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Technology's Role in Sustaining Supply Chain Amidst Persistent Wars, With Reference to Russia-Ukraine War

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ABSTRACT

The conflict and disruptions arising have an enormous impact on the traditional supply chain. This paper investigates the potential of technology to sustain these vital networks during this disruption. The Russia- Ukraine war serves as a case study, highlighting the vulnerabilities of the existing networks. While the intake of Industry 4.0 adoption continues, Industry 5.0 offers a revolutionary leap forward. Its focus on human machine collaboration and real-time tracking empowers supply chains with greater visibility, adaptability, and efficiency. These technologies enable proactive response to disruption, allowing for alternative routes, production adjustments and optimized allocation. Industry 5.0 put forth a more sustainable supply chain by minimizing disruptions and ensuring continued supply of goods. However, successful implementation requires investment in infrastructure, workforce upskilling and government support.

***Index Terms*—**Supply Chain Management, Technology, Sustainability, Russia-Ukraine War, Industry 4.0, Industry 5.0, Disruptions.

INTRODUCTION

In an era marked by geopolitical tensions and persistent conflicts, the role of technology in sustaining supply chains has become increasingly critical. As recurring armed conflicts continue to disrupt traditional trade routes and endanger the stability of global markets, the necessity to fortify supply chains against such adversities has never been thought about in brief. The damage to supply chain management (SCM) from the COVID-19 pandemic was just settling when the Russian-Ukraine war aggravated it. Beyond the immediate human tragedy, the conflict sent shockwaves through the global supply chain, exposing the cracks of the global system, turning trade routes into war zones, and posing a threat to food security.

Theoretically, SCM is the flow of goods, data, and finances for a particular product or service, from the farming of raw materials to the consumer procuring the finished product. Furthermore, we note that SCM has benefited greatly from technology 4.0, which is the incorporation of intelligent digital technology into industrial and manufacturing processes.

The focus of this research paper is on the Russia-Ukraine conflict as a reference of conflict's disruptive potential and understanding its domino effect on the movement of commodities down the supply chain. Through thorough research and analysis, we understand the vulnerabilities this conflict brought forward and how technology 4.0 has sustained SCM.

Our objective is also to see how modern technology 5.0 can be harnessed to mitigate these risks, diversify, and reconfigure supply chains and enhance transparency and traceability through real-time tracking and streamlining operations.

(Mohsen Brahmi, 2022) Their study says that the Internet of Things (IoT), robotics, sophisticated data, artificial intelligence (AI), virtual reality (VR), augmented reality (AR), and other components of technology 5.0 are constantly employed for the betterment of human workers and their well-being.

By understanding how technology can be leveraged to navigate the complexities of conflict- disrupted supply chains, there can be a more adaptable global system in place. This analysis further aims to contribute to this critical discussion, offering insights and recommendations that can help protect the SCM even in the face of persistent conflict.

REVIEW OF LITERATURE

(Atul Kumar, 2023) In their study they suggest that one of the very crucial ways of sustaining supply chain is by investigating alternative routes of transportation which guarantees unhindered commodities flow during times of upheaval and acts as a strategic buffer against conflict-ridden areas. The introduction of state-of-the-art technologies (I5.0) such as blockchain, IoT, and AI increases supply chain traceability and transparency, facilitating real-time monitoring and well-informed decision-making in turbulent times.

With the ever-changing landscape, managers will naturally find alternative solutions that will ensure reliability and growth. The supply chain executives adopted robotics in their supply chain logistics according to an article published in EMIS by (Santhosh Reddy , Shakedeal, 2024) leveraging the innovative technology that helps decrease long term costs and, optimizing picking, sorting, and storing and reduce the frequency of manual inefficiencies and faults. The mutually exclusive collaboration of technology with the introduction of industry 4.0 to support the stability in the supply chain showed superior performance, visibility and speed being precursors to resilience; although the gap presented at the management of each supply chain links are the outdated approaches and inefficient use of resources. (Krykavskyy, 2023). Disruptions such as wars cause scarcity of the right information on the product demand which may lead to an incorrect forecasting and mismatch in the supply-demand cycle of raw materials or commodities. Apart from that, the labor shortages, changes in consumer behavior of keeping essentials commodities such as staples constant while the prices to be low, maritime transport congestion which is another contributing factor of the demand- supply gap since certain companies halted certain travelling routes all suggest that it is a domino effect where quite a few industries face issues and qualms with the disruption of supply chain and lack of proper infrastructural and technological support, highlighting its need and importance. (Abirami Raja Santhi, 2022)

