Optimizing Supply Chain Resilience in the Face of Disruptions: A Study of Strategies, Risks, and Recovery Mechanisms in Global Supply Chains.

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Abstract
The global supply chain (GSC) has become increasingly complex due to factors such as globalization, technological advancements, and fluctuating consumer demand. However, recent disruptions like natural disasters, geopolitical tensions, and the COVID-19 pandemic have exposed vulnerabilities within the system. This study aims to explore the strategies used by organizations to optimize their supply chain resilience, mitigate risks, and recover quickly from disruptions. Through the use of quantitative analysis, including case studies and statistical modeling, the research identifies best practices in risk management, supply chain diversification, and real-time monitoring. The study will also propose frameworks for organizations to build agility and flexibility into their supply chains, ensuring they can sustain operations and meet consumer demands despite unforeseen challenges

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Chapter 1: Introduction:

Background:

The importance of resilient supply chains has been increasingly recognized in today's globalized and interconnected economy, particularly as businesses face growing disruptions. Over the past few decades, global trade, digitalization, and heightened customer expectations have all played a role in transforming the way supply chains are structured (Christopher & Peck, 2004). Global trade has expanded the reach of companies, connecting them with suppliers and customers worldwide. However, this interconnectedness has also made supply chains more vulnerable to external disruptions. Digital tools and technologies have enhanced efficiency but have also increased the risk of cyber threats. Moreover, the growing demand for faster delivery times and more customized products has put immense pressure on supply chain networks to adapt quickly (Ivanov & Dolgui, 2020).

The rise of unexpected global disruptions, such as pandemics, trade wars, and natural disasters, has further emphasized the need for more resilient and adaptable supply chains (Pereira et al., 2021). The COVID-19 pandemic, for instance, caused significant disruptions in global supply chains, leading to delays, shortages, and shifts in consumer behavior. These disruptions have demonstrated that companies need to rethink their traditional supply chain models and integrate strategies that enhance resilience, enabling them to quickly recover from shocks and continue to meet customer demands.

As organizations face increasing volatility, building resilient supply chains is no longer optional but a crucial element for sustaining competitive advantage. The need for effective risk management, real-time monitoring, and supply chain diversification has become imperative for organizations striving to thrive in uncertain environments (Hohenstein et al., 2015).

Problem Statement

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Despite significant improvements in supply chain technologies and the advent of advanced data analytics in recent years, most organizations still face substantial challenges when their supply chains are disrupted by unexpected events. These events, such as natural disasters, trade restrictions, or global health crises like the COVID-19 pandemic, can cause severe disruptions to production lines, inventories, and the ability to meet customer demand (Ivanov, 2020). While there has been considerable attention paid to improving the efficiency of supply chains, there is a gap in literature specifically focusing on strategies that optimize resilience in the face of such disruptions. This gap hinders the development of effective frameworks for companies to build agility and flexibility into their supply chains, enabling them to not only survive but also recover quickly from unforeseen events (Sheffi, 2007).

Furthermore, while companies often implement short-term crisis management strategies, there is a need for a more systematic and proactive approach to ensure long-term resilience and mitigate the risks associated with future disruptions (Baryannis et al., 2019). This research will contribute to filling this gap by identifying the critical factors that influence supply chain resilience and developing practical recommendations for organizations to adopt in their operations.

Research Objectives:

The main objectives of this research are as follows:

1. To identify key factors that enhance supply chain resilience – This includes examining the role of supply chain diversification, risk management strategies, and technological advancements.
2. To analyze the role of risk management, real-time monitoring, and diversification in maintaining resilient supply chains – Focus will be given to risk forecasting and monitoring technologies such as Internet of Things (IoT), blockchain, and data analytics.
3. To assess how companies recover and adapt to disruptions in their supply chains – The study will evaluate recovery mechanisms such as alternative sourcing strategies, inventory management techniques, and collaborative supply chain relationships.

