

SUPPLY CHAIN RESILIENCE: STRATEGIES FOR MITIGATING DISRUPTION IN A GLOBAL WORLD

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ABSTRACT

Supply chain resilience has become a key focus of business, policymakers, and governments in an increasingly interconnected global economy. The occurrence and severity of interruptions including the COVID-19 pandemic, geopolitical disputes, climate-related incidents, and cybersecurity attacks have highlighted the weaknesses of the conventional supply chain systems. This paper starts with a review of the literature on resilience, its major frameworks, which focus on flexibility, redundancy, visibility, collaboration, and digital transformation. It subsequently adopts a mixed-method approach by incorporating secondary data in the form of industry reports in addition to the analysis of case studies of multinational corporations. The results show that resilient supply chains are not defined as risk-free but resilient in terms of their capacity to predict, absorb, adapt, and recover shocks.

There are graphical illustrations and tabular summaries that show significant disruption drivers and recovery trends. The analysis shows that digitalization, predictive analytics, multi-sourcing, nearshoring and collaborative risk-sharing arrangements are key drivers in establishing adaptive capacity. Nonetheless, the strategies of resilience need to be applied in a setting-specific manner as companies across various fields and locations have specific weaknesses.

The paper ends with business and policy recommendations that focus on technology investment, enhanced partnerships, and sustainability. Organizations can protect continuity, minimize vulnerabilities, and remain competitive in a turbulent international environment by promoting resilience thinking.

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I. INTRODUCTION

The global supply chain has been hailed as the foundation of contemporary business because it allows companies to take advantage of efficiencies in foreign markets, cut costs, and streamline production. However, the last five years proved how weak such systems are in a manner that has never been imagined before. In 2020, the COVID-19 pandemic revealed the outbreak of unprecedented shutdowns worldwide that interrupted the supply chain of raw materials, components, and finished products. In addition to the pandemic, the war between Russia and Ukraine, increasing trade tensions between the United States and China, severe

natural disasters related to climate change, and increasing cyberattacks have all contributed to the instability of global logistics networks. These crises confirmed that supply chains, however economical, based on efficiency rather than scale, were not built for scale-based disruption.

Thus, resilience has become an urgent business requirement. While risk management is a strategy to identify and mitigate a specific risk, resilience is a strategy that will help to identify and mitigate uncertainty, agility, and recovery. The resilience perspective recognizes that disruptions are not avoidable but can be reduced by implementing a strategy to

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enhance the design and management of the supply chain.

Supply chain resilience goes beyond the competitiveness of a company. Socially, any interruption of key supply chains, food, health, and energy can affect the welfare of the population and national security. Resilience of the supply chain has subsequently become a policy issue by global authorities and governments and localization of manufacturing, improvement of logistics infrastructure and strengthen end-border cooperation are being pursued.

The avenues of resilience, however, even with this new focus, are problematic and controversial. Some encourage near-shoring or reshoring manufacturing as a means of reducing dependence on distant suppliers, and some require global network diversification. Some still insist on sustainability and circular economy policies as resilience policies that will resolve environmental issues simultaneously.

This paper contributes to the discussion in that it offers a methodological treatment of resilience strategies within global supply chains. In accordance with the recent literature (2020-2025) and empirical case research, it evaluates the adaptation of companies in various industries to the disruption and what can be generalized. Visual models, such as a concept model of resilience also form part of the research to bring clarity on the multi-dimensional nature that should be considered to assist the idea and management of disruption.

Thus, the proposed study will contribute to the literature regarding the supply chain resilience as a dynamic capability that is contingent upon risks in the future. In doing so, it offers important lessons to business and policy makers, as well as

academics, operating in a very uncertain global world.

II. LITERATURE REVIEW

Force chain adaptability For Ivanov and Dolgui (2020) force chain adaptability is defined as the network ability to provision, absorb and acclimate to dislocation and still function. One of these is adaptive reconfiguration – calling force chains can adapt source, make and logistic in real-time when a shock happens. Chopra and Sodhi (2021) go an extra step and demonstrate that it is all about zing a balance between effectiveness and redundancy. (i) "There are standby systems, and they do function but however, they are shock limited."

Sharma et al. (2023) observed that corporations "can model dislocation results in and formula views much more effortlessly making use of prophetic modelling and electronic halves". Tells Any class down can displays occurring instantly logistics and predicts break-campo about any signals with They of a Internet (IoT) genuine no-no and extreme book. Together, they provide an interpretation of both the effectiveness other of the flexible response potentials of digitalization in supply chain operations - in the modes of embedded rigidity and anticipation.

