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Survivability, resilience and sustainability of supply chains: The COVID-19 pandemic

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ABSTRACT
As a result of the COVID-19 pandemic, supply chains (SCs) have been exposed to their greatest disruption in recent memory. This unprecedented situation has given rise to the concept of SC survivability, which is based on the need to find a new temporary equilibrium allowing SCs to survive during extreme events. The purpose of this paper is to contribute to the conceptualization of SC survivability by providing some basic foundations for this new concept. Our analysis shows that dealing with SC survivability requires a larger scale than those adopted for the analysis of SC resilience. To solve this issue, we propose a new framework called “Human Needs Supply Chains”. This framework shows the interdependencies between SCs, society, and the environment and enables a shift from the classical SC’s product-profit view to a holistic view centred on the satisfaction of basic human needs. Another contribution of this research is to highlight the links between SC survivability, SC resilience, and SC sustainability. We show that the classical resilience capacities (i.e., absorptive, adaptive, and restorative) are not enough to deal with extraordinary and long-term disruptions such as COVID-19, and we propose an adaptation of the SC resilience concept to integrate a survivability capacity. Building resilience with a survivability capacity will allow SCs to stay alive in a temporary non-viable equilibrium of sustainability during a large disruption and to recover to a viable equilibrium at the end of the crisis.

1. Introduction
COVID-19 pandemic events and responses are unprecedented to modern operations and supply chains (Sarkis, 2020). It has caused one of the greatest economic crises in recent memory (Bremmer, 2020), and has raised a central question for humans and SCs: how to survive during a pandemic crisis? It has marked the beginning of a long-lasting struggle for companies survival and moreover, has posed a challenge to sustainability (Sharma et al., 2020). Managers have viewed this crisis as having had a more severe impact on their businesses than any other they have experienced before (Fabeil et al., 2020). Other natural disasters (e.g., California wildfires, the Icelandic volcanic eruption of March 2010, Japan’s earthquake and tsunami in March 2011, the flood in Thailand in August 2011, and so on) affected precise geographical areas and had a limited impact on certain types of SCs that were dependent on those areas. However, the COVID-19 pandemic has affected every known SC (Supply Chain) and highlighted their vulnerability and interdependence (Chowdhury et al., 2021). At the beginning of the pandemic, and as a result of government containment measures, several non-essential SCs ground to a complete standstill (automobiles, tourism, aeronautics, and so on), while essential ones experienced unprecedented peaks in demand and stock-outs (e.g., food, face masks, hand sanitizers, and disinfecting sprays) (Baral et al., 2021). Even several months after the beginning of the pandemic, SCs continued to experience shock after shock. We observed demand and supply ripples and chaos and resonance effects across global networks (Guan et al., 2020; Sarkis, 2020). These have weakened several types of SCs, and there is a huge struggle among firms for sustainability and survivability (Cohen, 2020).

COVID-19 crisis has led to calls in research journals and the popular management press for the development of more resilient SCs and new recovery scenarios and approaches (Gunessee and Subramanian, 2020; Ivanov and Dolgui, 2020; Linton and Vakil, 2020; Remko, 2020; Simchi-Levi, 2020). Resilience is defined as the “ability of SC to react to unexpected disruptions and restore normal supply network operations” (Rice and Caniato, 2003). However, the extraordinary disruptions generated by COVID-19 have exceeded the resilience capabilities of companies, which make it important to review the classical approach of SC resilience and to develop better resilience strategies (Chowdhury et al., 2021; Gunessee and Subramanian, 2020; Ivanov and Dolgui, 2020). Barriball et al. (2021) argue that SC risk reviews are often born

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out of a crisis, with organizations mobilizing rapidly to conduct a review to avoid further issues and recover from the immediate emergency. This results in missed opportunities to use the crisis to build durable capabilities (Barriball et al., 2021). Several studies conducted in the beginning of COVID-19 pandemic have shown that SCs have not been prepared to cope with very large disruptions such as a pandemic crisis. In a study conducted by Van Hoek (2020) reported that “several participating supply chain executives shared that they experienced insufficient preparedness for this kind of disruptions and a lack of applicability of existing contingency plans to the COVID-19 pandemic”, they also mentioned that “they have never been through this level of complexity and the shocks they are experiencing are different from disruptions and crises in the past”. This show that SCs are not as resilient as they should be (Chowdhury et al., 2021). The COVID-19 crisis many pushed governments to review the resilience plans of their critical SCs (Barriball et al., 2021).

The majority of pre-pandemic research on SC resilience has focused mainly on localized risks in time and space (e.g. natural disasters, plant fire, supply shortage). These studies have developed a set of useful strategies such as risk mitigation inventory, backup supplier and subcontracting capacities (Van Hoek et al., 2001; Hosseini et al., 2019). However, few researches have focused on long term and global risks, such as pandemics, which generate a sudden breakdown in supply, production and demand lasting for several months, as we have seen during the first months COVID-19 containment (Ivanov and Dolgui, 2020; Ivanov, 2020b). Another gap in literature, reported by Chowdhury et al. (2021), is that most of the COVID-19 related studies have focused on high-demand and essential SCs (i.e., critical SCs) and they have tried to apply existing resilience strategies. Few studies have focused on developing customized strategies for non-essential SCs, even though the COVID-19 shock was much more severe for these SCs (Chowdhury et al., 2021).

