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Physical Internet: A solution for the Supply Chain disruptions during the COVID-19 pandemic

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Abstract: In this paper, we will specify our research on the impact of the COVID-19 on Supply Chain Management and show up the critical issues and how the digital solution like the Physical Internet (PI, π) could solve the disruptions of production or delivery of a Supply Chain. The Physical Internet is still an emerging phenomenon in which it is intended to replace the current logistics model by encompassing new technologies such as Artificial Intelligence, Big Data, the Internet of Things (IoT), and others. This article aims to compose conceptual research to describe Supply Chain Management problems during the COVID-19 pandemic and represent the Physical Internet as a solution for this disruption based on various journal articles, papers, websites, and managers' experiences. Further, this study helps increase the understanding of scholars and practitioners on how the novel PI paradigm can solve COVID-19-induced Supply Chain disruptions. Furthermore, the Physical Internet and other modern technologies in the business world are necessary and recommended, as these current issues now require quick decisions and up-to-date knowledge.

Keywords: Supply Chain Management; Physical Internet; COVID-19; Supply Chain disruption; pandemic

1. Introduction

Since 2000, numerous studies and analyses have been conducted on Supply Chain disruptions and have shown great potential. However, researchers and experts like in [1], [2], and [3] have concentrated on disturbances of the Supply Chain, usually defined as disruptive events that interrupt the structure of the Supply Chain.

According to [4], the Supply Chain could be affected by various factors such as natural disasters, civil disputes, financial crises, crime, or breakdown in transport infrastructure. Moreover, the Supply Chain was interrupted by COVID-19 [5]. COVID–19 was declared a global pandemic by the World Health Organisation [6] in March 2020 and described it in terms of infectious coronavirus diseases. According to the most recent OECD Economic Outlook, the COVID-19 pandemic has led to significant health, employment, and welfare harm [7]. Practically every country in the world was contaminated with COVID-19. This generation has encountered nothing that can be compared to this epidemic.

During their stages, the Supply Chain has faced significant disruption due to this pandemic and the resulting global crisis for health, especially in the range of connectivity, knowledge, and data sharing between its participants [8]. Upstream, though hedging and panic buying triggered equivalent downstream volatility, supply and demand equilibrium was further impacted and disrupted in many countries around the world by the travel restrictions and closures. The latest short-term pandemic predictions and also their effect on the Supply Chain have proved to be critical for management and strategy due to these disruptions. It is crucial to focus on tactical and strategic planning to increase customer satisfaction and avoid trouble in the Supply Chain. Precise predictions of emerging conditions help handle excess demand across the Supply Chain more effectively. A common understanding and current reality suggest that the acceleration and growth of COVID-19 in countries are inducing reforms in the immediate real needs and behavior of clients (healthcare [9] and food [10]). These types of changes put enormous pressure on the Supply Chains. For example, the entire Supply Chain, including eggs, flour, and grains, is affected when customers start to worry about purchasing dry noodles. However, a pandemic has some unique effects on Supply Chains. Compared to natural events, the pandemic is not confined or limited to a single area. Sequentially or simultaneously, the various Supply Chain elements are affected: production, supply centers, consumers, and logistics may be interrupted by time overlap windows. A new notion of the Physical Internet was suggested by Benoit Montreuil in 2006 [11] as an instrument to improve the world's importance regarding sustainable logistics. It is designed to interconnect worldwide logistics networks through temporary and intermediate storage shipping and delivery, as the Digital Internet has done with computer networks that allow data transmission in packets in standardized formats through heterogeneous equipment. In the discipline of logistics, these systems already exist because every company possesses its network, but they are far from getting interconnected; the idea of the Physical Internet is to make these systems compatible and much more open. The following three questions guide the research objectives of this study:

What are the SCM problems during this pandemic?

What are the advantages of using the Physical Internet in the COVID-19 Supply Chain?

What is the capability of the Physical Internet that could solve these issues in SCM during COVID-19?

