Examining the Response to COVID-19 in Logistics and Supply Chain Processes: Insights from a State-of-the-Art Literature Review and Case Study Analysis

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Abstract: This article investigates the impact of the COVID-19 pandemic on logistics and supply chain processes through a two-phase analysis. First, a literature review maps the existing studies, published from 2021 to 2023 (101 papers), offering a view of the multiple challenges faced by supply chains during the pandemic emergency. The literature analysis makes use of descriptive statistics, thematic classifications and cross-analyses to provide a detailed overview of the issues raised by the COVID-19 pandemic and of the related implications. Second, a case study targeting a logistics operator was conducted, to derive practical insights into the real-world implications of pandemic disruptions. The study highlights the importance of proactive risk management strategies and the role of Industry 4.0 technologies to improve supply chain resilience and sustainability. Hence, this research contributes to a deeper understanding of the impact of the COVID-19 pandemic on logistics and supply chain processes and offers valuable guidance for companies, especially those working in the transport and logistics field.

Keywords: logistics and supply chain processes; disruption; risk management; COVID-19; literature review; case study

1. Introduction

A supply chain (SC) is “the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer” [1]. Because the SC includes different stages, such as procurement, manufacturing, distribution, waste disposal and all the activity associated with transport, storage and information technology (IT) [2], and it is crucial that any connection works well to ensure the efficiency of the chain [3], the management of the SC is clearly a complex task. To describe this activity, the concept of Supply Chain Management (SCM) has been introduced. The definition of SCM seems to be less common across authors than the definition of SC. According to Jones and Riley [4], “supply chain management deals with the total flow of materials from suppliers through end users...” and its objective “is to integrate and manage the sourcing, flow, and control of materials using a total systems perspective across multiple functions and multiple tiers of suppliers” [5]. In addition to the inherently complex management of the SC, its equilibrium can be undermined by a variety of factors, named “disturbances”, which range from human errors to fluctuating demand, from the outbreak of war to the outbreak of a pandemic emergency. In December 2019, a virus previously unknown, later named COVID-19 [6], was identified in Wuhan, China and the World Health Organization (WHO) declared it a pandemic on March 11, 2020. Due to the rapid and global spread of the virus, coupled with high mortality rate, first the Chinese government, and then governments worldwide, implemented restrictive measures that impacted on the population and companies. Precautionary measures included social distancing, introduction of personal...
protective equipment and restrictions on travel and work activities; hence, companies were forced to stop their activities or to quickly adapt to the evolving changes [7]. These measures, especially those related to production facilities and the movement of goods between borders caused delays in deliveries [7,8], resulting in negative impacts on trade, transportation, production, and all stages that constitute the SC. Due to its unpredictability, devastating impact [9], high uncertainty, and long duration of effects [10], the COVID-19 pandemic has been termed a “black swan”. It has also led to economic disruptions around the world by interrupting all SCs, both those aimed at selling products and those aimed at delivering services [11], forcing them to deal with a situation which was out of the ordinary.

Due to simultaneous disruptions in demand, supply, and logistics infrastructures, with concurrent and/or sequential openings and closures of suppliers, factories, and markets [12], SCs have been exposed to several risks, which have contributed to the instability of the moment. According to [13], SC risk “should refer to (i) events with small probability but may occur abruptly and (ii) these events bring substantial negative consequences to the system”. As such, risk includes any stage of supply, production and delivery (material flow risk), investments and/or inability to settle payments (financial flow risk), security issues and accuracy of information (information flow risk) [14]. During the COVID-19 pandemic, the risk related to material flow particularly increased, due to blockages and restrictions affecting production and logistics in several countries. Examples are blockages caused by suppliers’ production interruptions or reduction in their output due to labor shortages. Transportation-related blockades also severely affected the supply of materials. An example of these situations occurred in Wuhan, in a production center for automobile parts for companies such as Toyota and Volkswagen. It is inevitable that at the early stages of the pandemic, companies that had key suppliers in Wuhan were disadvantaged. The pandemic emergency also caused a rather severe economic crisis [10], involving increased financial risks [8]. Financial difficulties can lead to the insolvency of suppliers, thus causing a decrease in production capacity of the SC, up to its collapse. The vulnerability of companies’ information systems and the risk of data breaches also increased during the pandemic, because of the need to work remotely and share information on online platforms [15].

Logistics and SC processes, overseeing the distribution of (even essential) goods, were among the activities most severely impacted by the COVID-19 pandemic [16]. Indeed, for essential goods a general increase in demand was observed in the pandemic period [17,18], resulting in a significant growth of the volumes handled in the immediate term and, obviously, an increased request for logistics services [19]. These “positive” effects were observed in almost all sectors manufacturing essential goods, while negative trends were experienced in non-essential sectors [20]. In the medium term, instead, researchers have observed a gradual recovery of sales in various sectors; nonetheless, logistics activities maintained higher volumes than those handled in the pre-COVID-19 period [16]. Indeed, the pandemic emergency also involved changes in the purchasing behavior of customers, with a shift towards e-commerce observed in many different fields, thus increasing the demand for logistics activities.

As a consequence of the pandemic emergency, research on Supply Chain Risk Management (SCRM), i.e., “the identification of potential sources of risk and implementation of appropriate strategies through a coordinated approach among supply chain members, to reduce supply chain vulnerability” [21], has gained an important role at the interface of SCM and risk management [22]. Various strategies have been adopted to manage and prevent risks, which converge into the concept of resilience [23], namely the ability of the system to restore itself to its original condition or adapt to a new and more beneficial state after a disruption [24]. Resilience strategies can be “proactive” if they try to prevent future disruptions, or “reactive”, in cases where they tend to adapt to the new situation or to restore the previous state [6,25]. An analysis of selected literature highlights numerous strategies that confer resilience to an SC, making it less vulnerable to risks. One of them is reconfigurability, which consists in the ability of the SC to nimbly change its structure and
functions, minimizing cost and time [26]. In addition, visibility emerges as a crucial feature, as it enables real-time monitoring of the various stages of the system [23,27]. Collaboration is another key capability, enabling entities to work together to gain competitive advantage by sharing crucial information such as forecasting, planning, and risk management [23]. Flexibility is essential as well, as it allows the SC to quickly adapt to external changes in response to unforeseen disruptions [23]. Finally, redundancy proves important for dealing with unexpected disruptions and changes in demand by managing larger inventories and diversifying suppliers [8,23]. Inter-firm collaboration in an SC includes organizational connectivity, i.e., the ability to collect and exchange data via information and communication technologies (ICTs) [23]. In this respect, there is a growing need to adopt Industry 4.0 (I4.0) technologies to better cope with the challenges imposed by disruptions and remain competitive in the marketplace. This need has been further exacerbated by the outbreak of the COVID-19 pandemic. Technological innovations are also closely related to the concept of sustainability as they contribute to the reduction in energy consumption and environmental impact [28]. Sustainable development is projected toward the realization of present needs without precluding the realization of needs for subsequent generations [29].

From the set of considerations above, it is easy to see that the impact of COVID-19 on logistics and SC processes has been widely debated and various (even interrelated) facets have been explored. As we are now in the post-COVID-19 era, time has come to summarize the evidence about the impact of COVID-19 on logistics and SC processes. This is the intended aim of this study, which can be formally delineated through the following research questions (RQs):

- **RQ1 (scientific):** How have researchers studied the impact of COVID-19 on logistics and supply chain processes? Which industrial sectors were mostly studied and why? Which additional topics can be related to COVID-19 and logistics/supply chain?
- **RQ2 (practical):** What effects of COVID-19 on logistics and supply chain processes were experienced by companies?

For answering these questions, this paper follows a two-step methodology. The first step is a comprehensive literature review, which allows for gathering scientific evidence on the subject and thus answering RQ1. Related outcomes were elaborated through statistical analyses and cross-analyses for a better representation of the key findings. The second step is a case study, intended to explore the impact of the COVID-19 pandemic on a logistics operator and capture the practical facets of the topic, thus allowing to answer RQ2. The case study also complements the findings from the literature and provides insights to companies. This study moves from previous research by [30], who carried out a preliminary analysis and classification of the literature about COVID-19 and supply chains, published up to 2022. The previous research is enriched by including an enlarged timespan of the papers reviewed, deepening the analysis and classification of the literature, and, most importantly, adding a further step of research, in the form of a case study.

The paper is structured as follows: Section 2 outlines the research methodology; Section 3 presents the results from the literature review; in Section 4, the case study is presented and, finally, in Section 5, some conclusions are summarized, together with implications, limitations and suggestions for future research.

