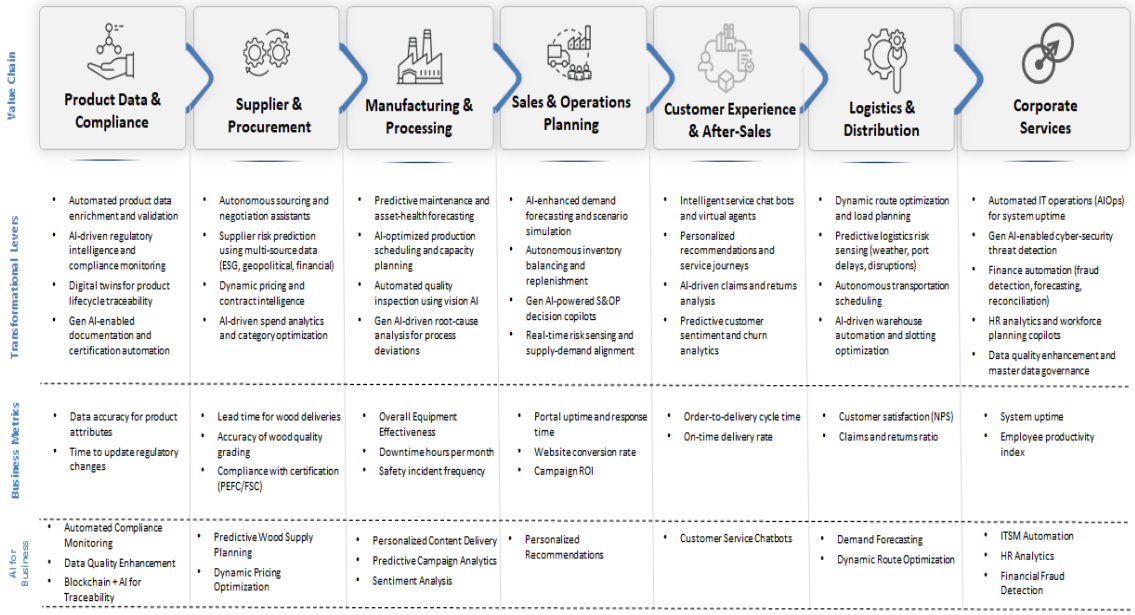
Additionally, this research not only provides an in-depth analysis and contextual richness of the existing gaps but also ensures a strategic approach to bridge the gap between high-level policy frameworks and operational business transformation, making it suitable for any organizational-level AI implementations.

3.6 Participant Selection

As part of the study it does not involve human participants, the main inclusions are the conceptual frameworks, AI maturity models and documented cases referenced from the identified sources. These units were chosen based on their relevance to the research objectives particularly their focus on AI adoption or disruption management. Each analytical unit contributes unique insights into capabilities and limitations. By analyzing

these units collectively, the study identifies patterns and gaps that suggest the development of the proposed Generative AI maturity model.

Figure 2 - End to End Business Value Chain



Through this study a qualitative research design to engage, explore and envision the applicability, strengths and limitations of existing AI adoption and assessment frameworks within the manufacturing supply chain organizations. By understanding the nature of the research problem that is interpretive in nature, it is important to understand how the prevailing frameworks support the AI adoption to overcome the real-time supply chain issues in the market and support organizations and customers in overcoming such situations.

Six prominent AI adoption and assessment frameworks are used to analyze and understand how they are shaping and supporting the supply chain operations in their implementation journey. By using comparative content analysis, the study identifies strengths, shortfalls

and cross-cutting gaps across frameworks and implemented ways to incorporate the findings to bridge the gaps.

The insights are further leveraged into the proposed business architecture specific for Gen AI adoption to improve the supply chain operations by incorporating key stakeholders roles, strategic business capabilities, channels and integration layers. This qualitative approach facilitates a nuanced understanding of both strategic and operational enablers required for effective AI adoption making it especially suitable for addressing the complex, cross-functional AI transformational initiatives in the supply chain business for manufacturing organizations. This approach not only provides an in-depth and contextual knowledge of the industry adaptability but also enables a strategic synthesis that bridges the divide between high-level policy frameworks and operational business transformation making it particularly suited for enterprise-level AI adoption journey.

In this study, each of the selected frameworks were systematically evaluated against a custom built analytical lens that includes ten critical success criterias that reflects core business capabilities, governance needs and an operational enablers for Gen AI adoption to execute a digital supply chain transformation.

A comparative analysis was conducted to identify gaps, overlaps and areas of improvements across each frameworks to enhance transparency and traceability of judgement.

3.7 Criteria for Evaluation and Analysis

In the current day global economy, the rate of global uncertainty is increasing due to complex disruptions. To achieve resilience, a transformative approach is required to identify the core capabilities that will help to adapt and recover from such critical situations. With the advent of advanced technologies like Generative AI which enhances

real-time adoption for data processing improves key business capabilities i.e demand forecasting accuracy, optimization of inventory management, predictive analytics to increase real-time visibility across supply chain operations reducing the risk of unexpected scenarios like stockouts or surplus inventory.

In order to adopt a well defined methodology for implementing and evaluating the AI technology in supply chain, it is important to have a structured approach. In this study the objective is to propose a conceptual framework for building a resilient supply chain through Gen AI Integration to improve operational efficiency and real time visibility. It is increasingly essential to implement a supply chain operating network supported by AI integration. On a similar note, it is equally important to have continous monitoring of its evolution till it reaches a state of maturity and self-driven improvements.

Lichtenthaler (2020) suggests that it is important to have an AI adoption framework that evaluates the rate of adoption emphazing strategic alignment resources and change readiness. As Artificial Intelligence becomes a strategic enabler for the growth of an organization, the need for a well-defined evaluation criteria is required for guiding a successful adoption

Evaluation criterias provide a systematic approach to assess the readiness, maturity and effectiveness of AI initiative across strategic and technical dimensions (Morgan et al., 2022). Without such criterias manufacturing organizations risk implementing AI in a fragmented or reactive manner leading to weaker alignment with business goals, limited scalability and inadequate data governance. Evaluation frameworks support organization benchmarking their progress, identify core capabilities, align investments with measurable outcomes ensuring strategic value realization and long term sustainability for AI deployments and gaining benefits in an resilient supply chain ecosystem (Smyth et al., 2024). Moreover a well defined criteria supports better decision making, mitigate risk

related to ethics and compliance and ensures that the successful AI adoption that delivers measurable business value.

As we carried out this study, we arrived at ten interlocking criteria that supply chain practitioners can use to track how Generative AI is being adopted and how it contributes to long-term value in manufacturing settings. The criteria are listed below.

3.7.1 Strategic value Alignment

It evaluates the extent to which an organization's AI initiatives are purposefully aligned with core business strategies, KPI and long-term vision. It ensures an explicit map linking each AI use case to concrete supply chain objectives i.e. forecast-error reduction or inventory-turn improvements. It provides an enabler to size the financial impact up-front and to review at the time of deployment.

3.7.2 Prioritized Use-case portfolio

Ensures that during the early adoption stages supply chain stakeholders should stay focussed by ranking different use cases along value and feasibility. Use cases with lower value and feasibility ideas drop off early and those with higher value / feasibility move first in the adoption phase.

3.7.3 Data fitness and Digital Infrastructure

A successful framework includes a data-readiness gate, quality of data from different sources should be verified before a project is given a go-ahead. Poorly managed data reports fail at the earliest point of adoption in the manufacturing supply chain.

3.7.4 AI governance and Risk Controls

The governance layer, shaped by the conceptual framework lays out the actions and stakeholders at each stage of the lifecycle. It clarifies which artifacts are needed and how issues should be escalated when they arise. By setting expectations early, it helps teams avoid confusion and stay aligned as the work progresses.

3.7.5 Human-in-the-loop and Change Management

It is important to ensure a collaborative aproach to co-design ,along with all the key stakeholders, so that the recommendation can be investigated or overriden based on the applicability.

3.7.6 Cross-Functional Operating Model

AI for supply chain touches all the major functions across the ecosystem. A strong framework specified establishes a hub and spoke model and clearly defines the decision rights.

3.7.7 Lifecycle Discipline

Continious integration and deployment, automated data drifts and rollback plans are explicitly required.

3.7.8 Supplier Ecosystem Integration

As manufacturing networks are multi-tiered, the framework defines secure data-sharing protocols and supplier onboarding criterias.

3.7.9 Scalability and Sustainability

Gen AI Architectures must be modular, licencing models are predictable and inferences must become broad level metrics.

3.7.10 Continous improvements and Innovation loops

The framework should schedule periodic AI maturity reviews to reassess the use-case backlog against new trends and evolving market conditions.Lessons learned are fed back to the ecosystem.

Each framework included in this study was evaluated using the above mentioned ten criterias derived from established literature on AI governance, digital supply chain transformation and resilience. These criterias were selected because they represent essential dimensions of effective AI adoption. Each criteria was assessed qualitatively using a three-level scale of Low, Medium and High. Through a structured evaluation it helps to enable a methodical way to compare the respective frameworks and highlight the aspects of there current strengths,weaknesses and areas of enhancement.Also these criteria serves as a foundational building blocks for the development of the proposed maturity model.

3.8 Instrumentation

Data collection concerns obtaining key information required for this study and it includes multiple sources to refer to and validate the data for finding answers to the defined research questions. In this study a qualitative methodology has been adopted for which secondary data sources have been referenced to understand the market trend on key issues and challenges, organization’s objectives and vision to define a strategic response to the supply chain ecosystem (Morgan 2023).

The primary instrument used in this study is a structured document review protocol designed to guide the extraction and organization of relevant data. The protocol includes predefined categories such as disruption types, risk indicators, capabilities and dimensions related to defining the maturity. This instrumentation ensures consistency, reduces research bias and enhances the reliability of the analytical process. Since the study relies exclusively on secondary data, no physical instruments or human subject tools were required.

The key focus of this research study is to understand how organizations can adapt to next-gen technologies based on dynamic market trends, disruptions and stay relevant through continuous improvement methodology. In this approach qualitative insights are derived from existing literature and documented evidence. Given the exploratory and interpretative nature of qualitative research, secondary data analysis was found appropriate to define contextual nature and future demand patterns and organizational adoption without direct interaction with participants.

During this phase a structured document gathering and analysis procedure has been followed that supported the identification, selection and evaluation of secondary documents. Multiple sources are considered including peer-reviewed articles, industry whitepapers, case studies, annual reports from manufacturing firms and publications from prominent consulting firms i.e. Mckinsey, Deloitte, publicly accessible database were used to search academic literature. The selection criteria for reference documents are within 5 years to maintain the relevance in view with latest technological advancements. Throughout the academic analysis, the approach was to ensure the reliability and validity of secondary data.

The reports published in organizations whitepapers were corroborated with academic case studies and industry analysis. Additionally a critical analysis was done to consider potential motivations that organizations want to achieve through successful initiatives. The

secondary data method limits the ability to probe deeper into organizational objectives but it gives significant insights while studying a large distributed supply chain where direct access to stakeholders may be limited. In the manufacturing supply chain organizations, confidentiality and propriteary concerns often limit primary data collections, secondary data provides a more comprehensive and rich alternatives for gaining qualitative insights.

In summary, as part of this study is a structured documented review along with thematic analysis is adopted to extract key insights from a range of secondary sources. Further it is ensured that the selection and interpretation of data are relatable and contexually robust.

3.9 Data Collection Procedures

The objective of this research is its detailed and methodical approach considered to identify and address the critical gaps by collaborating the People, Process and Technology into a single framework. Based on the same it provides actionable insights for enhancing supply chain resilience for manufacturing organizations. In this section, the objective is to elaborate the qualitative research methodology used to identify the importance of Generative AI for building a resilient supply chain in manufacturing organization.

Throughout this study the data collection process was systematic to ensure transparency. In the first step, a detailed search process was followed using keyword search i.e. Generative AI, Resilient Supply chain and Industry Maturity in AI Adoption in Google Scholar. After that all the documents were screened through abstract review to validate the relevance. Finally complete read out of these knowledge articles was carried out to ensure the alignment with the overall research topic. With this it verifies that the dataset is both elaborative and resourceful for the research.

With the recent focus towards improving the core operations in the existing supply chain operations it has become strategically imperative to keep a constant observation on

increasing demand, complexities and disruptions by enabling the supply chain stakeholders. This can be achieved by transforming their operating model, help them to identify the risk due to such disruptions and mitigate these global challenges through the adoption of digital technologies.

The information collated in this process provides an in-depth exploration of best practices recorded across manufacturing concepts. This will further provides a cost-effective and contextually rich foundation for identifying predictive insights for taking informed decisions.

As part of this phase a comprehensive search on the source of qualitative data is sourced from manufacturing specific materials for analysis and reference.

These includes

- Leading Industry Reports from leading consultancies e.g. Mckinsey and Company, BCG, Deloitte focused on Generative AI adoption in manufacturing and supply chain resilience.
- Manufacturing case studies
- Research published in Journal of Manufacturing Technology Management and Supply Chain Management articles.
- CIO Annual reports for identifying innovation and digital transformation initiative from manufacturing firms.

Data gathered through these sources were used as a source that provided the real scenarios in the manufacturing organizations and the actions that supply chain planners are implementing to introduce Gen AI technologies and manage supply chain disruptions. All documents have been reviewed to ensure contextual relevance and authenticity with special attention on how manufacturers operationalize resilience through digital technologies. In

this study public data and published data were utilized. All sources were appropriately referenced with a focus on intellectual proprietary compliance and academic integrity.

As part of this study a hybrid approach has been followed involving thematic and content analysis:

- Thematic Analysis: Core themes such as automation resilience, digital visibility and supplier risk mitigation were identified.
- Content Analysis: Firm-level reports and industry frameworks were examined to understand strategic narrative and resilience KPI's.

Sector specific difference were also explored i.e. the digital maturity gap between automotive manufacturers and adoption trends were analyzed and identified opportunities for improvements. An in-depth analysis of key manufacturing trends was studied and the rates at which manufacturing organizations are looking forward to adopt next Gen AI technologies to overcome for unexpected scenarios. In the same way the study also acknowledges certain limitations that should be recorded for future references:

Limited access to proprietary data as some internal practices within the manufacturing organizations remains protected or unpublished.

During the process of data collection it is noticed that not all manufacturing organizations highlight their transformation initiatives in detail. This leads to another point in terms of mapping them for comparative analysis. In spite of all such lags in the information's a comparison across all data points were mapped through cross-verifying trends that helped to maintain the validity of findings. The adopted qualitative methodology enables a structured and flexible approach to understand and evaluate the next-gen technologies enhances the resilience in the existing supply chain operations.

With the help of such strategic insights and industry trends, this study provides relevant and timely guidance to supply chain planners and manufacturing organizations to act in a timely manner and future-proof their operation by undergoing supply chain transformations.

3.10 Data Analysis

As part of this study multiple data points like Supply chain constraints, current industry trends, Market demands etc. are collated for analysis.

In the last 5 years, Manufacturing supply chain operations has witnessed the emergence of new transformation strategy through digital technologies (Ivanov 2021). This is coupled with the resilience journey by processing real-time data to improve the visibility of the problem scenario and its impact to the organization.

A unified approach to combine the qualitative research and industry published data from multiple sources were collected. This provides a richer and better understanding of the strategies that manufacturing organizations must adopt to shape up the future of their existing supply chain operations.