As a response to this extraordinary disruption of COVID-19, the research community in SCM (Supply Chain Management) has called for new lenses and new insights regarding resilience and recovery approaches (Chowdhury et al., 2021; Haren and Simchi-Levi, 2020; Ivanov and Dolgui, 2020; Sarkis, 2020). During the last 30 years, the SCM literature has addressed several issues aiming to increase the resilience, sustainability, and digitalization of SCs (Ivanov, 2020h). The current crisis has given rise to a new challenge relating to the survivability of SCs, which had not been studied intensively in the pre-pandemic SC literature (Ivanov and Dolgui, 2020). This new challenge, which has been raised in recent papers (Choi, 2020; Haren and Simchi-Levi, 2020; Ivanov, 2020a, 2020b; Ivanov and Dolgui, 2020; Sarkis, 2020; Sharma et al., 2020), requests a special response from the research community in the SCM field. Supply chain “resistance to big disruptions such as COVID-19 needs to be considered at the scale of survivability or viability to avoid SC and market collapse” (Ivanov and Dolgui, 2020). This calls for new insights and new theories concerning SC survivability conceptualization.

However, when addressing SC survivability, we are confronted to another challenge regarding the unit of analysis. SC resilience is often analysed at the company, SC, or network levels. But, given the global nature of the COVID-19 crisis, which has impacted the world population and almost all SCs at the same time (Chowdhury et al., 2021), traditional resilience units of analysis have become insufficient to address SC survivability. The question of SC survivability goes beyond the existing state of the art in SCM. They cannot be restricted within the classic SC perspective, but rather requires an analysis on a larger scale (Ivanov, 2020a; Ivanov and Dolgui, 2020). This new challenge requires the development of a new unit of analysis which takes into account the interactions and interdependencies between SCs, society and the environment.

In view of existing research gaps, this study tries to answer the following research questions: What is supply chain survivability? How to analyse supply chain survivability? What are the survivability strategies used by companies during the COVID-19 pandemic? What are the relationships between survivability, resilience, and sustainability? The purpose of this paper is to contribute to the conceptualization of SCs’ survivability during extreme disruptions such as pandemics. Our analysis shows that dealing with SC survivability requires a larger scale than that adopted for the analysis of SC resilience. To solve this issue, we propose a new conceptual framework that we have termed the “Human Needs Supply Chains” (HNSC) framework. This framework gives decision-makers a holistic view to develop survivability strategies that fit the criticality of human basic needs satisfied by SCs. Another contribution of this research is to highlight the links between SC survivability, SC resilience, and SC sustainability. We show that the classical resilience capacities (i.e., absorptive, adaptive, and restorative) are not enough to deal with extraordinary and long-term disruptions such as COVID-19, and we propose an adaptation of the SC resilience concept to integrate a survivability capacity. The development of these new concepts presented in this paper is mainly based on the analysis of academic and professional literature dealing with SCs’ resilience to the COVID-19 crisis and the observation of survivability strategies used by companies and governments during containment periods.

The remainder of the present study is structured as follows: in section 2 we present the HNSC framework. In section 3 we present some of the components of SC survivability concept. In sections 4 we outline the relationships between survivability, resilience, viability and sustainability. Section 5 presents the general procedure for using the HNSC framework. The conceptual results of this paper are discussed in section 6.

2. The Human Needs Supply Chains framework

SCM literature has a tradition of classifying SCs according to the finished products they manufacture (automotive SCs, aeronautical SCs, smartphones SCs, cosmetic SCs, health device SCs, milk SCs, and so on). These product-oriented SCs are called “manufacturing SCs” (Gross et al., 2018). This vision does not clearly highlight the main function of a SC, which is to provide a service (Ivanov and Dolgui, 2020) and to contribute to the satisfaction of a human need. It also considers that the center of the SC is the focal company and that the human being is only an end customer for the SC’s products. Manufacturing SCs are often described from the perspective of the so-called primary manufacturer that produces the end item and that typically has the largest revenue and therefore the greatest power in the SC (Gross et al., 2018). This product-profit oriented vision addresses the classical issues of SCM, but it is not suited to address the complex challenge of SC survivability in the case of a pandemic. Ivanov and Dolgui (2020) argue that “the analysis of disruption impacts at such a level is concerned with long-term securing of services provided to the society, i.e. ensuring the viability, rather than with performance impact of disruptions in individual SCs in terms of revenue or annual sales, as traditional SC resilience analysis usually does”. The COVID-19 experience has highlighted the interrelationship between human’s survivability and SCs survivability. The treatment of the issue of SC survivability therefore requires a broader vision (Ivanov, 2020a; Ivanov and Dolgui, 2020) that takes into account all the interactions between humans and SCs and considers the satisfaction of human needs as a central connection point on which all SCs ultimately converge. In the following sections, we propose a new classification of SCs based on the grouping of manufacturing SCs according to the human needs they satisfy. We call these human-needs-oriented SCs the HNSCs (Table 1). This offers a holistic view of the interactions between SCs, the environment, and society.