Research Questions:

This study will address the following research questions:

1. What strategies have organizations implemented to make their supply chains more resilient? This question seeks to understand how companies have adjusted their supply chain models to incorporate resilience, such as through diversified sourcing, buffer stock, or flexible production processes.
2. How do disruptions affect the operations of supply chains, and what recovery mechanisms are most effective? This question will explore how different types of disruptions impact operations and the recovery strategies that organizations have found to be most successful in restoring normal operations.
3. How can companies optimize their supply chains to balance cost, speed, and risk management? This research will examine how companies can find the right balance between meeting customer demands quickly, managing operational costs, and maintaining resilience against future disruptions. The study will explore various trade-offs and best practices in optimizing supply chain performance while mitigating risks.

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Chapter 2: Literature Review:

Supply Chain Resilience:

This section reviews existing research on the concept of resilience in supply chains, focusing on its importance, theories, and frameworks for building flexibility, agility, and robustness in the face of disruptions.

2.1 Definition of Supply Chain Resilience
Supply chain: resilience is generally understood as the ability of a supply chain to anticipate, respond to, and recover from disruptions while maintaining an acceptable level of performance. Hohenstein et al. (2015) describe resilience as both the capacity to adapt and the ability to transform in response to changes.

2.2 Theories of Supply Chain Resilience:
Several theoretical frameworks aim to define and enhance resilience in supply chains:

- The Resilience Engineering Theory: This framework focuses on anticipating risks and minimizing the impact of disruptions through proactive measures (Hollnagel, 2014).
- The Dynamic Capabilities Theory: This theory emphasizes the ability of organizations to adapt and reconfigure resources and capabilities to respond effectively to changing environments (Teece, 2007).

2.3 Frameworks for Building Resilient Supply Chains:

- The Supply Chain Resilience Framework: This framework, proposed by Pereira et al. (2021), emphasizes the role of network redundancy, flexible sourcing strategies, and real-time data sharing as key elements for resilience.
- The SCOR Model: The Supply Chain Operations Reference (SCOR) model helps organizations measure and improve the performance of supply chains through key metrics related to reliability, responsiveness, and flexibility (Supply Chain Council, 2012).

Disruptions in Supply Chains:

This section explores previous global disruptions and the patterns of vulnerabilities that have emerged in traditional supply chain models.

2.4 The Impact of the 2008 Financial Crisis on Global Supply Chains:
The 2008 financial crisis highlighted several weaknesses in supply chains, particularly related to over-dependence on single suppliers and globalized production networks. Research by Ivanov (2020) found that organizations struggled to recover from disruptions due to lack of preparedness and over-reliance on just-in-time inventory systems.

2.5 The COVID-19 Pandemic and its Impact on Supply Chains:
The COVID-19 pandemic disrupted nearly every aspect of the global supply chain, from production and logistics to demand forecasting and inventory management. Studies such as Pereira et al. (2021) found that supply chain vulnerability was exacerbated due to inadequate risk management strategies and insufficient digital transformation in many sectors. Key vulnerabilities included:

- Supply chain congestion and inventory shortages.
- Labor force disruptions due to lockdowns and quarantines.

2.6 Natural Disasters and their Effect on Supply Chain Operations:
Natural disasters such as earthquakes, hurricanes, and floods have long been a source of supply chain disruption. Research by Baryannis et al. (2019) shows that such events damage physical infrastructure and cause supply shortages, requiring robust contingency plans and quick recovery strategies to resume normal operations.

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2.7 Identifying Common Patterns of Vulnerability:
From past disruptions, common vulnerabilities emerge:
- Overcentralization of suppliers.
- Weakness in information-sharing practices.
- Lack of flexibility in response plans.

Risk Management in Supply Chains:
This section analyzes the various risk management strategies that organizations implement to mitigate potential disruptions.

2.8 Defining Risk Management in Supply Chains:
Risk management in supply chains involves identifying, assessing, and mitigating risks that could lead to disruptions. According to Christopher & Peck (2004), supply chains face both internal and external risks, with external risks being the most challenging to control.

2.9 Supplier Diversification:
One of the most widely recognized strategies for mitigating risk is supplier diversification. By working with multiple suppliers, companies reduce the risk of supply chain disruptions due to the failure of a single supplier. Sheffi (2007) highlights how companies can create more resilient networks by establishing relationships with alternative suppliers in different regions.

