




## Article

# Logistics Trends and Innovations in Response to COVID-19 Pandemic: An Analysis Using Text Mining

Niels A. Zondervan <sup>1,†</sup> , Frazen Tolentino-Zondervan <sup>2,†</sup>  and Dennis Moeke <sup>2,\*</sup> <sup>1</sup> Wallet Recovery NL, 6709 TB Wageningen, The Netherlands<sup>2</sup> Research Group Logistics and Alliances, HAN University of Applied Sciences, 6826 CC Arnhem, The Netherlands

\* Correspondence: dennis.moeke@han.nl

† These authors contributed equally to this work.

**Abstract:** The disruptions caused by the COVID-19 pandemic have forced many companies in the logistics sector to innovate, or even transform their business and underlying processes. Closing borders, limited supply and manpower, and continuous changes in regulations challenged many logistics firms to innovate. This study analyzes 5098 abstracts of logistics articles using text mining to identify and to quantify the changes in logistics trends and innovations before and during the COVID-19 pandemic, and if these trends and innovations were accelerated by the COVID-19 pandemic. Results indicate that (1) resiliency is an ongoing trend in logistics and has shown increasing importance during the COVID-19 pandemic; (2) there appears to be acceleration in digitalization trend in logistics based on emerging focus on blockchain, Internet of Things, data, drones, robots, and unmanned vehicles during COVID-19 pandemic, and (3) there seems to be no evidence of acceleration in sustainability due to COVID-19 despite an observed shift in sustainability trends in terms of bioenergy and biofuel before COVID-19 pandemic to low-carbon, hydrogen and electric vehicles during COVID-19 pandemic. This paper recommends logistics firms, especially Small and Medium Enterprises (SMEs), to analyze their readiness to adopt digitalization in terms of data, resources, and technology via, e.g., the use of a maturity scan, to contribute to sustainable and resilient logistics and to make sure that they remain competitive and future-proof. Policy makers can provide support to these SMEs by providing information, funding, and template solutions.

**Keywords:** COVID-19; digitalization; logistics; resiliency; sustainability; text mining



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## 1. Introduction

The COVID-19 pandemic has brought huge disruptions and challenges to supply chains, affecting many industries worldwide. For instance, in various countries, healthcare systems have been under extreme levels of stress due to the capacity issues such as shortage in personnel, equipment, and space in hospitals and the poor governance of infections [1–3]. Many airlines suffered huge losses and bankruptcies because of increased travel restrictions and uncertainties posed by changing regulations [4]. Recreational industries such as restaurants, hotels, and gyms were also hit by huge losses due to implemented lockdowns to curb the spread of infections [5].

The logistics sector is also experiencing risks and challenges brought by COVID-19 pandemic. Crossing border of goods became much more complex due to imposed lockdowns at national and international levels, hampering logistics operations and causing delays in delivery of goods. A decline and shortage of logistics service providers (LSPs) for transporting goods were also observed, especially at the beginning of the pandemic [6]. Many manufacturing companies were forced to close plants due to government regulations, thereby reducing the supply of goods. Other companies shifted their focus on manufacturing in-demand products during COVID-19. In the global logistics transportation alone, the

value of losses in revenue due to COVID-19 pandemic is estimated to be 1.1 trillion euros in 2020 [7].

The COVID-19 pandemic has also affected, both positively and negatively, the adoption of innovation in the logistics sector. On the one hand, authors have argued that the COVID-19 pandemic sped up the transformation and innovation in the logistics sector, e.g., [8–11]. Online businesses blossom since the start of the pandemic and lead to increased need for innovations in logistics to deliver goods to consumers [8]. Companies have also recognized the need to adopt robust and resilient supply chains and logistics by making them smart, digitalized, and sustainable during the COVID-19 pandemic [9,10]. For example, in airline industries, COVID-19 led to innovations such as the utilization of touchless technologies at airports, the use of ultraviolet light (UV) for disinfecting aircrafts, and the use of biometrics to accelerate check-in processes [11]. COVID-19 is also reported as a main driver behind the adoption of digitalized and data-driven solutions in LSPs [6]. On the other hand, some authors reported that many logistics companies still struggle to innovate mainly due to the obstacles brought by COVID-19, e.g., [12,13]. Even though many EU countries have adopted the use of digital freight documents during the pandemic, a few countries have not yet switched to digital freight documents, causing bottlenecks in the operational processes of the LSP sector [6]. For Small and Medium Enterprises (SMEs), their capacity to innovate has been limited due to their size, ownership structure, and vulnerability to external shocks such as the pandemic [13].

The literature studies show that the COVID-19 pandemic led to innovations in the areas of marketing, technologies, and collaborations, e.g., [14–16]. Other studies have also explored the innovations brought by COVID-19 among logistics service providers and airline [6,11,12,17]. Authors of these studies employed either qualitative or quantitative methods. Although there is research available that use text mining to analyze the impact of COVID-19 on businesses [18] and on COVID-19 research in general [19], to our knowledge, there is no research published to date that specifically examines the impact of COVID-19 on the logistics sector using text mining approach. This paper fills this gap in the literature.