2.1. Human Needs Supply Chains

The idea of human basic needs originated in the psychology literature of the 1940s and more specifically in an article by Albert Maslow in the Psychological Review (Maslow, 1943). In 1970, this idea inspired
the development of the United Nations’ (UN) Basic Needs Development Strategy (Emmerij, 2010). The HNSC framework, proposed in this paper, shares the same principals as the UN’s Basic Needs Development Strategy.

Indeed, every human being has the following basic needs: to eat, to dress, to live, to receive treatment, to be secure, to learn, to move, to communicate, to be entertained, and so on (Table 1). Several manufacturing SCs may work together within one HNSC (Human Needs Supply Chain) to meet the same human need (Fig. 1). For example, the Mobility HNSC is composed of: the automotive, aeronautics, maritime, rail, and energy SCs which have the ultimate goal of meeting the human need for mobility (Fig. 2). Another example is the Housing HNSC: several manufacturing SCs for construction, furniture, and household appliances aim to satisfy the human need for access to good-quality and comfortable housing.

Every HNSC is made up of several manufacturing SCs that work independently but aim together to satisfy the same basic human need (Fig. 2). Each manufacturing SC is made up of a focal company, tier 1, 2, and so on suppliers, distributors, and customers (Croxton et al., 2001; Gross et al., 2018; Mentzer et al., 2001). All HNSCs are connected downstream at the human link (i.e., as customers) and upstream by environment and natural resources (Fig. 1). In fact, HNSCs share the same suppliers of basic raw materials (steel, wood, lithium, and so on) and have the same final customers. Upstream suppliers (i.e., 4, 5 tier suppliers) supply multiple HNSCs at the same time. For example, a supplier of basic electronic components (such as diodes, transistors, silicon chipsets, and so on) can supply almost all HNSCs (mobility, communication, health, textiles, housing, and so on) (Fig. 3).

As we can see in Fig. 1, all HNSCs are closely connected in the upstream and in the downstream. The major crises that have affected SCs in recent decades have been located mainly at the level of upstream connection points, i.e., from focal companies to the suppliers of natural resources. As a result, these crises only impacted the SCs that were dependent on those connection points. The particularity of the COVID-19 crisis is that it has affected the downstream and central connection point that links all HNSCs (i.e., the human connection). The COVID-19 experience has shown that crises affecting the downstream central connection point have a greater impact than those affecting an upstream connection point.

### 2.2. The pandemic and the classification of Human Needs Supply Chains

In the context of a pandemic, HNSCs can be classified into three groups, according to their degree of criticality for the survival of humans in the short term and to their contribution to the implementation of containment measures (Fig. 4). Class A includes critical HNSCs: food HNSC, health HNSC, and security HNSC. The negative effect of their cessation can become apparent very quickly, whether in terms of the protection of human lives or of the establishment of public order. Class B includes moderately critical HNSCs such as communication and education. The COVID-19 experience has shown that these HNSCs have positively contributed to the establishment of containment measures, such as online education. Class C brings together the non-critical HNSCs: mobility, textiles, housing, and leisure. The negative effect of stopping Class C services on society does not become apparent until several weeks or months later.

### 2.3. Circulation of financial flows in the Human Needs Supply Chains

The human performs a double role in HNSCs. He is both a worker in one of the HNSCs and at the same time, a customer of all the HNSCs. The latter role gives him a central place in the circulation of financial flows. Indeed, a person receives a salary from a HNSC as a worker, and ensures the distribution of this salary among all the other HNSCs, because he needs to consume the services of all these HNSCs. This salary is shared at different ratios depending on the person’s priorities.

From a technical point of view, the human performs a double function in HNSCs: as a worker in a HNSC (e.g., in a textile HNSC) he plays the role of a receiver of the financial flow, and as a customer, he acts as a provider who ensures the distribution of the financial flow between the different HNSCs (Fig. 5). During the months of the total confinement of COVID-19 pandemic, we observed that several non-critical HNSCs stopped paying employees. This situation impacted all the critical and non-critical HNSCs, because the deregulation of the receiver function automatically deregulates the provider function, and vice versa.

### 3. Supply chain survivability

In this section we present some basic elements of the new concept of SC survivability.