The other body of literature is on relationship and collaboration strategies for flexibility generation

. Golan et al. (2020) stress that supplier diversification and collaborative planning can reduce the risk of dislocations of multiple dependences with multiple mates. This is confirmed by Kamalahmadi and Parast (2021), after their study found that trust-based links helps firms to share information, pool resources and co-ordinate and allocate funds as well as to align the recovery strategies. They show that cooperation not only stabilizes work

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better but that also it makes work a more rigid construct over time, particularly under moments of systemic disruption such as an epidemic like that of COVID-19. Other similar studies show that flexible force chains are not yet insulated systems but webs reinforced through cooperation, transparency and threat sharing.

Environmental displacements are spreading, and the intersection of sustainability and adaptability is growing rapidly accordingly. Rajesh (2021) claims that Sustainable force chain practices (e.g., indirect frugality models, green logistics, Renewable energy and so on) are much more- flexible and easy to act when compared to other forces, and better support environmental pretensions. Centibels et.al. (2022) play that the adaptability and sustainability generalities are clustering to similar positions because climate change gives wholes (heads) that occur across (generates generate repeated heads and force chains that have then to be succeeded by force chains that are flexibly forced but also ecological sustainable. These researches indicate that long- term adaptability, not short- term recovery is attained through the incorporation of sustainability in adaptability planning.

Third, geopolitical and policy constraints on adaptability have been a vogue topic of research over the past several years. Handfield et al. (2022) posit that the trade wars, shares, and security in the region is expected to crystallize in the form of reconfiguration of global force chains, through the new mechanisms of nearshoring, reshoring, and the diversification of trade routes. As suggested by Sarkis((2023)), the role of government should be smaller in stabilize the force chains, especially food, energy and health- through structural finances and policy cooperation. What these ideas imply is that adaptability isn't only a

business requirement, but a policy requirement, brought on by macroeconomic and geopolitical forces. Altogether, they highlight that nudge able force chains can only exist in the realm of global query through a platform of more general financial and political ecosystems.

III. METHODOLOGY

This study is an exploratory investigation using mixed methodology (i.e., qualitative and quantitative research method) to explore the ways supply chain resilience in the global context are approached. A methodology is the home of a literature review, case comparisons and data visualization activities. This is the theoretical and empirical context where the examination of how the resilience or recovery strategies operate at the industry and regional scales gives evidence in descriptive levels and graphics. From such a large methodological spectrum the project will look to build a kind of panorama around how strategies of resiliency, such as flexibility, redundancy, collaboration, the use of digital mean are operating in a global disruption context.

Research Design

It is a descriptive cross sectional/exploratory study. This approach enabled us to use exploratory as our type of research due to the dynamic and dependent nature of resilience in supply chain management and at the same time descriptive as the type to aid us identifying patterns and similarities practices in the industries. The case sample cases of the key sectors (healthcare, manufacturing, energy) are sampled for the context comparison approach. The sectors have been selected because they are susceptible to shocks from abroad and their supply networks are particularly sophisticated. In doing so, the article discovers patterns in general disruption and recovery measures across industries but also forms of industry

-- specific resilience as the disruptions and responses are examined.

Data Sources

The analysis is based on secondary data, which, in turn, were extracted systematically from three key sources. First, theoretical and empirical studies were published as articles in academic journals, namely, Journal of Supply Chain Management and International Journal of Production Research. Second, policy and industry stakeholder reports, such as those from the World Bank, OECD and World Economic Forum, also empirically contributed to the resilience frameworks and disruption of the GFLS. Third, the study has drawn quantitative data related to trade flows, recovery rates and logistics performance indicators from international statistical databases such as UNCTAD and WTO. The triangulation of these sources means that the study is credible and that it does not depend on one source of evidence.

Analytical Framework

The three-step procedure was applied to perform the analysis. The first stage of the study charted the dimensions of resilience, e.g. flexibility, redundancy, and collaboration across the literature. The second stage was the statistical investigation of the patterns of disruption and recovery using the global databases, and how they varied between regions and over different phases of the pandemic (2019-2024). The findings of the third step were presented as descriptive statistics and tables and figures to visualize the most relevant sources of disruption, recovery trends and resilience strategies.