The purpose of this paper is to identify and quantify trends and innovations in logistics and whether they accelerated during the COVID-19 pandemic. Two questions are addressed in this research. First, what are the sustainability and digitalization trends and innovations in the logistics sector before and during COVID-19 pandemic? Second, did the COVID-19 pandemic accelerate the shift towards resiliency, sustainability, and digitalization to achieve smart logistics? These questions are answered by analyzing abstracts of 5098 logistics articles published between 2016 and 2021. We use text mining to identify the trends in the logistics sector worldwide and to quantify the significance in these trends before and during the COVID-19 pandemic. Text mining is a data science technique for discovering and quantifying patterns in text from records/files, social media, and other sources of information [20]. Statistics, visualizations, and text analyses were used to identify and quantify the differences in trends when comparing the pre-COVID-19 period of 2016–2018 with the COVID-19 period of 2019–2021. The results and insights of this study can help firms to recognize and cope with changing trends and can be used by policy makers to identify areas that might require support.

## 2. Literature Review

The COVID-19 pandemic revealed the vulnerability of many businesses that rely on traditional way of operating [11]. This enhanced the demand for business innovations to cope with the challenges brought by the COVID-19 pandemic. Innovations are not only related to the introduction of new products such as goods or services to the market, but also to the improvements and advancements in the business processes, procedures, and routines [21]. However, there are opposing views when it comes to the response of firms to innovation during a crisis. Some studies argue that hardships and crises, such as the COVID-19 pandemic, incentivize companies to innovate to cope with the shocks and effects of the crisis [11,21]. Other studies suggest that crises reduce and discourage

firms to invest in innovations as many innovation activities become unsustainable [12,22]. Following the first point of view, this paper assumes that overall, the COVID-19 pandemic has encouraged (or even forced) companies in the logistics sector to innovate their business and underlying processes.

Innovations play an important role in keeping supply chains and the underlying logistics processes viable, especially in times of disruptive events such as COVID-19 pandemic. As defined by Ivanov and Dolgui [23], viability is the ability of the system to cope with demands of surviving in a changing environment. Viability is an important aspect for businesses to survive, avoid market collapses, and secure provision with goods and services [23].

Resiliency, sustainability, and digitalization are key concepts towards viable supply chains and logistics [9]. These key concepts have emerged through time and have been individually studied by scholars. The COVID-19 pandemic period demonstrated that the (potential) added value of these key concepts should be considered in conjunction. Figure 1 shows the evolution of these concepts and the ways in which it leads to the development of smart logistics and supply chains. Ivanov [9] argued that logistics and supply chain viability can only be achieved by approaching the resiliency, sustainability, and digitalization at an holistic perspective and not individually. This paper uses the concepts of resiliency, sustainability, and digitalization found in Figure 1 to analyze the trends and innovations in logistics before and after the onset of COVID-19 pandemic. The remainder of this section elaborates these concepts.

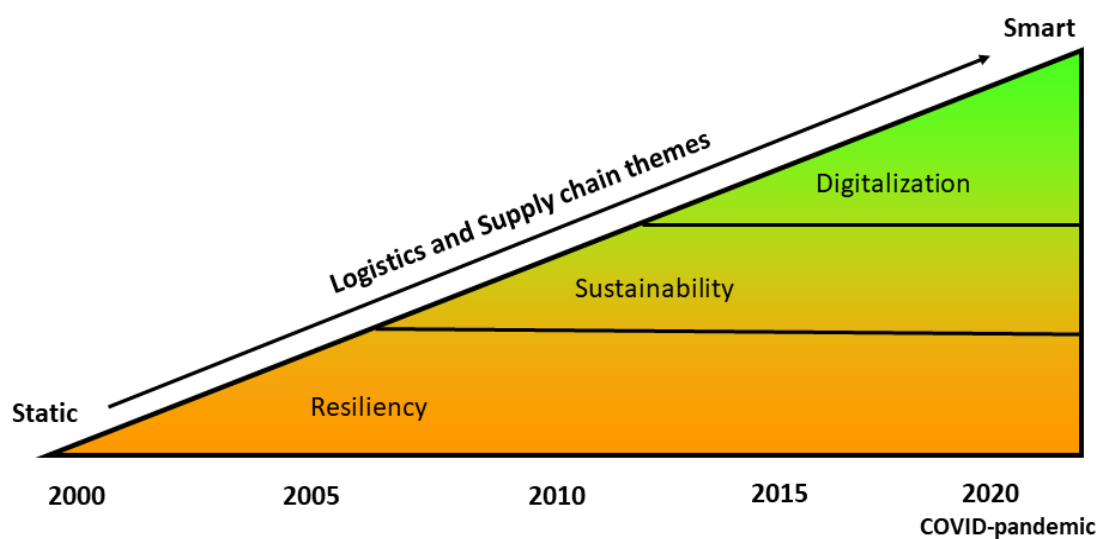


Figure 1. The evolution of the three key concepts based on Ivanov [9].