Through this research every data point has been referenced cross-functionally to understand the core initiative and connect the data. An extensive review of secondary sources is also done by referring the following:

- Industry reports
- Digital readiness indexes
- Logistics performance data
- Peer-reviewed articles (2021-2025)

Adopting content analysis, key digital enablers of resilience such as Gen AI, Digital supply chain twins, predictive analytics and automated exception management are identified. These sources were helpful in providing

- Industry trends in digital technologies adoption across industries
- Quantified resilience metrics
- Industry Benchmarking and best practices

Throughout this analysis process multiple interpretations are referenced to uncover the meaning and relationship from these published reports. In this process an in-depth review of all collected materials was enabled to develop familiarity and identify trends and pattern relevant to supply chain disruptions and the need for the adoption of Generative AI. These preliminary insights were organized into meaningful categories to generate recurring ideas, relationships and operational themes that are emerging from the data. During this process these categories were further refined and linked to broader concepts such as resilience, digital maturity and innovation and transformation readiness. This further enabled the development of high-level themes that details out the findings and its interpretation that supported the construction of the proposed Generative AI maturity model.

Throughout the analysis, careful attention was given to maintain consistency and ensuring that the resulting themes were captured. With such analysis, it sets a foundation for designing qualitative analysis methods to identify gaps for better understanding of the problem scenarios.

Finally it enhances the quality of the research by bringing out the insights that are relevant to real life problem scenarios. With methodical analysis and interpretation of data, strategic decision towards innovation frameworks gets surface towards deeper insights that can guide manufacturing organizations to stay resilient in the event disruptions.

3.11 Research Design Limitations

Silverman (2021) suggested that in supply chain organizations, analytical challenges can arise any time due to unstructured data and quality of secondary data that complicates the scenario and comparison across sources. Findings based on secondary qualitative data may have limited generalizability due to their contextual nature.

In a qualitative research exploring resilient supply chains, the use of secondary data offers efficiency, accessibility and broader scope during primary data collection. A key concern during this study is to ensure data relevance as secondary data is often collected for different research purpose and may not directly align to specific research questions.

During the collection and research process for such secondary source of data, the study acknowledges few limitations:

- Limited access to proprietary data: some valuable internal practices remain unpublished or protected.
- Sectorial variations: Not all manufacturing sector reports transformation initiatives can complicate comparative analysis.
- Non-uniform reporting standards: Differences in how firms describe digital initiatives can complicate comparative analysis.

Considering the combination of multiple data types and applying a theoretical lens and classifying the boundaries can further enhance the trust worthiness and applicability of the findings.

As part of this study, it is observed and documented the limitations and possible strategies that researchers should adopt to mitigate the issues in order to ensure that it does not impact the overall findings.

Table 1: Limitations and Mitigation Strategy

Limitation	Description	Mitigation Strategy
Data Relevance	Secondary data may not directly address supply chain resilience in manufacturing.	Select sources that closely align with your research question.
Data Quality and Credibility	Risk of bias, incomplete data, or unreliable sources.	Prioritize peer-reviewed, government, and industry reports. Cross-check themes across multiple sources.
Lack of Depth or Context	Missing background details limit interpretability.	Triangulate multiple data types. Analyze with consideration of time, industry, and organizational context.
Timeliness Issues	Data may not reflect recent disruptions or trends.	Supplement with recent literature and industry news. Contrast historical and current practices.
Ethical or Legal Barriers	Confidentiality concerns.	Use publicly available data. Follow ethical secondary data reuse guidelines.
Limited Generalizability	Findings may not apply broadly across manufacturing sectors.	Frame findings as transferable, not generalizable. Select diverse case examples.
Analytical Challenges	Unstructured or inconsistent data formats.	Apply a consistent coding scheme aligned to research objectives.

Sources: Belhandi et al., 2021

The limitations mentioned in the above table are inherent to the research design and those should be addressed respectively. The reliance on secondary data restricts access to proprietary industry insights that limits the depth of understanding regarding real-world AI adoption challenges.

Finally, a comparative evaluation of frameworks is constrained by variations in terminology, scope and structure across sources. By recording such limitations, it does not undermine the study's validity but highlights areas where future research specially, empirical validations would be beneficial.

3.12 Conclusion

In this chapter, the qualitative analysis and the purpose of using the qualitative case studies are captured that are relatable to the overall analysis of the context. Every document and

data point was analysed to ensure its relevance to the topic on how organizations are planning to achieve resilience through adoption of digital technologies.

During this, thematic coding was adopted to collate data to define key themes i.e., Transparency and Visibility, Flexibility and Redundancy and Operational Agility to achieve a resilient supply chain ecosystem. Together, these themes demonstrate that effective supply chain operations require a structured operational framework enhanced by next-generation capabilities such as Gen-AI. This will enable the design strategies that allow safer operations while supporting adaptability in an increasingly dynamic environment.

The study exclusively utilized publicly available data ,ensuring no proprietary or confidential information of any organization to be referenced. Institutional ethics with a focus on intellectual property compliance and academic integrity were also considered. Through this methodology and analysis of secondary data it provides a structured and flexible approach to understand how next-gen technologies enhance supply chain resilience in the manufacturing organizations. By analysing strategic inputs and published trends and case, this research offers relevant and timely guidance for manufacturers aiming to future-proof their supply chains amidst ongoing digital innovations.

In summary, the overall methodology outlined in this chapter highlights a structured approach to find the answers for the identified research questions. Using a qualitative document analysis and comparative framework evaluation this research systematically identifies the possible disruption factors, identifies and maps AI–enabled capabilities and process the insights into a conceptual maturity model.

This methodological approach ensures the key findings presented in the following chapters in a robust way and contribute meaningfully to highlight the benefits and outcomes of Generative AI's role in building a resilient supply chain operational ecosystem.

CHAPTER IV: RESULTS

In the previous chapter, the methodology to collate the data, design and validate the research findings and triangulation approach were discussed. This chapter highlights the details about different dimensions that are considered for the analysis, refine and present the findings around the overall research. The outcomes are also in line with the literature of the study to address and deep dive into the research questions.

As part of the study, it is observed that in the past, supply chains were often perceived as linear static process of moving consignment from point A to point B. Then the primary focus was on efficiency and cost reduction. Today due to globalization and closely interconnected business environment the meaning and importance of supply chain operations have changed a lot. As a result, organizations are shifting their focus the aspect of cost to a broader pursuit of resilience (Jockel et al., 2025).

Even today many industries are facing a challenge of managing complex, multi-dimensional systems that requires more traditional tools. The volume of operational transactions coupled with global unpredictability has created a demand for more sophisticated intelligent solutions. At such junction, the emerging power of Gen AI is revolutionizing the overall field (Ellström et al., 2022) not by merely automating the tasks but adding an element of predictive and prescriptive intelligence that powers up the overall transformational journey for most of the organizations. The generative AI acts as a cognitive layer that synthesizes information predicts outcomes and generates novel solutions making it a powerful catalyst for achieving the goals of transparency, flexibility and agility.

1) Transparency and Visibility – Seen the Unseen

Supply chain transparency and visibility are often used alternatively but they represent distinct concepts. This has been a long-standing goal of many organizations to improve their supply chain operations. In the recent years, the supply chain operations are enabled by GPS tracking, RFID tags and warehouse management system with an objective to overcome the blind spots and provide a single unified view of the entire operations network (Saetra et.al, 2023).

Transparency builds trust with all the stakeholders by revealing details about ethical sourcing, sustainability and production conditions. A transparent supply chain is a trustworthy one and in today's market this should be a significant competitive advantage (Belhadi et al., 2021).

2) Flexibility and Redundancy – Building in Resilience

Supply chain operations are vulnerable and prone to disruptions (Agrawal et al., 2024). Due to such behavioral pattern in the ecosystem; it has given rise to the concepts of flexibility and redundancy as crucial components of supply chain resilience. On the other hand, redundancy involves backup plans and duplicate resources in place to ensure continuity. This encompasses having multiple suppliers, holding a strategic buffer of inventory or establishing a network of backup distribution centers (Ando et al., 2022). Ensuring a right balance between flexibility and redundancy is a key strategic challenge as too much of either can be costly.

3) Organizational Agility –The Speed of Action

Responding to a situation with speed and agility is a pertinent need that an organization should focus on. Today many manufacturing organizations are working closely with all their stakeholders and internal departments to achieve the same and empower the decision makers (Wamba et al., 2024).

An organizations supply chain operations will fail if they are not agile and work on the aspect of building such capabilities that will enable to act in the right way to its situations. Adopting a decentralized decision making model rather than a centralized one will help organizations to make quick decisions based on real-time data insights (Ellstrom et al., 2022). This will act a key driver for developing a robust and resilient supply chain eco system. With the support of real time data analysis, the supply chain planners can be benefitted by identifying the bad indicators of disruptions.

In summary, a holistic framework can be institutionalized for conducting a robust analysis on the leading factors of supply chain disruptions. To support this, key variables and related information's are required to model such disruptions and categorize them appropriately to assess its impact and find out suitable corrective actions.

Finally provisioning an organizational agility supports them to analyses the most impactful resolutions and best practices for navigating the uncertainties. Together it allows a comprehensive framework to provide resolution to the supply chain disruptions by guiding through key transformational levers. Also this will give solutions through next-gen technologies to build a more resilient global supply chain network.

4.1 Research Question One

What are the leading factors of disruption in the current supply chain operations?

In today's globally connected world, supply chain operations are forced to change the ways in which they are operating a decade ago. The recent impact of COVID-19 followed by geopolitical tensions and economic imbalances across the world has exposed how easily global operations can be disrupted. These events have forced organizations to rethink the basic assumptions behind sourcing materials, manage suppliers and move products.

For years, the focus was on lean systems and cost efficiency. That mindset is now giving way to a different priority building supply chains that can absorb such disruptions and adapt quickly to anticipate risks before they escalate (Jockel et al., 2025). Today Manufacturers are facing challenges that need more integrated, intelligence-driven approach to reflect the complexity in which they operate today.

As part of this research, we have identified and grouped the major sources of supply chain disruption into four categories based on the type of impact on the day-to-day operations. Some of them are from physical bottlenecks like shipping delays or container shortages, while others arise from the growing trends of digital enablement in connected supply chains.

Another one is around rethinking the inventory strategies in a dynamic world where demand and supply patterns shift quickly. At the end, many issues originate due to increasing complexity of managing diverse suppliers across multiple regions. In total these categories reflect the different ways of disruptions that emerges and the respective responses organizations must look upon to stay resilient.

As part of this research we have classified the leading factors of disruptions into four categories:

1. **Logical and Physical Bottleneck** that is based on Operational challenges that causes delays due to unexpected operational scenarios.
    - **Volatile freight and shipping cost**: The price of moving goods has become highly volatile due to multiple factors including rising fuel cost, labor shortages and multiple geopolitical crises that force ships to reroute, adding delays in transit times. This creates an impact on high cost rise for customers during receipt of materials at their end (Morgan et al., 2022).

- **Container shortage and imbalances**: Containers can become stranded in the wrong locations due to disrupted shipping schedules leading to shortages in key export hubs and exorbitant freight cost.

2. **Cyber security and the Connected Supply Chain:** As supply chains become more digitized and interconnected through technologies like IoT and Cloud-based platforms, they have become a prime target for Cyber-attacks. As industries today are more connected, the risks they face now are far beyond a company's own internal systems (Saetra, 2023). Every third-party vendor and partner introduces another point of vulnerability, especially as sensitive information from product designs to customer data that moves across multiple platforms. Protecting such data across so many systems has become a major challenge. A single cyber-attack can shut down essential tools used for ordering, tracking and communicating with all stakeholders. This growing exposure is forcing organizations to strengthen their intelligence and security frameworks so they can identify threats proactively and respond with informed decisions.
3. **Reimaging Inventory Management for a Volatile World**:

   As per the recent trends the need to integrate a balanced and resilient approach for addressing inventory management and manage operational complexities is the at most priorities of all leading manufacturing organizations (Wamba 2024).

   Many organizations are struggling with operational challenges of managing high-cost of excess inventory. This requires state-of-art data-driven frameworks that should highlight respective actions to be followed during market uncertainties. Most of the operating teams from such organizations are now looking for Next gen solution i.e. Gen AI to consume real time data from multiple sources to create dynamic and accurate forecasting.

To overcome such situations and improve the performance indicators organizations are shifting from large distribution centers to a network of strategically located warehouses. This will add up a complexity layer of managing inventory across multiple regions to optimize the last mile delivery for end customers.

4. **Sourcing and Supplier Management Complexity**:

   As organizations shift there dependencies from a single supplier to a greater supply chain diversification has highlighted a new set of operational challenges. Managing a wider network of third-party partners each with different processes and risks has made coordination among stakeholders an important aspect to be considered. Using multiple suppliers for single components increase resilience but on the other hand increases the operational burden of managing relationships, ensuring quality control and co-coordinating logistics with a more suppliers their unique process and standards. Operational Teams should always keep rigorous audits and continuous monitoring of suppliers in multiple countries with varying labor and environmental laws that is resources-intensive and complicated task. Collation of vast amount of data to identify potential risks before they cause a disruption is a major task to be monitored to avoid any sort of disruption.

Through the analysis of secondary data collated, there are three critical categories of disruptions are emerging in the current manufacturing supply chain operations:

- Operational Disruptions - such as inventory imbalances, production delays and logistics bottlenecks.
- Technological Disruptions – Particularly cyber security vulnerabilities and system integration failures, demonstrated the highest severity due to their potential to break the end-to-end supply chain operations.

- External Disruptions - Scenarios arise due to geopolitical tensions scenarios. Such situations are less frequent but it carries significant strategic implications for global supply chain operations.

In the current scenario organizations are increasingly realizing the need for real-time visibility across their supply chains to record the overall performance. This further drives toward next-generation solutions that can help identifying disruptions before they arise.

One of the biggest initiatives considered is the move from a reactive approach to a proactive one, where predictive intelligence plays a key role. By implementing AI solutions and machine learning it will help to analyze huge volumes of historical and real-time data to anticipate future events with greater accuracy. This gives supply chain stakeholders the ability to make smarter and data-driven decisions about inventory, production planning and supplier choices. It also helps them use resources more efficiently that means optimizing delivery routes based on weather conditions or identifying the right time to reorder stock to avoid both shortages and excess inventory.

In today's scenario, supply chains operate in a world where logistics, technology, strategy, and people are all tightly connected. Reacting to disruptions post its occurrence is no longer enough. Organizations need to anticipate issues before they occur and worsen the situation. By using predictive intelligence and informed decisions a more holistic view can be considered based on which manufacturing companies can reshape their supply chains into systems that are resilient and adaptable for future. This approach not only helps to maintain business continuity but also strengthens their competitive position in an environment that is constantly changing.

4.2 Research Question Two

How to classify such disruptive factors to identify new initiatives?

Today Manufacturing companies are operating in a phase that feels more unpredictable than ever. Geopolitical tensions, extreme weather events, rapid shift in technological paradigm and sudden shifts in market are no longer unexpected scenario. As global supply chains have grown more connected and efficient over the years, they are also more exposed to such vulnerabilities.

This is a real scenario especially for organizations like automotive and industrial equipment, manufacturers where long lead times and complex supplier ecosystems make disruptions really painful.

Many organizations are now realizing that the old methods built around cost-cutting and just-in-time inventory are no longer effective in such scenarios. The thoughts are now shifting toward resilience to identify and understand the kinds of disruptions that are impacting the operations along with their frequencies and severity.

To study in detail, thematic coding approach has been applied to the secondary data that will help grouping the disruptions with the underlying causes. From this analysis around six major categories are emerged: Environmental, geopolitical, operational, technological, regulatory and market-driven. Each category was then assessed for its severity and frequency to that will help organizations to determine the key focus areas to achieve resilience.