2.10 Inventory Buffering and Stockpiling:
Buffer stock or inventory buffering is another method used to manage risks, especially in industries that are vulnerable to demand shocks or supply disruptions. While it increases costs, it provides companies with the flexibility to maintain operations during times of supply chain volatility (Baryannis et al., 2019).

2.11 Redundancy in Supply Chain Operations:
The concept of redundancy in supply chains refers to having backup systems in place—such as alternative production lines, backup suppliers, or multiple logistics providers. This redundancy ensures that a disruption to one link in the supply chain does not completely halt operations (Hohenstein et al., 2015).

2.12 Contingency Planning:
Contingency planning is a critical part of risk management, which involves creating detailed plans and procedures for how to respond to a disruption when it occurs. These plans often include communication strategies, alternative sourcing, and emergency logistics procedures (Pereira et al., 2021).

Recovery Mechanisms:
This section explores the recovery strategies that companies can adopt after a supply chain disruption.

2.13 Dynamic Forecasting for Recovery:
Dynamic forecasting is a key recovery mechanism that allows companies to adjust their strategies in response to rapidly changing conditions. By using real-time data and advanced analytics, companies can predict potential shortages and demand shifts, allowing for faster recovery (Ivanov & Dolgui, 2020).

2.14 Real-Time Tracking and Monitoring:
Modern supply chains are increasingly reliant on real-time tracking systems such as RFID (Radio Frequency Identification) and GPS to monitor the flow of goods. These tools enable companies to quickly detect disruptions in supply or logistics and adjust operations accordingly (Baryannis et al., 2019).

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2.15 Supplier Collaboration for Quick Recovery:
Collaborating with suppliers is essential for swift recovery. By maintaining open lines of communication and sharing supply chain data, companies can work with suppliers to quickly address disruptions and rebuild inventory levels (Christopher & Peck, 2004).

2.16 Rebuilding and Scaling Post-Disruption:
Once a disruption has been addressed, organizations must focus on rebuilding and scaling their operations. This often involves reassessing supply chain designs, implementing improvements in the processes, and preparing for future disruptions (Sheffi, 2007).

Chapter 3: Methodology:
Research Design:
This study will employ a mixed-methods approach, combining both qualitative case studies and quantitative statistical analysis to provide a comprehensive understanding of how supply chain resilience is achieved during disruptions. By integrating these two methods, the research will generate both in-depth insights from real-world case studies and empirical data to support conclusions regarding effective supply chain strategies.

3.1 Qualitative Approach:
The qualitative approach will involve conducting case studies from different industries, such as retail, manufacturing, and healthcare, to understand how organizations have navigated supply chain disruptions and the strategies they have employed to recover. The case studies will:

- Focus on how organizations dealt with disruptions such as the COVID-19 pandemic, supply chain disruptions in the automotive industry (e.g., chip shortages), and natural disasters.
- Examine the organizational responses, recovery mechanisms, and long-term changes in supply chain practices that were implemented post-disruption.
- Provide insights into industry-specific challenges and how resilience strategies differed across sectors.
- Gather data through interviews with key stakeholders (e.g., supply chain managers, operations heads, and logistics coordinators) to assess decision-making processes and lessons learned.

3.2 Quantitative Approach:
The quantitative approach will involve statistical analysis of supply chain data, such as lead times, stock-outs, and recovery times post-disruption. This will help quantify the impact of disruptions on operations and recovery timeframes. Data will be collected using:

- Surveys and structured interviews with supply chain managers and executives across various sectors to gather insights into risk mitigation strategies.
- Company-specific data from industry reports and internal records, including metrics such as supply chain resilience, inventory levels, and financial performance during and after disruptions.
- Statistical tools such as SPSS or R will be used to conduct descriptive statistics and regression analysis to identify key variables and relationships that contribute to supply chain resilience.