(Atul Kumar, 2023) The direct consequence of the war on not only Ukraine but also on the interconnected international trade was the thriving supply chain disruption. Certain ripple effects included but not limited to be the destruction of logistics centers, loss/closure of business, relocation of business and reduction in number of suppliers. The domino effect of the conflict could be seen through increased insurance premiums for cargos, production disruptions, infrastructures, agriculture, and increased commodity prices – from oil and gas to the general groceries (at least in the European region). Although strategies were implemented to mitigate the conflict's effect on supply chain, and the pandemic had left behind the lesson of supply chain diversification and trade coalitions and partnerships, the lack of technological implementation with respect to real time tracking and risk mitigation and prediction was a very visible gap to be research upon. To help with this, (Sitharaman, 2023) in the G20 summit and also in the recent Budget 2024, proposed that the making of India-Middle East-Europe corridor will significantly reduce the logistical problems faced for trade with European nations and sustain such shocks which may occur during future crises along with (Shruti Agrawal, 2023) suggesting to adopting green technologies starting with human machine collaboration as the next core focus of I5.0 – facilitating human work system and ensure efficiency of repetitive procedures. The perceived benefits of implementation of I5.0 in supply chain can be the improvement in restorative, absorptive and adaptive capacity in supply chain, making it more resilient through AI and IoT, tracking technologies, collaborative robots, and Augmented Reality.

It is imperative to implement these technologies into supply chain because diversification and trade reallocation will not work eventually. In a study conducted by (Tobias Korn, 2022) where they estimated trade allocation effects during a civil war remains the same for almost up to nine years since the market finds its equilibrium within that time frame, making it difficult for both the countries which were a part of the conflict to recover their international economic standing

before the conflict and makes the burden fall on the shoulders of the reallocated countries who might not have adequate resources to sustain the supply chain for that long of a period, especially if its commodities such as natural gas or agriculture.

RATIONALE

We decided to conduct the study on this area because the supply chain is the main part of any business and trade that exists; we are in a world where wars and conflicts are taking place daily and are a real foe to any supply chain. Also, after the war and covid-19 pandemic we have seen a huge boost in the technology sector. Hence it becomes particularly important to understand the behavior of supply chain in control with the use and benefits of I5.0.

SCOPE AND OBJEVCTIVE OF THE STUDY

Our study talks about the existing problems and shocks faced by supply chain management. The objective is to particularly look at how the new and advanced technological advancements will help sustain such shocks to the SCM and how the technology can be integrated into SCM for most efficient functioning. This study also sheds light on how and where I5.0 can be used at each stage of the SCM.

RESEARCH METHODOLOGY

Hypothesis: The implementation of Industry 5.0 technologies in Supply Chain Management proves to be instrumental in sustaining and enhancing the resilience of supply chains during periods of persistent conflicts, such as the Russia-Ukraine war. The integration of advanced technologies contributes to the optimization and adaptability of supply chain processes, thereby mitigating disruptions and ensuring a more robust and responsive global supply network.

This research paper is primarily based on primary qualitative data where we have interviewed an expert in this field and gathered data by questionnaires with over 20 responders, the study is backed by secondary quantitative data gathered from various sources such as Journals, documents, programmes, case studies, research papers, and other stats. Our study focuses on a casual research design.

DATA

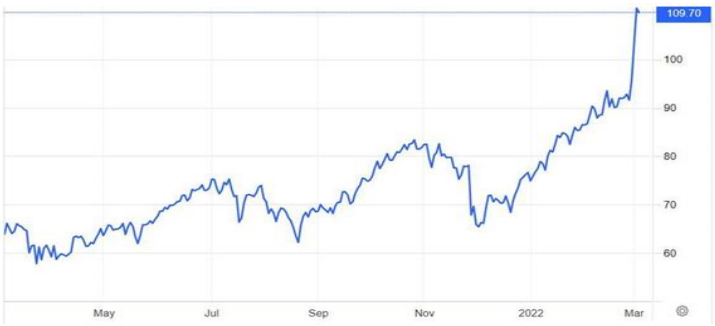
An interview was conducted, and information was gathered and interpreted to understand the topic in depth. This interpretation helped provide context for the data collected through survey, which is included in Annexure B. The survey itself allowed us to gather significant information and understand different perspectives through the participants. The survey data helped confirm the findings from the interview. The interview questions can be found in Annexure A for reference.

DATA INTERPRETATION

The breakout of the war bought forth challenges to many different industries and their supply chain; the fuel and crude oil supply from Russia was sanctioned, agriculture chain was shaken which unveiled vulnerabilities of countries that were dependent on Russia and Ukraine on certain commodities.