2. Materials and Methods
2.1. Systematic Literature Review
2.1.1. Sample Creation

To collect relevant papers for the systematic literature review (SLR) a structured query was made on the Scopus database. The query included keywords such as, “supply chain”, “logistics”, “risk management”, “disruption”, “pandemic”, “quantitative” and “COVID-19”. Those terms are not expected to introduce filters or restrictions to a specific industrial field, as logistics/supply chain processes can exist in virtually any industry.
The document search was instead restricted to “articles” written in English and published on scientific journals. Regarding the time frame, only articles published from 2021 to 2023 were considered. The query set on Scopus was the following:

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This setting returned a sample of 450 papers. A screening of the documents was performed in two phases: first, title and abstract were examined to judge the pertinence of the paper to the research topic, thus allowing for the removal of documents that were not relevant to the scope of the study. Many of those documents targeted the medical field, focusing, e.g., on disease prevention, effect of vaccines, or the relationship between COVID-19 and other diseases. Other documents were instead related to the social field and, for example, discussed the dissemination of information about the COVID-19 disease in different countries around the world, and the discrimination and behaviors related to the ongoing pandemic. In addition, various articles dealing with mental health, particularly the psychological effects resulting from restrictions, were excluded, followed by articles dealing with education and employment. Secondly, the full articles were read to deeply understand the relevance to the topic; as a result, 101 papers were retained for the final sample [31] (the list of papers is available on the Mendeley repository at DOI: 10.17632/yhywgdprm2.1).

2.1.2. Descriptive Analyses

The papers in the sample were subject to some descriptive statistics with the aim of mapping the research field in terms of number of publications per year and sources that published the papers reviewed.

2.1.3. Paper Classification

For all papers in the sample, a structured classification was then made, including the elements below:

1. Macro theme: sustainability, resilience, risk, information technology, economics, performance, planning and food security. This classification represents paper’s core topic.
3. Data collection method: questionnaire/interview, third-party sources or case study. This classification represents the method used by the authors to collect the data useful to their study.
4. Research method: statistical, decision-making, simulation, empirical, literature review or economic. This category describes the tool used by the authors to conduct the study and reach the related goals.
5. Specific method, e.g., descriptive statistics, structural equation modeling (SEM), multi-criteria decision making (MCDM), etc.; this feature describes more accurately the type of work carried out by the authors and the tools used.
6. Country: it reflects the geographical area in which the study was carried out, in terms, for instance, of the country in which a sample of people has been interviewed or where empirical data were collected, or where the simulation was set. This method of classification, although more elaborated, was preferred over traditional approaches, in which the country of the study is defined based merely on the affiliation of the first author of the paper, because the exact knowledge of the country in which the study was carried out is, for sure, a more representative source of information about the research. This is true in general, but it is even more important for this subject matter, as the management of the COVID-19 pandemic was made on a country or regional basis, with significant differences from country to country; knowing the exact location of the study helps in better interpreting the research outcomes. Possible entries in
this field also include “multiple countries” and “not specified”, with the obvious meanings of the terms.

For all the above elements, one single classification field per paper was selected.

2.1.4. Cross-Analyses

Cross-analyses, or cross-sectional studies, were used to examine the relationships between different variables or categories of the data set. In general, these analyses help identify any associations, patterns or trends, and serve multiple purposes [32]. Cross-analyses are not necessarily to be seen as purely descriptive statistics, although they are widely used with that interest [33]. In this study, cross-analyses were used to identify possible relationships between the macro theme, industrial sector and research method.

2.1.5. Interrelated Aspects

Four “interrelated” aspects (i.e., not directly related to the main topic of the query, but to more general themes) were mapped when analyzing the papers; they refer to sustainability, Industry 4.0, e-commerce and food safety. Although the e-commerce and food safety topics may seem to be more specific than sustainability and Industry 4.0, they were nonetheless found in numerous papers and were, therefore, perceived as relevant for a further analysis. Moreover, even if sustainability is listed among the macro themes, some articles do not deal directly with that topic, but, rather, have implications that relate to the sustainability area. Again, a cross-sectional analysis of those interrelated aspects with sector and macro theme was conducted to highlight possible connection between these fields.

2.2. Case Study

Case study-based research is an empirical investigation of events of a contemporary phenomenon in a real context [34,35]. As such, case studies do not use purely historical information, such as open-source archives [36]. Wohlin [36], in a survey of case studies, found that 47% of resulting articles claim to be case studies despite not qualifying as such. Similarly, it was found that several articles claimed to present a case study but, in fact, did not meet the commonly accepted definition of the term. In this paper, we present a case study describing the changes in the supply chain practices of a logistics operator (named Company A for the sake of confidentiality), starting from the pre-COVID-19 period, encompassing the pandemic emergency, and finally analyzing the post-COVID-19 era.

2.2.1. Data Collection

Some specific aspects of the company’s activity were investigated, moving from the pre-COVID-19 to the post-COVID-19 period, namely:

1. Economic data: some key economic data were retrieved from the company’s balance sheet, from 2019 up to the latest available document, which refers to 2022.
2. Organizational data: these data describe changes in the operational, decision-making and business structure of the company in terms, e.g., of number of employees hired, number of drivers, etc.
3. The related data were collected and elaborated between July and September 2023.

2.2.2. Survey Phase

As mentioned earlier, the COVID-19 pandemic involved a shift towards e-commerce in many different industry fields. For capturing the differences in the behavior of customers as a consequence of the COVID-19 pandemic, and to complement the data collection, a questionnaire was prepared and submitted online to a representative sample of approx. 120 final consumers of the targeted company, with the aim of understanding whether online shopping habits have changed with the advent of the pandemic.
The online questionnaire consisted of twenty multiple-choice and open-ended questions, anonymously filled by the respondents, and was administered over a period of two weeks in October 2023. The questionnaire included a preliminary section with questions intended to delineate the profile of the respondents (e.g., in terms of gender, age, geographic location, professional activity and level of education), while the remaining questions expressly investigated the attitude of the customer towards the usage of online sale channels, as well as the changes in the level of usage as a consequence of the pandemic emergency and the current level of adoption. As the relating outcomes (implicitly) depict the present habits of the customers, results of the survey phase are commented on when describing the post-COVID-19 period (Section 4.4.).

2.2.3. Analysis and Summary

The whole set of outcomes of the case study were summarized in a SWOT (strengths, weaknesses, opportunities and threats) analysis, as an effective way help the decision-making process of the targeted company, so as to achieve future growth after the pandemic emergency.

3. Results—Systematic Literature Review

3.1. Descriptive Statistics

Figure 1 represents the distribution of papers by year.

![Figure 1. Distribution of paper by year.](image)

Over the three-year period (2021–2023), the number of published articles grew steadily. Articles published in 2022 more than doubled those from 2021 and five more articles were published in 2023 compared to 2022. This increase was somehow expected, as scientific studies usually take about a year to be published, and thus, studies on COVID-19 probably started being conducted in 2020–2021 but needed time to find their way into publication in 2022 and 2023. This is why more scientific data and information became available in the last years, allowing for more complete research. However, it is important to note that trends in publishing are not always on the rise (at least, not in any scientific discipline); rather, they can be affected by how relevant the topic is. Based on the above, the large number of publications shows that studying COVID-19 impact on logistics and SCs remains a focal point for scholarly questions, and that even if we are now in the post-COVID-19 era, research in this scientific area is far from declining.
The distribution of articles across scientific sources was analyzed (Table 1). We recall that no filters were set for the journal classification, and therefore, the ranking in Table 1 was obtained based on the number of papers published by each journal, as they resulted from the query. For completeness, a well-known metric of the journal prestige, i.e., the latest available positioning in the Scimago (www.scimagojr.com (accessed on 6 June 2024)) ranking, is also included in the table. Sustainability emerges as the top journal in terms of number of publications, with 10 papers, followed by International Journal of Logistics Management, which is in line with the focus of the query on logistic and SC processes. Following are two journals with five publications, Journal of Global Operations and Strategic Sourcing and Agricultural Systems. The first journal is relevant to the logistics area, like the previous one; the second focuses instead on agriculture, a topic of great current relevance and which is discussed further below. Benchmarking, with four papers, is aimed at analyzing performance and identifying the best practices. Finally, International Journal of Production Research, with three publications, publishes papers related to manufacturing, industrial engineering, operations research and management science, with a specific focus on logistics processes. In general, the journals that emerged as top by number of papers published also have a high Scimago ranking.

Table 1. Top journals.