#### 3.1. Supply chain survivability: A definition

Survivability derives from the Latin “supervivens”. The concept has aroused the interest of different research disciplines: ecological, military, engineering, naval, information systems, and so on. Each discipline offers definitions of survivability that best fit the context. For a literature review on the definitions of survivability, we refer the reader to the work of Westmark (2004). The most important aspect of a definition of survivability is the ability to remain alive and continue to exist during a disruption. Hellmann et al. (2016) state that “survivability is conceptually similar to the notion of finite time stability”, as “studied in linear

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**Table 1** Human needs and their corresponding HNSCs.

| Basic human needs | Human needs supply chain (HNSC) |
|-------------------|--------------------------------|
| To eat            | Food HNSC                      |
| To dress          | Textile HNSC                   |
| To be secure      | National security HNSC         |
| To learn          | Education HNSC                 |
| To live           | Housing HNSC                   |
| To receive treatment | Health HNSC                  |
| To move           | Mobility HNSC                  |
| To communicate    | Communication HNSC (internet, TV, mobile, and so on) |
| To be entertained | Leisure HNSC (hotels, restaurants, tourism, culture, and so on) |
control systems” (Amato et al., 2001). There “the focus is on finding a particular control scheme that will ensure that the resulting closed loop system stays within a particular region for some time, possibly in the presence of disturbances” (Hellmann et al., 2016). In this paper, we consider that survivability of SCs in the case of a pandemic corresponds mostly to this notion survivability in control theory. Indeed, we define SC survivability as the ability to stay alive in a temporary non-viable equilibrium during a large disruption.

3.2. Survivability strategies in nature

Human well-being derives from services provided by SCs that combine different kinds of natural, manufactured, and human capital (Baumgärtner and Quaas, 2007). Ivanov (2020a) states that SCs are the backbone of economies and societies, and interact largely with nature. The interactions in these SC ecosystems are very complex and are triggered by mutual interrelations and feedback between SCs, nature,
3.3. Why developing a supply chain survivability strategy for supply chains?

The human lies at the interconnection of all HNSCs and ensures the circulation of financial flows from one HNSC to another (Fig. 5). To make an analogy with the body, the human plays the role of a heart that receives blood and pumps it to the organs. The organs represent SCs and the blood represents financial flow. The COVID-19 experience has shown that during the first months of full containment in several countries, financial flows were oriented mainly to critical HNSCs: health, food, and safety. The non-critical HNSCs experienced massive reducing expenses, and living on liquidity reserves. During the first months of the COVID-19 containment, many companies (e.g., the American car rental company Hertz) preferred to declare bankruptcy to reduce non-essential expenses and to preserve cash and liquidity (Spector & Guillaume, 2020). Other companies in the United States have come under Chapter 11 protection, for example distributors, restaurants, and oil and gas companies.

1. Hibernation strategies used by animals such as bears. These consist of building up enough fat (savings) during the spring, going into hibernation during the winter, and reducing energy expenditure as much as possible.

2. Migration strategy used by migratory birds. These consist of changing the geographic location rapidly depending on the availability of food.

These two strategies can be a good source of inspiration for companies and SCs when preparing their survival strategies during a pandemic crisis.

3.4. Supply chain survivability strategies during COVID-19

The COVID-19 effect was unexpected and therefore had not been taken into consideration by classical SC risk mitigation and resilience strategies. It has created intense pressure on organizations to provide both core and non-core services, and hence many are switching to new forms of SCs (Sharma et al., 2020). During the first months of the COVID-19 pandemic, several non-critical HNSCs were forced to shut down due to containment measures established by various countries to reduce the spread of the virus. As a response to this unprecedented situation, we have observed the emergence of three types of survival strategies that have been adopted by companies working in non-critical HNSCs:

1. **A subsidies strategy** that consist of asking for public financial aid (helicopter money) to maintain salary payments and to continue operating in an uncertain market. This traditional strategy resembles a “cardiopulmonary resuscitation” that maintains artificially the circulation of financial flows, in the short term, to the heart of the HNSCs. This strategy, which was adopted by several governments to ensure the survival of sectors such as tourism and air transport, may be ineffective if there is not a real revival in customer demand in the months following the end of the containment.

2. **A hibernation strategy** that consists of stopping production, massively reducing expenses, and living on liquidity reserves. During the first months of the COVID-19 containment, many companies (e.g., the American car rental company Hertz) preferred to declare bankruptcy to reduce non-essential expenses and to preserve cash and liquidity (Spector & Guillaume, 2020).

