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# A Framework Based on Blockchain, Artificial Intelligence, and Big Data Analytics to Leverage Supply Chain Resilience considering the COVID-19

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**Abstract**: In the global supply chains era, firms are more connected, integrated, and interdependent, bringing along a set of benefits and a number of risks. It is clear that the singular COVID-19 epidemic outbreak has led to unparalleled disruptions and considerable challenges for supply chains (SCs). For example, the sluggish economic environment provoked by the COVID-19 has negatively impacted the flow of goods, generating shortages and interruptions through the SCs. At the global level, many markets are enduring the effects of these disruptions. In this challenging context, the firms and their SCs must apply useful and efficient strategies to minimize and adapt their operations during and after these disruptions. In this view, this study aims to propose a novel framework based on Artificial Intelligence, Blockchain, and Big Data Analytics, to bring useful ideas and contribute to overcoming such disruptions. Besides, we propose novel categorizations that can support new insights for scholars and practitioners about the use of cutting-edge technologies during and after severe disruptions.



*Keywords*: Blockchain; Artificial Intelligence; Data Analytics; Supply Chain; Epidemic; Outbreaks; Resilience; COVID-19

## 1. INTRODUCTION

The unprecedented and singularity of the Novel Coronavirus (2019-nCoV), simply known as the COVID-19 epidemic outbreak, has challenged the global supply chains (SCs), bringing unparalleled disruptions (Ivanov, 2020; Ivanov and Dolgui, 2020; Queiroz *et al.*, 2020) and thus rendering the decisions and operations of managers more complex, with a significant impact on the entire relationships within SCs.

The ongoing COVID-19 epidemic outbreak has led to devastating disruptions in the SCs (Haren and Simchi-Levi, 2020), thereby seriously affecting the flow of products and resources and creating a shortage in various SC nodes. Furthermore, virtually all SCs worldwide are expected to suffer severe damage during and after the COVID-19 crisis (Fortune, 2020).

In this unheard-of scenario, SC members need to fully grasp the main complexities at stake and generate insights to manage and outperform this crisis. And apart from increasing the SC resilience (Chen, Das and Ivanov, 2019), it is fundamental to develop new skills and capabilities to better prepare for new crises. In this context, this study looks forward to bridging this gap by proposing a novel framework based on Artificial Intelligence (AI) (Fosso Wamba *et al.*, 2021), Blockchain Technology (BCT) (Wamba and Queiroz, 2022), and Big Data Analytics (BDA) (Ivanov *et al.*, 2021) cutting-edge technologies to support and bring insights to SCs.

We identify three main disruptions categories that occur in practical all SCs. To outperform these complexities, we propose a framework considering the following stages continuous monitoring, preparedness, response, and recovery. For each step, we provide insights into the technologies mentioned.

## 2. THEORETICAL BACKGROUND

### *2.1 Organizational Resilience Theory*

Organizational resilience has been used extensively in different contexts over the years (Horne, 1997; McManus *et al.*, 2008; Duchek, 2019). The concept "organizational resilience" is defined in different ways, including as "a firm's ability to effectively absorb, develop situation-specific responses to, and ultimately engage in transformative activities to capitalize on disruptive surprises that potentially threaten organization survival" (Lengnick-Hall, Beck and Lengnick-Hall, 2011, p. 244). Another widespread definition of organizational resilience takes it as "the incremental capacity of an organization to anticipate and adjust to the environment" (Ortiz-de-Mandojana and Bansal, 2016, p. 1617). These definitions clearly indicate that organizational resilience considers different stages of disruption and the related recovery plan (Duchek, 2019).

In the SCs landscape, resilience represents a hot topic (Ivanov, 2018, 2019a; Queiroz et al., 2022), primarily because of the variety of the disruptions that emerged and were amplified from the 2000s (Christopher and Peck, 2004; Craighead *et al.*, 2007; Ponomarov and Holcomb, 2009; Queiroz *et al.*, 2020). The definition of supply chain resilience (SCR) is quite similar to that of organizational resilience. In this regard, the resilience


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of the SC refers "[…] not just the ability to recover from mishaps, but is a proactive, structured and integrated exploration of capabilities within the supply chain to cope with unforeseen events" (Priya Datta, Christopher and Allen, 2007, p. 187). In this context, we developed a framework based on the link to resilience and organizational capabilities by exploring the SC's stages of anticipation, coping and adaptation (Duchek, 2019).