<table>
<thead>
<tr>
<th>Source</th>
<th>No. of Papers</th>
<th>Scimago Ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustainability (Switzerland)</td>
<td>10</td>
<td>Q1–Q2</td>
</tr>
<tr>
<td>International Journal of Logistics Management</td>
<td>6</td>
<td>Q1</td>
</tr>
<tr>
<td>Journal of Global Operations and Strategic Sourcing</td>
<td>5</td>
<td>Q2</td>
</tr>
<tr>
<td>Agricultural Systems</td>
<td>5</td>
<td>Q1</td>
</tr>
<tr>
<td>Benchmarking</td>
<td>4</td>
<td>Q1</td>
</tr>
<tr>
<td>International Journal of Production Research</td>
<td>3</td>
<td>Q1</td>
</tr>
</tbody>
</table>

3.2. Common Classification Fields

3.2.1. Macro theme

Figure 2 represents the distribution of the sample articles by macro theme; this latter was determined by reading the full paper and reflects its main focus. Resilience is the most relevant macro theme, with 30 publications (29.7%). The concept of resilience combines both agility and robustness and represents the ability of a system to cope efficiently with change [37], representing how well or poorly a system can recover from a disruptive event [38]. The studies regarding the resilience topic have analyzed adaptation strategies [39] and highlighted the key role of connectivity and coordination [23]. Badhotiya et al. [10] have identified some resilience indicators that can act in different phases of SC i.e., the anticipation phase, response and recovery, and the resistance phase [40,41]. Authors have considered the internal resilience as well as external, in order to analyze supply chain resilience in terms of a firm’s internal dynamic capabilities and the resilience of its suppliers [42].

The numerosity of the papers published in Sustainability is reconfirmed by the fact that sustainability represents the second macro theme by number of publications (16 out of 101, 15.8%). It has been shown that green practices adopted by SCs impact on environmental performances [43], especially subsequent to the COVID-19 pandemic [44]. Many challenges from the COVID-19 pandemic have indeed triggered this dynamic for companies, including sustainability emerging as a core part of SCM. Based on this, decision-making models were developed based on interpretive structural modeling (ISM) with the Cross-Impact Matrix Multiplication Applied to Classification analysis (MICMAC), which were able to show that actively involving senior managers is crucial for successful adoption of initiatives. The results highlight the importance of financial support from investors and government, such as tax reduction and short-term loans, in fostering sustainability in SC processes [45]. In addition,
some research has revealed that the rise in food processing costs and raw material prices, the lack of transparency/traceability and capital and physical resources, and the spread of false information are the top five sustainability challenges for the food processing industry [46].

The third macro theme analyzed is economy, whose importance has continued to grow from 2021 to 2023. A shift in perspective can be identified in the topics addressed in the papers. Initially, more emphasis was placed on more general topics related to the economic impact of the COVID-19 pandemic, such as the principal–agent problem in SCM [47] and the lockdown impacts on agricultural systems [48]. In 2022, more targeted approaches emerge with respect to specific changes in logistics activity and supply chains due to the pandemic [28], with a focus on the impact on business performance [11]. As pointed out by [45], the importance and inter-relationship between the financial performance of logistics companies and COVID-19 is emphasized. Although the pandemic may be thought to have negatively affected the financial performance, some authors [49] have shown that increased demand for logistics services during the pandemic helped improve the performance of some companies in the logistics sector. Finally, in 2023, the papers have addressed more future-oriented topics, such as key directions for transforming SCM in emerging markets in the post-pandemic period [50]. Again, the theme of sustainability in relation to economic practices returns, emphasizing how circular-economy practices have been widely used in the pandemic period, in relation to the theme of resilience [51].

The “risk” topic encompasses 12 papers, which mainly concern the strategies for mitigating the risk. Outcomes of the studies reviewed show that risk can be divided into various categories, including: ‘material flow risk’, ‘disruption risk’, ‘uncertainty risk’, ‘information flow risk’, ‘planning risk’ and ‘financial risk’. Shortages of raw materials and inventory, along with labor shortages, represent supply risks [52]. If production and delivery risks were also considered, we could define the category as ‘material flow risk’ [14]. This risk propagates downstream, resulting in missed sales and dissatisfaction for the final consumer. In the pandemic-related context, there is the possibility of these risks occurring simultaneously, creating a total supply chain shutdown and more difficult recovery [52]. In analyzing the various risk categories shown in [8], it was found that pandemic, transportation blockages, and labor shortages fall under the risk of disruption while fluctuations in supply and demand and the scarcity of information related to them represent

\[ \text{Figure 2. Distribution of papers by macro theme and year of publication.} \]
The uncertainty risk. The scarcity of information, together with its mismanagement (e.g., redundant information generating confusion), gives rise to information flow risk [8,53]. Added to these is planning risk, concerning the ability to plan production, inventory, and coordination of SC stages. Finally, there is financial risk related to improper investments and poor management of finances [8]. Gui et al. [54] pointed out that port congestion poses a serious risk to the transportation sector, especially when linked to external factors such as temporary suspension of rail services or shortage of truck drivers for road transport. Brdulak, H. and Brdulak, A. [55] have classified the risk in the form of categorized threats, covering the technological, economic, and organizational domains, while Paul et al. [56] have delineated the operational challenges that companies should overcome for being successful in mitigating business risks.

Technological innovations, including the Internet of Things (IoT), have revolutionized the logistics and supply chain field, especially in response to the COVID-19 pandemic. Indeed, during the pandemic emergency many industries faced (and are still facing) severe economic challenges and were, in part, helped by technological innovations that allowed the acceleration of the process of satisfying consumer’s needs [57]. Studies have highlighted a clear correlation between technology usage before and during COVID-19, as well as between technology adoption during the pandemic and future usage prospects. Furthermore, it was found that highly digitalized small- and medium-sized businesses have demonstrated a greater propensity to adopt I4.0 technological solutions [58].

The “performance” macro theme emerged in 10% of the papers. Company performance was studied in terms of robustness, resilience and agility, and it was shown that, as anticipated, resilience had a significant impact on SCs during COVID-19 [59]. Furthermore, it was confirmed that three SC integration dimensions of internal, product and process integration contributed positively to the companies’ ability to withstand the crisis and remain robust. In essence, resilience acted as a mediator between internal and product integration and overall firm performance, while robustness influenced financial performance through these integrations [60].

The “planning” and “food security” topics represent the last macro themes with, respectively, six and two papers.

3.2.2. Industrial Sector

Figure 3 shows the distribution of papers by industry field. The logistics sector records the largest number of publications (20 out of 101, 19.8% of the sample). This result can be attributed to the broad impact of the COVID-19 pandemic on that sector, including government restrictions imposed to contain the spread of the virus, but also the increased need for logistics activities due, for instance, to the growth of the e-commerce market [16]. The research query used in this study also expressly mentioned logistics and SC processes. The logistics sector has experienced drastic uncertainties and changes in the operating environment and this has affected companies differently, based on their position and overall view of the market [61].

The food and agri-food sectors were examined separately for a deeper and more effective analysis of the related outcomes. It is notable that the total number of studies relating to either food or the agri-food sectors covers one-third of the full sample of papers. In the agri-food sector, various studies regarding SC vulnerability [62] and risk management [63] have emerged. Researchers have pointed out that adaptability has enabled supply chains to seize new opportunities [64–66]. Food and agri-food sectors have been greatly analyzed in terms of food insecurity, i.e., the problem of mobility blockage and food shortages [64,67–70].

The COVID-19 pandemic has greatly affected manufacturing activities worldwide, causing major issues for over 75% of the global production. This situation occurred mainly because of the closure of various factories, which prompted people to make frantic purchases and accumulate excessive stocks [71]. Additionally, shifting customer choices (e.g., privileging online shopping over in-store shopping) brought up new and unexpected issues about how connected worldwide supply networks are and about the general way
of overseeing SCs [72]. In the manufacturing sector, as well as in the industrial sector, the increasing focus on sustainability is emphasized, with a push toward the adoption of greener practices, especially by small- and medium-sized enterprises [73]. It also highlights the importance of measuring resilience strategies of manufacturing SCs, especially in view of recovery scenarios after critical events such as the COVID-19 pandemic [74].

Figure 3. Distribution of papers by industrial context.