3. **A migration strategy** that consists of becoming a support of a critical HNSC to guarantee the continuity of financial flows (Fig. 6). This migration can be adopted by an entire SC, as was the case with some textile companies that have directed, during total containment, all their production capacity towards the manufacturing of masks on behalf of health HNSC (Laarousi, 2020). This migration can also be partial: a number of auto parts suppliers shifted some of their capacity to the manufacturing of ventilators (Badnjević et al., 2020; Davies, 2020). A migration
4. Survivability, resilience and sustainability relationships

4.1. Survivability as a component of resilience

According to Christopher and Peck (2004), resilience is the “capability of SCs to operate in the face of disturbances and disruptions with or without a limited decrease in their performance”. The major objective in designing a resilient supply network is to strengthen the capability of SC entities to withstand against disruptions and recover quickly from disruption with minimal costs and efforts when they are disrupted (Hosseini et al., 2019). A resilient SC is based on the development of resilience capacities of SC entities. Biringer et al. (2013) identified three resilience capacities that companies can develop and use according to the stage of the disruption:

- At the beginning of a disruption a company can use its Absorptive capacity to absorb or withstand the impact of a disruption and minimize its negative impacts. This is first line of defense against disruptions.
- During the disruption, and if the Absorptive capacity is not sufficient, the company can use its Adaptive capacity to adapt its resources to overcome the disruption by implementing non-standard operating practices.
- At the end of the disruption the company could use its Restorative capacity to quickly restore its resources to the state before the disruption.

These classical resilience capacities are based on the development of redundancy and flexibility strategies (Hosseini et al., 2019) and deal mainly with localized disruptions in time and space (e.g. supply shortage, hurricane, earthquake) (Ivanov, 2020a). Even though the cost of implementation is relatively high for companies, classical resilience capacities are not enough to deal with very large disruptions that have a long duration and cover a very large geographical area, such as COVID-19 (Ivanov, 2021). If a company seeks to restore normal operations rapidly, it can spend a lot of resources without any results because of the severity and long duration of these disruptions.

For this reason, we propose to extend the SC resilience capacities (Biringer et al., 2013) to integrate a new capacity of SC survivability. This capacity is mainly addressed to companies belonging to non-critical HNSCs. To build a survivability capacity, companies could develop proactively survivability strategies, such as migration and hibernation. These strategies allow to companies to mobilize and combine external resources from outside their classical business sphere and SC to cope with very large disruptions, as it was the case of several clothing companies that have oriented their production capacity towards the manufacturing of masks during the first months of COVID-19 containment. This innovative strategy enabled these companies to survive during the crisis. Indeed, the survivability capacity can be used if a company observes that the classical absorptive, adaptive and restorative capacities are not enough to cope with a very large disruption. This new capacity allows to companies to enter into a survivability temporary equilibrium to avoid the destructive effect of very large descriptions. This can be observed from the case of many companies operating in the leisure HNSC (e.g., hotels, car rental companies, etc.) who struggled to survive during COVID-19 crisis due to the lack of a survivability strategy.

If classical resilience is the ability to return back quickly to the initial position before the disruption, resilience with survivability capacity gives a company the ability to stay in a non-viable temporary equilibrium and wait until the reduction of the disruption’s severity to start recovering (Fig. 7). However, the position reached after the recovery is not necessarily the initial one; it could be a future position on the same evolution trajectory. We observed that COVID-19 disruption has accelerated the pace of change, e.g., the acceleration of the energy transition in the automotive industry and the acceleration of the digitization and automation of several supply chains. In fact, the recovery after a survivability period due to a pandemic is not necessarily an orientation towards a new normal as it is stated by Ivanov and Dolgui (2020); it could be just an acceleration of the normal change trajectory.

Indeed, the SC’s reaction to different types of disruptions (Klibi et al., 2010; Ivanov and Dolgui, 2020; Ivanov 2020b) is determined by the nature of the resilience capacities implemented inside the SC (i.e., resilience with classical capacities or resilience with a survivability capacity).
capacity. The main differences between these two types of resilience are summarized in Table 2.

### 4.2. Resilience as a component of sustainability

COVID-19 has threatened the sustainability of supply chains, particularly in the social and economic dimensions. Sustaining business through the development of resilience capabilities of companies was qualified as the most suitable response to COVID-19 crises. The link between sustainability and resilience was one of the hot research topics in the last decade (Marchese et al., 2018). Several researches show that resilience can be considered as a component of sustainability (Marchese et al., 2018). They consider that increasing the resilience of a system makes that system more sustainable. Sustainability defines the global objectives of the system whereas resilience participates in the process of meeting those objectives (Anderies et al., 2013). A sustainable system is subject to different disruptions during its lifecycle. Its design process should consider the implementation of resilience capabilities allowing to that system to recover after disturbances (Blackmore and Plant, 2008) and return back to a sustainable equilibrium.

Even that sustainability and resilience have different similarities, these are separate concepts and their main differences can be observed at the level of spatial and temporal scales (Marchese et al., 2018). Sustainability actions are often deployed on larger spatial scales and longer temporal scales than resilience (Marchese et al., 2018; Meacham, 2016). The main goal of sustainability is to ensure viable conditions for future generations (Meacham, 2016). Thus, the effects of sustainability actions may have a negative impact on present conditions, but it should have a substantial positive impact on long term conditions. On the other hand, resilience actions are deployed to protect the system from potential disturbances and the positive results should be observed in the short term temporal scales (Lew et al., 2015; Marchese et al., 2018).