Through this classification supply chain leaders gets a practical way to prioritize their responses, strengthen governance and design initiatives that genuinely improve supply chain agility. These initiatives range from building redundancy and improving ESG-aligned sourcing to strengthening digital transformations and preparing for regional and regulatory shifts.

This approach should further be coupled with clear governance structures and meaningful performance metrics for tracking. It will help organizations to translate technical risks into business specific decisions. Finally, mapping disruptions to defined actions enables supply chain organizations to reduce dependency risk and respond faster to build a competitive and resilient supply chain operations.

The table below defines the respective disruption categories, its definition, real-world examples and strategic implications towards supply chain transformation:

Table 2 - Disruption Categories

Category	Definition	Examples	Strategic Implications
Environmental	Natural or ecological events that disrupt supply continuity or infrastructure.	Earthquakes, floods, wildfires, climate change, pandemics	Requires climate-resilient sourcing, disaster recovery planning, ESG compliance frameworks.
Geopolitical	Political tensions affecting trade, cross-border operations, or supplier access.	Trade wars, sanctions, regional instability	Demands multi-region sourcing, near shoring, trade scenario modeling.
Operational	Internal or supplier-side failures impacting production, logistics, or quality.	Supplier insolvency, logistics bottlenecks, labor shortages, quality issues	Calls for supplier benchmarking, logistics redundancy, workforce up skilling.
Technological	Digital vulnerabilities or lack of integration disrupting operations.	Cyber-attacks, legacy systems, system outages, poor visibility	Necessitates cyber security protocols, cloud SCM platforms, AI-driven forecasting.
Regulatory	Legal or policy changes affecting compliance, trade, or permissions.	Import/export restrictions, ESG mandates, policy shifts	Requires compliance automation, legal audits, and regulatory horizon scanning.
Market-driven	Volatility from economic or consumer behavior.	Raw material shortages, inflation, demand surges, customer churn	Needs dynamic pricing, install base analytics, retention strategies.

Sources: Ivanov (2025); Fraunhofer IML (2025); Deloitte (2024)

By laying out these disruptive factors in clear categories the supply chain teams get a practical way to understand the vulnerabilities in their networks. Each category highlights a respective strategic risk that can easily escalate into greater failures due to negligence. When organizations define these disruptions and connect to real-world examples they will get resolutions to build resilience into their ecosystems rather than finding temporary fixes. This approach helps them design focused initiatives, align governance and embed the right KPIs. It also strengthens collaboration across multiple functions by defining responsibilities i.e. whether its procurement dealing with material shortages or sustainability teams ensuring ESG compliance. Finally this classification becomes a reference point for developing supply chains that are adaptable, resilient and capable of maintaining a competitive edge during unexpected conditions.

To effectively translate disruption classification into actionable strategy, supply chain operators must deploy a structured mapping framework that links each disruption type to targeted initiatives, governance ownership, and operational priorities. As part of evaluation of each disruptive nature, a Strategic Mapping Matrix is required as a decision-support tool that evaluates disruptions based on their severity and enables supply chain operators to prioritize interventions accordingly.

The following is a representative view of a matrix that supports in the process of making decisions and take corrective actions for most of the supply chain operators.

Table 3 - Decision vs. Corrective View

Disruption Type	Severity	Frequency	Mapped Initiative	Governance Owner
Raw material shortage	High	Frequent	Install base analytics + alternate sourcing	Procurement + Operations
Cyber security breach	High	Moderate	Cyber protocols + cloud migration	IT + Risk Management
Tariff volatility	Medium	Moderate	Near shoring + trade scenario modeling	Strategy + Legal
Labor shortage	High	Frequent	Workforce up skilling + automation	HR + Operations
ESG compliance volatility	Medium	Frequent	ESG scorecards + supplier audits	Sustainability + Procurement

In case of raw material shortages which are classified as high-severity and frequent, immediate attention is required through install base analytics and alternate sourcing strategies. These initiatives should be governed by procurement and operations teams, with clear KPIs such as supplier risk index and forecast accuracy.

Likewise, cyber-security breaches which are even though moderate in frequency, pose high-severity risks and they demand a robust digital transformation through cloud migration and zero-trust protocols. The table mentioned above brings attention to disruptions that may occur occasionally but still carry significant impact like sudden tariff changes. These situations require thoughtful scenario planning and in some scenarios, decisions around near-shoring typically guided by strategy teams. Labor shortages remain a persistent operational challenge due to which organizations need to invest in workforce up skilling and automation programs. At the same time, ESG compliance has become increasingly complex as regulations continue to evolve, requiring companies to strengthen supplier audits and embed performance scorecards. By linking each disruption to a specific initiative, supply chain planner creates clear accountability and encourages cross-functional collaboration for decision-making.

This approach also enables the use of KPI dashboards that monitor progress and support real-time adjustments across transformation programs. Based on such scenarios, manufacturing organizations are now thinking of deploying portfolio of strategic initiatives aimed to bring resilience, improve agility and prepare their supply chains for long-term transformation (Das et al., 2022).

These initiatives are classified under five central issues: operational resilience, environmental and ESG alignment, technological adoption, regulatory adaptability and market responsiveness.

This ensures operational resilience through the development of multiple networks of suppliers, digital twin modeling and benchmarking for suppliers in terms of comparable performance. That could be achieved through the redundant supply chain networks developed to cope with possible scenarios of supplier failures and logistics bottlenecks. Benchmarking has been developed on SLA and KPI frameworks to ensure objective supplier evaluation (Das et al., 2022; Fernandes et al., 2022):

1. Environmental and ESG alignment has risen to a level of strategic imperative specifically on those industries that find themselves under tightening regulatory scrutiny and face new sustainability imperatives. Organizations are sourcing climate resilience to meet ESG scorecards to onboard suppliers, embracing circular economies, thus reducing waste and furthering resource efficiency. Above all, such affords benefits not just in the stated risk mitigation for environmental concerns but also in brand reputation and indeed the confidence of the investor.
2. Technological adoption is critical for addressing the vulnerability of legacy systems and cyber threats. Financial investment has been channeled to upgrade cyber-security in manufacturing, implement cloud-enabled supply chain platforms, and provide AI-powered demand forecasting. These technologies provide better visibility,

responsiveness, and increased predictive ability to create smart inventory and procurement decisions.

3. Regulatory adaptability is being assured by automating compliance, horizon scanning, and conducting legal risk audits. Gen AI automation tools monitor and respond to policy changes as required, whilst horizon scanning anticipates the shape of future regulation.
4. Market responsiveness is enhanced via dynamic pricing models, customer retention analytics, and Install base segmentation. This will enable organizations to adjust to demand volatility, protect margins, and prioritize sourcing based on operational versatility

In today's global supply chain environment is surfaced by volatility, complexity and deep interdependence. The ability to classify disruptions has become essential. When organizations group disruptions into clear categories like environmental, geopolitical, operational, technological, regulatory and market-driven, supply chain planners gain a sharper understanding on the source of risks that come from and how they might unfold. This clarity helps them to build resilience proactively.

A structured classification framework always becomes the backbone for designing targeted initiatives, aligning governance and integrating meaningful performance indicators. It gives cross-functional teams the visibility to assign ownership, prioritize actions and allocate resources with confidence.

In a world where supply chain volatility can destabilize entire industries, this approach turns uncertainty into strategic advantage (Dubey et al., 2020). It enables manufacturers to anticipate risks, respond quickly and build networks that are adaptable to unexpected

situations. Ultimately, disruption classification forms the foundation of a resilient and transformation-ready supply chain network.

4.3 Research Question Three

How organizations can understand the impact due to such disruptions and apply improvement initiatives and track the performances.

In today's era of global uncertainties, disruptions in supply chain operations have become more frequent, more complex and far more expensive to manage (Deloitte 2024). Whether its raw material shortages, problems due to port closures, cyber-attacks or sudden regulatory changes such events can significantly undermine operational performance. For manufacturing organizations, understanding the scale and nature of these impacts is essential not only for immediate problem-solving but also for long-term resilience building and strategic transformations (Melnyk et al., 2020).

Modern supply chain operations face a growing range of interconnected risks from geopolitical tensions and environmental crises and volatile market conditions. Such disruptions can ripple through manufacturing operations, causing production delays, rising costs and declining customer satisfaction (Queiroz et al., 2021).

This study examined how different categories of disruptions influence operational outcomes. The findings show that disruptions do not affect all KPIs in the same way. Each type of disruption leaves its own distinct footprint across operational, tactical and strategic performance areas. Like supply-side disruptions such as unreliable suppliers, shortages of raw materials and delays in sourcing are strongly linked to higher lead-time variability, lower inventory turnover and increased procurement costs. These challenges often trigger cascading effects across the value chain.

Organizations may find themselves holding extra safety stock, rushing shipments, or constantly adjusting production schedules i.e. actions that quickly drive up costs and strain service levels. The inference through this study is to manage such kind of complexities. Teams need a structured way of working that helps them interpret these trade-offs, act with greater confidence, and direct their energy where it truly makes a difference. In practice, such a methodology should enable them to:

1. Measure how disruptions are affecting day-to-day operations
2. Apply improvement strategies that address the root causes
3. Track progress through meaningful business performance metrics

1. Measure the operational impact of disruptions

Understanding how supply chain disruptions affect day-to-day operations requires a structured approach that captures both the measurable and less tangible effects across the entire value chain. Disruptions can stem from many sources natural disasters, geopolitical tensions, supplier failures and their consequences often spread quickly across procurement, logistics and customer service activities (Fraunhofer et al., 2025).

Process-related disruptions, such as equipment breakdowns, quality issues or production bottlenecks are having the greatest impact on Overall Equipment Effectiveness (OEE), schedule adherence and first-pass yield (Ivanov et al., 2021).These issues directly undermine production flow and stability resulting in more downtime and additional rework.

In contrast, disruptions driven by demand such as sudden order surges, inaccurate forecasts or market volatility mainly affect forecast accuracy, order-fulfillment performance and customer service levels. The analysis showed that even small shifts in demand patterns can magnify inefficiencies upstream, especially in organizations with limited operational flexibility or long replenishment cycles.

The following are the Key Impact Dimensions that should be followed during the assessment of impact due to disruptions occurs in the daily supply chain operations:

Table 4 - Key Dimensions

Financial	Includes increased procurement costs, revenue loss from missed sales, and margin erosion due to expedited logistics or penalties.
Operational	Captures production downtime, reduced throughput, inventory imbalances, and supplier delays.
Customer-facing	Encompasses missed delivery windows, reduced order fill rates, and declining customer satisfaction or loyalty.
Strategic	Reflects long-term consequences such as ESG non-compliance, reputational damage, and erosion of market share.

Based on the understanding and the insights from the references (Veldhoven et al., 2022 and Tortorella et al., 2025) it is clear how disruptions truly affect operations calls for a mix of analytical and qualitative methods. This combination helps capture the measurable impacts and the respective experiences:

a. **Baseline Benchmarking:** Begin by defining normal performance levels for key metrics such as throughput, cycle time and OTIF, so that any deviation during a disruption can be clearly identified.
b. **Variance Analysis:** Compare real-time data from ERP and SCM systems against these baselines to quantify the performances.
c. **Severity–Frequency Matrix:** Assess and priorities disruptions by evaluating how severe the impact is and how often they occur (Ivanov, 2021).
d. **Root Cause Analysis:** Apply structured problem-solving tools such as Fishbone Diagrams and FMEA to uncover where disruptions originate and how they spread through the system.

e. **Qualitative Feedback:** Complement the data with insights from suppliers, logistics partners and customers to better understand the context behind the numbers.

By combining each type of disruption to the respective KPIs and its effects, this study offers organizations a clear and structured way to quantify operational impacts and prioritize mitigation efforts based on real, measurable performance outcomes.

2. Apply targeted improvement strategies

Once the operational impact is understood, organizations need to put in place focused improvement strategies that tackle the underlying causes of each disruption and strengthen long-term resilience. These actions should be tailored to the specific type of disruption and woven into the organization's wider transformation efforts.

Table 5 - Transformation Initiatives

Disruption Type	Improvement Strategy	Functional Owner
Raw material shortage	Alternate sourcing, install base analytics	Procurement + Operations
Cyber-security breach	Zero-trust architecture, cloud migration	IT + Risk Management
ESG compliance volatility	ESG scorecards, supplier audits	Sustainability + Legal
Labor shortage	Workforce up skilling, automation	HR + Manufacturing
Demand volatility	AI-driven forecasting, dynamic pricing	Sales + Supply Chain Planning

These improvement strategies should be regularly updated as new performance feedbacks emerge and the risk landscape continues to evolve.

3. Monitor progress using business performance metrics

Monitoring the effectiveness of supply chain improvement initiatives requires a robust performance management framework built based on clearly defined business performance metrics. These metrics act as a connect between strategic intent and operational execution,

enabling organizations to track progress, identify bottlenecks, and recalibrate interventions in real time (Melnyk et al., 2020; Queiroz et al., 2022).

Key performance indicators (KPIs) such as supplier risk index, forecast accuracy, inventory turnover and Net Promoter Score (NPS) provide quantifiable insights into how best improvement initiatives are mitigating disruption and strengthening resilience (Ivanov and Dolgui, 2021; Wieland, 2021). For example, reductions in single-source dependency or improvements in forecast accuracy often indicate successful implementation of alternate sourcing strategies and advanced demand-planning capabilities (Shen et al., 2022; Chowdhury et al., 2021).

Embedding these metrics into balanced scorecards and transformation dashboards ensures that improvement strategies remain aligned with broader business objectives and deliver measurable value across financial, operational and customer dimensions (Melnyk et al., 2020; Wieland, 2021).

In an environment where supply chain disruptions are increasingly unavoidable, the ability to measure their operational impact, deploy targeted improvement strategies and monitor progress through BPMs becomes a critical differentiator. A structured methodology rooted in disruption enables organizations to convert volatility into resilience and agility (Chowdhury et al., 2021; Ivanov, 2023).

By integrating digital tools, cross-functional governance and continuous feedback loops, supply chain specialists can build adaptive networks that not only withstand shocks but also leverage them as opportunities for improvement (Dolgui and Ivanov, 2023; Wieland, 2021).

Finally, measuring disruption impacts and tracking strategic initiatives through business performance metrics is essential for building resilient and future-ready supply chains. With a disciplined methodology that links disruption types to performance outcomes,

organizations can anticipate risks, respond with precision and develop supply chains that are both robust and adaptable. In an era where disruption has become the norm, visibility and agility are emerging as the defining markers of supply chain excellence (Ivanov, 2023; Queiroz et al., 2022).

4.4 Research Question Four

How Organization can plan to overcome these disruptive scenarios by applying Next-Gen technologies?

In today's connected world, supply chain operations face unprecedented levels of complexity and uncertainty. Environmental disruptions, geopolitical tensions and operational failures can interrupt production, hinder the ability to meet customer demand and ultimately affect organizational profitability. Recent research highlights how such disruptions have become more frequent and more difficult to predict in globally intertwined supply networks (Ivanov, 2023; Chowdhury et al., 2021).

Generative AI is emerging as a powerful enabler in this context, offering the capability to predict, identify and mitigate disruptions through real-time data analysis, scenario modeling and more informed decision-making. Studies show that AI-driven analytics significantly enhance visibility, responsiveness and resilience across supply chain ecosystems (Queiroz et al., 2022; Dolgui and Ivanov, 2023). By building an intelligent, data-driven ecosystem, organizations can shift from reactive crisis management to proactive resilience planning, strengthening their ability to anticipate risks and adapt to rapidly changing conditions.