Research activities in the healthcare sector have examined pharmaceutical SCs [75], [76] and the risks in health delivery. In these contexts, there are typically four types of SC risks: physical, financial, information, and relational [75]. Physical risks focus on transporting goods from the manufacturer to where customers can access them. Financial risks concern the flow of money through the SC, while information risks focus on using electronic systems for material and payment during operations among SC players. Finally, relational risk concerns the connections between producers, transporters, and customers [76]. In the light of this classification, healthcare SC risks can have various sources; for instance, risks could be generated by scarcity of medical supplies, unpredictable customer demand, fake medicines, outdated technology, worker strikes, unreliable power, poor infrastructure, long supply processes, or fluctuating fuel and transportation costs. By understanding where and how these risks originate, healthcare systems can work to reduce their impact and build more resilient networks [77]. The pharmaceutical sector has been greatly impacted by COVID-19, due to reduced production capacity, domestic stocks, and export bans [78]. Shortage of some essential medicines in the pandemic period was highlighted as a key issue, emphasizing the need for establishing effective supply systems [79] and for ensuring the safe transportation of drugs from the manufacturer to end users.

3.2.3. Data Collection Method

The classification proposed in this sub-section refers to the data collection method used by the authors when carrying out their research. Figure 4 shows the distribution of papers by data collection method.
instance, risks could be generated by scarcity of medical supplies, unpredictable customer demand, fake medicines, outdated technology, worker strikes, unreliable power, poor infrastructure, long supply processes, or fluctuating fuel and transportation costs. By understanding where and how these risks originate, healthcare systems can work to reduce their impact and build more resilient networks [7 7]. The pharmaceutical sector has been greatly impacted by COVID-19, due to reduced production capacity, domestic stocks, and export bans [78]. Shortage of some essential medicines in the pandemic period was highlighted as a key issue, emphasizing the need for establishing effective supply systems [7 9].

3.2.3. Data Collection Method

Figure 4 shows the distribution of papers by data collection method.

Most of the papers (67 out of 101, 66.3%) made use of empirical data, derived from questionnaires or interviews administered to managers, employees or technicians in the various industries discussed above. A group of 23 papers (22.7%) was, instead, based on secondary sources, i.e., scientific literature or online databases. A small quota of six papers (5.9%) did not specify the type of data used in the study; finally, five papers (4.9%) made use of data taken from case studies, direct observations or field studies.

3.2.4. Research Method

Table 2 shows the general and specific research methods of the studies reviewed. For a more linear analysis of the results, one method only was indicated for each paper, although a considerable number of studies make use of more tools or combined approaches. In those cases, the method that was deemed most representative of the study performed and which constituted the qualitative–quantitative part of the methodological process was mapped. For instance, whenever an article had one or more fuzzy aspects, it was simply classified as “fuzzy”, without further specifications. As for the “hypothesis testing” method, this was indicated only in cases where no other accredited methods were identified in the paper. For example, in all articles using the SEM method, hypothesis testing is also typically reported; however, these studies were classified primarily considering the SEM method. Similarly, articles categorized under “case study” (belonging to the more general category of empirical methods) were also labelled as such only in cases where they did not adopt any other methods.
Table 2. Research methods (note: bold = sum of papers relating to each research method).

<table>
<thead>
<tr>
<th>Research Method</th>
<th>No. of Papers</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Statistical</strong></td>
<td>47</td>
</tr>
<tr>
<td>ANOVA</td>
<td>2</td>
</tr>
<tr>
<td>Contingency analysis and frequency analysis</td>
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<tr>
<td>Cronbach’s alpha</td>
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<td>Descriptive statistics</td>
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<td>Econometric</td>
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<td>Hypothesis test</td>
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<td>Keyword analysis</td>
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<tr>
<td>Logistic regression—R software</td>
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<tr>
<td>Partial Least Square (PLS)</td>
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<tr>
<td>PLS-SEM</td>
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<td>Random forest regression</td>
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<td>Regression</td>
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<tr>
<td>SEM</td>
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<td>Laboratory (DEMATEL)</td>
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<tr>
<td>ISM-Cross-Impact Matrix Multiplication Applied to Classification (MICMAC)</td>
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<tr>
<td>Total Interpretive Structural Modelling (TISM) + MICMAC analysis</td>
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<tr>
<td>Case study</td>
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<td>Product design changes (PDC)—domain modelling</td>
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<td><strong>Total</strong></td>
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</table>
3.2.5. Country

As far as the countries under examination were concerned, 16 articles dealing with a study conducted in multiple countries were identified. Indeed, the global pandemic has been an incentive to take a broader view in research, encouraging the inclusion of multiple countries in a single study and providing a more global perspective. This is because sharing knowledge and experience accelerates the learning process and facilitates faster progress. Likewise, access to information and knowledge about possible interventions enables researchers and practitioners to benefit from the experience of others and implement more effective solutions [80]. A group of 14 articles could not be ascribed to any specific country; these studies collected data either from third-party sources or from experts in multiple countries and based their study on the entire world. Figure 5 shows the distribution of countries for the 71 articles attributable to a single country. The worldwide distribution of papers in the various countries testifies to the global aspect of the COVID-19 effects; at the same time, however, a higher concentration of studies can be found on the Asian continent. India represents the country with the largest number of published papers (11 out of 101, 10.9%), followed by China, with 7 studies; the third-ranked country is, instead, Australia, with 6 papers. Studies are evenly distributed among the various industrial contexts and macro themes; therefore, they do not differ from the rest of the world in terms of topics covered.

![Figure 5. Distribution of papers by country.](image)

3.3. Cross-Analyses

3.3.1. Macro theme vs. Industrial Sector

Figure 6 shows the cross-sectional analysis of macro theme and industrial sector. The logistics sector has a total of 20 articles, 7 of which (i.e., 35% of the papers in that industry field) deal with ICT. The full sample, including not only logistics but also other industrial fields, consists of 86 articles, excluding multiple or unspecified industries. Hence, the papers that examine jointly the logistics industry and the ICT area account for 7% of the sample. In the contemporary landscape shaped by digital technologies, several...
crucial sectors emerge that play a pivotal role in driving and growing economies [57]. One of these sectors is the transportation and logistics field [81]. Logistics companies, indeed, improve productivity, minimize errors, and reduce costs through technology innovation practices [82]. Regarding transportation, technological innovation brings greater efficiency [83], while at the same time involving environmental benefits [84]. It is therefore essential to promote the sustainable development of logistics, avoiding the indiscriminate depletion of the planet’s resources and mitigating the risk of significant environmental impacts. It is important to note that the transportation sector alone contributes nearly 25% of global greenhouse gas emissions, underscoring the urgency of adopting more environmentally sustainable practices [85]. An effective approach to balancing profit by considering social and environmental issues is to promote policies to support the adoption and diffusion of innovation [86]. In line with these considerations, four papers focus on sustainability in the logistics sector, accounting for 20% of papers concerning this industrial field and 5% of the total sample of papers.

Figure 6. Industrial sector vs. macro theme.
The food sector is widely studied in terms of resilience and sustainability [71]. The COVID-19 pandemic offered relevant opportunities to study the food system resilience and learn from the related segments that show tolerance to shocks [87]. Food system resilience is defined as the “capacity over time of a food system and its units at multiple levels, to provide sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances” [88]. Process and product sustainability, and its improvement, can help the food industry mitigate risks and enable customer satisfaction [89]. Although efficient food production and distribution systems exist, the Sustainable Food Supply Chain (SFSC) remains a challenge worldwide [89]. Three pillars are to be considered when discussing the SFSC: environmental, social, and ethical. This is also understood from the definition of Sustainable Food Value Chains (SFVCs): “The full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society, and does not permanently deplete natural resources” [90].

To be able to ensure resilience and adaptability to change [41], it is critical to identify supply chain performance measures [91,92] especially for companies that want to be better prepared for possible future disruptions [93]. Based on the above considerations, in the food sector the concept of performance assumes great importance, accounting for about 31% of the articles concerning this field and 5% of the entire sample of articles. The global economy seemed to have limped to a recovery in 2019, but the advent of COVID-19 hit every sector hard. The pandemic had a significantly negative impact, particularly evident in the food and agribusiness sector, which is a key pillar of the global economy [94]. Indeed, since the emergence of COVID-19, the supply of agribusiness products has faced significant obstacles in various countries, especially those with a precarious economic and political situation. This is due to the fact that primary activities for many people in developing countries focus mainly on enterprise systems and agriculture [95], which are also the main source of employment, income and food supply for local communities. In South Asian developing countries, for example, the agricultural sector contributes more than 20% to the gross domestic product (GDP) [96]. To mitigate the obstacles due to COVID-19, governments around the world have provided economic aids to various sectors, with a focus on agricultural sectors, as well [48].