### 4.3. Survivability as a component of sustainability

Sustainability involves an attempt to find a viable equilibrium between the economic, environmental, and social dimensions under normal operating conditions of a SC (Fiksel et al., 2014; Marchese et al., 2018). However, as has been noted, COVID-19 and international containment measures have disrupted all SCs, and many of them have come to a partial or complete standstill. This has compelled several companies belonging to non-critical SCs to find a new temporary equilibrium to ensure their survival. Compared to sustainability which puts the economic and environmental dimensions at the center of its concerns (Hallinger, 2020; Sarkis, 2020), survivability attaches a great importance to the social dimension in order to protect human lives and jobs.

During the pandemic, new social sustainability norms emerge as people live differently (Sarkis, 2020). Containment responses have resulted in work from home, fewer physical meetings and closing non-essential businesses (Sarkis, 2020). These measures have clearly had a negative effect on non-critical HNSCs, but have also allowed the protection of the double function played by the heart of SCs (i.e., the human as a worker and as a customer). The COVID-19 experience showed that this temporary equilibrium of survivability was achieved at the expense of the economic dimension but led to a great improvement in the environmental dimension (Kanda and Kivimaa, 2020; Muhammad et al., 2020; Schaltegger, 2020).

Baumgartner and Quaas (2007) conceptualize sustainability under uncertainty as ecological-economic viability: “Viability means that the different components and functions of a dynamic, stochastic system at any time remain in a domain where the future existence of these components and functions is guaranteed with sufficiently high probability” (Baumgartner and Quaas, 2007). In economics and finance an “enterprise or management action is called viable if it continually generates a cash flow higher than a certain predefined level” (Baumgartner and Quaas, 2007). While viability is a desirable state for a system, survivability is a temporary state that allows the system to stay alive in the face of extraordinary disturbances. Hellmann et al. (2016) conceptualize the survivability of a dynamical system as “the fraction of initial system states (i.e., arising from an initial large perturbation) giving rise to evolutions that stay within a desirable regime up to a given time”. “Survivability has a natural interpretation as the conditional probability of a system to survive random, large perturbations that do not kill it immediately” (Hellmann et al., 2016). In the same direction, SC survivability consists in finding a temporary equilibrium allowing to a SC to stay alive during a crisis period while waiting to reach its viability zones, mainly in the economic dimension. Ivanov (2021) argues that “survival and adaptation in confronting such super-disruptive changes requires a special supply chain property – the capability to survive, to remain viable. Mechanisms to adapt seem to be most critical in a pandemic setting. At the pandemic times, it is no more about making profits or bounce-back to an old supply chain structure or sales performance; it is about to survive and maintain the business”. Therefore, survivability can be considered as a degraded mode of sustainability allowing to SCs to find a temporary equilibrium during a crisis period.

Fig. 8 is a three-dimensional graph that illustrates this relationship between survivability, viability, and sustainability. It displays the three dimensions of sustainable development: economic, environmental, and social. Each dimension begins with a survivability zone followed by a viability one. These two areas are separated by a line called the Viability Lower Bound (VLB). From this line, the SC begins to provide a performance that ensures the relative viability of each dimension.

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**Table 2**

| Criterion                        | Classical Resilience | Resilience with survivability capacity |
|----------------------------------|----------------------|----------------------------------------|
| Disruption type                  | Small to large       | Very large                             |
| Time horizon of disruption       | Short term           | Middle to Long term                    |
| Geographical area of disruption  | Limited              | Global                                 |
| Localization of disruption in the SC | Mainly one supply chain side | Supply and production and demand sides |
| Recovery time                    | Immediate            | Recovery after a survivability time to a future point |
| Recovery point on the evolution trajectory of a SC | To the point before the disruption | Human Need Supply Chain (HNSC) |
| Unit of analysis                 | Supply Chain, company|                                        |
| Strategies                       | Redundancy, flexibility, etc | Hibernation, migration, etc, etc. |
| Cost of strategies               | Incurred before the disruption | Incurred after the disruption |

Fig. 8. Survivability, viability, and sustainability.
Sustainability represents a space that combines the viability zones of the three dimensions. The Point on the graph illustrates the case of a non-critical HNSC during the COVID-19 pandemic. During the first months of the crisis, several countries observed a decline in economic activity in non-critical HNSCs, a degradation of the social dimension due to the loss of employment, and an improvement in the environmental dimension as a result of the decline in economic activity and transportation.

As a synthesis of the different relations mentioned in the above subsections, we can deduce that there is a strong interrelation between survivability, resilience, and sustainability. Survivability is a new capacity that allows the companies belonging to non-critical HNSC to become more resilient to the extraordinary disruptions of pandemic crises. This capacity should be combined with classical resilience capacities (i.e., absorptive, adaptive, and restorative) to allow these companies to stay alive during containment periods and start recovering when health restrictions are eased. If these companies become more resilient and can survive during a pandemic crisis, it can avoid a ripple effect for all HNSCs and sustain profits for business and jobs for society.