1. Methodology

Our conceptual research is based on various journal articles, papers, websites, and managers' experiences. Currently, the topic is still in its infancy, ruling out the opportunity for a systematic review of the literature. The study's main objective is to highlight the Physical Internet's critical role in solving disruptions in the Supply Chain. First, we will present the different impacts of COVID-19, such as socioeconomic, macroeconomic, demand, and supply impacts. In the other part, we will explain the SCM challenges in resolving these disruptions by referring to transparency, estimation of stocks, improvement of customer and employee relations, estimation of risks, and cash management and networking, and how these methods are not enough. In the next section of this study, we will interpret the Physical Internet's ability to resolve SCM disruptions using an intelligent container that offers online access and identifications and environmentally friendly, that complies with international standards. It can be used in various transport modes—finishing our article with a summarized conclusion.

2. Impact of COVID-19 on SCM

"The effect of the COVID-19 initially identified in Wuhan, Hubei Province, China, in late 2019" [12] is illustrated in this section. But the effects of this virus on SCM have already been brought to the attention of academics (Choi 2020 [13]; Govindan et al. 2020 [8]; Lin et al. 2020 [14]; Sarkis et al. 2020 [15]), as well as industrial specialists (Business Insider 2020 [16]; Deloitte 2020 [17]; Fortune 2020 [18]).

2.1. Socioeconomic impacts

"The COVID-19 pandemic is far more than a health crisis: it is affecting societies and economies at their core" [19]. COVID-19 has a widespread human impact with unknown duration and unknown effects. There is a long-term public fear, and risks are invisible. Furthermore, there is a significant drop in international trade. Coronavirus causes a $47B drop in world exports [20]. Moreover, the overall scope impacts both goods and services. On the one hand, the movement of commodities is likely to be significantly interrupted. That could be because there was an insufficient workforce to transport the goods physically. The government acts such as port limits

on the handling of goods could theoretically impact them. On the other hand, for companies delivering services, workers' inability to reach and leave the regions concerned may be an essential obstacle to the supply of resources [21]. Nonetheless, workforce capacity has been reduced globally. Also, travel was restricted due to long breaks and extended quarantine times or work permit difficulties. "Without urgent socio-eco-nomic responses, global suffering will escalate, jeopardizing lives and livelihoods for years to come. Immediate development responses in this crisis must be undertaken with an eye to the future. Development trajectories in the long-term will be affected by the choices countries make now and the support they receive." [19].

2.2. Macroeconomic impacts

Due to COVID-19, according to Stephan [22], a recession likelihood in global GDP growth or has likely already begun. However, there is a wide range of economic impact timelines and various estimates about the recovery from V to U to other potential shapes over different time horizons. Therefore, there are very uncertain expectations. That means a heavy attachment to the global financial system and a heavy reliance on cooperative government interventions to sustain economies. The macroeconomic influence on world food production and food safety has already been significantly impacted by the COVID 19 Pandemic [23]. That should be considered by politicians when adopting steps to counter the full effects of the latest pandemic. According to Arslan, Drehmann, & Hofmann [24], the dissemination mechanisms of the COVID-19 shock into the economy, the interplay of policy decisions, epidemics, and political consensus need to be better understood.

2.3. Demand and Supply impacts

COVID-19 has a potential impact on consumer demand. We realize that specific product categories for personal protection, hygiene, medical supplies, and even some necessary foods are out of stock in some countries during this pandemic. This phenomenon is known as stockpiling. However, Tinglong Dai, from the Johns Hopkins University Carey business strategy and operations management and business analytics specialist, describes stockpiling in 2020 as "a spike in demand in the short term, and an immediate effect is you start seeing many empty shelves"[25]. Additionally, online shopping has increased due to social distancing, self-quarantining, and consumer avoidance of physical stores and crowded meeting places.