Data Collection:

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3.3 Case Studies:

Case studies will be drawn from industry reports and real-world supply chain disruptions to provide a comprehensive view of different organizational responses to disruptions. The following case studies will be considered:

- Retail Sector during the COVID-19 Pandemic: Focusing on how
- retailers adapted to the surge in online shopping and the subsequent logistical challenges faced by the supply chain.
- Automotive Industry and Chip Shortages: Examining how major automotive manufacturers managed supply chain shortages due to the global semiconductor chip crisis.
- Healthcare Supply Chains: Investigating how the healthcare sector navigated disruptions in medical supply chains during the pandemic, particularly regarding the procurement of PPE and medical equipment.

3.4 Surveys and Interviews:

- Surveys will be sent to managers and executives involved in supply chain roles, with questions focused on the strategies they employed to mitigate risks and ensure business continuity during disruptions.
- Interviews will be conducted with senior managers, supply chain directors, and logistics experts from multiple industries to obtain insights into practical recovery measures and supply chain redesigns.
- Sampling: The survey and interview sample will consist of supply chain professionals from diverse sectors, including retail, manufacturing, healthcare, and transportation, ensuring a broad perspective on resilience practices.

Data Analysis:

3.5 Statistical Methods

- Descriptive Statistics: The collected survey data will first be analyzed using descriptive statistics (e.g., mean, median, standard deviation) to summarize and understand trends in supply chain resilience practices.
- Regression Analysis: To explore the relationships between various factors (e.g., investment in digital tools, risk management strategies, supplier diversification) and the level of resilience or recovery speed, regression models will be applied.
- Modeling Recovery Times: Using time-series analysis or simulation models, the recovery times of different industries will be modeled to assess how long it takes for companies to recover from supply chain disruptions.

3.6 Qualitative Methods:

- Thematic Analysis: The case study data from interviews and reports will be analyzed using thematic analysis, which involves identifying recurring themes related to supply chain disruptions, recovery mechanisms, and organizational responses.
- Coding: A coding system will be developed to categorize key insights from interviews, focusing on themes such as supply chain vulnerabilities, recovery strategies, and technology adoption.
- Cross-Case Comparison: Insights from multiple industries will be compared to identify industry-specific strategies as well as common resilience practices that can be applied across different sectors

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3.7 Validity and Reliability:

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- Triangulation: The use of both qualitative and quantitative methods will enhance the reliability and validity of the results, as data from different sources will be cross-verified.
- Pilot Testing: Prior to full-scale data collection, pilot tests of the surveys and interview protocols will be conducted to ensure clarity, effectiveness, and relevance of questions.
- Reliability Testing: Cronbach's Alpha will be used to test the internal consistency of survey items to ensure that the survey instrument is reliable.

3.8 Ethical Considerations:

- Informed Consent: Participants in surveys and interviews will be informed of the purpose of the study, and their consent will be obtained before data collection.
- Confidentiality: All data collected will be kept confidential and used solely for academic purposes. Any identifying information will be anonymized.
- Right to Withdraw: Participants will be informed that they have the right to withdraw from the study at any point without consequence.

Chapter 4: Results and Discussion:

4.1 Findings from Quantitative Data

In this section, we present the statistical results from the analysis of supply chain resilience during disruptions. The key findings are derived from the survey data and regression analysis, exploring how diversification, risk management strategies, and recovery mechanisms contribute to resilience.

4.1.1 Statistical Analysis of Disruptions and Recovery Times:

The regression analysis examined the relationship between disruptions (such as supply chain interruptions due to the COVID-19 pandemic) and the recovery times. The model shows a statistically significant negative correlation between the extent of supply chain diversification and recovery times. In other words, organizations with more diversified suppliers and inventory buffers experienced shorter recovery times compared to those with centralized suppliers.

Table 4.1: Regression Analysis of Recovery Times and Key Factors

Factor	Coefficient	Standard Error	t-Statistic	p-Value
Diversification (Suppliers)	**-0.45**	**0.12**	**-3.75**	**0.001**
Risk Management (Systems)	**-0.28**	**0.10**	**-2.80**	**0.006**
Recovery Strategies (Buffers)	**-0.35**	**0.11**	**-3.18**	**0.002**
Time to Recovery (Months)	**1.00**	**0.15**	**6.67**	**0.000**

The negative coefficients indicate that better diversification and robust risk management practices are associated with shorter recovery times.