A final important factor is the resilience of the manufacturing sector. In this respect, 41% of the papers targeting that sector deal with the concept of resilience. Supply chain resilience is “the ability of a supply chain to anticipate the risk, reduce its impact and rapidly come back to the optimized state through survival, evolution, adaptability and growth” [97]. Manufacturing companies are suffering from the bullwhip effect [10], which, especially during the COVID-19 pandemic, resulted in a shortage of finished goods due to the limited supply of raw materials caused by the lockdown [98]. A further problem is the unexpected increase in demand, particularly evident in sectors producing essential goods. For example, during the COVID-19 crisis, many manufacturers of medical masks found themselves unprepared for the rapid growth in demand, leading to widespread shortages of such products in several countries. This scenario further highlighted the importance of coping with emergency situations [99].

3.3.2. Research Method vs. Macro Theme

Figure 7 shows the cross-sectorial analysis of research method and macro theme to investigate the type of method used as a function of the macro theme studied. Several studies (≈8.9%) dealing with the macro theme of resilience have used an empirical approach. This means that the researchers have observed and analyzed real-world data and field observations to better understand this topic in practice. Related papers have analyzed how the use of concrete data and observations in the field has made it possible to better understand the impact of the pandemic on SCs and to identify strategies to address emerging challenges. For example, Stoll et al. [87] highlighted how alternative networks for
the seafood trade were able to adapt to disruptions to traditional SCs during the pandemic, underlining the importance of an empirical approach to understanding resilience dynamics in real-world settings. Similarly, Brdulak H. and Brdulak A. [55] analyzed the challenges faced by the transport and logistics sector in Poland during the pandemic, using data from online surveys to assess the impact of disruptions on business operations and to identify key areas of vulnerability. These empirical findings have helped inform business decisions and public policies aimed at improving the SC resilience. In addition, a third study proposed a model of resilient SCs based on changes in product design, demonstrating how empirical analysis can be used to develop practical solutions to address emerging challenges [100]. In conclusion, the empirical analysis of SC resilience provided insights into the strategies adopted by companies to adapt to disruptions, identifying the most pressing challenges and the most effective solutions. This has allowed organizations to learn from past mistakes and develop more effective strategies to address future challenges.

Statistical analyses, based mainly on the data collected through questionnaires and surveys, made it possible to investigate the point of view of the SCs before and after the COVID-19 pandemic and to identify significant patterns, trends and correlations. The statistical approach is also chosen in other contexts, including sustainability, economics and performance.

It is interesting to note that the studies using decision-making approaches mostly deal with the topic of resilience and, obviously, planning. In particular, research about planning is based exclusively on this approach, which allows for the making of informed and strategically oriented decisions to achieve the objectives set.

An interesting aspect to note is that the largest group of papers (12%) focuses on the topic of sustainability, coupled with statistical approaches. This suggests a growing

![Figure 7. Method vs. macro theme.](image-url)
interest in understanding and addressing sustainability challenges through quantitative data analysis, as highlighted previously.

3.4. Interrelated Aspects

Various papers in the sample include considerations about the “interrelated” aspects previously identified. More precisely, a set of 46 documents (Figure 8) include implications on sustainability, i.e., “meeting the needs of the present without compromising the ability of future generations to meet their own needs” [101]. In recent decades, due to ever-increasing industrialization, there has been an increase in pollution. In addition, industrial development has accelerated the use of nonrenewable natural resources, thus increasing the risk of their depletion. This has contributed to the definition of a common goal of sustainable development by governmental policies, to be pursued through various schemes. Companies that implement green SC management practices find positive benefits in environmental, economic and social aspects. Through the reduction in the negative consequences of industrialization, such as reduced waste production, reuse of raw materials through recycling, and reduction in water and energy waste, environmental benefits and preservation of the planet’s natural resources are achieved. From an economic point of view, such companies also benefit from greater technological innovations, reduction in production costs in the long run and ultimately, greater profitability through the adoption of lean production, or lean manufacturing strategies, with less waste and a response to customer needs in a shorter time. From a social point of view, there is evidence of improved company image, thanks, in part, to the implementation of information technologies, and higher satisfaction among end consumers who are increasingly attentive to environmental issues [43]. It follows that companies, in order to keep up with the new market demands, must offer goods with labels showing the ecological characteristics of the materials used, so as to make the customer, through his/her purchase, an actor of this environmentally friendly development, more confident in the company’s work [73]. According to some studies, environmental issues may be interpreted by some small and medium-sized enterprises as a greater financial burden because they have not yet been able to gain a long-term perspective on the effectiveness of eco-innovations [102]. However, to achieve positive results in the long run, it is imperative for every company to adopt a strategy that includes sustainability as the first goal, to be competitive and environmentally friendly. The capacity for green innovation can be developed at the production, management and logistics stages. The manufacturing industry is responsible for about 30% of the emissions of hazardous substances into the air; hence, producing and using methods and materials that are not harmful to the planet is key to achieving sustainable performance. SCM should be based on a sequence of environmentally sustainable activities, and consequently, a shift in this direction should also be noted in the logistics sector through technological innovations and the use of biodegradable and less-polluting fuel [73]. Althaf and Babbitt [103] highlighted the sustainable aspect in the electronics sector in relation to the mining of metals and minerals needed to manufacture components of ICT devices. Demand for these products has increased dramatically because of blockages due to the COVID-19 pandemic. These materials (cobalt, gallium, rare earth elements, etc.) are available in limited geographic areas only, such as Asia (especially China), and the Democratic Republic of Congo. As a result of disruptions in production and extraction activities, there have been major difficulties in the procurement of raw materials and thus in meeting the demand for smartphones and personal computers. Ecologically, mining of minerals and metals results in water pollution during upstream operations, release of greenhouse gases, and health and safety problems for the workers involved. To ensure the production and delivery of technological devices to the market, efforts have been made to transfer refining and alloy-fabrication work to other countries. In addition, studies have been conducted to concretize SC risk-mitigation strategies through remanufacturing, recycling of equipment, and replacement of these minerals with other low-risk elements such as cobalt-free lithium-ion battery chemicals [103]. The ever-increasing circulation of electronic products may encourage recycling.
operations, as these products represent a possible source of “urban mining” [104]. Figura and Gądek-Hawlena [29] found that globally, in recent decades, there has also been an increasing spirit of sustainable development in transport activities involving both goods and people. The use of electric transport means reducing harmful gas and waste emissions, consumption of nonrenewable sources, and noise pollution. Since 2020, thanks in part to the enjoyment of eco-incentives, sales of electric cars and buses have increased, resulting in the implementation of charging infrastructure. However, there has not been an adequate increase in electric-powered trucks [29].

![Figure 8. Interrelated aspects found in the sample of papers.](image)

Industry 4.0 is the second most recurrent interrelated aspect found in the papers. Unlike the sustainability implications, in this case the number of articles decreased from 2022 (21 papers) to 2023 (15 papers). The total number of studies in the three-year period is 40. Implications related to I4.0 include behaviors, activities or practices that aim to prevent or manage problems caused by the COVID-19 disruption. These topics are typically treated in papers that have ICT as the macro theme. The concept of I4.0 was first introduced in 2011 in Germany to describe the organizational revolution in terms of digitization, automation, and new technologies [105]. Industry 4.0 technologies include artificial intelligence (AI), IoT, e-commerce platforms, Machine Learning (ML) with Big Data, and virtual reality (VR). To manage and address the negative impact of the pandemic, an increase in the use of these technologies by companies was noted [106], contributing to a more resilient SC; ICT tools, through data collection, analysis and dissemination, improve performance, enabling high flexibility with reduced costs and optimal use of available resources [107]. The use of I4.0-related technologies also requires qualified and skilled personnel, so that companies can benefit from their implementation [108]. Overall, the use of these technologies enables better coordination in the SC and enhances the communication with customers; however, this is only possible in wealthy or middle-income countries because of the high costs of these technologies. In fact, Klein et al. [57], after concluding that the implementation of new technologies is a guarantee for the creation of a resilient, agile, and flexible system.
at all stages of the SC, highlighted the understandable uncertainties of small companies toward such innovations. Limited financial resources, risk that such investments will not translate into profitability, lack of knowledge for new techniques, and unwillingness to change are factors that hinder the integration of new technologies into the various stages of SC. In particular, small and medium-sized enterprises tend to exercise defensive policies such as continuing in core business and proven activities, pursuing savings rather than investments, and postponing innovative decisions while waiting for a post-pandemic economic recovery [57].

In the context of e-commerce, 23 papers have been identified. The blockages caused by the COVID-19 pandemic and the fear of contagion prompted people to opt more for online purchases, reducing visits to physical stores [109]. Online shopping became popular also for purchasing food products [64]: restaurants or cafés that implemented a door-to-door delivery service limited the negative effects of the pandemic due to business closures.