One of the most significant impacts of COVID-19 is many manufacturers' production delays or stoppages due to labor shortages because of quarantine and some cities' lockdown. That's why we have lacked many products. According to

[26], responding to the COVID-19 pandemic, the European Commission prioritizes citizens' welfare. That implies that necessary items such as emergency equipment and other essential goods are carried out. From a logistical point of view, the labor shortage caused congestion at airports and seaports. However, alerts about limited export loads and additional delays in port operations due to the lack of shipping operators and staff in the port have been released from the Clecat European Freight Forwarding Association and the Polish Chamber of Forwarding and Logistics [27]. As a result of the coronavirus, the eastern countries understand that the European economic situation is growing and improving.

COVID-19 is the crucial reason behind the Demand and Supply shock [28]. But other reasons make the situation even worst, such as the lack of horizontal collaboration, the inadequate response to technology trends, and inaccurate planning and forecasting [29]. Organizations should be ready for natural or environmental occurrences.

3. SCM challenge during COVID-19

This section describes SCM's various challenges during COVID-19, such as transparency, inventory estimation, relationships with customers and employees, risk estimation, cash managing, and networking.

3.1. Transparency

Keeping the Supply Chain sustainable needs transparency, which "involves communicating with key stakeholders about the firms' current activities and incorporates stakeholder feedback for Supply Chain improvement" [30]. We could create transparency in Supply Chains at multiple levels by listing critical components, determining the supply's origin, and identifying alternative sources [31]. Knowing the lineage of suppliers is very important in our current situation as it can detect whether or not the suppliers are in severely affected regions. And to go through transparency, Nancy Jalbert, management consulting at CPA [32], notes that it is essential to develop good relationships with vendors by cash flow management so that orders can be paid for on arrival. Second, decide who the leading suppliers are and how they are affected by the situation. Third, identify and notify replacement suppliers as soon as possible, if necessary. Finally, agree with the payment terms of the manufacturers.

3.2. Inventory Estimation

The COVID-19 pandemic has taught different lessons for all facets of the Supply Chain. However, during the COVID-19 pandemic, organizations that don't have

good inventory management processes and don't have access to accurate numbers will likely struggle to meet demand in specific categories or have oversupply articles that are suddenly less of interest to customers. That's why the accuracy and reliability of an organization's inventory levels have become extremely important. Moreover, companies must assess the stock available along the Supply Chain to provide replacement parts and components to be used as a bridge for continuing production and consumer distribution. Furthermore, to better track inventory levels, Nancy Jalbert [32] offers some great solutions to follow, for example, calculating sales variation to allow for efficient estimating of demand; identifying critical inventory levels and constructing inventories where necessary; designing quarantine areas for specific products and utilizing detailed list and refill roles of management systems.

3.3. Strengthen relationships with customers and employees

The pandemic of COVID-19 pressured corporations to preserve and establish connections with customers as their environment was changed. This global crisis is really about customer moments that matter. By putting your customers' interests first, maybe now is the time for your company's brand to take leadership. [17] suggests some ideas to help companies manage their customers in the current situation. Besides, businesses need to be brand loyal, as customers will see how their enterprises fare in such difficult times. Suppliers should strengthen their relationship with customers through communication, especially in a difficult situation. Customers will appreciate the supplier's assistance and gain an audience from a simple gesture. Not only with customers but also with employees, especially those in direct communication with your clients, has a significant effect on your business. Therefore, they are representative of your products, and they should be helpful and take care of hygiene responsibility to reduce the transmission of the virus. Moreover, to ensure employees' safety, it is essential to optimize the production and distribution capacity by working from home. It's also necessary to provide protective equipment to the workers and educate them on the virus's risks. These measures would help managers take into account the existing and expected capacity levels of personnel and machines.