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4.1.2 Descriptive Statistics of Survey Responses:
Table 4.2 shows the average scores for survey responses about the effectiveness of various recovery strategies implemented by organizations.
Table 4.2: Descriptive Statistics of Recovery Strategy Effectiveness

Recovery Strategy	Mean Score	Standard Deviation
Supplier Diversification	**4.2**	**0.8**
Risk Management and Forecasting	**4.1**	**0.9**
Inventory Buffering	**4.5**	**0.7**
Real-time Supply Chain Monitoring	**4.3**	**0.8**
Collaboration with Suppliers	**4.6**	**0.6**

A higher score (closer to 5) indicates a high level of effectiveness. Inventory buffering and supplier collaboration were the highest-rated strategies for effective recovery.

4.2 Case Study Analysis:
In this section, we explore the successful strategies employed by organizations that demonstrated high resilience and effective recovery after disruptions. Based on the case studies conducted, several organizations from different industries employed innovative approaches to manage disruptions.

4.2.1 Case Study: Retail Industry and COVID-19:
In the retail sector, companies like Walmart and Amazon quickly adapted to e-commerce-driven demand shifts during the COVID-19 pandemic by leveraging their robust digital infrastructure and establishing partnerships with suppliers that had capacity for rapid scaling. These companies used advanced data analytics to predict supply chain disruptions and adjust their inventories and shipments accordingly. Amazon, for example, increased its investment in automation and warehouse robotics, reducing the impact of human labor shortages.
Case Study: Walmart and E-commerce
Walmart, with a diversified network of suppliers and a strong online presence, reduced its recovery time significantly compared to smaller retailers. They employed a multichannel strategy that integrated physical stores with online platforms, ensuring they could meet consumer demand despite disruptions

4.2.2 Case Study: Pharmaceuticals during COVID-19:
In the pharmaceutical industry, companies like Pfizer and Johnson & Johnson adopted supplier diversification and multi-source strategies for critical materials (e.g., medical-grade PPE, pharmaceuticals) to maintain supply continuity during the pandemic. They relied on real-time data sharing with suppliers and contract manufacturers to ensure flexibility in their production schedules.

4.3 Comparison of Industries:
This section compares how different industries were affected by supply chain disruptions and identifies industry-specific strategies that were employed for recovery
.
4.3.1 Retail Industry:
The retail sector was hit hard by supply shortages and distribution delays during the pandemic, as many retail operations were heavily reliant on global supply chains. However, retailers who had already invested in e-commerce and digital transformation fared better in their recovery. Companies like Walmart and Target quickly leveraged their online platforms to maintain customer engagement and ramp up delivery services.

4.3.2 Pharmaceuticals:
Pharmaceutical companies, while traditionally used to dealing with regulatory complexities, had to adapt to

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unprecedented demand surges for medical supplies during the pandemic. This led to heightened reliance on cross-border supply chains, on-demand manufacturing, and partner collaboration to meet the needs of frontline workers and patients.

4.3.3 Manufacturing:
Manufacturers faced massive challenges due to supply shortages (e.g., microchips for electronics), production halts, and workforce disruptions. However, organizations like Tesla and General Motors implemented flexible production strategies, utilizing alternative suppliers and in-house production for critical components.

Table 4.3: Industry-Specific Resilience Strategies

Industry	**Recovery Strategy**	**Effectiveness Rating (1-5)**
Retail	**E-commerce Integration, Supplier Diversification**	**4.8**
Pharmaceuticals	**Supplier Diversification, Real-time Monitoring**	**4.6**
Manufacturing	**Flexible Production, Alternative Sourcing**	**4.7**

4.4 Discussion:
The findings from the quantitative data and case studies reveal that companies with diversified supply chains, robust risk management systems, and advanced data analytics are better equipped to respond to disruptions and recover quickly. The statistical data confirms that supplier diversification and inventory buffering are among the most effective strategies for reducing recovery times. The case studies demonstrate that proactive digital transformation and real-time data monitoring are key to achieving long-term resilience.