This gave rise to opportunities to different countries as the market equilibrium shifted to the countries who could supply the produce that was demanded by the markets; an example being Indian wheat producers gained an opportunity for supply of wheat. But India, primarily is not a wheat producer, so when the country faced shortage of the produce for its own population, its restricted its volume of trade export. USA also saw a shift of demand for their oil as supply of crude oil from Russia was put on a ban, allowing them to hike up the prices as prices went up to $110 per barrel.

Crude oil per Barrel rate after the war:



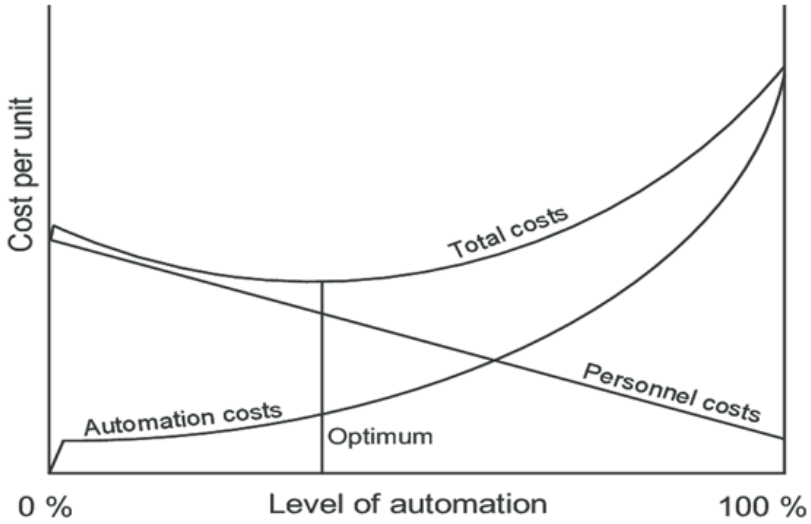
(Fig. 1) *(source: world economic forum)*

This caused a ripple effect on the transportation cost of commodities like essentials and medicines as transportation and storage prices also had gone up as a result, the increased price being borne by consumers.

The losses were faced by the countries that were directly involved in the war and those countries that earn through transportation of these commodities. The industries, during the war, were trying to find alternative sources and routes, already having been burdened and clouded with the effects of Covid-19 and the global manufacturing reducing their volumes and slowly shifting away from China.

The current technology, Industry 4.0 is largely still in the process of adaptation, but with the Indian government pushing forth the manufacturing industries to grow and have an indigenous manufacturing, with initiatives taken up by the Andra Pradesh state government and the Make in India scheme (Deloitte, 2018) . New avenues are opening indicating that adoption of industry 4.0 is high but, in business terms, the adoption of modern technology in the Indian market is vis-à-vis cost vs. return. In India particularly, labor is relatively cheaper and there is a significant skill gap in areas of advance technology, putting automation on the back burner and not so popular on the uptake. For example, taking labor and automation as parameters; if labor is cheap, the company would much prefer workforce as its easily affordable as compared to automation, where although 3-4 workers only need to be employed, there is a huge investment cost to it. Also, from the graph below we understand that as of today 100% automation is not optimal for any industry nor is complete labor usage, to achieve maximum production efficiency industries must start to shift towards the usage of modern technologies to an extent of at least 37-40%.

Optimal combination of workforce and automation:



(Fig. 2) *(source: Research Gate)*

Technology has been on the lower side of automation adaptation where there is a clear difference of productivity or quality, but adoption has been higher on the information side, an example being the FMCG (Fast Moving Consumer Goods) sector which has started utilizing technologies that require minimal supervision and work alongside human labor helping reduce lead time and have optimum utilization. Different technologies of Industry 4.0 have had different acceptance levels, with context to the industry and technology used.

Even with newer technologies, such as Industry 5.0, which has applications in places where human productivity is reaching a limit, it does solve the problem but also escalates the cost as adoption comes with a higher price tag (Vaidya, 2018). The question remains the same even with Industry 5.0 – Which gives a better return? Disruptions like the Russia Ukraine war exposed weaknesses. Industry 5.0, with its focus on human machine collaboration and advanced data comes up as a solution by using its real time data and Artificial Intelligence to create more accurate and nuanced scenarios for disruptions. This could lead to better risk mitigation, forecasting and even minimize environmental hazards; Industry 5.0's data analysis can strengthen risk management strategies, as supported by research (Wang, 2023). The essence of industry 5.0 is human collaboration with technology; and on a case-to-case basis, it will have a lot of takers due to this aspect.