### *2.2 The Role of Cutting-Edge Technologies: Blockchain, AI and BDA*

Cutting-edge technologies like BCT (Wamba & Queiroz, 2020), AI, and BDA have captured scholars, managers, and practitioners' attention in different industries worldwide. BCTs are defined as a tamper-proof distributed ledger of a book in which, after the network validates the transactions, no modifications can be performed (Queiroz, Telles and Bonilla, 2019). Although BCT is still in its infancy (Fosso Wamba *et al.*, 2020), it has been recently used in many supply chain applications (Wamba and Queiroz, 2020). BCT can rely on its ability to foster trust within networks to efficiently curb traceability issues in supply chains while guaranteeing the right provenance of products. For example, vaccine traceability and provenance (Yong *et al.*, 2020). But the BCT holds more impressive benefits such as increased visibility for SC members, real-time information sharing, the minimization of reconciliation and transaction costs, and greater accountability. Moreover, with smart contracts, the relationship between SC members is improved significantly.

In relation to AI, it is defined as "the ability of machines to mimic intelligent human behavior and specifically refers to' cognitive' functions that we associate with the human mind, including problem-solving and learning" (Syam and Sharma, 2018, p. 136). AI has been leveraging the efficiency of organizations and SCs at different complexities levels. For example, AI has played a critical role in vehicle routing, logistics follow-up, distribution with autonomous vehicles, etc. Considering the resilience context, AI can be particularly instrumental in supporting all stages of SC decision-making processes. Furthermore, the utilization of AI techniques between SC members can transform inter-organizational partnerships, collaboration, and innovation.

Regarding the BDA, it is defined as "[…] datasets whose size is beyond the ability of typical database software tools to capture, store, manage, and analyze" (Manyika *et al.*, 2011). Therefore, BDA appears as a fundamental approach to exploring different types of data in a prescriptive, descriptive and predictive form (Phillips-Wren and Hoskisson, 2015), supported by the 5Vs view (volume, velocity, variety, veracity, and value). The BDA approach has proved to be a powerful technique in SCs context, empowering agility, adaptability, and performance (Wamba *et al.*, 2020). BDA also represents an important tool to support disaster management and humanitarian operations through patterns analysis to predict disasters at the response stage and mobilize resources (Akter and Fosso Wamba, 2019; Fosso Wamba, 2020).

In this context, it should be noted that modern supply chains are more reactive than proactive (i.e., changes in customer demand are difficult to predict, and SCs struggle to adapt). In that case, by employing AI and BDA, the patterns trends in the SCs could be visualized; as also with AI, it is possible to run several realistic scenarios of the SCs quickly. Besides, modern supply chains suffer from a lack of visibility and consequently cause complex problems for inventory managers (i.e., where goods are in transit); this issue can be easily improved by using BCT. Furthermore, modern supply chains present considerable accountability lack (i.e., many companies have teams of staff dedicated to mitigating this risk of a failure to deliver). In that case, transactions performed by BCT are immutable, and the network's members can audit the origin node rapidly; consequently, more transparency is brought to the buyer-supplier relationships.

### *2.3 Epidemic outbreaks on supply chains*

The impacts of epidemic outbreaks on logistics and operations and SCs have been frequently discussed in the recent literature (Queiroz *et al.*, 2020; Dasaklis, Rachaniotis and Pappis, 2017). The potentially harmful effects have also been studied, as organizations and their supply chains worldwide have been suffering from these. The literature has highlighted the negative repercussions of different epidemic outbreaks on supply chains. Some of the epidemics that are being studied from this perspective are influenza (Liu and Zhang, 2016), ebola (Büyüktahtakın, des-Bordes and Kıbış, 2018), cholera (Anparasan and Lejeune, 2017), smallpox (Dasaklis, Rachaniotis and Pappis, 2017), among others. Yet, the impact of the COVID-19 pandemic (Lin *et al.*, 2020) is particular, far-reaching on all aspects of human life and supply chains around the world (Ivanov and Dolgui, 2020; Queiroz *et al.*, 2022).