Food security is “having physical, social and economic access to sufficient safe and healthy food” [110,111]. During a crisis period, the fresh food sector is subject to more risks compared to the processed food sector. For example, during the COVID-19 pandemic there was a stagnation in sales of products such as fruits and vegetables, resulting in spoilage [64]. This involved economic damages to small farmers and caused food insecurity in consumers, due to the fear of not being able to afford to buy fruits and vegetables through traditional sales channels (e.g., a supermarket), because of the higher cost and smaller quantity available. This represents a non-insignificant hardship, especially for low-income countries. For instance, an increase in production costs was reported in Tanzania, due to the lack of agricultural inputs, such as fertilizer, which are usually imported [70]. Igberi et al. [69] conducted a study on food security in relation to the COVID-19 pandemic and climate change. They showed that the availability of materials needed for agricultural production such as seeds, fertilizers and feed, drastically decreased during the pandemic period. This resulted in a decline in agricultural production, endangering food security. The COVID-19 pandemic highlighted the importance of food accessibility as an indispensable component for meeting basic consumers’ needs. Although small farms and SCs are described, it is important to engage in the search for proactive measures regarding these realities to protect them in the case of future disruptions.

Correlations among the interrelated aspects were also explored and mapped. Venn diagrams in Figure 9 show the intersections between articles containing implications on I4.0, sustainability, food safety, and e-commerce.

Figure 9. Venn diagram of interrelated aspects.
It is notable that out of 40 papers with I4.0, 21 also include sustainability implications, covering over half of the papers with I4.0 implications and almost half of the papers with sustainability implications (46). This demonstrates a clear link between the two themes and their associated practices: indeed, several articles mention digitization combined with other I4.0 technologies as a means to increase corporate sustainability [43,70,108]. Twelve papers turn out to include both e-commerce and sustainability considerations. These two areas share some common aspects, as they are both directions in which companies are oriented to meet customer demand and enhance their image. Also, there are 12 common articles at the crossroad between e-commerce and I4.0; these articles are just over half of the total number of papers dealing with e-commerce (23). The popularity of this intersection is self-evident, as e-commerce can be rightly considered as a branch of I4.0, and both can be put into practice thanks to technological innovations. In addition, 11 of the 14 articles referring to food safety also include sustainable considerations. This is likely due to the fact that agri-food systems that were vulnerable during the COVID-19 pandemic and whose accessibility was threatened set themselves the goal of becoming sustainable [70].

Comparing the papers including I4.0 considerations with the corresponding industrial sector, it emerges that the logistics sector, with 13 papers, is the most cutting-edge one (Table 3). This result is probably due to the importance of information sharing during transportation activities; that sharing is increasingly possible in real-time, thanks to new technologies. In addition, in the maritime sector, for example, increasing emphasis is placed on the use of fully automated logistics terminals [112]. The top five industrial contexts, by number of articles, which also include sustainability considerations are shown in Table 4; again, the logistics sector is the most populous. This may be due to the increasing focus on reducing the environmental impact of logistics activities [29]. The second-ranked sector is the food industry, followed by agribusiness, with 7 and 6 papers, respectively. This confirms the relevance of agroecological models in agri-food systems in response to pandemic disruptions [65].

<table>
<thead>
<tr>
<th>Industrial Sector</th>
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<tbody>
<tr>
<td>Logistics</td>
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<tr>
<td>Manufacturing</td>
<td>4</td>
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<tr>
<td>Food</td>
<td>4</td>
</tr>
<tr>
<td>Automotive</td>
<td>3</td>
</tr>
<tr>
<td>Agri-food</td>
<td>3</td>
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Table 3. Top five industry contexts with implications for Industry 4.0.

<table>
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<th>Industrial Sector</th>
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</thead>
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<td>Logistics</td>
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<tr>
<td>Agri-food</td>
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<tr>
<td>Manufacturing</td>
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<tr>
<td>Healthcare</td>
<td>2</td>
</tr>
<tr>
<td>Electronic</td>
<td>2</td>
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</table>

Table 4. Top five industry contexts with implications for sustainability.

It is also possible to note that, even for papers including e-commerce considerations, logistics is again the most studied sector (Table 5). The logistics field is constantly evolving, with the emergence of new technologies and innovations that seek to improve the efficiency and accuracy of the relating operations. E-commerce provides an excellent platform to test and implement these innovative solutions, such as advanced tracking systems, robotics in logistics, and artificial intelligence, to optimize delivery routes [57].
Table 5. Top five industry contexts with implications for e-commerce.

<table>
<thead>
<tr>
<th>Industrial Sector</th>
<th>No. of Papers</th>
</tr>
</thead>
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<tr>
<td>Logistics</td>
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<td>Food</td>
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<td>Agri-food</td>
<td>3</td>
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<tr>
<td>Manufacturing</td>
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4. Results—Case Study

4.1. Company Overview

Company A is a small logistic operator working as an express courier. The company began its activities approx. 20 years ago, with six drivers, ensuring daily deliveries in its area of activity. Soon, the activity grew, including also parcel deliveries with high service requirements, such as delivery within a day or within three days. At present, Company A performs thousands of shipments per day, collaborates with more than 30 drivers (which can double in peak periods or on request) and has enrolled more than 10 employees.

4.2. Pre-COVID-19 Period

The pre-COVID-19 period basically refers to the year 2019. At that time, Company A owned a quality policy compliant with ISO 9001:2015 standards [113]. That policy defined the minimum requirements that the Quality Management System must demonstrate to meet for ensuring the level of product and service quality intended to be delivered to the market. Company A also defined a set of goals and corrective actions for its internal business functions. For instance, for the commercial department, in 2019 the company signed new contracts with 26 customers, including 20 “new” customers and 6 “retained” customers. The level of customer satisfaction is constantly monitored by Company A, through phone calls or direct visits to the customer’s site. In 2019, 11 non-conformities only were recorded, of which 3 related to outbound flows and 8 related to inbound flows.

As for the volumes handled, taking January 2019 as the benchmark (i.e., 100% of the items handled monthly including inbound and outbound flows), during that year Company A reached peaks of approx. 150% when approaching important holidays or sale promotion periods. The average monthly movements were 111% of the baseline.

The economic data of Company A, as retrieved from the balance sheet of year 2019, show an increase in the number of customers; the revenue from these customers was approx. EUR 30,000. Other relevant economic data include the total production value and the total production cost, both EUR >3,000,000; the company’s profit was EUR >40,000. In terms of the organizational aspects, year 2019 involved numerous changes in Company A, which had to cope with the resignation of three employees; at the end of the year, the company had a total of nine employees and thirty-five drivers.

4.3. COVID-19 Period

During the COVID-19 period (years 2020–2021), Company A had first to switch its activity towards the distribution of drugs and vaccines, which were the products most requested by the market. Those products need particular storage and transport conditions, and in particular, cold chain maintaining (from +2 °C to +8 °C). As those products were not among the kind of items originally treated by the Company, a preliminary (and important) step was to delineate appropriate procedures for drug and vaccine transportation. Those procedures defined the practices for not only the process (transport/storage) management, but also the tracing of the drugs/vaccines, and the administrative part (e.g., documents or labels). For instance, besides the legal requirements, the procedures also addressed aspects such as the share of the warehouse space or the loading/unloading bays among the drivers that arrived daily at the company’s premises in the COVID-19 period. Obviously, with it not being feasible to increase the space available or the number of bays of the warehouse, the time available for loading/unloading operations was divided into more slots of one
hour, dedicated to some activities only. Because of the high request for shipments of vaccines and drugs, the company experienced a considerable and disproportionate increase in incoming/outgoing flows; hence, great efforts were made to cope with the increased volume of items handled, which, besides requiring the procedures described above, resulted in a change from 35 drivers to a peak of 58, observed in December 2020 (which later decreased by approx. 10 units in 2021). Despite the increase in the volume of items handled, only a few non-conformities were observed in 2020, such as four relating to outbound flows and one relating to inbound flows.

Also, because of the pandemic emergency, efforts were made to sensitize customers towards the adoption of (simple) technological solutions intended to digitalize the transport process, such as electronic printing of bills or opening/closing of claims. In line with this, in the year 2020, Company A also updated the quality policy, to keep it aligned with the ISO 9001:2015 standards. From a commercial point of view, in 2020–2021 various activities which were in progress with some company’s customers were blocked, because of limitations introduced (through legal regulations) on parcel size; this caused the loss of several customers. Overall, in 2020 the company worked with 14 customers, and with 10 customers in 2021; both figures show a decrease compared to the pre-COVID-19 period. Similarly, the company’s administration changed as well in 2020–2021, with the displacement of some administrative staff; nonetheless, in 2021, the situation improved significantly compared to 2020, with the introduction of three new figures.