3.4. Risk estimation

The estimation of the risk is a step to avoid them. According to The Global Fund [33], there are many risks to be taken into account, specifically related to logistics like capacity estimation, a summary of high-risk items or product types, and a description of existing buffer inventory and locations. Also, conduct scenario preparation to consider the consequences of Supply Chain disruption. Therefore, collect the appropriate demand for some months to create the necessary supply. At the same time, we must avoid these risks by exploring options to develop alternative

products, suppliers, and additional sourcing options. Moreover, change the mode of transport and take advantage of other existing logistics capabilities to reduce replenishment times. Finally, strengthen the market management mechanism to correct the excessive demand to minimize the bullfighting impact.

3.5. Manage cash and networking

COVID-19 has a crucial impact on the management of cash and network capital. However, according to [31], companies can perform stress testing to consider the economic effect of Supply Chain problems by planning for processes such as challenging key assumptions, identifying rapid mitigation actions, and developing an action plan for building simulation with different scenarios to understand short-term needs. With the recession unfolding, small production channels, sluggish deliveries, and shrunk profits contribute to the strain of earnings and liquidity even further. Companies are used to planning ambitious projects, and a great deal of realism is now required to unlock resources. Businesses would have to test their capital requirements weekly and monthly with the complete internal forecasting capability available.

4. The need for Physical Internet

The World Economic Forum WEF [34] highlighted the need to reengineer and adapt SCs to its potential trade problems. Therefore, we suggest Physical Internet as a workable solution to the logistical disruption of the COVID-19 pandemic. PI is an innovative concept of logistics network interconnection, which can be considered an extension of horizontal collaboration. The Physical Internet depends on the global interconnection of logistics. This concept aims to create an open and interconnected global logistics system that is economically, environmentally, and socially efficient and sustainable.

At this stage, we present a systematic literature review. First of all, we frame research questions that are mentioned in the introduction. In the second step, we identify the most relevant literature, such as journal articles, papers, websites, that mention the words "Physical Internet" and "COVID-19" in their titles or keywords. After that, we analysed this literature and arranged our summarised knowledge on this topic. In the last step, we provide valuable recommendations for organizations about the various benefits and solutions of the Physical Internet to face Supply Chain challenges during COVID-19.

4.1. Physical Internet: Definition and concept

Benoit Montreuil was the first researcher who introduced Physical Internet terms on 15th June 2006 and was inspired by an Economist magazine article title [35]. According to Benoit Montreuil, Physical Internet is "the way in which physical objects are handled, moved, stored, produced, delivered, and used, with a focus on global logistical efficiency and sustainability" [36]. Notice that physical goods' movement close to the data flow can be structured in the Digital Internet. Between the Physical Internet and the Digital Internet, there is an analogical similarity [36]. However, on Digital Internet, there is a flow of information from a host computer to another host computer. And the Physical Internet is a vision related to managing the physical flow in the logistic process from an origin point to the desired destination via a set of systems and procedures. This metaphor has generated interest within the university and has attracted substantial business coverage.

The novel term Physical Internet is grabbing the attention of a lot of practitioners and academics. Montreuil defines PI as "a global logistical system based on the interconnection of logistical networks through a standardized set of collaboration protocols, modular containers, and smart interfaces for increased efficiency and sustainability." [37]. However, the Physical Internet concept presented as a solution and response to the Global Logistics Sustainability Grand Challenge [36] founded on physical, digital, and operational interconnectivity, consisting of PI-hubs run by encapsulation, interfaces, and protocols through various services.

The PI is based on standard containers easily transported by different PI hubs through various transport means (planes, trucks, and cars) by several operators. Hence, this logistical structure can be shared with all customers, including manufacturers, suppliers, and consignees, including complete horizontal and vertical logistical cooperation through uniform interconnections, standard encapsulation, standard intelligent interfaces, and standard coordination protocols to optimize the loading and unloading. Open hubs and open logistics material are part of the network, enabling a global Logistics Web. The Physical Internet aims to maximize the transport of goods in terms of costs and speed, creating an efficient and sustainable logistics network similar to the way data packages flow in the Digital Internet in a reliable and resilient manner.