Unlike traditional analytical tools that rely on historical data, Generative AI model consumes vast volume of structured and unstructured data to generate predictive insights and recommend optimized decisions (Silverman, 2021). Based on the analysis from such

vast data sets it can enhance forecasting accuracy based on market sentiments, geopolitical developments that traditional forecasting model often overlook. This capability enables organizations to proactively adjust production plans, inventory levels and distribution strategies even before the disruptions escalate.

Next-Gen solutions i.e. Gen AI models can provide an insightful details about how organizations are performing by processing vast amount of data sets from logistics to IoT sensors to weather forecast to bring out a 360-degree view of information to simulate the possible "What-if" scenarios and propose respective actions and risk mitigation strategies. These technologies that belong to the realm of next-gen technologies i.e. Gen AI a branch of machine learning that can create new insightful findings by applying logics and business rules on the existing data. (Sheffi, 2023) This can be further attributed to four elements

1. Increasing the computing power
2. Enhanced model architecture
3. Pre-training using vast qualities of unlabeled data
4. Advancement in training techniques

Disruptive technologies, AI and Gen AI will lead to a surge in productivity and revolutionize supply chain operations (Ivanov, 2021; Sheffi, 2023).As Generative AI moves from concept to practical reality and it becomes increasingly important to recognize the breadth of capabilities it offers. Its adoption enables a deeper and more nuanced understanding of state-of-the-art AI, positioning it as a critical asset in the rapidly evolving landscape of supply chain operations and laying the foundation for future advancements in the field.

Unlike traditional automation tools, Generative AI can interpret context, summarize disruptions, prioritize response actions and even draft communications for stakeholders. Supply chain engineering and operations continue to evolve at a rapid pace and remain a

central topic of discussion (Dolgui and Proth, 2010). The accelerated integration of Generative AI within the supply chain domain demands a shift in organizations understanding, evaluation and application of these emerging technologies. Beyond automation, Generative AI supports the identification of cross-functional dependencies, simplifies complex regulatory information, analyses supplier contracts and generates actionable plans.

The Following are some of the key business benefits that Gen AI implementations can offer to the organizations to improve the supply chain operations.

1. Enhancing organizational agility and transparency
2. Speeding up compliance and governance processes
3. Enhance cross-functional co-ordination globally
4. Reduce decision making time from days to just minutes
5. Reduce manual efforts and minimize human error

Applying Gen AI to Specific Disruption Types

In today's volatile business environment, Generative AI provides powerful new ways to address a wide range of supply chain disruptions. By integrating large language models, predictive analytics and digital-twin simulations, Generative AI enables organizations to anticipate emerging risks, develop adaptive response strategies and maintain operational continuity even under rapidly changing conditions.

The following are details on each of the major disruption categories that occur in the supply chain operations with respective Gen AI solutions and their business benefits:

Table 6 - Disruption Categories with Gen AI Solutions

Disruption	Challenges	Gen AI solutions	Business Benefits
Environmental	Unpredictable weather, climate-driven material	• Climate risk forecasting using satellite and IoT data • Generative disaster-response planning	• Reduced downtime from weather events and faster contingency execution

	shortages, sustainability mandates.	• AI-driven sustainability optimization	• Improved brand reputation through proactive sustainability initiatives • Cost savings
Geopolitical	Conflicts, sanctions, border closures and trade wars.	• Real-time monitoring of political/trade news and disruptions • Generative scenario modeling for policy shifts and border closures • AI-driven supplier diversification and route optimization	• Reduced dependency on high-risk geographies • Avoidance of revenue loss from sudden trade restrictions • Strengthened resilience and diversified sourcing strategies
Operational	Equipment failures, human error, workforce shortages.	• Predictive maintenance through sensor + AI data synthesis • Automated scheduling and workforce optimization • Generative modeling of production workflows for higher throughput	• Fewer stoppages and improved productivity • Lower labor and maintenance costs • Faster response times and consistent output
Technological	System downtime, cyber-attacks, integration issues.	• AI-generated incident simulations and recovery blueprints • Anomaly detection for cyber security threats • Intelligent systems integration across ERP/SCM/CRM stacks	• Faster recovery from system failures • Reduced cyber security risk exposure • More streamlined digital ecosystem and improved data accuracy
Regulatory	Rapid regulatory changes, global trade compliance	• Natural-language processing to summarize and interpret new regulations • Automated compliance documentation and audits • Generative simulations of regulation impact across supplier / networks	• Faster compliance reporting and audit readiness • Decreased risk of penalties and reputational damage • Improved governance efficiency and transparency
Market-Driven	Demand volatility, shifting consumer preferences, inflation.	• Generative demand forecasting using social media, POS, macro-indicators • Dynamic pricing and inventory optimization • AI-assisted scenario generation for product planning and launch	• Improved demand-supply alignment and fewer stock-outs /overstocks • Increased sales and customer satisfaction • Enhanced agility to shift business models or products rapidly

Strategic Recommendations for Implementation

The following steps based on the understanding and inferences throughout this study, offer a simple overview of how organizations can capture real value from Gen AI in their supply chain operations. They reflect the patterns we observed, the lessons practitioners shared and the insights that emerged across our analysis. Together, these steps highlight what tends to work in practice and where organizations can focus their efforts to see meaningful impact.

1) **Build a Unified Data Foundation**:

   Bring together internal data sources—such as ERP, SCM and CRM systems with external inputs like weather, trade and market data to ensure Generative AI models operate with complete and accurate context.

2) **Develop AI-Enabled Digital Twins**:

   Create virtual replicas of supply chain networks to simulate potential disruptions, test response strategies and optimize resilience in a risk-free environment.

3) **Strengthen AI Governance**:

   Establish clear guidelines for ethical use, data quality and oversight to ensure responsible and transparent deployment of Generative AI.

4) **Up-skill the Workforce**:

   Equip planners, analysts and operations teams with the skills needed to work confidently with Generative AI tools and make informed, data-driven decisions.

5) **Pilot and Scale Strategically**:

   Begin with high-value use cases such as predictive logistics or supplier-risk assessment and expand across global operations once the benefits are validated.

Business Benefits:

- Accelerated ROI from technology investments

- Long-term competitive differentiation
- Enhanced overall supply chain agility and responsiveness

Generative AI empowers supply chains to predict, adapt and thrive amid disruption. From real-time visibility to automated decision-support, it transforms traditional linear networks into intelligent, self-healing ecosystems. Organizations that integrate Gen AI into their supply-chain ecosystems can expect tangible business gains reduced costs, faster recovery, improved compliance and stronger customer trust. In an era of constant uncertainty, resilient supply chains will be intelligent, adaptive, and empowered by Gen AI.

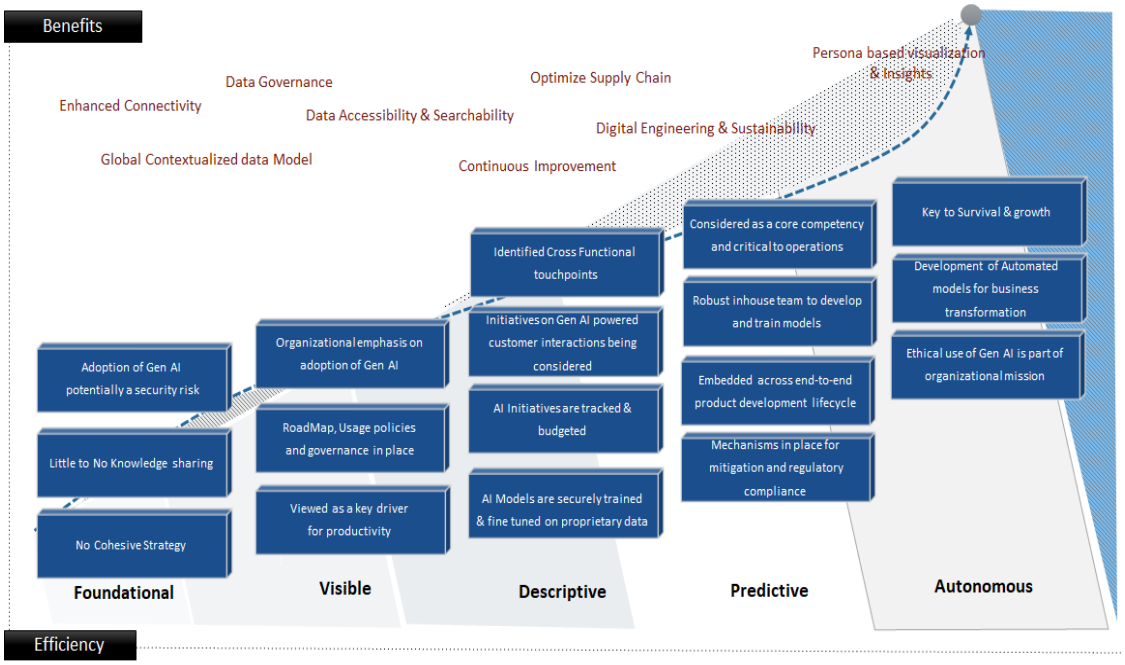
4.5 Research Question Five

How to introduce a conceptual framework to monitor the Gen AI maturity in the organization?

As organizations lead towards the path of modernization and accounting their adoption journey of Generative AI there is an absolute growing need to implement a maturity model to measure the progress of adoption of Gen AI capabilities across all levels and dimensons of startegic ,operational and technical operations. An AI maturity assessment and alignment framework is required to be implemented in an organization to evaluate, implement and monitor the progress of AI adoption for an organization its stakeholders and customers.

Generative AI represents a transformative leap for organizations to innovate , automate and stay competent in the market without a structured framework. Organizations pursuing Gen AI initiatives that are uncoordinated,non compliant or misaligned with business goals. A well defined AI assessment framewrk provides a systemenatc approach to monitor, measure and guide Gen AI adoption ensuring that innovation happens responsibly, efficiently and strategically.

Figure 3 - Organization Maturity Framework for Gen AI Adoption



The proposed Generative AI maturity model emerged from an analysis of patterns observed across the reviewed literature and industry reports. The model outlines a five stage progression that reflects how the supply chain organizations for manufacturers evolve from basic awareness of AI to fully autonomous, intelligence driven supply chain operations.

The first stage is **Foundational** where organizations begin to recognize the potential of AI but have not yet established structured initiatives or formal programs.

The second stage, **Visible**, involves early experimentation through isolated pilot projects, allowing organizations to test AI tools without fully integrating them into broader operational workflows.

The third stage is **Descriptive** marks a meaningful shift as AI capabilities start to become embedded within core operational processes, providing visibility and insights into what is happening across the supply chain.

The fourth stage is **Predictive**, represents a more advanced level of maturity in which organizations use AI-driven insights to anticipate future scenarios, optimize production schedules and improve logistics efficiency.

The final stage is **Autonomous Intelligence** reflects a fully adaptive supply chain ecosystem. At this level, AI systems continuously learn from operational data, optimize workflows and execute decisions with minimal human intervention.

An advanced AI maturity model ensures that:

- **AI investments align with business strategy**: It links Generative AI capabilities to outcomes such as revenue growth, cost optimization and improved customer experience.
- **Performance is measurable**: It introduces KPIs and maturity indicators that help organizations track progress against clearly defined milestones.
- **Resources are allocated effectively**: It identifies redundant, underperforming, or non-strategic AI initiatives, enabling consolidation and better prioritization.

A Generative AI assessment framework is no longer optional. It has become a strategic necessity. It ensures that AI adoption is not only rapid but also responsible, ethical and value-driven. By assessing maturity across dimensions such as strategy, data, technology, people and governance, organizations can confidently progress from experimentation to full-scale transformation.

To achieve this, organizations should be evaluated across **five core dimensions** and **four maturity levels**, ensuring a structured and holistic approach to AI-enabled evolution.

In the below tables, every dimension captures a key capability domain critical for Gen AI excellence.

Table 7- Core Dimensions with Assessment Criteria

Core Dimension	Key Assessment Criteria
Strategy and Leadership	Presence of AI roadmap, Executive champions defined ROI metrics
Data and Infrastructure	Data quality integration, security and compute infrastructure maturity
Technology and Innovation	Breath of use cases,model lifecycle management, RandD capability
Governance and Responsible AI	AI governance body, Compliance mechanisum, Risk mitigation processes
People and Culture	AI literacy, Training Program, Change Management,Collaboration culture

Table 8 - Maturity Levels

Foundation	Experimental stage – Isolated Gen AI Pilot, no formal strategy or Governance
Defined	Established roadmap, data fouccation and early governance models
Advanced	Enterprise – wide Gen AI integrations measurable business outcomes
Transformational	Continuous innovation,Autonomous decision system, AI – First culture

Benefits from the Proposed Maturity Model

Today manufacturing organizations that are facing challenges in their day to day supply chain operations understand the readiness and looking forward to adopt Generative AI. In relation to this a well-defined maturity model will help in bringing clarity about the current status of the organization and provide guidance for its respective future state.

The following are the key benefits that organizations gain due to the adoption and fitment of the proposed Gen AI Maturity model towards its growth.

1. Enables data-driven visibility into AI maturity across the enterprise: This gives organizations a clearer picture of where they truly stand in their AI journey, rather than relying on assumptions or scattered impressions. It helps teams see which areas

are progressing well and where capability gaps still exist. With this kind of visibility, organizations can make decisions that feel grounded and intentional.

2. Supports industry benchmarking:

By comparing their progress with peers and broader industry standards, organizations gain a more realistic sense of how they're performing. Benchmarking highlights where organizations are ahead and where falling behind. It also offers helpful reference points that guide future investments and capability building.

3. Speeds up responsible scaling of Gen AI solutions:

A clearer maturity view helps organizations scale Gen AI in a way that's fast but still thoughtful and controlled. It ensures that the right guardrails, governance and readiness checks are in place before expanding solutions. This balance allows teams to move confidently, reducing risks while accelerating the value they can deliver.

4. Strengthens strategic alignment between AI initiatives and business priorities: This helps ensure that AI work is genuinely connected to what the business is trying to achieve, rather than running as a separate technical effort. It brings clarity to why certain initiatives matter and how they support real goals on the ground.

By assessing readiness across Strategy, Data, Technology and Governance, it provides leadership with the insights needed to build a sustainable, ethical and high-impact Gen AI ecosystem enabling continuous improvement strategies and competitive advantages in this AI driven era.

4.6 Summary of Findings

The summarization of analysis tends to enrich and provides a new dimension using qualitative methods to collate the trends and findings ,observations and documents from the literature review that provides different data sets to illustrate various aspects of the

study. It helps to validate the hypothesis with the set of findings that will help us to move to a directional way yo finalize the findings and analysis. As part of the study the following trends are collected and summarised that form the basis for further analysis.

These trends represent the foundation for a next-generation supply chain that is aiming digital, to be sustainable and agile and built to absorb uncertainities while sustaining growth and competitiveness.

Modern supply chains are being reshaped by constant disruptions, shifting customer expectations, and rapid advances in digital technology. Manufacturers can no longer rely on the old, linear ways of working. Across the industry, leaders are experimenting, learning and redesigning their supply chains to stay resilient in an unpredictable world (Dolgui and Ivanov 2021). The themes that follow reflect the inference from these shifts, highlighting where organizations are putting their energy to build stronger, more responsive supply chain ecosystems.

1. **Flexible, Agile and Decentralized Supply Chain Models**

   Linear supply chains are brittle however modern networks must be flexible and can be localised.

   - **51%** of supply chain leaders have increased the number of network locations over the past two years focussing on diversification (Gartner, 2022).
   - **63%** of manufacturers have increased inventory levels to overcome supply chain disruptions (Gitnux, 2025).