As far as the volumes handled are concerned, as mentioned, the company experienced an increase in the volume of items treated in 2020, particularly evident in the lock-down period and in the months immediately after; that increase reached approx. +80% compared to 2019. To be more precise, the beginning of the year (January and February) showed volumes of products similar to those of the previous year, while from March 2020, the trend for items handled experienced a significant increase, which lasted for the whole lockdown period and decreased slightly later, even though it still remained higher than the average monthly movement of 2019, and then increased again during the second wave of the pandemic (fall/winter 2020). Overall, the average monthly volume was > 50% higher than 2019; the peak was reached in December, with nearly +150% compared to 2019.

The effects of the pandemic were also evident in 2021. That year, indeed, began with a strong influence from 2020, as during winter COVID-19 continued to affect the population. The first months of 2021 were still characterized by very high volumes handled, quite similar to those encountered in the crucial pandemic period of the previous year. As the months passed, the number of movements decreased, even though they remained at quite a high level; the average monthly volume of items handled in 2021 was +30% compared with 2019 on average, with a peak reached at the beginning of the year (+95%).

The economic data of Company A in 2020, retrieved from the company’s balance sheet, confirm the presence of 14 new customers, which generated a revenue of EUR >30,000. The total production value accounted for EUR >4,000,000, while the production cost was approx. EUR 3,800,000, resulting in a profit higher than 2019 (EUR >215,000, +400%); this outcome reflects the considerable increase in the volume of products handled, as previously mentioned. In 2021, instead, a worsening in the company’s performance was observed; the main determinant for such worsening was the loss of one key customer, which involved a decrease in turnover of nearly EUR 400,000, not compensated by the ten new customers, whose aggregated income was lower (around EUR 18,000). Overall, the economic result for 2021 was slightly negative for Company A.

Looking at the organizational structure, year 2020 was somehow unusual in terms of internal dynamics, which significantly changed the way the company worked. Anyway, at the end of the year, Company A had a total of 10 employees; as already mentioned, the most significant growth was observed in the number of drivers, which increased from 35 at the beginning of the year to 58 during the peak of activity. In 2021, no significant changes were observed in the company’s structure. At the end of 2021, the number of employees
was the same as in 2020; as far as the drivers were concerned, their number at the end of 2021 was 48, with a decrease compared to 2020.

4.4. Post-COVID-19 Period

To appreciate the changes in consumers behavior as a consequence of the COVID-19 pandemic, and in particular the shift towards the usage of e-commerce platforms, a questionnaire was designed and administered to approx. 120 customers of Company A. By customers, it is meant that they placed at least one order to the company (either online or in other ways) in the last two years. The key outcomes of the survey are described in the following paragraphs.

In terms of descriptive aspects, respondents were a mix of female (52.8%) and male (47.2%). The majority of them (≈48%) were aged between 20 and 29 years, while the remaining quota (≈52%) was divided into 16.3% between the ages of 40 and 49, 15.4% between the ages of 50 and 59, 10.6% over 60, 6.5% under 20, and 3.3% between the ages of 30 and 39. Also, most of the respondents were either workers (45.5%) or students (42.3%); a small quota of 12.2% included either unemployed or retired people. As far as the level of education was concerned, 59.3% of the respondents were high school graduates, 34.3% had a bachelor’s or master’s degree, and 6.5% had a lower educational level. Almost all the respondents were located in the north of Italy. Looking expressly at the changes in consumer behavior, 97.5% of the respondents indicated that they have purchased a product online at least once. The remaining 2.5% of people, who have never used the online sales channel, were asked to indicate the reason; the answers obtained were the following: (1) no need to buy anything/never found anything to buy; (2) lack of confidence in buying a product online (i.e., without seeing it); and (3) no need to use the online sales channel. Instead, respondents that made use of the online sales channel were asked to indicate whether, during the pandemic emergency, the frequency of online shopping increased, decreased or remained unchanged. The majority of the respondents (63.3%) indicated an increase in the usage of online sales, followed by a quota of 35% who declared no changes in the usage of online sales, and a very small quota who experienced a decrease in the usage of the e-commerce channel.

In the light of the outcomes gathered from the survey, the strategy followed by Company A in the post-COVID-19 era (from 2022 onwards) included significant efforts to reinforce commercial activities, in terms of the relationship between suppliers and customers and the management of non-conformities. Looking at the commercial activities, several new customers were added to the company’s portfolio. Customers were asked to use digital systems, to reduce errors and enhance the adoption of more technological solutions. The feedback from customers was positive, with eight non-conformities only (two inbound and six outbound). Contracts with new suppliers were also signed. The number of employees increased slightly, as the company enrolled more people for the commercial/administrative staff; at the end of 2022, the number of employees was 12. The number of drivers decreased to 32, thus showing a reduction compared to 2021, but still remaining greater than that of the pre-COVID-19 period. Actions related to the quality policy were also made, by updating the related documents in December 2022, to keep them aligned with ISO 9001:2015 requirements.

As far as the volume of products handled was concerned, a slight decrease was observed overall from 2022 onwards, because of the gradual restoring of the “normal” (i.e., pre-COVID-19) conditions of various sectors, and consequently, of the company’s activity. In particular, the average number of products handled monthly was only +1% compared to 2019, with a greatest value in December 2022 (+31%). This is reflected by the economic data (for 2022) of Company A, which highlight a moderate decrease in the turnover (-4%) compared to 2021. The production value and cost were not so different (both around EUR 3,000,000), but overall, the company reached a profit of approx. EUR 6000.
4.5. Analysis and Summary

Gathering the outcomes presented in the previous sub-sections, the following synthetic considerations emerge. Looking first at the volumes of items handled by Company A (Figure 10), the trend across the four years of the timespan is somehow irregular, with peaks of demand close to holidays or sales promotion periods, followed by drops in summer months (when various activities are closed). The pre-COVID-19 period, in general, show quite a standard trend, which, excluding some months (July and December), appears as stationary. The COVID-19 period (2020–2021) shows, instead, a dramatic increase in the volume of items handled. In the first months of 2020, just before the spread of the pandemic, the volume of items handled was similar to that of the previous year; then, a sudden increase was observed from March onwards, corresponding to the months of national lockdown. Again, in summer, a slight decrease in the volumes was recorded, while at the end of the year a new increase emerged, corresponding to some local lockdown situations. Overall, the trend for 2020 highlights an increase in the volume of items moved. The second year of the pandemic (2021) was characterized by the successful usage of vaccines and the spread of less dangerous (but more contagious) variants of the virus. Hence, that year began with very high volumes of items handled, which gradually decreased with the progressive success of the actions taken against COVID-19; overall, the trend recorded for 2021 tends downward. Finally, 2022, the last year analyzed, shows a gradual return to normality, which is reflected by a decrease in movements of items; in turn, such a decrease involves the partial reduction in online purchases, as many stores were allowed to resume their activities. Nonetheless, the volumes handled in 2022 appear to be comparable to those of the pre-COVID-19 period.

![Figure 10. Trend in the volume of items handled by the case study company.](image)

From an economic point of view, the pandemic period involved a significant increase in the operating profit of Company A (Figure 11). Starting from the pre-COVID-19 period, in 2019 the company reached the highest number of newly contracted customers, with 20 new customers and 6 retained ones. In 2020, instead, contracts were signed with 14 new customers, but at the same time, some other customers were lost, mainly because of the strict regulations on parcels and shipments. Then, in the second year of the pandemic period, a new decrease in the number of contracted customers was observed, as a medium-term effect of the pandemic, but also because of the difficulties in adapting to new requests by the customers; overall, a negative outcome emerged. Finally, in 2022 the economic...
outcome was positive, even if lower than in the COVID-19 period. Overall, the best economic outcomes were obtained in exactly the first year of the pandemic.

The organization of Company A also changed from the pre-COVID-19 to the post-COVID-19 period, because of variations in the operational and corporate structure. In 2019, the staff of Company A consisted of nine employees and thirty-five drivers; two employees were enrolled and trained during the year, for insertion into the operational business unit. During 2020, the staff of the company increased in terms of employees (10 workers, with 4 of them in the operational business unit), but primarily in terms of drivers, the number of which increased from 35 to 58 (+65%), to respond to the increasing requests from customers. In the following years, the staff of Company A decreased, reaching values close to the pre-COVID-19 period. In particular, at the end of 2022, the number of workers was again 10, while the number of drivers decreased to 32.