4.2. Physical Internet as a solution during COVID-19

The Physical Internet uses and extends to logistics the ideas of the digital Internet. PI is a network of more flexible, agile, and resilient logistics networks globally, open and interconnected. PI uses many collaborative protocols and standard innovative interfaces to transmit and receive physical products [36]. These goods are stored in standardized modules to increase global logistics efficiency and sustainability [38].

The purpose of the Physical Internet is to make intelligent containers accessible online and exploit them. The omnipresent use of PI containers allows any logistics services provider to manage and store the goods of any organization while it does not process and store its items. PI aims to maximize the capability of intelligent PI-containers connecting to the Internet of Things and their integrated smart objects to enhance customer efficiency and the overall performance of logistics networks (Fig. 1.) [39].

The Physical Internet may solve several Supply Chain Management issues stemming from the COVID-19 pandemic. During this time, the planet experienced significant disruptions in transportation and distribution. The PI-nodes allow us to ensure that the intelligent containers are loaded, unloaded, composed, decomposed, sent, moved, and traced quickly. Note that PI-nodes should generally be linked to the logistics activities to encourage cooperation and knowledge sharing among various players and companies. The run-on Blockchain technology can anonymously and transparently transfer data between operators. The proper order of these transfers may be confirmed by the possession of the moved items in the whole shipping process [40]. The higher point density in a PI system enables multiple tours at the same service level to be shortened and means of transportation to be improved [41]. Moreover, the π-nodes provide higher-scale economies. However, the bigger the distribution network's size, the more participating parties are involved [42].

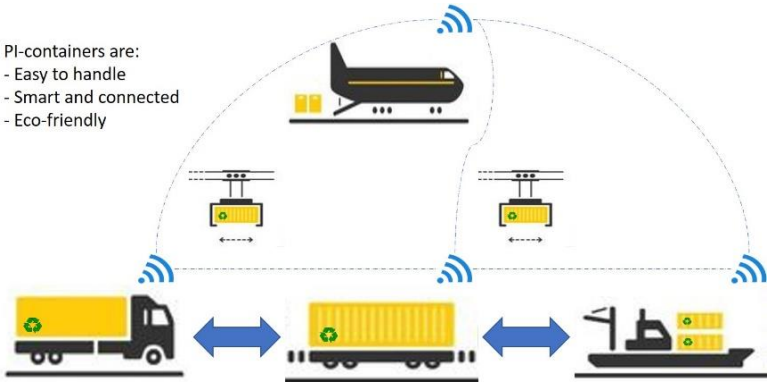

Figure 1. An integrated transport system through Physical Internet containers

As a result, the transport network can be faster and cheaper by consolidating shipments due to the cross-docking of π-hubs (Fig. 2.). Hence, the loan consolidation of goods from different parties is faster, easier, and more efficient [43]. The processes between procurement and shipment can be long and complex, but transportation is where a business comes into direct contact with its customers across

all other operations. The distribution point represents the image of the entire organization. If a business delivers its goods late, the client takes a very unfavourable opinion of this company and therefore may not re-use the services.