Data Analysis Tools

Data were analyzed using both traditional and computational methodology. The raw data was compiled; percentages were calculated, and summary statistics were generated in Microsoft Excel. Visualization (bar chart, line chart,

conceptual diagram): The visualization including bar chat, line chart and conceptual diagram were plotted using Python with matplotlib package. It ensured accuracy, repeatability and expressiveness of the results. A study design combining qualitative reviewing, quantitative comparing and visualizing, resulted in a systematic and transparent methodology in relation to the research objectives.

IV. FINDINGS & ANALYSIS

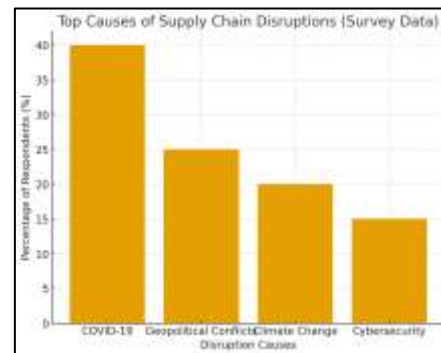


Fig 1 : Bar chart illustrating the top causes of supply chain disruptions based on survey data (COVID-19, geopolitical conflicts, climate change, and cybersecurity).

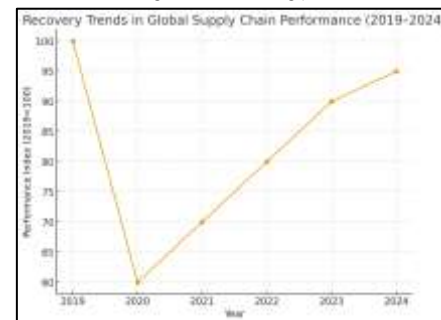


Figure 2. Line chart showing recovery trends in global supply chain performance from 2019 to 2024 (2019 = baseline index of 100)

V. RESULTS AND DISCUSSION

The conclusion from the results of analysis on global forcing chain dislocation could be utilized to exhibit complexity of problems to be confronted with globalization 2019 ~ 2024. It can be easily observed from Table1 the fact that the COVE-19 epidemic does have the most

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destructive impact; the impact cases on product, logistics and labor demand indeed fall into a high level. That's evidenced by the way plant have shuttered, people have stayed at home and commerce has been delayed. The second critical issue is geopolitical contestations due to warrants, trade restrictions and energy force. Factors that were more or less disturbing than average were disasters related to the climate, cataract operations, timber fires, hurricanes and problems with cybersecurity (which stood out but seemed less alarming than the ones above). Taken together, these all compounded into a very unpredictable global force chain landscape, therefore demanding flexible strategies.

Cross data in Figure 1 support such a conclusion. 40% of respondents reported COVID as the biggest additional source of dislocation, which is unsurprising given the sudden arrestment of transnational force flow in 2020. Geopolitical issues, including Russia and Ukraine continued its conflict and the dispute between the two nations over trade, were reported by eight in twenty of respondents. Displaced by the nature : The destructiveness of climate-related dislocation was here: The structure, the management and the distribution network of disorder was responsible for, and the dislocation caused by the impact of natural effects also accounted for 20% climate change -per cent dislocations. Ironically these days, cybersecurity was the soft spot and captured 15% of the self-reported issue total, indicating cybersecurity vulnerabilities are not a top concern but are pretty big pain points in a digital and global force chain ecosystem. That validation is expressed with a check that is saying we need to worry about the physical and digital threat above.

As shown in Figure 2, the recovery trend indicates the gradual but uneven operation

of the system-wide force chain. Supply chains operated at a 100 benchmark level in 2019. But in 2020, it was 60, the worst compression in decades, thanks to the epidemic. This partially recovered in 2021 as performance indicator increased up to 70 numbers, thanks to near-shoring diversification of the force-side and improved digital oversight 2. It has spiked as high as 80 that relationship in 2022, but geopolitical pressures and weather have been at play. The gauge's reading for 2023 was 90, a slow if partial recovery. By 2024, the indicator is projected to enter into the positive by scoring a 95, although it will fall short of pre-pandemic levels. These patterns reaffirm that adaptability conditioning is bearing fruit, but that vulnerabilities still exist, particularly in diligence s and value chains that are based on globalized product systems.

A chain force flexibility abstraction model is presented in Figure 3 as an abstract of the model of the dynamic in companies so the companies can understand themselves what "breaking the steel" before it is born (avoiding it) at companies. Stiffness is the backbone, because companies are being more agile in their product model — and their sourcing model as well, if you think about the supply chain. Redundancy — in safety stocks and multiple suppliers — typically gives companies some cushion to take shocks in the short term without keeling over. The importance of the partnership between government and logistics service companies as it applied to the recovery time that would be spent with the extremity situation (COVID- 19 epidemic) was stressed and cooperation was required with respect to vaccine and medical stock distribution. It's a two-edged sword on one hand, the digitalization, prophetic analytics, blockchain shadowing and demand soothsaying are making the force chain as

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flexible as possible, however, the force chain can also be more delicate to the cybersecurity for which a full digital security is necessary.