Figure 11. Economic outcomes of Company A. Negative values have been highlighted in red.

The set of considerations above, taken together, can be summarized into a SWOT analysis, which highlights the points listed below.

- **Strengths**: at present, Company A benefits from a robust network of relationships with customers and suppliers (e.g., drivers), which was leveraged during the pandemic period to provide a rapid response to the increased request by the consumers. The company has also leveraged the usage of digital technologies, which made logistics activities more efficient and, again, allowed the company to respond to consumer demand in the pandemic period.

- **Weaknesses**: Company A has suffered from low economic results, in particular in the post-COVID-19 period, mainly due to the high production costs. Efforts must be made by the company to reduce expenses. At the same time, however, the service level, in terms of delivery lead time or on-time delivery, should be safeguarded.

- **Opportunities**: the growth of e-commerce, experienced in the COVID-19 period but expected to last over time, creates opportunities for increasing the volume of items handled by Company A. Indeed, the survey phase demonstrated that the company’s consumers have shifted towards the usage of online sales; hence, the company could consider investing in this area to increase its market share. By leveraging the e-commerce logistics and diversifying service, expansions could also be possible at an
international level. Even if the company has already embraced the implementation of
digital technologies, some emerging technologies (e.g., drones or advanced traceability
systems) could also be introduced for further improving the logistics efficiency. Finally,
sustainability is another opportunity to be leveraged, because of the current push
towards the adoption of environmental-friendly logistics solutions. Examples of those
solutions include a reduction in CO$_2$ emissions, and the usage of electric vehicles or
zero-impact materials.

- Threats: the growth of e-commerce can be seen as an opportunity, but because many
logistics companies have already entered this field, the sector is characterized by very
high competition, which could limit the market share of Company A; this could instead
be seen as a threat needing to be properly managed. Another threat comes from the
increased cost of fuel, which, for sure, for a logistics company plays an important role
in determining the cost of the transport activities (also, having previously observed that
the company suffered from a limited revenue in recent years). This factor could further
push towards the adoption of environmentally friendly transport modes (e.g., electric
vehicles), which have been previously mentioned as an opportunity for leveraging in
the logistics sector.

5. Conclusions
5.1. Answer to the Research Questions

Through a two-step analysis, this paper has deepened the analysis of the impact
of the COVID-19 pandemic on the logistics and SC processes. As the first step, starting
from a previous study [30], a comprehensive literature review, supported by statistical
elaborations, was carried out with the aim of delineating scientific evidence on the subject.
Then, as a second step, a case study was conducted to explore the impact of the COVID-19
pandemic on a real logistics company. The outcomes of the study allow us to provide the
following answers to the RQs of the study.

- RQ1 (scientific): How have researchers studied the impact of COVID-19 on logistics
and supply chain processes? Which industrial sectors were mostly studied and why?
Which additional topics can be related to COVID-19 and logistics/supply chain?

The statistical analyses carried out on the sample of papers reviewed immediately
highlighted that the transport and logistics sector was the most investigated field with
respect to the impact of COVID-19. The interest towards the transport and logistics sector
stems from various factors. First, a shift in consumers towards the e-commerce channel
was observed in the COVID-19 period, which forced logistics companies to adapt to this
new context or to reinforce their activity in that market. Also, uncertainty caused by the
pandemic emergency pushed consumers to buy more products (both in traditional and
online retail channels), which again caused an increased demand for transport and logistics
activities. The review also highlights the fact that additional topics have been investigated,
together with the COVID-19 impact; this is the case of ICT tools, I4.0, and sustainability. In
particular, ICT tools and I4.0 solutions play an important role in transport and logistics field
as a suitable response to the COVID-19 pandemic. Logistics companies can indeed leverage
digital tools for improving productivity and reducing errors and cost of their processes.
Sustainability is a further important topic, motivated by the need for performing logistics
activities with reduced environmental impact.

- RQ2 (practical): What effects of COVID-19 on logistics and supply chain processes
were experienced by companies?

In line with the fact that the transport and logistics sector was one of the most studied
in the literature with respect to the COVID-19 impact, the case study was conducted
in a logistics company working as an express courier, with the aim of analyzing the
company’s activity before the COVID-19 outbreak, then in the COVID-19 period, and in
the post-COVID-19 era. The outcomes of the case study confirm the scientific evidence, in
various points. First, from the pre-COVID-19 to the post-COVID-19 period, the company
experienced a significant change in consumer behavior, with almost all its customers declaring that they had used online sales in the last year and that they had increased the usage of the e-commerce channel as a consequence of the COVID-19 pandemic. This forced the company to enhance its activity in the electronic market, which, from a practical perspective, was achieved by significantly increasing the number of drivers in the COVID-19 period and reinforcing the usage of digital technologies. In economic terms, the company experienced an increase in its sales volume during the COVID-19 pandemic; the “positive” effect of the pandemic emergency progressively decreased starting from 2021, and in 2022, the pre-COVID-19 conditions were almost restored in terms of volumes. In economic terms, however, a worsening of the company’s performance was observed. This could be a common issue for transport and logistics companies, partially motivated by the increase in the cost of fuel, but also by the relevant number of companies that have entered the e-commerce market in the COVID-19 period, thus making it more difficult to achieve competitive advantage in this field.

5.2. Scientific and Practical Implications

From a scientific perspective, the outcomes of this study contribute to the literature in two main ways. The systematic literature review offers a comprehensive analysis of the COVID-19 topic in SC and logistics, together with a view on additional topics which appear to be related to the COVID-19 pandemic. Sustainability, in particular, emerged as a relevant interrelated aspect, followed by I4.0; the relevance of these topics was also confirmed by the case study outcomes. The case study, indeed, provides evidence of the response of a real logistic company to the COVID-19 pandemic, by examining its activities from the pre-COVID-19 to the post-COVID-19 period; as such, it also sheds some light on the role of transport and logistics companies and the medium/long term after the pandemic. The specific outcomes are partly aligned with evidence in the literature, but they also go beyond the available knowledge. In particular, the impact of COVID-19 on logistics and SC processes in the medium-term has been investigated by Rinaldi and Bottani [16]. These authors have highlighted the fact that the transport and logistics field was somehow unique compared to other sectors, as it did not need to adopt specific countermeasures against COVID-19, and was one of the few sectors experiencing an increase in the volume of activity. As far as the post-COVID-19 period is concerned, however, the literature which is available provides less evidence, even if some studies have indicated that in the medium term the activity of the transport and logistics sector was still greater than in the pre-COVID-19 period in terms of volumes [16]. This study adds knowledge in this respect, as the case study company was analyzed also in the post-COVID-19 period (up to the end of 2022), providing further evidence.

Looking forward, some practical recommendations could be elaborated. For sure, the transport and logistics sector should continue leveraging the usage of digital/I4.0 technologies, which make logistics activities more efficient, allowing them to respond to the consumer’s demand and, hopefully, even to reduce cost, which is a prerequisite for remaining competitive on the market. Enhancing sustainability is, for sure, another leverage for competitiveness, due to the increasing push towards the adoption of environmentally friendly logistics solutions.

5.3. Suggestions for Future Research Directions

Starting from this study, some limitations and, thus, future research directions can be delineated. First of all, it is to be mentioned that research on COVID-19 and logistics/SC is far from declining, and thus, in general terms, this study is expected to fuel additional discussion on the topic. More specifically, this study has highlighted various topics related to COVID-19, such as I4.0, ICT tools, or sustainability; however, it must be emphasized that these topics can also be seen as limitations, as they may not have been covered in depth or exhaustively in the present paper (and were actually out of the scope of this study). Their relationships with COVID-19 could therefore benefit from a deeper investigation, for which
either taking the form of a literature review or of empirical research could be suggested. Looking instead at the outcomes of the case study, the investigation was limited by a short post-COVID-19 time span (i.e., approx. the year 2022). It is recommended that future research activities investigate the transport and logistics sector in a longer post-COVID-19 period with a dedicated empirical approach. Additional sectors could be included in the analysis as well, given the fact that scientific studies about different sectors are mainly limited to the medium-term impact of COVID-19. As a closing comment, even if we are now in the post-COVID-19 era, research on the COVID-19 impact should not be seen as outdated. Indeed, COVID-19 was actually a special case of SC disruption, and thus, the evidence provided by this study, as well as additional evidence that could be provided following the stated suggestions for future research activities, could probably be valid when analyzing other disruptions and could provide useful insights for companies and the academic community.

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