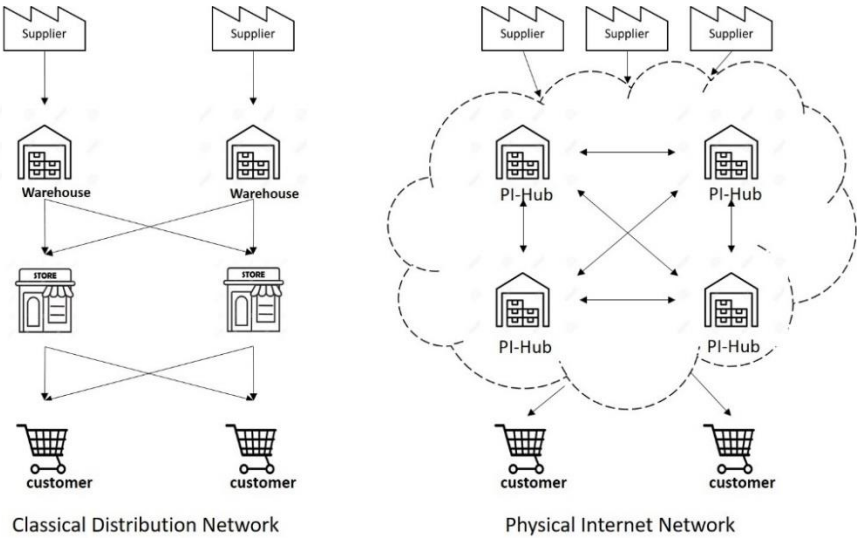

Figure 2. Difference between Classical Distribution Network and Physical Internet Network

The COVID-19 pandemic has also created significant stock problems worldwide, which led us to minimize an average overall expense, decrease an average stock, and decrease remaining service levels using a PI-inventory management model [44]. Moreover, it offers more options for repositioning and replenishment between hubs and also more opportunities for multi-sourcing. Furthermore, it provides different ways to adjust inventory positions rapidly (e.g., in case of demand variations) [45]. Effective transport maintains a seamless operation of the Supply Chain. Stock can be held lean by efficient operation of the vehicle and can be carried rapidly in and out of a store. This increases warehouse turnover, decreases lead time, and saves storage capital.

The inventory has a direct impact on the manufacturing system. However, in the PI manufacturing system, all resources are interconnected, providing better control, focus on processes, "quick response, balanced production, highly effective throughput, low consumption, and scientific decision-making in a manufacturing system" [46]. After all, "inventory models using PI respond to SC facility disruptions and their resilience." [47]

We can't discuss the transportation and inventory process without referring to π-containers in which they have a potential effect on the transport and the storage of goods. Hence, similar to the Digital Internet packets, there are containers created for the Physical Internet called π-containers. They have physical content and structure rather than being purely informational. From a functional perspective, the main objective of π-containers is to facilitate their handling, storage, transport, sealing, locking, loading, unloading, construction, and dissociation. These PI-containers are standardized containers with the global norm. The sizes, duties, and fittings are particularly modularized and standardized worldwide [48]. Besides, unit loads are constructed from modular containers loaded into trucks to optimize size and weight [49]. From a marketing perspective, π-containers should be easy to panel with publicity, and precise product information supports for business marketing. The enterprise can advertise in big and flashing image sizes without confronting any constraints by using PI-container as a billboard. Businesses can reach a large audience with an economical marketing step that can generate a permanent impact and achieve great results.

From an environmental perspective, π-containers must have a limited footprint when away from service, dismantle, and assemble on demand. They should be as environmentally friendly as possible, in range with toughness principles [50]. The efficient utilization of PI-containers will reduce space and transport many goods with lower fuel consumption. Also, PI-containers have a longer life cycle than pallets and cartoons and can be reused and recycled.

From an informational perspective, each container is attached with a smart tag to act as the agent that it represents. It supports the coverage, protection, routing, tracking, traceability, and security of containers across the Physical Internet [39]. PI provides real-time visibility using radio frequency identification and leads to better decision making, increased quality, and efficiency through advanced information sharing and models. Also, PI offers closed-loop visibility, methods, development, and expense tracking capability. [51]. Visibility in the PI gives the possibility to access some reliable information about the movement of PI-containers in the logistics network in real-time, leading to better analysis and improvement of Supply Chain processes.

For collecting this big data, we run to Cloud computing usage and sharing. Nonetheless, in this decade, the cloud has driven innovation for many organizations and companies. New, fast, private, safe, and efficient, all of these characteristics distinguish the cloud from traditional data treatment methods. The PI is a supporter of cloud development and storage to ensure the growth and sharing or support from virtually present specialists [52]. Besides, the cloud can provide the ability to pool resource use, save time and costs, reduce risks, and enhance interaction promptly,

and contribute to economic and environmental sustainability and socially by offering the passive capacity to other participants in an open logistics network. Among the many incentives for using the cloud, the cost of shipping and distribution through warehouse PI hubs closer to end-users is reduced [53].