Though many of such effects are relatively new to the SCs, scholars have managed to shed light on and better understand the resilience issue concerning SCs (Ivanov, 2020; Ivanov and Dolgui, 2020; Queiroz, Fosso Wamba and Branski, 2021) in the COVID-19 context. In this regard, some authors have suggested insightful ideas for predicting and getting prepared for the impacts of epidemic outbreaks on global supply chains (Ivanov, 2020; Ivanov and Dolgui, 2020; Sarkis *et al.*, 2020). For example, simulation techniques can help decision-makers to gain valuable insights and develop strategies at all stages of the disruption process (Ivanov, 2020). Consequently, global supply chains' resilience could be more responsive. In addition, the COVID-19 forced the SC managers to have an in-depth understanding of the concept of survivability in more sophisticated supply chains/supply chain networks, including intertwined supply networks (Ivanov and Dolgui, 2020).

## 3. METHODOLOGY DESIGN

We adopted a multi-method approach, considering three main stages. First, we used an adaptation of the Literature-related discovery (LRD) method (Kostoff *et al.*, 2008; Kostoff, 2011; Kostoff and Patel, 2015) to discover potential knowledge (Kostoff *et al.*, 2008), followed by an analysis of papers' references. In the LRD, following Kostoff et al. (2008), we applied the four steps to performing the literature analysis stage – i. recover core literature on the problem; ii. characterization of the core literature; iii. extension of the core literature; and iv. generation of the potential discoveries.

Second, we performed a careful secondary data analysis in different databases (e.g., WEF, WB, Consultancy Reports, FT, among others). We identified public reports on these databases employing a set of keywords related to disruptions, emergency situations and technologies. Finally, we integrated the sources using the best practices in data triangulation (Yin, 2014), with the support of the QDA miner software to the data categorization. Finally, after these steps, we propose a framework. Figure 1 points out the various steps of the process.

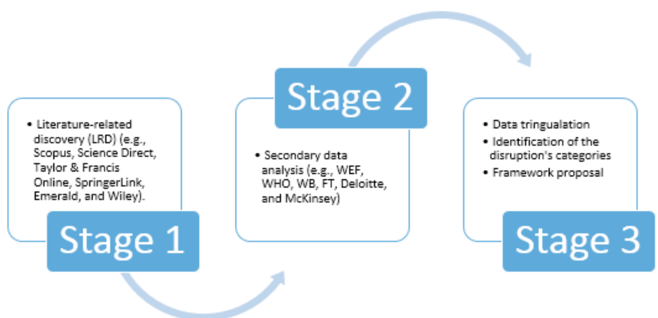


Figure 1. Operationalization of the methodology Note: WEF = World Economic Forum; WHO = World Health Organization; WB = World Bank; FT = Financial Times

## 4. DISCUSSION

Applying the previous three stages, we identified the main issues reported in Figure 2 as the most recurrent and complicated categories during an epidemic outbreak context. Firstly, we found three basic complexity categories, namely data, relationship, and process (DRP), impacting all epidemic outbreaks stages. These complexities affect the anticipation, coping, and adaptation resilience stages.

The data category refers to all data that one organization acquires, processes, and shares within its SCs. The relationship category is related to the integration level between the organizations and their SCs. Ultimately, the process category refers to the upstream and downstream activities in all stages of the epidemic outbreak.