5. How to use the HNSC framework

5.1. A general procedure for using the HNSC framework

In this section, we will describe the general procedure for using the HNSC framework to build resilience and survivability capacities.

The company can start by identifying the main Human basic need satisfied by its SC. This will allow the company to select the HNSC to which its SC belongs among the 9 HNSCs presented in Fig. 1 in some cases, the SC of the company may belong to different HNSCs, but the decision must be taken according to the main basic need satisfied by the finished product or the service offered by the SC. In the next step, the company should identify the impacts of a containment period due to a pandemic on its HNSC (e.g., complete shutdown, decrease in demand, increase in demand, component and finished product shortages). Based on these impacts and the COVID-19 experience, the criticality of the HNSC can be determined (i.e., critical or non-critical). We have observed, during the containment periods of COVID-19, that governments have completely stopped non-essential businesses and left essential ones operating. Based on the criticality type, the company can choose two main directions. For critical HNSCs, classical resilience capacities (absorptive, adaptive, restorative) should be adapted by developing pandemic-specific resilience strategies, such as: local suppliers, redundancy and automation. For non-critical HNSCs, which are more exposed to the risks of complete shutdown, a survivability capacity should be developed and integrated with classical resilience capacities. It is possible to build this capacity through the development of innovative survival strategies such as: migration, subsidies, hibernation, etc.

In the last step, the company should evaluate different scenarios by varying and combining survivability strategies. With the help of system dynamic simulation, it is possible to calculate the time to survive inside the non-viable zone of the economic dimension of sustainability. In Fig. 9, we present a flowchart describing this procedure of using the HNSC framework.

5.2. Calculating time to survive

We illustrate the assessment of time to survive inside the non-viable zone (i.e., survivability zone) of the economic dimension through a simple model of system dynamic simulation (Fig. 10). More sophisticated models can be developed by companies to simulate real-life situations.

In this simulation, we consider the case of a textile company X that has a revenue of 1000000 €/month, variable costs represent 50% of revenue, and fixed costs are 200000 €/month. The initial value of its cash accounting is 400000 €.

We simulate the 3 following scenarios:

- Scenario 1: The company operate under normal conditions;

5. How to use the HNSC framework

5.1. A general procedure for using the HNSC framework

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We simulate the 3 following scenarios:

- Scenario 1: The company operate under normal conditions;
• Scenario 2: Complete shutdown due to a pandemic containment period and the company do not have a survivability strategy. This situation results in a stoppage of the company’s revenues.
• Scenario 3: Complete shutdown due to a pandemic containment period, and the company starts manufacturing masks on behalf of the health HNSC. This migration strategy allowed the company to ensure a part of its monthly revenue, representing 300000 €/month.

As we can see in Fig. 11, under scenario 1 conditions, the company X is profitable and its business is running normally. For scenario 2, Fig. 12 shows that due to the cessation of income, the company begins consuming cash from its cash account to pay its fixed costs, such as staff salaries. In this situation, the company can resist for only 2 months before being unable to pay its fixed costs. Concerning the scenario 3, we can observe in Fig. 13 that the company can survive for 8 months before being unable to cover its expenses. If the containment ends before this period has elapsed, the company can recover gradually to a normal situation. In the COVID-19 experience, it has been shown that this migration strategy (presented in scenario 3) has allowed several textile companies to avoid bankruptcy.

6. Discussion

The majority of research on SC resilience during the COVID-19 crisis has focused on companies belonging to critical HNSCs that have experienced peaks in demand and supply shortages. Few researches have studied the case of non-essential businesses that have experienced a sharp drop or a total stop in demand (Chowdhury et al., 2021).

Due to the containment periods, companies belonging to non-critical HNSCs have been much more affected by the COVID-19 crisis than those belonging to critical HNSCs. We have noticed that governments have made a lot of effort to save these companies from bankruptcy. These governmental efforts were mainly represented in the form of financial aids and easing of laws. In a report published by OECD organization in 2022 states that “some countries around the world suspended the obligation to file for bankruptcy for part of 2020 as the COVID-19 crisis hit. In recognition of the vital economic role smaller companies play, this allowed SMEs survive a massive economic shock as the pandemic unfolded. This temporary strategy prevented a much greater economic crisis and were key in sustaining businesses of all sizes” (OECD, 2021).

While many governments around the world have rolled out economic relief to businesses, much of it will not be enough to save many small and medium-sized businesses. (Linton and Vakil, 2020). In addition to this survival strategy based on subsidies, some companies were more innovative by developing a migration strategy. This is the example of automotive suppliers who have manufactured components for respirators; clothing companies that have manufactured masks; and cosmetics companies that have manufactured hand sanitizers. These survival strategies developed by companies in collaboration with governments have saved many companies from bankruptcy. By ensuring the survival of companies belonging to non-critical HNSCs, governments have avoided a ripple effect for all HNSCs and have ensured the sustainability of business (i.e., economic dimension) and jobs (i.e., social dimension). One can imagine the consequences of the crisis if governments and companies did not mobilize these survivability strategies. For all these reasons, survivability strategies should become an integral part of resilience strategies in order to prepare companies to withstand future crises.
pandemic crises.