Additionally, by applying the Physical Internet worldwide, we will have intelligent city logistics that offer operators a variety of easily understandable information, facilitating the execution of the urban freight transport plans. However, logistics and transit services can be used (public and private) for developed metropolitan areas. And these cities become smart logistics cities by reducing transports fuel consumption and CO2 emissions in cities and reducing traffic jams [54].

To sum up, "Physical Internet is a solution for the logistics disruptions during the COVID-19 pandemic" [55] (Table 1 and 2). However, "Physical Internet is the logistics of the future" [56].

Table 1. The SCM challenges and the main technological opportunities of PI Part 1.

Supply Chain challenges during COVID-19	How can the Physical Internet overcome these challenges?	Benefits	Technologies
Transparency	The integration systems and collaborative mechanisms of the PI will lead to improving transparency along with the Supply Chain network [57].	Competitive advantage Data transparency and safety Predictability Agility Flexibility	Blockchain [40] Cloud computing [53]
Inventory estimation	The real-time traceability of PI-containers will improve the efficiency of the inventory estimation [58]	Real-time identification Better service to consumers Protection from demand fluctuations Shorter lead times	Blockchain [40] RFID [58] Bare code [58] Cloud computing [53]

Table 2. The SCM challenges and the main technological opportunities of PI Part 2.

Supply Chain challenges during COVID-19	How can the Physical Internet overcome these challenges?	Benefits	Technologies
Strengthen relationships between consumers and employees	The availability of the goods in the markets under challenging events will increase trust between customers and organizations [59], and technology will also facilitate consumers' purchases in a secure manner [60]. The use of technology will facilitate the work from home, and employees will feel safer and more comfortable [61]	Trust Loyalty Safety Low the risk of getting infected	Internet of Things [60] Artificial Intelligence & machine learning [61]
Risk estimation	The adoption of the Internet of Things will guide the managers to select the appropriate risk estimation technique [62]	Reduce future uncertainties Training and enhancement Improve decision making Proper results forecast	Internet of Things [62]
Manage cash and networking	For effective cash flow control, it's essential to use the new generation of technologies to solve recent problems [63]	Develop better cash-flow forecasts Reduce the risk of loss Faster access to cash and data Increase operational efficiency Cost savings	ERP software Blockchain Artificial Intelligence [63]

5. Conclusion

After the COVID-19 crisis started, shipping and logistics companies were led by sustaining shelves and vital supply lines. However, the year began with global demand expansion already behind existing trends, and now the sector faces

worldwide disruption. No corporation was resistant to the recession, with a significant impact on the transportation and logistics sector. The Supply Chain is disrupted, and executives should make rapid and operational decisions to secure and help their workforce and guarantee vital company processes to fulfill society's current and long-term needs.

The Supply Chain network can benefit enormously from digital technologies in terms of transparency, visibility, cost savings, reliability, and resiliency. The stakeholders of the PI network, such as suppliers, consumers, and logistics service providers, must implement and improve emerging technology to enable the whole network to be agile with continuous delivery, which has a significant effect on reducing inventory risk mitigation. We can ensure a digital future through the Physical Internet to serve individuals and organizations' logistics needs. However, providing an online and maintained connection enables the physical movements of goods to be transported to other locations. Therefore, it avoids shortages and conflicts of the whole content system thanks to an increased and timely flow of information—moreover, shorter lead times due to PI interconnections and increases digitalization's effect on inventory management. Mainly, data coordination and PI visibility qualities are enabled by Blockchain, IoT, RFID in the simulation, and activation of the reorganization plan.

Consequently, businesses become data-driven organizations aiming to maximize data importance and uses it as an essential strategic instrument for forecasting and reacting to future events. Not only to anticipate future events but also to create a new organizational model, processes, and update technical capabilities to enhance flexibility, achieve speed, adaptiveness, and stability.

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