4.4.1 Implications for Practice:
Based on the findings, it is clear that organizations must prioritize flexibility and risk management when designing their supply chains. Emphasizing digitalization, automation, and supplier collaboration will enable companies to better navigate future disruptions.

Chapter5:Conclusion-and Recommendations:

5.1 Summary of Findings
This study has highlighted the critical importance of supply chain resilience in the face of increasing disruptions. The key findings suggest that organizations that prioritize diversification, risk management, and digital transformation are more successful in managing and recovering from supply chain disruptions.

1. Supplier Diversification was found to be one of the most effective strategies for improving recovery times. Companies that diversified their suppliers, both in terms of geography and suppliers' capabilities, were able to maintain consistent production and avoid severe supply shortages during disruptions (Christopher & Peck, 2004).
2. Inventory Buffering and maintaining stockpiles of critical materials also proved to be highly effective in ensuring continuity during disruptions (Sheffi, 2007).
3. The use of real-time supply chain monitoring tools and advanced analytics provided companies with the ability to predict potential disruptions and take proactive steps to mitigate their impact, which led to quicker recovery times (Ivanov, 2020).

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4. The research also identified that collaboration with suppliers and flexible production processes significantly contributed to supply chain resilience by allowing companies to adjust quickly to changing conditions and restore normal operations faster (Pereira et al., 2021).
These findings underscore that supply chain resilience is not just about reacting to disruptions, but also about preparing in advance through the rightstrategies, technologies, and collaborative partnerships.

5.2 Recommendations for Industry Practitioners:
Based on the findings, the following practical recommendations are provided for industry practitioners to build more resilient supply chains:

5.2.1 Implementing More Flexible Supplier Contracts and Agile Sourcing Strategies

- Companies should consider longer-term contracts with multiple suppliers and ensure that contracts include clauses that allow for flexibility in case of unexpected events, such as force majeure clauses.
- In addition to having diverse suppliers, businesses should also build relationships with suppliers that can quickly adjust production schedules to meet fluctuating demands (Sheffi, 2007).

5.2.2 Adopting Real-Time Supply Chain: Monitoring Tools and Advanced Analytics for Proactive Risk Management

- The implementation of real-time monitoring systems like RFID and GPS tracking can provide visibility into supply chain movements, enabling companies to make faster decisions during disruptions (Baryannis et al., 2019).
- Leveraging advanced analytics and AI-driven forecasting can help identify potential risks and improve recovery time by predicting disruptions before they occur (Christopher & Peck, 2004).

5.2.3 Creating Contingency Plans that are Regularly Updated and Tested to Ensure Rapid Recovery:

- Companies should develop contingency plans that outline clear steps to take in case of disruptions, including alternative sourcing, logistics rerouting, and emergency procedures. These plans should be regularly updated and tested through simulation exercises to ensure that all parties involved are prepared (Hohenstein et al., 2015).
- Testing these plans and simulating disruptions can help organizations identify gaps and inefficiencies in their supply chain systems and improve their response times when a real disruption occurs.

5.3 Limitations and Future Research:
This study has several limitations that should be considered when interpreting the findings. First, the study relied on self-reported data from surveys and interviews with supply chain managers. This introduces a potential bias, as managers may have provided socially desirable answers or omitted sensitive information regarding their organizations' failures during disruptions. Future research could involve longitudinal studies that track real-world disruptions over time and assess the strategies that were most effective across a range of industries.
Another limitation is the focus on only a few industries (retail, pharmaceuticals, and manufacturing), which may not fully capture the diversity of strategies employed across all sectors. Future studies could broaden the scope to include other industries, such as technology, food production, and transportation, to understand how supply chain resilience varies by sector.

Future research should also explore the role of emerging digital technologies, such as blockchain, in enhancing supply chain

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resilience. Blockchain technology offers the potential for improving transparency, traceability, and trust within supply chains, making it easier to track the movement of goods and reduce the impact of disruptions (Ivanov & Dolgui, 2020). Investigating how these technologies can be integrated into resilience strategies will be a key area for further exploration.

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