   This is an important aspect as it triggers Regional diversification and multi-sourcing reduce dependency on single points of failure.

2. **Supply Chain Visibility and End-to-End Transparency**

   Manufacturers are investing in full-spectrum visibility across suppliers, logistics, production, and distribution.

- **49%** of manufacturing firms report using AI and data analytics to enhance supply chain visibility (Zipdo, 2025).
- Around **73%** of companies say supply chain disruptions impacted their profits in the past year (Gitnux, 2025).
- **70%** of companies adopted transformational journeys around supply chain network changes in the past two years, to improve its resilience and flexibility (Gartner, 2024).

Through this it enables agility, proactive risk mitigation and faster decision-making during disruptions.

3. **Technology and Automation (AI, IoT, Automation)**

Advanced technologies are of key importance for manufactureres for building resilience, efficiency, and flexibility.

- Globally **76%** of manufacturers report some level of AI adoption in supply chain processes (All About AI, 2025).
- Around **63%** of manufacturing companies have integrated IoT devices into their operations (Zipdo, 2025).
- **28%** of firms currently use AI in supply chain operations, with another **54%** planning adoption within five years (Fonseca Advisers, 2025).

Adoption of AI and automation enable predictive, data-driven operations that enhance responsiveness and continuity.

4. **Customization, Speed to Market and Digital Supply Networks**

The Customer expectations for personalization and rapid fulfillment are reshaping the overall supply chain networks.

- 72% of manufacturers reported that digital transformation journey has improved their supply chain resilience (Zipdo, 2025).

- 50% of organizations are deploying or exploring digital twin and automation technologies to optimise supply chain performance (Zipdo, 2025).

The digital supply chain network enables dynamic, real-time responsiveness and speed to market.

5. **Risk Management, Resilience Planning and Ecosystem Thinking**

   Globally manufacturing organizations are entering an era defined by volatility, complexity and rapid technological evolution.With respect to this, organizations are adopting data-driven technologies to transform the way of designing, producing and delivering there products to customers.

   - 60% of supply chain digital-adoption efforts are expected to fail in delivering promised value by 2028 ensuring the need for robust governance (Gartner, 2025).
   - 55% of companies are increasing investments in supply chain technology and innovation (Gartner, 2025).

To achieve resilience in supply chain operations, it requires strategic investment, cross-functional coordination, and ecosystem collaboration.

The next generations of resilient supply chain operations will be defined not just by cost optimization, but by the ability to adapt, recover and evolve in the face of ongoing disruption. Companies that build strong visibility, embrace digital intelligence, prioritize sustainability and participate in collaborative ecosystems will be far better positioned to succeed. Manufacturers that invest today in smart, sustainable and adaptive supply chain networks will secure both operational stability and long-term competitive advantage.

The analysis also underscores the transformative impact of Generative AI in strengthening supply chain resilience. Capabilities such as AI-driven forecasting, anomaly detection,

scenario simulation and optimization significantly enhance an organization's capacity to anticipate risks and respond effectively to disruptions.

Finally, the proposed Generative AI maturity model provides a clear and structured roadmap for scaling AI adoption from early awareness to fully autonomous, intelligence-driven operations. Together, these insights form a strong foundation for the discussion and strategic implications explored in Chapter 5.

4.7 Conclusion

To strengthen supply chain resilience in the manufacturing sector, organizations need a Global AI Adoption Maturity Model that acts as a universal standard and a data-driven framework for assessing and accelerating AI implementation across manufacturing networks. The aim is to help companies understand their current level of AI readiness, benchmark themselves against global leaders and identify opportunities where AI adoption can directly enhance resilience, visibility, and sustainability.

Although manufacturers worldwide are increasingly investing in AI to manage rising disruption and complexity, many still lack a structured roadmap that links technological maturity to measurable resilience outcomes. The proposed model addresses this gap by offering a clear, multi-dimensional assessment of where organizations currently stand and the steps they can take to progress.

The maturity model will be structured around five progressive levels from:

1. **Foundational**
    - Organizations at this stage lack a cohesive Gen AI strategy
    - There is a minimal awareness or understanding of Gen AI's potential
    - Knowledge sharing is limited or non-existent
    - Gen AI may be seen as a novelty rather than a stretegic asset

2. **Visible**
    - Gen AI is recognized as a key driver of productivity
    - Initial roadmaps,usage policies and governance structures begin to take shape
    - There is growing awareness of Gen AI's potential but implementation is still fragmented
3. **Descriptive**
    - AI models are securely trained and fine tuned on proprietary data
    - Organizations begin to track and budget for Gen AI initiatives
    - Emphasis is placed on data governance ,accessibility and searchability
4. **Predictive**
    - Gen AI is embedded across the product development lifecycle
    - Ethical use of AI becomes part of the organizational mission
    - Cross-functional touchpoints are identified and a robust in house AI team is in place
    - Gen AI is used for customer interactions ,supply chain optimization and digital engineering.
5. **Autonomous**
    - Gen AI is considered a core competency and critical to operations
    - Organizations develop automated models that drive business transformation
    - Continuous improvement and sustainability are embedded in the AI strategy

The proposed Generative AI–Enabled Maturity Model offers a structured framework that shows how manufacturing organizations can progress from traditional, silo operations to fully autonomous, intelligence-driven supply chain ecosystems. It defines five progressive stages: Foundational, Visible, Descriptive, Predictive and Autonomous.

As organizations move through these stages, they shift from reactive decision-making and limited visibility to proactive disruption prediction, real-time optimization and self-healing operational processes enabled by Generative AI. The model not only supports strategic alignment and capability assessment but also provides a practical roadmap for manufacturers aiming to strengthen resilience, agility and long-term competitiveness.
Each maturity level outlines the required depth of AI integration, data-management sophistication and organizational adaptability needed to progress to the next stage

Key Enablers

At the most basic level, organizations need clarity, commitment and a clear direction before they can progress toward these enablers. This starts with understanding of Gen AI to the business and having leaders willing to support the journey. Teams also need early experimentation, accessible data and a mindset open to learning and adaptation. Once these foundations are in place, the higher-level enablers can take shape more naturally.

1. Governance and Risk Mitigation:

As organizations mature, they become more thoughtful about how AI is built and used. Secure model training, ethical safeguards and regulatory compliance start to feel like non-negotiable rather than add-ons. This focus helps reduce risks and builds trust across the business.

2. Data Strategy:

With higher maturity, data becomes easier to access, cleaner and better organized for AI use. Teams can draw deeper insights and make decisions that feel more grounded and informed. A strong data foundation makes AI efforts more reliable and impactful.

3. Cross-Functional Collaboration:

Mature organizations understand that AI only works well when teams work well together.

They intentionally connect functions so ideas, data and solutions can flow across the business. This collaboration makes it easier to scale Generative AI in a consistent and meaningful way.

4. Organizational Culture:

At advanced maturity levels, AI becomes part of how people think and work every day. Employees grow more comfortable experimenting with new tools and leaders champion AI as a driver of progress. Over time, this creates a culture that embraces innovation and continuous learning.

The model will be underpinned by four **key capability pillars**:

1. **Data and Infrastructure Readiness** – Examines the quality, governance and interoperability of data needed to support effective AI deployment.
2. **AI and Automation Integration** – Assesses how extensively AI is embedded across key supply chain functions such as forecasting, procurement, production, logistics and risk management.
3. **Human–Machine Collaboration** – Evaluates workforce skills, governance structures, and change-management maturity to ensure people and AI systems work effectively together.
4. **Resilience and Sustainability Outcomes** – Measures the extent to which AI enhances organizational agility, visibility, sustainability performance and overall responsiveness.

To put the model into practice, the first step involves conducting a global baseline assessment using surveys, workshops and case studies across different manufacturing sectors and regions. The insights gathered from this process will guide the creation of both quantitative and qualitative indicators that define each maturity level and capability pillar.

The next phase focuses on validating and refining the model through pilot implementations with manufacturers in industries such as automotive, electronics and industrial equipment. Once validated, an interactive digital assessment tool or dashboard will be developed, allowing organizations to evaluate their AI maturity, benchmark themselves against peers and generate tailored transformation roadmaps. This will be supported by practical resources including best-practice guides, case studies and maturity-progression pathways to ensure smooth adoption and scalability.

The expected outcomes include a globally recognized benchmark for AI-driven supply chain maturity, actionable transformation roadmaps for manufacturers aiming to enhance resilience and agility and stronger collaboration among OEMs, suppliers and technology partners through shared standards of AI capability.

Ultimately, the model is designed to help manufacturers move beyond reactive, efficiency-focused operations toward predictive, adaptive and intelligent ecosystems where AI supports continuous learning and rapid recovery from disruption. This approach positions manufacturing organizations not only to withstand volatility but also to convert data and intelligence into a long-term competitive advantage.

In closing, this chapter has provided a clear understanding of how disruptions influence supply chain performance and how Generative AI can support organizations in navigating these challenges. By categorizing disruptions, analyzing their impacts and examining AI-enabled solutions, the chapter demonstrates that resilience is not merely about responding quickly it is about building systems that can anticipate and adapt. These insights lay the foundation for the next chapter, which explores the broader implications for strategy, leadership and long-term transformation.

CHAPTER V: DISCUSSION

5.1 Discussion of Results

The findings from the previous chapter reveal a clear pattern about disruptions in manufacturing supply chains that are multifaceted, deeply interconnected and often intensified by limited visibility and fragmented decision-making structures. This aligns with the Dynamic Capabilities perspective that describes organizations must continuously sense, seize and reconfigure resources to remain competitive in volatile environments (Teece, 2020; Wilden and Gudergan, 2021).

Classifying disruptions into supply-side, demand-side, process-related and technology-related categories reflects established research on supply chain fragility and risk propagation (Queiroz et al., 2020). However, this study extends existing knowledge by positioning next gen technologies like Generative AI as an enabler of resilience, complementing recent work on AI-driven supply chain intelligence and digital transformation (Dubey et al., 2021; Wamba and Queiroz, 2022; Hazen et al., 2023).

The results also show that disruptions rarely occur in isolation. A delay on the supply side can quickly cascade into downstream process inefficiencies, while a technology failure can halt operations entirely. This reflects the view of modern supply chains as complex adaptive systems that propagate disruptions rapidly (Ivanov and Dolgui, 2021; Xu et al., 2023). At the same time, the findings highlights the potential of Generative AI to strengthen sensing and response capabilities by offering predictive insights, real-time visibility and insightful decision support (Choi et al., 2020; Dubey et al., 2023).

In today's scenario, supply chain operations acts like the critical backbone of manufacturing organizations global operations. It connects people, processes and stakeholders across departments and beyond organizations. Yet these operations are

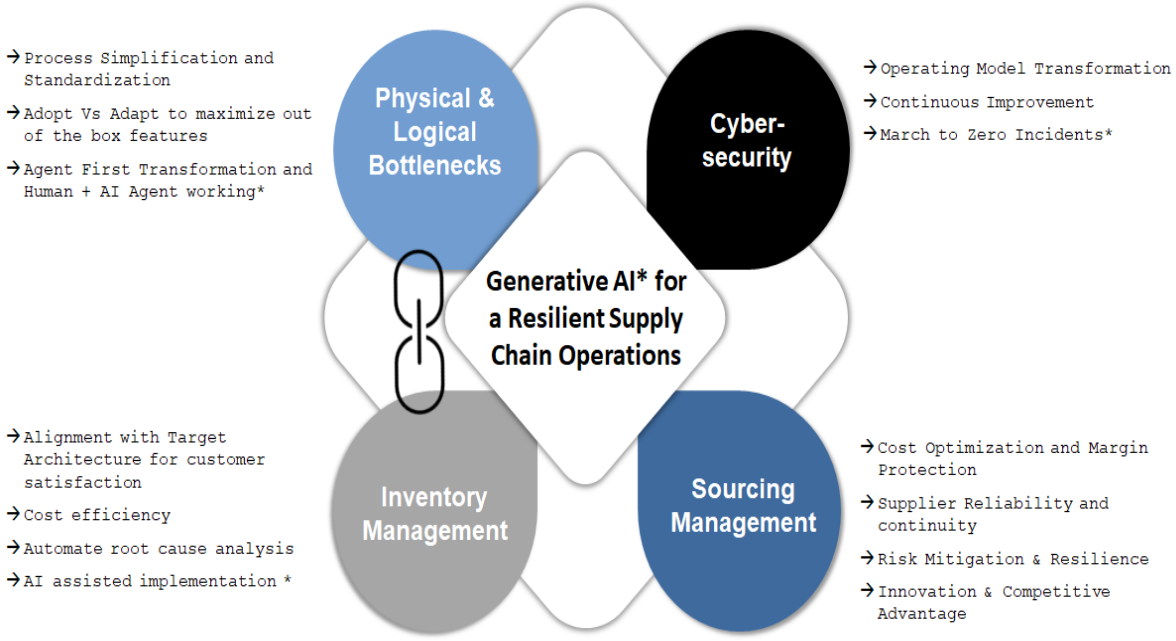
becoming increasingly complex due to multiple factors that disrupt the smooth flow of demand and supply (Wieland, 2021; Chowdhury et al., 2021).

Considering these insights indicating that supply chain resilience is no longer built solely on redundancy or flexibility. However, it increasingly depends on the digital intelligence embedded throughout the value chain. Although prior research has examined specific vulnerabilities such as logical and physical bottlenecks, inconsistencies in inventory management and sourcing-related challenge. It is increasingly becoming important to group these issues into clear categories and design targeted strategies to address them. For example, deploying sophisticated inventory-planning techniques and establishing more cooperative supplier-management models.

Equally important is the establishment of continuous monitoring mechanisms and closed feedback loops. These capabilities enable supply chain teams to detect emerging issues in the early phases to respond more effectively and create the conditions for ongoing innovation and controlled disruption within operations.

The image below illustrates how Generative AI strengthens supply chain resilience by supporting four key domains: physical and logical bottlenecks, cyber-security, inventory management and sourcing management. At the center, Generative AI functions as a transformative engine simplifying processes, enabling predictive analytics and fostering collaboration between humans and intelligent systems. Each domain demonstrates clear strategic benefits from improving cost efficiency and reducing risks to enhancing supplier reliability and minimizing operational incidents. Together, these capabilities show how AI-driven insights and automation can boost agility, improve stakeholder coordination and reinforce long-term competitiveness across the entire supply chain ecosystem.

Figure 4 - Role of Gen AI in building Resilient Supply Chain



5.2 Discussion of Research Question One

Indicators highlighting the potential disruptions impacting supply chain operations

The linking of different categories within physical and logical disruptions provides multiple scenarios that required attention and resolution.

1. **Physical and Logical bottlenecks**
   - Insufficient Transportation capacity will impact movement of goods from suppliers to warehouses or from warehouse to manufacturing plants/end customers in a timely manner.
   - Limited production or warehouse capacities develop constraints within facilities that impact the maximum speed of an assembly line or physical storage space in a warehouse.

- Inaccurate demand forecasting – Errors in predicting the right customer demand may lead to either stock out or overstocking of goods causing disruptions with misalignment of actual demand.

To overcome such scenarios it is important to categorize such factors of disruptions into logical buckets and rank the intensity of impact to the overall supply chain operations.