Efficiency, as a measure in Industry 5.0, is in very general terms as different technologies will have different uses and applications. In supply chain in particular, an important challenge is the track and trace of the goods, and in times of disruption, it becomes even more of a challenge. Tracking and tracing, of say, shipments throughout the supply chain is not very easily achievable, which makes the ability to do so of paramount importance.

Taking the example of a pharmaceutical company having various production units in different countries, which are coordinated, has chosen the lowest cost supplier and has a strong distribution network. Even if a war breaks out in one area, the other units take over the supply and meet the market demand. Industry 5.0 helps in being able to manage a large complex distributive network, being able to customize it and deliver it. With current and older technologies, demand identification and immediate response was not possible on a large scale, but Industry 5.0 shows promise of being able to customize products at a large scale and responding to the demand, which comes in as a big advantage.

When the Russia- Ukraine war did break out, the global supply chain did take a hit and it took industries and the supply chain some time to adapt to it, causing shortages and disruption in that period. In the current scenario, the industry has become wiser, and risk assessment and pre-emption has become of importance – which industry 5.0 helps to better predict. In supply chain, the only way to reduce risk is by having an option "B" or a false back up plan. – an alternative at every step of the way – from suppliers to transport, and these alternatives can be best identified, evaluated, or managed using AI.

Industry 5.0 is a relatively newer tech, which is still in its implementing and testing stage, making it hard to pinpoint their accuracy level as it is something that will get finetuned and more customizable over the years, only then will the accuracy level increase. There are two objectives of the supply chain – (I) timely delivery and (ii) lowest cost available. Success in the supply chain means fulfilling these objectives. Although industry 5.0 might not always guarantee the lowest cost available, but its effectiveness should be judged by its ability to (I) reduce disruption impact such as production delays and overall financial loss incurred from these disruption and, (ii) preparedness and the ability to anticipate potential disruptions and develop mitigation strategies beforehand using scenario based simulations (running simulations using previous historic data and potential future disruptions to evaluate prediction and mitigation) (Singh, 2021).

CONCLUSION AND SUGGESTION

Supply Chain: The cascading effect of the war exposed the limitations of traditional approaches and highlighted the urgent need for resilience in the supply chain. This research explored the potential of Industry 5.0 technology as a powerful tool for mitigation of disruptions.

While Industry 4.0 adoption is still ongoing, Industry 5.0 offers a promising leap forward. Its focus on human machine collaboration, advanced analysis, technologies such as AI, IoT, and real-time AI-powered scenarios are significant advantages for supply chain management. Industry 5.0 facilitates enhanced risk management, improved visibility and traceability, and agile response and customization. While it may not always guarantee the lowest cost, its effectiveness lies in reducing disruption impact and enhancing preparedness.

Industries and companies must find the perfect balance in usage of such technologies and existing labor and machinery to obtain the maximum productivity and maximum resilience to any shocks. It must also fully understand the functioning and capabilities of these nuance technologies before investing heavily into them as we understand that to sustain the supply chain in the long run, relying blindly on these technologies might not be beneficial if they are not used at their maximum capacity and are just being a monetary liability to the SCM.

For the way ahead, certain suggestions which could be helpful are:

(i) Investing in technology by building necessary infrastructure, upskilling, and technology adoption

(ii) Government support by providing incentives for technology adoption and promoting research and development.

(iii) Use technologies like I4.0 and I5.0 to find the best and most optimal alternate routes of transportation and diversify the supplier base.

(iv) Adoption of AI and cloud sharing for real time monitoring and well-informed decision making which all leads to enhanced collaboration and information sharing.

(v) The use of big data analytics and predictive AI can help in simulation scenario-based risks, this would enable the user to understand the market sentiment and see whether there is going to be any potential crisis.

(vi) Augmented reality and Virtual reality should be preferred to create multiple scenarios with multiple possibilities and multiple supply chain settings to understand how the supply chain should be managed in any given situation or scenario.

Annexure A

Impact of the War:

1. In your experience, how has the Russia-Ukraine conflict affected the industry's supply chain?
2. Can you describe specific challenges you have faced due to the war, such as sourcing raw materials, transportation, or logistics?
3. Have you witnessed any ripple effects of the war impacting other industries or sectors?
4. *Existing Technology and Industry 4.0:*
5. Prior to the war, what technologies, or Industry 4.0 (I4.0) applications were already in use and were the industry standard in your supply chain?
6. What is the percentage of industry that use I4.0, (if the % is less, why is the industry not adopting these latest technologies)
7. Are there any specific examples where technology helped your organization predict the losses that may occur due to the war or any disruption?
8. *Potential Technological Solutions:*
9. In your opinion, what new technologies or Industry 5.0 applications hold promise for preparing the industry to sustain supply chain disruptions during crises
10. What are some potential challenges in implementing and adopting new technologies in your field?
11. *Measuring Efficiency and Comparison:*
12. How do you currently measure the productivity of your supply chain?
13. If the companies are adapting and adopting I5.0 in the current landscape, how will they measure the results?