In this paper, we consider survivability as a component of resilience and resiliency as a component of sustainability. In this sense, we proposed the addition of a ‘survivability capacity’ to the classical three resilience capacities: absorptive, adaptive and restorative. Unlike resilience which seeks to initiate the recovery process immediately after a disruption, resiliency with survivability capacity seeks to find a temporary equilibrium, which allows to a SC to stay alive during a crisis period while waiting to reach its viability zones, mainly in the economic dimension (Fig. 8).

The classical capacities of SC resilience based on redundancy and flexibility strategies are very useful in the case of different natural and man-made disruptions. However, COVID-19 experience showed that these capacities are not enough to cope with extreme events that have a global impact and a very long disruption time (Ivanov, 2020a). Many companies, especially those belonging to non-critical HNSC, were struggling to survive during COVID-19 crisis. So, it has become important that alongside the development of classical resilience capacities, companies belonging to non-critical HNSC should develop proactively their survival capacities during extreme events. This new capacity based on innovative strategies, such as migration, would allow companies to mobilize external resources from outside their conventional SCs. We observed that several companies, which were seriously affected by the crisis during the first months of COVID-19 containment, succeeded in achieving this migration. The innovative strategy mobilized by these companies deserves to be further explored to be integrated into resilience and management theories. For example, the research community can study the key success factors that have allowed these companies to migrate quickly from one supply chain to another and analyse the impact of this migration on their survivability. Another research direction is to simulate the time to survive by varying and combining survivability strategies, and to calculate the duration a company can withstand inside the survivability zone.

7. Conclusion

Supply chains worldwide have experienced the largest disruptions in recent memory as a result of the COVID-19 pandemic. This experience showed that the traditional SC risk mitigation and resilience strategies are not enough to deal with this new challenge. To deal with this issue, recent papers, published in the aftermath of the COVID-19 crisis, mentioned the importance of developing the new concept of SC survivability during pandemics (Sarkar et al., 2022; Choi, 2020; Haren and Simchi-Levi, 2020; Ivanov, 2020a, 2020b; Ivanov and Dolgui, 2020; Sarkis, 2020; Sharma et al., 2020). The present paper contributes to setting up the basic foundations of this new concept and explains its relationships with SC resilience and sustainability. Given the global nature of a pandemic disruption, we proposed a new representation of SCs that we called the HNSC framework. This is based on a holistic view that demonstrates the interrelationships between the different types of SCs, society, and the environment. The HNSC framework is centred on the satisfaction of basic human needs and shows that all HNSCs are linked in the upstream by the natural environment and downstream by the human being. Although the resilience analysis of individual SCs is useful in the case of localized disruptions in time and space, the global disruption of COVID-19 makes it important to perform the analysis at the scale of the HNSCs to have a holistic view and a good understanding of SCs’ survivability challenges.

Conceptual papers are not intended to provide empirical data (Hirschheim, 2008). One of the purposes of this paper is to inspire future research about SC resilience, survivability and sustainability strategies that fit the extraordinary events surrounding COVID-19. Additionally, SCs reaction to the COVID-19 pandemic is a new phenomenon, so an initial broad exploration of SC survivability seems fitting. We recognize that the HNSC framework is not exhaustive and that it is difficult to group all the individual SCs within the nine HNSCs proposed in this framework because there are many interactions between the SCs and one SC can offer its service to several HNSCs at a time. This task can be facilitated if managers carry out a functional analysis and ask the following question: what is the basic human need satisfied by the main function of the finished product of their SC? They can notice that this need has a good chance to be among the nine basic needs identified in the framework.

Our aim with this Framework is to provide decision-makers with an analytical tool allowing them to have a holistic view and a classification of SCs according to a vision centred on humans and not on products and profit, as is the case today. According to the criticality of the basic needs satisfied by these HNSC during a pandemic, decision-makers can build proactive survivability strategies that fit every SC. For example, companies belonging to a non-critical HNSC can study pro-actively different scenarios of a temporary migration toward a critical HNSC to ensure the continuity of the financial flow. From a research perspective, more empirical and mathematical modelling studies are needed to make these concepts operational to help different stakeholders to design the survivability strategies that best fit each HNSC. Given the global and longitudinal nature of the COVID-19 crisis, survivability strategies for HNSCs should be developed by adopting a holistic approach that brings business and governments together. New innovative survivability strategies could be developed by research community to deal with pandemic crises. These strategies should have as a common goal the maximization of survivability time inside the survivability zone and ensure a smooth transition to sustainability at the end of crises.

CRediT authorship contribution statement

Akram El Korchi: Conceptualization, Methodology, Study design, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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