Table 9 - List of Issues: - Physical and Logical Bottlenecks

Issue Descriptions	Business Criticality	Scenario Complexity	Operational Stability
Insufficient Transportation Capacity	High (3)	Medium (2)	Medium (2)
Limited Production or Warehouse Capacity	Medium (2)	High (3)	Medium (2)
Equipment Failures or Poor Maintenance	Medium (2)	Medium (2)	High (3)
Geopolitical and Natural Events	High (3)	High (3)	Medium (2)
Miscommunication and Lack of Collaboration	Medium (2)	High (3)	Medium (2)
Outdated Technology and Data Silos	Medium (2)	Medium (2)	High (3)
Regulatory and Compliance Issues	Medium (2)	Medium (2)	Medium (2)
Lack of Contingency Planning	High (3)	Medium (2)	Medium (2)
Port and Customs Congestion	Medium (2)	Medium (2)	Medium (2)

High (scoring) – Severely impact the situation, need intervention.

Medium (scoring) – Moderate impact / but needs action

Low (scoring) – Less impact – can be managed

The analysis of multiple disruption factors revealed that supply-side vulnerabilities, technological failures and operational inefficiencies remain the most persistent challenges for manufacturing supply chains. These findings align with previous research showing that supplier unreliability, fluctuating demand and logistics bottlenecks remain major sources of disruption (Rapaccini et al., 2020). This study brings attention to the rising impact of technology-related disruptions specifically cyber-security threats and system integration failure that are becoming increasingly significant as organizations deepen their dependence

on digital systems and platforms. As part of the operational analysis, significant literature review and study of multiple surveys are considered that highlights the deep impact of such factors of disruptions in the global supply chain and the need to implement next-gen technologies i.e. Gen AI to bring back the stability towards seamless operations.

A key insight from the analysis is that many disruptions originate from deeper structural gaps in visibility and coordination. When transparency is limited across multi-tier supplier networks and information systems remain fragmented, organizations struggle to anticipate issues and respond effectively (Belhadi et al.,2021).The supply chain fragility is closely tied to poor information alignment and the absence of real-time insight.

The result of the study provides strong evidence supporting the need for a global Gen AI framework that provides multiple options to improve and implement Gen AI enabled use cases that will not only bring resolution to the disruptions but also tend to resolve severe business problems.

In a connected supply chain operations, cyber-security issues typically arise from the extended network of external parties, shared data and tightly coupled systems. Common examples that are identified by organizations include:

1. Cyber criminals encrypt critical data and systems like transport tracking and demand payment for the decryption keys.
2. Use of deceptive mails to manipulate employees into providing confidential information like financial data.
3. Lack of access control - Overly boarded information for external parties allows infiltrators compromise one account to move freely within the network.

To overcome such situation, organizations should incorporate AI in the existing supply chain operations and enable its adoption to identify opportunities for improvements and suggest suitable interventions to overcome.

In summary these findings indicate that the most impactful disruptions are those that spread rapidly across the value chain, causing a series of cascading effects. This underscores the importance of integrated digital systems and predictive technologies capable of identifying early warning signals before disruptions escalate the situation (Wamba et al., 2020).

Table 10 - List of Cyber-security issues

Issue Descriptions	Business Criticality	Scenario Complexity	Operational Stability
Data Breaches	Medium (2)	High (3)	Medium (2)
Malware and Viruses	Medium (2)	Medium (2)	Medium (2)
Third-Party and Vendor Vulnerabilities	High (3)	Medium (2)	High (3)
Ransom ware Attacks	High (3)	High (3)	Medium (2)
Phishing and Social Engineering	Medium (2)	Medium (2)	Medium (2)
Compromised Software Updates	High (3)	Medium (2)	High (3)
Outdated/Unpatched Systems	Medium (2)	Low(1)	Medium (2)
Lack of Access Control	High (3)	Medium (2)	Medium (2)
Poor Data Handling Practices	High (3)	Medium (2)	Medium (2)

High (scoring) – Severely impact the situation, need intervention.

Medium (scoring) – Moderate impact /but needs action

Low (scoring) – Less impact – can be managed

2. Inventory Management and Sourcing complexities

In a volatile situation of supply chain operations, where inaccurate demand forecasting, inadequate safety stock and stringent replenishment cycles can lead to stock out and delayed customer order fulfillments. These issues if not noticed at the early phase increases the sourcing complexities i.e. dependencies on single supplier, distributed supplier network and lack of transparencies. This leads to creation of a fragile supply chain ecosystem where due to minor disruptions escalates to major operational setbacks.

According to Mckinsey organizations faces an average losses of around $184Mn annually due to such supply chain vulnerabilities.

Through this study, it is emphasized that it is becoming imperative to incorporate Gen AI interventions to identify such factors of disruptions and implement best of possible scenarios to highlight the upcoming issues well ahead they occur and implement the course corrections.

Table 11 - List of Issues: - Inventory Management and Sourcing Complexities

Issue Descriptions	Business Criticality	Scenario Complexity	Operational Stability
Real-time Visibility and Data availability	High (3)	Medium (2)	Low(1)
Demand Fluctuations	Medium (2)	Medium (2)	High (3)
Omni-channel Integration Challenges	Medium (2)	Medium (2)	Medium (2)
Optimizing "Just-in-Time" inventories	Medium (2)	Medium (2)	Low(1)
Manage Multiple stock locations	Medium (2)	Medium (2)	Medium (2)
Supplier Network Management	Medium (2)	Medium (2)	Low(1)
Product Quality Control	Medium (2)	Low(1)	Medium (2)
Lack of collaboration	High (3)	Medium (2)	Medium (2)
Cost Volatility	High (3)	Medium (2)	Medium (2)

High (scoring) – Severely impact the situation, need intervention.

Medium (scoring) – Moderate impact /but needs action

Low (scoring) – Less impact – can be managed

To reap the benefits of generative AI impactful in an existing supply chain transformation, organization should begin by quantifying the leading disruptive factors across the business value chain i.e. demand forecasting, supplier reliability and logistics delay and by using structured method in a global framework leads to transformation initiatives to improve the resilience in the overall supply chain operations.

Quantifying these disruption factors helps translate abstract risks into concrete, actionable initiatives that Generative AI use case scenarios can enhance, prioritize and even simulate. Also incorporating disruption scores into a unified framework makes it possible to pinpoint

the most relevant Gen-AI applications like intelligent supplier scoring process, advanced inventory-management system or addressing lead-time issues in order fulfillment.

By classifying each issue based on its criticality, complexity and stability, the resulting insights remain both technically rigorous and aligned with key business KPIs, including time-to-market expectations and governance standards.

Overall, this quantification process becomes a strategic capability for supply chain leaders, enabling them to evaluate and select the most suitable Gen-AI use cases. It also supports for effective stakeholder training and implementation planning, ultimately helping organizations strengthen confidence across their supply chain ecosystem.

5.3 Discussion of Research Question Two

Classification of disruptive factors and resolving with new initiatives and implementation plans

To ensure efficiency in operations, manufacturing organizations have adopted multiple strategies to improve the situations but on the other hand it opens up vulnerabilities and market uncertainities that lead to disruptions. Eventually natural calamaties and human made crisis created a negative impact on the operational performances of supply chain.

Organizations in the recent past are facing a new wave of disruptions due to climate volatity, geopolitical tensions, regularoey compliances and labor issues. Due to such type of tensions,the supply chain strategies are looking for more demanding and adaptive strategies for improving the overall performances.

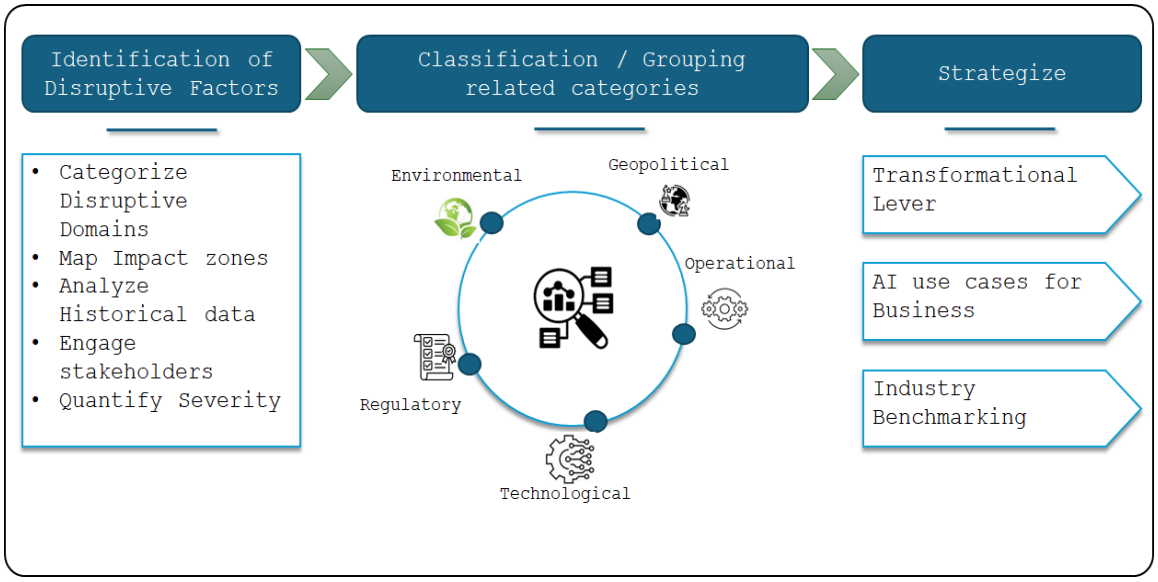
Following are some of the quantified trends in manufacturing and supply chain disruptions according to (Mckinsey and World Economic Forum, 2025)

1. Environmental – 28% of the overall impacts in supply chain operations are due to Floods, Hurricanes and Wildfires that disrupt the logistics and halts production capacities.
2. Geopolitical – 18% of impact are due to disruptions in Asia-pacific instability that raises freight cost of shipments
3. Operational – 12% of issues are due to persistent gaps in skilled labor slowed manufacturing.
4. Technological – Around 10 % of overall impact in the supply chain operations are due to Cyber-attacks and Ransomware due to IT outage and data loss.
5. Regulatory – Approxmately 22% of issues are due to non compliance of regulations i.e. carbon taxes and localization mandates.

According to World Economic Fourm (2025) around 60% of organizations are reporting direct operational impacts due to the above mentioned scenarios. Organizations must opt for strategies to be more proactive towards technogical and business transformatuions. Those adopting swiftly should be in a position to safeguard business continutity and gain competitive advantages in the ever evolving global economy.

To overcome such scenarios, manufacturing organizations must adopt a structured classification approach that group different disruptions by categories of origin i.e. regulatory , technological , geopolitical etc. This approach should enable a path to assess the scenario,prioritization and mitigation planning. By doing this, such organisations can find early ways to resolve the situations by defining contengency strategies and deploy Gen AI use cases that can predict and assess the early warning signals and ideate resolution strategies to overcome such scenarios. A clear and well-structured classification framework is required to support cross-functional governance and enable consistent benchmarking across business units.

Figure 5 - Proposed Approach towards classification of disruptions



In today's volatile manufacturing environment, supply chain disruptions are no longer one-off the events. They are driven by multiple interconnected factors. To manage this evolving complexity, organizations need a structured and scalable approach that supports early issue detection, clear categorization of disruption types and targeted responses across business units and geographic regions.

1. **Identification of Disruptive Factors**

As part of this approach, the process begins with a thorough diagnostic assessment of potential disruption triggers. Organizations start by grouping these triggers into key domains like environmental, geopolitical, regulatory, technological and operational. These domains are then linked to specific impact areas within the supply chain, such as logistics, sourcing and compliance and production activities.

Historical data is examined to identify recurring patterns and vulnerable points, while structured stakeholder engagement helps ensure cross-functional visibility and alignment.

Finally, disruptions are quantified using severity scoring that evaluates their likelihood, potential business impact and expected recovery time. Together, these steps create a strong foundation for proactive risk management and long-term transformation planning.

Classification and Grouping

Based on the disruptive factors identified, they can be organized into five main categories:

- Environmental : Like floods ,wildfires and extreme weather.
- Geopolitical : Trade tensions , sanctions and regional conflicts
- Operational : Labor shortages,equipment failure and internal process breakdowns
- Technological : Cyberattacks,IT outages and digital vulnerabilities
- Regulatory : Carbon border taxes and localization policies

This classification method helps organizations break risks down by their source to understand and design mitigation strategies that are better tailored to each type of disruption.

2. **Strategize and Act**

Once these disruptions are clearly classified, organizations can begin activating the strategic levers required to strengthen supply chain resilience. These levers typically fall into three areas:

A. Transformational Levers:

Supplier diversification, integrated sourcing models, digital-twin simulations and cloud-based solutions that enhances end-to-end visibility.

B. AI-Driven Use Cases:

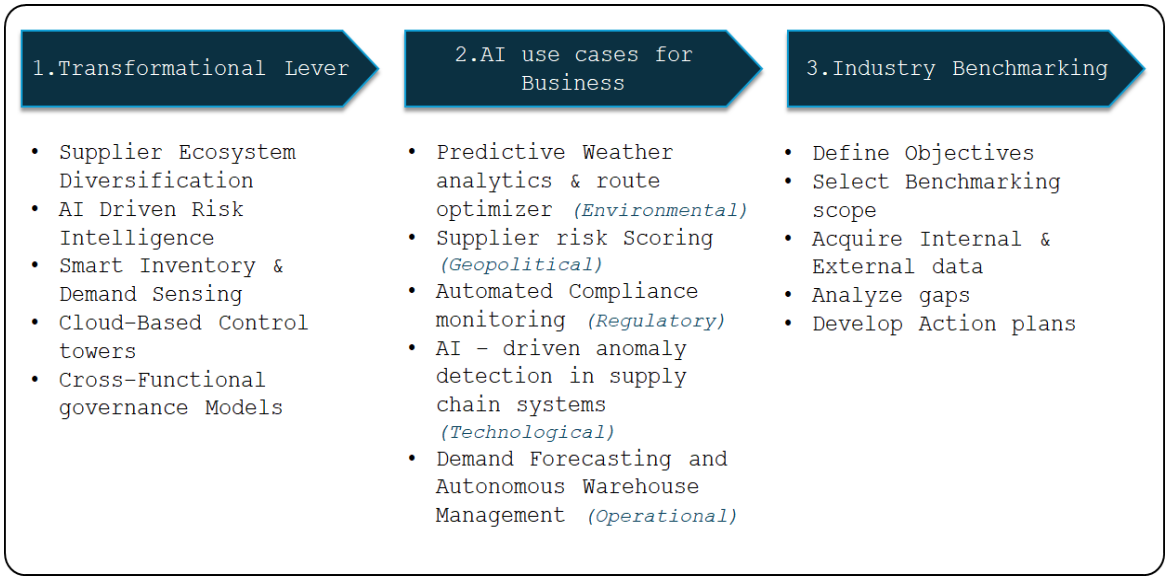
Predictive analytics for weather and demand fluctuations, autonomous inventory management and intelligent supplier-risk scoring.

C. Industry Benchmarking:

Assessments of key performance indicators, supplier-maturity levels and resilience metrics across peers and regions.

Together, these elements support a proactive approach to disruption management and help shape the organization's broader transformation roadmap. They also give senior management a clearer view of risk exposure, enabling them to prioritize investments and align sourcing strategies with long-term business objectives.

Figure 6 - Steps to strategize and identify suitable options to overcome the situation



In these situations, supply chain teams need to move away from treating disruptions as an isolated event and focus on building smarter and predictive solutions that help prevent issues before they occur. Rather than relying on a global solution, organizations should tailor their actions to the specific risks they face.

For example:

1. Climate data can be used to reroute logistics
2. Supplier networks can be strengthened to reduce dependency

3. AI can be embedded into sourcing and fulfillment processes
4. Investments can be directed toward next-generation technologies as digital risks continue to grow.