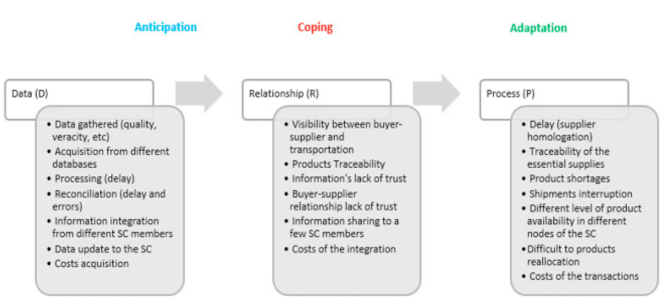


Figure 2. Disruptions categories found on supply chains in the epidemic outbreaks context

According to the stage of the disruption and the integration between SCs members, some of the elements can cause more impact (positively or negatively) to promote (or at least try) survivability. The data category emphasizes the supply chain members' need to adequately manage the different sets of data to enable decisions with robust information from its partners. For example, BDA applications it is likely to monitor supply trends worldwide, integrating a vast of sources, considering dynamically different information from the market, thus, contributing to minimizing the delay and uncertainty of the information (Akter and Fosso Wamba, 2019; Food and Agriculture Organization of the United Nations - FAO, 2020).

Regarding the relationship category, in complex disruptions scenarios, the matters of visibility of the information and the lack of trust between supply chain members gain a devastator amplification. Besides, relationships harmful also impact product traceability in the supply chains and, consequently, increase the shortages in various chain nodes. Furthermore, affecting the integration efforts negatively. With respect to the process category, different complex and lethal problems appear as product shortages and shipments interruption. Thus, contributing negatively to the responsiveness and resilience of the entire supply chain. Furthermore, other complicated issues like different types of delays (e.g., supplier homologation, product reallocation) cause interruptions in the chain. Considering these supply chain disruptions categories in epidemic outbreaks, in the following section, we provide a useful framework to SCs contexts, as also policymakers gain a more in-depth understanding of how AI, BDA, and BCT can leverage the resilience of the supply chains.

## 5. FRAMEWORK PROPOSAL TO SUPPLY CHAIN RESILIENCE IN EPIDEMIC OUTBREAKS

In response to the complexities reported in Figure 2, based on the literature on resilience and the cutting-edge technologies, we propose a framework (Figure 3) to mitigate or, when possible, outperform the DRP complexities. From this perspective, the framework highlights four main stages *i. continuous monitoring; ii. preparedness; iii. response* and *iv. Recovery*. In addition, the framework shows the integration of the previous stages with AI, BDA, and BCT technologies and how organizations can use them to face the complexities and some benefits examples. It may be observed that the DRP effects are considered in all stages.

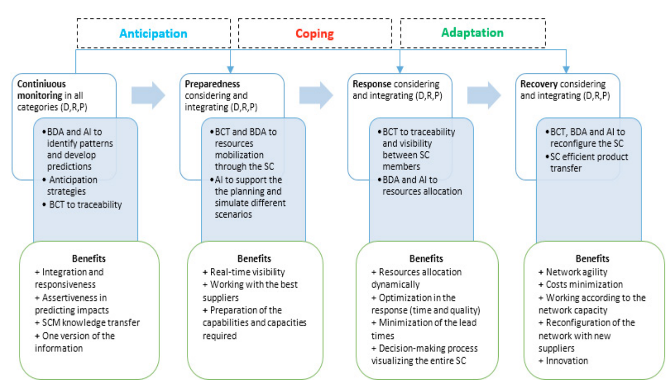


Figure 3. Framework based on AI, BCT and BDA technologies to supply chain resilience

Bearing in mind the ***Continuous monitoring*** stage, this is focused on BDA (Akter and Fosso Wamba, 2019) and AI technologies (Dwivedi *et al.*, 2021) to identify abnormal behavior' not only in its supply chains but in other networks that are not necessarily directly connected; thus, signalizing insights to the decision-makers anticipate. Moreover, with BCT integrating the SC members in several operations and transactions (Wamba and Queiroz, 2020), the information's trustworthiness is leveraged, then increasing the quality of the middle and long term planning also the reaction and responsiveness.

The ***Preparedness*** stage lays a fundamental influence on the other stages. Our framework posits that with AI techniques (Ivanov, 2020; Sarkis *et al.*, 2020), the resilience of the SCs could be improved significantly. Specifically, AI operating in the DRP enhance the "intelligence" of the information, enabling more reliable relationships between SC members and saving time in all process. Consequently, improving the preparedness stage. Besides, with BCT and BDA supporting this stage, the resources mobilization between the SCs is also raised due to the BCT features' traceability and sharing of information between members. Applying BDA is possible to model in real-time different scenarios impacts and discover the network's weaknesses.