Annexure B

Q. How many years of experience do you have in the above-mentioned industry.

- 0-3
- 4-7
- 7-10
- 10+

Q. Overall Experience in the Supply Chain Management

- 0-5
- 6-10
- 10-15
- 15+

Q. Are you aware about these advanced technologies.

- Internet of Things (IoT)
- AI and machine learning
- Big Data Analytics
- Cloud Computing
- Additive Manufacturing (3D Printing)
- Robotics and Automation
- Augmented Reality (AR) and Virtual Reality (VR)
- Cyber-Physical Systems (CPS)
- Autonomous Vehicles and Drones
- Blockchain Technology

Q. What advanced technologies are currently integral to your supply chain operations?

- Internet of Things (IoT)
- AI and machine learning
- Big Data Analytics
- Cloud Computing
- Additive Manufacturing (3D Printing)
- Robotics and Automation
- Augmented Reality (AR) and Virtual Reality (VR)
- Cyber-Physical Systems (CPS)
- Autonomous Vehicles and Drones
- Blockchain Technology

Q. Where these used in your industry before the major disruptions that were have been caused by Russia-Ukraine war.

- Yes
- No

Q. Did such shocks like Russia-Ukraine war demand the switch to these advanced technologies.

- Yes
- No
- Not really, but there was an increase in the use.

Q. How do you prioritize implementing new technologies within your supply chain?

- Based on immediate operational needs and pain points.
- According to potential ROI (Return on Investment) and cost-effectiveness.
- Aligned with long-term strategic goals and objectives.
- In response to competitive pressures or market demands.
- Considering scalability and adaptability to future changes.
- By evaluating compatibility with existing systems and infrastructure.
- Taking into account regulatory compliance requirements.
- Balancing risk and innovation.
- Other:

Q. Are there any specific pain points or inefficiencies in your current supply chain that you believe could be addressed with technology?

- Yes
- No

Q. If yes, then what?

- Inventory management and tracking
- Forecasting and demand planning
- Transportation and logistics optimization
- Warehouse management and automation
- Supplier management and collaboration
- Other:

Q. Which emerging technologies do you believe have the most potential to revolutionize supply chain management in the near future?

- AI and machine learning

- Big Data Analytics
- Robotics and Automation
- Cyber-Physical Systems (CPS)
- Blockchain Technology
- Advanced Human-Machine Interface (HMI)
- Predictive Maintenance
- Other:

Q. How do you assess the ROI (Return on Investment) of implementing new technologies in your supply chain?

- Quantitative metrics such as cost savings, increased revenue, or improved productivity.
- Qualitative factors such as enhanced customer satisfaction, better decision-making, etc.
- Tracking specific key performance indicators related to the technology implementation.
- Conducting pilot projects or trials to measure the impact before full-scale implementation.
- Utilizing predictive modelling or simulations to forecast potential ROI.
- Assessing the impact on overall supply chain efficiency and responsiveness.
- Considering long-term strategic benefits beyond immediate financial gains.
- Other:

Q. What barriers or challenges do you face when adopting new technologies in your supply chain?

- Cost of implementation and ongoing maintenance
- Lack of budget or funding
- Integration with existing systems and processes
- Resistance from employees or stakeholders
- Limited expertise or skills in implementing and managing new technologies.
- Other:

Q. Do you currently utilize any automation or robotics technologies in your supply chain processes? If so, how have they impacted efficiency and productivity?

- Do not use.
- Significant improvement in efficiency and productivity.
- Moderate improvement in efficiency and productivity.
- Minimal improvement in efficiency and productivity.
- No noticeable impact on efficiency and productivity.

Q. How important is real-time data analytics and visibility tools in managing your supply chain operations?

- Extremely
- Moderately
- Minimally
- Not Important

Q. Based on current usage, what role do you see artificial intelligence and machine learning playing in the future of supply chain management?

- Extremely significant - Transformational impact on efficiency or productivity.
- Very significant - Significant impact on efficiency or productivity.
- Moderately significant - Moderate impact on efficiency or productivity.
- Somewhat significant - Minor impact on efficiency or productivity.
- Not at all significant - No impact on efficiency or productivity.

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