Table 12 - Mapping table – Disruption factors with categories

Type of Disruptions	Leading Factors of Disruptions	% of Impact	Categories
Logical and Physical Bottleneck	Insufficient Transportation Capacity	2%	Operational
	Limited Production or Warehouse Capacity	4%	Operational
	Equipment Failures or Poor Maintenance	2%	Operational
	Geopolitical and Natural Events	8%	Geopolitical
	Miscommunication and Lack of Collaboration	5%	Operational
	Outdated Technology and Data Silos	10%	Technological
	Regulatory and Compliance Issues	4%	Regulatory
	Lack of Contingency Planning	5%	Operational
	Port and Customs Congestion	5%	Geopolitical
Cyber-security issues	Data Breaches	5%	Technological
	Malware and Viruses	2%	Technological
	Third-Party and Vendor Vulnerabilities	3%	Operational
	Ransom ware Attacks	5%	Technological
	Phishing and Social Engineering	5%	Technological
	Compromised Software Updates	2%	Technological
	Outdated/Unpatched Systems	2%	Technological
	Lack of Access Control	2%	Operational
	Poor Data Handling Practices	2%	Operational
Inventory management and Sourcing Complexities	Real-time Visibility and Data availability	5%	Technology
	Demand Fluctuations	5%	Operational
	Omni-channel Integration Challenges	5%	Technology
	Optimizing "Just-in-Time" inventories	6%	Operational
	Manage Multiple stock locations	8%	Operational
	Supplier Network Management	5%	Operational
	Product Quality Control	6%	Regulatory
	Lack of Collaboration	8%	Operational
	Cost Volatility	7%	Operational

Impact level :- High: > 8% , Medium: 5 ~ 8% , Low : 0 ~ 4 %

This classification is valuable because it gives organizations a practical way to prioritize their mitigation efforts. For instance, a supply-side disruption that ranks high in both

frequency and severity requires a stronger supplier-risk monitoring and diversification strategies (Ando, Kimura and Obashi, 2022).

In contrast to that a technology-related disruptions, though less common, require robust cyber-security measures and reliable system-redundancy mechanisms to prevent operational breakdowns (Belhadi et al., 2021).

By using this structured approach, organizations gain a clearer understanding of each disruption type, enabling them to plan more effectively, strengthen their supply chain operations and navigate uncertainty with greater confidence. Organizing disruptions into meaningful categories also lays the groundwork for more targeted resilience strategies and supports the development of AI-enabled early-warning systems that can detect and respond to risks before they worsen the situation (Dubey et al., 2020).

5.4 Discussion of Research Question Three

Assess how disruptions affect overall operations and apply targeted improvement strategies to track progress using relevant business performance metrics.

Organizations in the manufacturing and logistics sectors have experienced a series of disruptions of varying intensity in recent years. The COVID-19 pandemic experience that led to widespread shortages as goods became stuck at major ports around the world. Other challenges like geo-political tensions and cyber-attacks have further exposed how vulnerable global supply chains can be when unexpected events occur.

Mapping these disruptions to key performance indicators shows that each type of disruption affects operations differently. Supply-side disruptions tend to influence lead times, inventory turnover and procurement costs, aligning with the SCOR model's focus on reliability and responsiveness. On the other hand process-related disruptions have a

strong impact on key performance indicators like Overall Equipment Effectiveness (OEE), first-pass yield and schedule adherence (Tortorella et al., 2020).

Organizations that actively measures resilience and track disruptions are far better equipped to respond and return to normal operations (Belhadi et al., 2021).

Regular monitoring transforms disruption management from regular exercise to a decision-grade capability as it delivers the following benefits:

1. It translates operational variability into clear business implications.
2. It helps organizations make informed investment choices i.e. comparing the value of increasing safety stock versus adopting dual sourcing or automation.
3. Continuous measurement shortens learning cycles by pinpointing which disruptions create the largest ripple effects and where resilience improvements will have the greatest impact.

The analysis also shows that technology-related disruptions can be the most damaging as they have the potential to impact the operations entirely. System outages and cyber-security breaches directly affect digital system uptime and data accuracy both of which have become critical KPIs in modern supply chain operations.

By linking disruptions to measurable indicators, this research offers organizations a practical way to monitor resilience and identify areas that require immediate actions. Industry leaders, including Wamba et al. (2020), recommend combining baseline metrics, event-level telemetry and scenario simulations to strengthen this capability.

Defining a clear process to identify and baseline the impact from such disruptions

For Manufacturing and logistics following are the broad categories to classify the disruptions that can be used for measurements:

1. Physical bottlenecks – Machines, Conveyors, trucks, Logistics routes.
2. Logistics Bottlenecks – Process design, System sequencing, ERP/MES latency

3. Cyber security Incidents – IT/OT outages, ransom ware, Supply-chain compromise.
4. Inventory Management Failures – Stock-outs, misplaced inventory inaccurate records.
5. Sourcing / Procurements complexities – Supplier OTD failure, Single source vulnerabilities, trade/tariff impacts.

Enabling a clear process to classify the categories for disruptions and use methods to measure the impact should be a right alignment to capture the data and define reporting across multiple functions.

Recommended actions baselines and severity thresholds must be data-driven

1. Collate data for 12-24 months of historical data to measure core business and operational KPI's i.e. throughput, cycle time, machine OEE order cycle time and inventory accuracy.
2. Define deviation thresholds in percentage and absolute terms e.g. 10% throughput decline equals to 'Moderate', >30% = Major impact and map those to cost buckets.
3. Maintain canonical event taxonomy e.g. start and end time, severity, root cause, affected SKU's and estimated financial impact.

This enables incident records for later consolidation and future model training.

A. Continuous Data Collection

For better management of impact assessment it is required to capture the following data sets across OT, IT and supply chain networks.

1. For Manufacturing –
    a. PLC/MES data like Cycle times, rejects or alarms
    b. Sensor/IoT feeds like Temperature ,throughput counters

c. Maintenance logs and quality test results

2. For Logistics –

    a. TMS/WMS events – Arrivals /Departure scans, dwell time

    b. Telematics : ETA , Speed, EDI/ASN messages

    c. Carrier Performance dashboards

Key Measurement artifacts to capture

- Raw telemetry – Sensor/scan logs
- Event metadata – root cause tags, Manual events
- Financial mappings and customer impacts

All these data sets allows both real-time alerting and post-event forensic attribution

B. Analysis and Quantitative Models

Measurement is meaningful when organizations can attribute the cause, effect and cost.

- Root cause and process discovery

Process mining, value stream mapping and RCA validate causal relationships between an event and KPI modifications. The process is especially effective in identifying logical bottlenecks and non-standard execution paths across the ERP-PLM systems.

- System-level Modeling
    - It quantifies how a single bottleneck reduces plant throughput and significant benefits.
    - Estimates how delays propagate across warehouse hubs and routes
    - What-if analysis in resilience planning to identify operational alternatives in logistics and manufacturing.

C. Reporting, visualization and continuous improvement cycle

Typically measurement must feed decisions. Effective reporting layer required to include Real-time operational dashboards for shifts and planners, tactical dashboards for supply

chain planners and executive dashboards for leaders. Post incidents reviews with standardized templates, Feeding incidents labels and cost outcomes into predictive models and periodic stress test and digital twin scenarios to validate mitigations to reduce the impact are some of the key aspects to perform continuous improvements methods to observe the overall process and implement necessary changes to overcome unexpected scenarios.

D. Apply Improvement Strategies

For manufacturing and logistics, organizations mapping improvement strategies to the disruptions patterns should be directly tied. Initiatives aimed at improving equipment reliability and stabilizing production flow should be tied directly to physical bottlenecks on the shop floor. However efforts to enhance workflow efficiency focus on addressing logical bottlenecks i.e. those system delays or procedural gaps that slow operations down. Cyber-security improvements should prioritize strengthening operational resilience and implementing network segmentation to reduce the risk of downtime. Inventory-related enhancements involve improving data accuracy, refining demand-forecasting capabilities and optimizing safety-stock levels.

Finally, sourcing improvements benefit from the use of structured risk scorecards and broader multi-sourcing strategies to ensure stronger and more reliable supply continuity.

E. KPI-Driven Governance and Reporting

Effective monitoring depends on having a well-structured KPI governance model. Executive dashboards in an organizational setup typically highlight overall resilience posture, financial exposure and recovery readiness. Meanwhile, tactical and operational dashboards offer real-time visibility into bottlenecks, warehouse performance and critical alerts.

5.5 Discussion of Research Question Four

How organizations can overcome these disruptive scenarios by leveraging Generative AI and other next-generation technological advancements?

The introduction of next-generation technologies specifically Generative AI is reshaping the manufacturing supply chain by enabling organizations to better anticipate, manage and recover from disruptive events. Traditional supply chain operations have long relied on historical data and reactive processes, leaving them vulnerable to physical bottlenecks, supplier failures, inventory imbalances, and demand volatility.

This study shows that Generative AI can significantly strengthen supply chain resilience by improving forecasting accuracy, enhancing anomaly detection and enabling real-time scenario simulation. These capabilities directly address many of the root causes of disruption identified in the analysis like AI-driven demand forecasting reduces the risk of stock-outs and excess inventory (Choi, Wallace and Wang, 2020).Similarly AI-enabled supplier-risk monitoring helps organizations anticipate supply-side failures before they arise (Dubey et al., 2020).

Generative AI represents a paradigm shift by offering predictive insights, automated decision-making, advanced simulation capabilities and an intelligent orchestration layer that brings end-to-end visibility across the value chain. These capabilities align closely with the Dynamic Capabilities framework that emphasizes the importance of sensing and reconfiguring. Generative AI enhances sensing by detecting weak signals of disruption and supports reconfiguration through rapid scenario testing (Ivanov and Dolgui, 2021). At the same time, the analysis highlights several challenges like data-quality limitations, integration complexity and the need for organizational readiness. These findings reflects broader digital-transformation study that highlights that successful AI adoption requires

parallel investments in digital infrastructure and workforce capability development (Van Veldhoven and Vanthienen, 2022; Ellström et al., 2022).

AI-enabled business scenarios improve disruption management primarily by enhancing predictive visibility. By integrating multi-dimensional data like sensor outputs, MES/ERP data, supplier-performance indicators and logistics signals, Generative AI models can forecast a wide range of scenarios, from equipment failures to early signs of bottlenecks or deviations in material flows. This creates a more proactive approach to identifying operational risks and enables timely interventions that prevent disruptions from cascading through the supply chain. Generative AI-driven forecasting models also adapt to real-time signals, improving inventory availability and reducing the likelihood of stock-outs or overstocking situations.

Generative AI further strengthens decision support by simulating complex supply chain scenarios, including transportation delays, cyber-attacks and capacity constraints. These models can recommend optimal responses such as rerouting of shipments, switching to alternative suppliers, reallocating inventory or adjusting production schedules. In sourcing and supplier-risk management, Generative AI automates the analysis of unstructured and semi-structured data like financial indicators, geopolitical developments and regulatory changes to generate dynamic supplier-risk scores. This allows manufacturers to detect supplier instability early and identify opportunities for improvement, such as cost-reduction measures that do not compromise resilience.

Production planning and scheduling that is one of the most complex areas in manufacturing also benefit from Generative AI. The technology can generate optimized production schedules that minimize bottlenecks and maximize throughput. During disruptions, these models can rapidly re-compute schedules, helping maintain production stability even when critical equipment or materials become temporarily unavailable.

Generative AI also enhances decision automation by enabling autonomous exception handling. When disruptions occurs like shipment delays or supplier-quality issues ,Generative AI models can automatically trigger corrective actions, including generating alternative purchase orders or notifying logistics partners. This reduces reliance on manual intervention and reduces response times from hours to minutes.

Finally, Generative AI supports continuous improvement and resilience monitoring by learning from historical disruptions, identifying recurring patterns, recommending process enhancements and predicting future risks. When combined with key performance indicators, Generative AI can autonomously evaluate performance deviations and propose operational adjustments making the supply chain increasingly proactive and self-correcting over time.

Table 13 - Improvement Strategies

Disruption Area	Improvement Strategies	Leading KPIs
Physical Bottlenecks	Predictive maintenance, line balancing, buffer optimization, layout redesign	MTTR, anomaly alerts, downtime ratio, through-put variance
Logical Bottlenecks	Process redesign, automation, ERP/MES optimization	Queue length, response time, conformance rate, manual overrides
Cyber-security	Segmentation, patching, backup testing, cyber drills	Open vulnerabilities, patch compliance, MTTD, anomaly detection
Inventory Management	Cycle-count accuracy, forecasting, IoT tracking, safety stock optimization	Forecast error, inventory accuracy, ASN completeness
Sourcing and Procurement	Dual sourcing, risk scoring, capacity planning	Lead-time variability, supplier risk index, defect rates

5.6 Discussion of Research Question Five

How an organization can introduce a conceptual framework to monitor the Gen AI maturity?

The growing need to develop and adopt a conceptual framework for monitoring Generative AI maturity reflects the importance of bringing structure and clarity to how organizations integrate Gen-AI into their supply chain operations. As AI technologies evolve rapidly, manufacturing firms often struggle to adopt them in a way that is both effective and sustainable. A maturity framework helps address this challenge by offering a systematic way to track progress and ensure that AI adoption strengthens resilience across the entire value chain.

The Generative AI Maturity Model outlines five stages: **Awareness, Experimentation, Integration, Optimization and Autonomous Intelligence** that help manufacturers assess their current capabilities and plan for a meaningful advancement. Each stage highlights a different level of technological sophistication and organizational readiness. The model also encourages alignment across supply-chain processes ensuring that AI-driven improvements support operational efficiency and prepare the organization for future disruptions. While it builds on established digital-maturity frameworks (Marx et al., 2021; Van Veldhoven and Vanthienen, 2022), it extends them by focusing specifically on the unique capabilities and requirements of Generative AI.

By offering a clear roadmap for continuous improvement and innovation, this framework enables organizations to adopt AI in a strategic and coordinated manner. It reinforces the idea that digital maturity is essential for successful AI-enabled transformation and long-term resilience (Wamba et al., 2020). Ultimately, it helps organizations unlock the full transformative potential of Generative AI while ensuring that adoption is both responsible and future-ready.

The main objective of this framework can be understood through the following six key objectives:

- **It provides a holistic approach** for adopting and integrating Generative AI use cases across supply chain processes, including those linked to sustainable technologies.
- **It strengthens alignment between leadership and key stakeholders,** ensuring that AI adoption is coordinated and cohesive.
- **It supports continuous improvement** by using staged maturity levels that help supply chain operations progress step by step.
- **It is tailored specifically for supply chain environments**, addressing their unique needs for flexibility, relevance and practical value in manufacturing settings.
- **It closes the gap between Generative AI's potential and its real-world application**, helping organizations move from experimentation to meaningful impact.
- **It encourages collaboration and benchmarking across the manufacturing sector**, enabling shared best practices and accelerating progress industry-wide.

Application of Gen AI Maturity Model

The Generative AI Maturity Model serves as a practical tool for manufacturing organizations particularly within supply chain operations to strategically implement and scale Generative AI across departments and stakeholder groups.

1. **AI Strategy Development:**

   The framework helps organizations assess their current maturity level across external factors, technology readiness and capability requirements. This

assessment supports the development of a clear AI strategy aimed at improving operational performance.

2. **IT Strategy Alignment:**

   It guides organizations in evaluating the technological needs at each maturity stage. This includes planning infrastructure upgrades, selecting suitable Generative AI tools, and ensuring compatibility with the existing technology landscape.