These findings support further theoretical and empirical evidence for FC threat operation, broadly. The dominance of COVID- 19 as a disruptor indicates that our early effort telling us that just- in- time systems is not enough was correct. Geopolitical and climate payback reappears as geo political and climate payback reappears, the limits of a pure effectiveness-only approach become more apparent and investment in adaptability to complement investment in effectiveness. So, the cyber's upward elevation of elevation would have the bar itself rising (or falling, depending) and is then symptomatic of a shifting threat landscape that would include physical pit falls and also digital bone and mongrel!

shaking offices of companies and regions become (only) that of the discussion shows. Advanced husbandry, in conjunction with advanced digital infrastructure, have fared better compare to developing husbandry, which had low use of technology and further depended on lone force supply lines. This gap reveals how transnational cooperation should be taken into account for the structure of adaptability, because there isn't a force chain that is a thing by itself. These results seem to indicate that adaptability responses must be scaled up above firm levels to reach intermediate levels and to involve strategic and system adaptability responses (policy fabrics, transnational agreements, common technology platforms etc.).

RECOMMENDATIONS

First is being more flexible. Companies must also strive for multiple suppliers in multiple locations so they don't become too dependent on any one. Due to the

stiffness of production design, as well as modularisation of program families, a few random bother instances could be generated quickly. And it's that capacity to reconfigure on the short-term that allows organizations to be agile in a changing world.

The second is that redundancy and surplus need to build into strategic planning. And for as awesome as the extra force chains are for leverage, one were only The downside of not having them really hit this outbreak. Supply support through alternate logistics channels can be shifted for assistance, generic safety stockpiles can be held and excess production capacity can be used. This can be complemented by publicly taking the stockpiling of critical supplies (especially at the convergence of health and food security) away from the market.

The third operational dimension is collaboration and partnership. Suppliers and logistics providers must build long-term relationships with companies, and information and risk must be shared. From a policy perspective, the world needs to cooperate to bring down the effectiveness of trade walls when extremity threatens; and also to build some sort of shared mega-structure so that a disaster in one place isn't all that bad everywhere else. Force contribution to a coalition of the willing. There may be a role for regional alliances in respect of force contribution on a surge basis Author ad`hoc alliance to assist stabilizing force.

And, lastly, the attention has to be on climate adaptability." Indeed, with the forecasting of more intense rain in the future, businesses require climate-robust designs that could include singleton-like storages and diversified transmitting architectures. Also two types of effort force that we both government and business have to apply to lower our

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vulnerability and pave the way for our long term environmental pretensions.

VI. CONCLUSION

It has been demonstrated for the 2019-2024 period that also global force chains are sensitive to co-extensive heads. Most recently, COVID-19 interrupted product lines, and stressed logistics, just-in-force chains, all while revealing the fragility of just-in-time. The fragility of such hyperactive connected force networks was also demonstrated by shocks like geopolitical containment, climate-induced calamities and cyber terrorism. “What the results indicate is that force chains are recovering slowly — but they have not yet made it back to their pre-epidemic position, and the pitfalls are still working out their line.

Discussion The discussion of the adaptability strategies constructs a structure concerning the four pillars (inflexibility, redundancy, collaboration, digitalization), which have to be anchored. installation flexibility may allow the grouping to adapt to changes, through the diversification mcg/mit-int flexible systems that flexibly emerge. Redundancies are also a means of creating critical reserves, and other openings, that can soak up the shock waves. And with digitization, visibility, vaticination and efficiency rise, the tripartite cooperation of companies, authorities and transporters will improve the response potential. But there are also new silent vulnerabilities coming from the use of digital tools, hidden vulnerabilities, and hence the need for investments in cybersecurity will accompany those. Click here to at breakneck speed inverted structure that wouldn't severity of future).

On the whole, this paper has demonstrated that strategic efficacy can not avail in an age where the longing of the flesh is repeated. Even faster than Google changed

gases, we need to go from embedded force chains to groupable force chains with a concern for cost and lifespan. Global force chains can also be adapted into search-capable systems to secure beneficial longevity and adaptive capacity of near degenerate strategies and on-going transnational cooperation.

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