Concerning the ***Response***, this is one of the most time-effort-cost (TEC) consuming stages, mainly because of the chain breaks that come up in various network points. For that reason, the resource allocation dynamically (Savachkin and Uribe, 2012) plays a fundamental role in the response quality. By employing BCT, decision-makers could improve the traceability and visibility in different SC nodes (Dubey *et al.*, 2020). Moreover, with AI and BDA, the dynamics of the patterns could be more understandable, making the resource allocation dynamically possible.

Ultimately, the AI, BCT, and BDA worked together to speed up the network's reconfiguration in the ***Recovery*** stage. The reconfiguration plan involves primary the schedule of the material flows in the network (Ivanov *et al.*, 2016) that are influenced by various features like costs, capabilities, network structure, the experience of the SC members in crisis and disruptions, among others (Ivanov and Dolgui, 2019). With AI and BDA, the reconfigurations and the agility of the network could be improved by a critical investigation of the nodes more affected and employing simulation (Araz *et al.*, 2013; Ivanov, 2019b, 2020) to understand the recovery behavior and the capabilities and resources required. Furthermore, with BCT, this process could minimize costs (e.g., transactions, product traceability, information sharing) between the SC members (Wamba and Queiroz, 2020). On the one hand, Recovery, Response, and Preparedness are temporary categories; on the other hand, the Continuous monitoring category does not end.

Regarding implementing this framework, first, the companies should have a digital transformation project to support in a deeper way all the benefits that these cutting-edge technologies could bring to their operations. Accordingly, for better implementation, the companies should present a good digital culture, top management support, and workers with digital and communication skills. Due to the infancy stage of the main cutting-edge technologies, it is important to note that the technology itself cannot minimize the uncertainties through supply chain operations. Furthermore, the cost-effectiveness of the technologies can represent a barrier to the implementation.

### *5.1 Managerial implications*

In this work, we identified critical features in managing the crisis in supply chains. We found that such categories differently affect the various disruption stages, particularly affecting the continuous monitoring, preparedness, response, and recovery. In this regard, Table 1 highlights the main managerial implications. The framework can be applied in companies to support the continuous monitoring of the disruptions and for recovery plans.

**Table 1. Managerial implications considering the DRP (data, relationship, and process)**

| Category | Continuous monitoring (AI, BCT, and BDA) | Preparedness (AI, BCT, and BDA) | Response (AI, BCT, and BDA) | Recovering (AI, BCT, and BDA) |
|---|---|---|---|---|
| **Data** | AI, BCT, and BDA adoption | Visibility of critical data and information for resources mobilization | Capabilities to examine large database from its SC and other indirect SCs | Data sharing and agility through the network to Integrate, reconfigure and restore the SC |
| **Relationship** | Intertwined supply network (ISN) strategies to integrate more in-depth the members | New levels of trust between SC members to leveraging the network capabilities | Integrated and coordinated actions with high levels of information sharing and transparency | Closer integration to enable the network balancing |
| **Process** | Supply chain digitalization to provide adequate infrastructure to continuous monitoring | Development of the required capabilities and skills for crisis operations and management | Innovation policies to transform the traditional operations into smart operations by Industry 4.0 concepts | Implementation of the survivability concepts to avoid breakdowns in the SC and to minimize the recovering time |

## 6. CONCLUSIONS

This study proposed a novel framework considering the integration of Artificial Intelligence, Blockchain Technology, and Big Data Analytics in epidemic outbreaks scenarios on supply chains. This is one of the first studies that integrates insights relating to these three cutting-edge technologies in a useful framework for managers and scholars to understand and enable strategies for other disruptive contexts. The framework was not yet tested; it can be highlighted as the main limitation of this study. Consequently, it can open new directions for future studies empirically test the framework and adapt it to other disruptive situations.

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