3. **Training and Development Needs:**

   The model provides direction on the skills and knowledge required at each stage of maturity. Organizations can design targeted training programs to equip employees with the right competencies as they progress through the maturity levels.

4. **Performance Evaluation and Benchmarking:**

   Institutions can use the framework to track progress over time and benchmark their maturity against industry peers. It also supports the sharing of best practices and helps identify gaps in implementation.

5. **Collaboration and Partnership:**

   The model encourages cross-department collaboration, accelerates adoption, and fosters innovation. It ensures that organizational initiatives remain aligned with operational needs and that AI adoption is both coordinated and impactful.

Overall, this framework provides a comprehensive roadmap for integrating Generative AI into supply chain operations, helping organizations remain resilient when unexpected disruptions occur. It enables companies to move beyond fragmented, ad-hoc adoption and instead pursue a strategic and scalable approach. This ensures that supply chain functions

stay aligned with global technological advancements that are better prepared for future uncertainties.

Ongoing refinement and collaboration will be crucial to keep the framework relevant as new trends emerge. Ultimately, organizations that adopt this model not only strengthen their operational performance but also position themselves at the forefront of cutting-edge innovation.

CHAPTER VI: SUMMARY, IMPLICATIONS AND RECOMMENDATIONS

6.1 Summary

This study takes a closer look at how sustainability and advanced technologies come together to strengthen supply chain ecosystems across large, medium and small manufacturing organizations. By examining real cases, the study categorizes a wide range of disruption factors i.e. from supplier dependencies and inventory mismanagement to cyber-security threats and logistics challenges. It has also becomes evident that people and processes is always at the center of every supply chain and when this system fails due to any of the disruptions then it is the people that experience its impact.

The study also shows that integrating dynamic capabilities specifically those enabled by next-generation technologies like Gen AI can offer significant strategic benefits. With the right framework such capabilities provides manufacturers a multidimensional understanding to evolve, anticipate disruptions and simulate scenarios for more proactive planning.

The proposed Generative AI maturity model connects the academic theory with practical industry experience. It outlines a structured path for manufacturers to move from fragmented and isolated operations towards a fully automated and resilient ecosystem. Regarding achieving the model positions Generative AI as a strategic tool for helping organizations shift from reactive crisis management to proactive value creation.

A key insight from the research is that disruptions rarely occur in isolation. They unfold as interconnected events those impacts across the entire value chain. Situations like heavy reliance on single suppliers during the Covid-19 pandemic triggered cascading risks in logistics, inventory and ultimately customer fulfillment. The study further highlights that when implementing Generative AI in a planned manner it becomes a powerful tool for resilience and collaboration across the manufacturing landscape.

Leveraging insights from existing literature, industry practices and documented disruption patterns, the study highlights the key factors shaping supply chain performance and outlines a structured method to categorize, address and mitigate these challenges.

By classifying these disruptions into categories and linking them to measurable KPI's, demonstrates how organizations can quantify resilience rather than managing it in isolation.

The following are some of the key observations by Research Questions (RQ)

RQ1: What are the leading factors of disruption in the current industry operations?

The analysis shows that in today's manufacturing the operations are primarily disrupted by five major factors:

- Operational inefficiencies
- Supplier-related vulnerabilities
- Logistics bottlenecks
- Gaps in digital infrastructure
- External shocks such as pandemics or regulatory changes.

These insights reflects the conclusions of earlier studies by Ivanov and Dolgui (2021) and Queiroz et al. (2020) that highlight how fragile global supply networks remain and its limited end-to-end visibility that continues to be a persistent challenge.

RQ2: How can such disruptive factors be classified and addressed?

A structured classification method was developed to group disruptions according to their severity, frequencies of occurrence and its control organizations have over them. This helps organizations focus their efforts where it matter most and create targeted improvement plans. The value of this approach is reinforced by earlier resilience research including

Dolgui and Ivanov (2021) that highlights the importance of dynamic scenario-based planning.

RQ3: How can the impact of disruptions be measured and monitored?

The study introduces a risk-assessment model that relies on leading indicators and key performance metrics such as downtime, forecast accuracy, supplier reliability and logistics responsiveness. Together, these measures act as early warning signals, giving organizations the insight they need to make more informed and timely decisions.

RQ4: How can Generative AI help overcome disruptive scenarios?

Generative AI emerged as a powerful tool for predictive analytics, anomaly detection and automated decision support. Prior studies confirm that AI-enabled systems significantly enhance forecasting accuracy, reduce operational variability and strengthen collaboration (Choi et al., 2021; Wamba et al., 2020).

RQ5: How can organizations adopt a methodical approach to Generative AI maturity?

The research presents a conceptual Generative AI Maturity Model designed specifically for manufacturing supply chains. It outlines how organizations can progress from basic digital foundations to more advanced Gen AI-driven autonomous operations, while placing strong emphasis on developing human capabilities, establishing effective governance and fostering cross-functional collaboration.

6.2 Implications

Saetra (2023) and Van Veldhoven and Vanthienen (2022) highlight that adopting next-generation technologies fundamentally reshapes both the strategic culture and

day-to-day operating models of manufacturing supply chains. This study further reinforces that supply chain resilience varies significantly depending on an organization's size, resources and market position. By reducing cognitive load and improving situational awareness, it supports better problem-solving, collaboration and innovation.

Small and medium-sized enterprises often face tighter resource constraints, limited digital infrastructure and greater exposure to disruptions. The proposed Generative AI maturity model offers a gradual, step-by-step pathway for these firms to adopt AI capabilities without overwhelming their existing operations. Starting with basic automation and progressing toward predictive analytics, Supply chain planners can steadily improve visibility, forecasting accuracy and customer responsiveness. This makes resilience both achievable and scalable, even for organizations with modest technological investments.

For large enterprises, the impact is equally significant but plays out across far more complex, globally distributed supply chains with multiple supplier tiers and varied regulatory environments. Integrating Generative AI into logistics, procurement and quality management enables these organizations to reduce volatility, optimize costs and strengthen collaboration with stakeholders. The findings also show that AI-enabled resilience becomes a strategic differentiator allowing firms to compete not only on efficiency but also on adaptability and sustainability (Wamba et al., 2020).

Generative AI represents more than a technological upgrade. It calls for a shift in mindset from cost-centric thinking to customer-centric value creation and from reactive responses to proactive engagement. The research emphasizes the need for organizations to foster a culture of continuous learning to empower supplier chain operators to use AI tools that support decision-making and drive innovation.

6.2.1 Practical Implications for Industry Leaders

The study offers a clear guidance that supply chain operators can incorporate in the overall strategy

- **Short-Term (0–6 months)**
  - Plan and Kick-off Generative AI pilot projects in forecasting, scheduling or quality control
  - Establish disruption dashboards using existing data
  - Train teams on AI-assisted decision-making
- **Medium-Term (6–18 months)**
  - Collate cross-functional data touch-points
  - Detail out Generative AI use cases to logistics and supplier management
  - Build internal AI governance frameworks
- **Long-Term (18+ months)**
  - Scale Generative AI across the end-to-end value chain
  - Embed continuous maturity assessments
  - Foster a culture of digital curiosity and experimentation

6.2.2 Unique Contribution of the Proposed Generative AI Maturity Model

The proposed maturity model addresses an important gap in the existing literature. Although frameworks like the NIST AI RMF, Gartner's Digital Maturity Model and various Industry 4.0 readiness assessments offer broad guidance but they do not bring together several essential elements like Disruption classification, Risk assessment, Generative AI adoption pathways and Manufacturing-specific operational realities

This model brings these components together and creates a bridge between technological capability and human-centric transformation. It provides a practical roadmap that organizations can use regardless of its current status in their digital journey.

By combining Generative AI with digital-twin simulations, organizations can better anticipate demand shifts and design adaptive logistics strategies that reduce waste and lower carbon emissions. This approach allows small and medium-sized enterprises to build resilience step by step by enabling large enterprises to streamline global operations and foster a culture that prioritizes customer value and sustainability.

Overall, the implications are both strategic and operational. The model positions resilience as a core source of competitive advantage in an increasingly volatile and disruption-prone environment.

6.3 Recommendations for Future Research

The study not only highlights key vulnerabilities within supply chains but also offers a structured set of actionable recommendations that organizations can adopt to strengthen resilience across their ecosystems. It further provides prescriptive options aligned with the proposed Generative AI maturity model, enabling organizations to advance in a phased and manageable way.

- **Interdepartmental alignment:**

  The findings emphasize that resilience cannot be achieved when functions operate in isolation. Procurement, logistics, quality control and customer engagement must work together to ensure smooth and coordinated operations. Implementing a Generative AI platform requires shared data ownership, unified KPIs and cross-functional governance. When departments are aligned, insights generated by AI models can translate into coordinated actions across the entire value chain.

- **Governance as a strategic enabler:**

  As supply chains become more digital, issues such as intellectual property protection, regulatory compliance and sustainability reporting become increasingly important.

The study stresses the need for a strong governance framework that provides the guardrails necessary for continuous innovation while supporting long-term resilience.

- **Capability building and workforce readiness:**

  A recurring theme in the literature is the widening gap between rapid technological adoption and workforce preparedness. To close this gap, organizations must invest in digital skills development and structured change-management programs that help employees adapt and thrive in AI-enabled environments.

- **Scenario planning and risk assessment:**

  Embedding scenario planning into daily operations is another key recommendation. When Generative AI is combined with digital-twin simulations, organizations can anticipate disruptions, test alternative strategies and design adaptive responses. This shifts firms from reactive problem-solving to proactive resilience.

- **Evolving performance measurement systems:**

  Traditional KPIs focused mainly on cost and efficiency are no longer sufficient. The study proposes expanding performance metrics to include customer satisfaction, stakeholder collaboration, sustainability impact and adaptability. These broader indicators ensure that resilience efforts support both operational effectiveness and long-term strategic value.

- **Customer-centric transformation:**

  Finally, the research underscores that resilient supply chains are not just efficient, but are customer-focused. By using AI for demand forecasting, predictive maintenance and adaptive logistics, organizations can improve order fulfillment, reduce downtime and enhance overall service reliability.

In summary, these recommendations collectively help organizations advance along the Generative AI maturity model not as a one-time initiative, but as a set of continuous, embedded capabilities that strengthen competitiveness and support long-term sustainability

Recommendation for Future Research

This study establishes the groundwork for a conceptual maturity model and a strategic framework to strengthen supply chain resilience. To advance this work, future research should focus on empirical validation, cross-industry comparisons and integration with emerging technologies and alignment with sustainability goals. These directions will help transform resilience from a theoretical idea into a scalable, customer-centric and sustainability-driven practice.

1. **Empirical Validation of the Generative AI Maturity Model**

- Conduct in-depth case studies across diverse manufacturing sectors such as automotive, pulp and paper and medical devices to empirically test the maturity model proposed in this dissertation.
- Assess adoption stages using KPIs like downtime reduction, defect rates, logistics cost savings and customer satisfaction to evaluate the model's predictive accuracy.

2. **Cross-Industry Comparative Studies**

- Examine how resilience frameworks vary across industries with different levels of supply chain complexity.
- Compare highly regulated sectors with less regulated ones to identify sector-specific barriers and enablers of AI adoption.

3. Integration with Emerging Technologies

- Explore how Generative AI interacts with complementary technologies such as block-chain for traceability, IoT for real-time monitoring and robotics for automation.
- Future studies could develop hybrid frameworks that combine these technologies to enhance transparency, sustainability and overall supply chain resilience.

4. Human and Organizational Dimensions

- Investigate the cultural and workforce transformations required for successful AI adoption.
- Future research should examine change-management approaches, digital literacy programs and stakeholder engagement strategies.
- Additional focus should be placed on how organizational culture shapes resilience outcomes and how leadership styles influence the pace of AI adoption.

5. Sustainability and ESG Alignment

- Extend the research to quantify the environmental and social impacts of AI-enabled supply chains.
- Develop metrics that connect resilience not only to operational performance but also to sustainability outcomes such as carbon-footprint reduction and ethical sourcing.

6. Global and Regional Perspectives

- Study how geopolitical dynamics, trade regulations and regional infrastructure affect the success of resilience strategies.
- Comparative research between developed economies and emerging markets could reveal differences in adoption maturity and contextual challenges.

7. Scenario-Based Simulation Models

- Design advanced simulation models that replicate high-impact disruption scenarios such as pandemics or cyber-attacks to test the effectiveness of AI-driven mitigation strategies.
- Such models would offer practical tools for organizations preparing for extreme events.

8. Customer-Centric Resilience Metrics

- Broaden KPIs beyond traditional operational measures to include customer experience, trust and loyalty.
- Future research could explore how AI-enabled supply chains shape customer perceptions of reliability, sustainability and responsiveness.

6.4 Contribution to Knowledge

This study makes multiple meaningful contributions to the academic understanding of supply chain resilience and the evolving role of Generative AI in manufacturing operations.

1. A Structured Framework for Classifying Supply Chain Disruptions

The research presents a clear and practical method for categorizing disruption factors based on their origin, impact and connection to value-chain processes. This adds depth to existing literature by offering a more actionable and systematic approach than the broad, high-level classifications commonly used in earlier studies.

2. Advancing Resilience Theory through Generative AI Integration

Although AI has been widely examined in supply chain research, the specific contribution of Generative AI is still emerging. This study expands theoretical understanding by showing how Generative AI strengthens predictive risk detection, scenario modeling and

decision support. By connecting these capabilities to Dynamic Capabilities Theory this research introduces a fresh conceptual foundation for technology-enabled resilience.

3. Development of a Generative AI Maturity Model for Manufacturing Supply Chains

A major contribution of this work is the development of a conceptual maturity model specifically designed for Generative AI adoption in manufacturing. Unlike general digital maturity frameworks this model brings together process, technology and culture and sustainability dimensions, offering organizations a structured pathway toward AI-enabled operational excellence.

4. Practical Insights for SMEs and Industry Practitioners

The study also addresses the unique challenges faced by small and medium-sized manufacturers such as limited digital infrastructure and fragmented supplier networks. By doing so, it broadens the relevance of AI-driven resilience strategies and provides practical guidance for organizations seeking scalable and realistic transformation pathways.

6.5 Conclusion

This research makes it clear that the future of manufacturing supply chains depends on building resilience through the strategic adoption of next-generation technologies such as Generative AI and other advanced digital tools. By classifying disruption factors and linking them to measurable KPIs, the study offers both a solid theoretical foundation and a practical maturity model that organizations can use to guide their transformation efforts.

The findings reinforce that resilience is not a fixed capability it is a dynamic, ongoing process that requires strong cross-functional alignment, robust governance and a cultural shift towards customer-centric and sustainable practices.

Generative AI, in particular, opens up new possibilities for improving visibility, predicting disruptions and strengthening collaboration across the value chain. For small and medium-sized enterprises, the maturity model provides a step-by-step pathway to build resilience despite limited resources. For larger organizations, it supports the harmonization of complex, globally distributed networks. The benefits extend far beyond operational efficiency, touching on sustainability, regulatory compliance and stakeholder engagement, ultimately positioning resilience as a key source of competitive advantage in an increasingly volatile environment.

Overall, this research contributes to both innovation and practical adoption by bridging the gap between academic theory and real-world application. It highlights that resilient, next-generation supply chains powered by Generative AI will form the backbone of sustainable manufacturing and long-term value creation in the global economy.

The journey toward the next generation of supply chains is not driven by technology alone. It requires the combined strength of people, processes and advanced digital capabilities and it begins with a willingness to rethink the new possibilities.

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