Resiliency refers to the ability of an entity to adapt to both positive and negative shocks and disruptions caused by both internal and external environments [24]. The first studies on resiliency in the context of supply chains and logistics, which are still of relevance today, date back to the early 2000s [9,25,26]. The resiliency of the chain relates to visibility, managing risks, and reducing the complexity of networks [27].

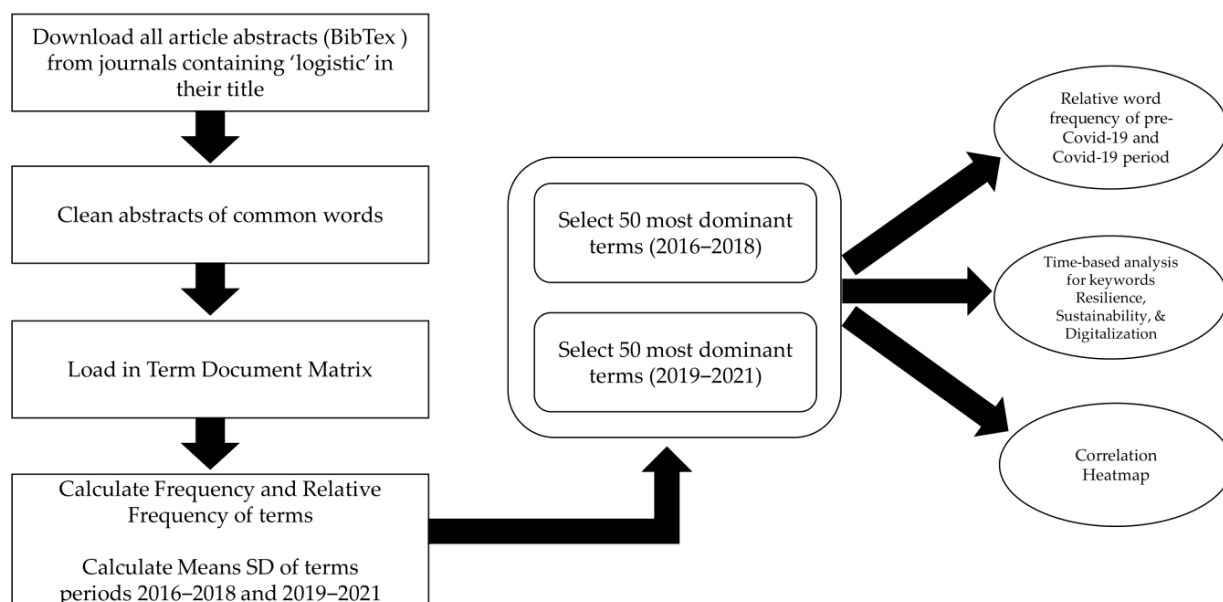
The resiliency of supply chains and logistics processes can be enhanced via sustainability strategies. Sustainability plays an important role in reducing the environmental impacts of commercialization and industrialization and in reducing inefficiencies and wastes in the operation. The era of sustainability in supply chains and logistics started around 2010 [9]. The early focus on sustainability revolves around three themes, namely reverse logistics, emission assessment and the greening of logistical activities and supply chains [28]. Specific examples under these sustainability themes include reduced CO<sub>2</sub> emissions of freight and transport companies, using green packaging, bundling goods, optimizing routes, using spaces more efficiently and reducing wastes in processes [29].

As the definition of sustainability continues to evolve, the social and economic aspect of sustainability also began to be incorporated in the study of sustainability in relation to supply chains and logistics [30]. Social topics include the incorporation of corporate social responsibility such as fair trade and wages, good employment practices, good working conditions, and responsible relationships with suppliers and customers. Economic aspects include the maximization of shareholder wealth or value while taking into consideration the environmental and social values.

Digitalization has also been linked to transforming supply chains and logistics towards a more sustainable and resilient state than before [31]. The availability of digital solutions, data and computing powers makes it possible to model and analyze logistics in an integrated and more detailed manner. Specifically, digitalization has potential impact to reduce CO<sub>2</sub> emissions from logistics, empty drives, fuel consumption and number of vehicles to deliver goods to consumers [31,32]. Although digitalization has been an ongoing topic for decades, the era of digitalization that includes Industry 4.0 and Data Analytics only started to dominate the field of supply chain and logistics since the beginning of 2015 [33,34]. Digitalization in logistics includes implementation of new information technologies such as Internet of Things (IoT), blockchain, simulation, sensors and the use of generated data to make logistics smart [35]. The advantages of digitalization in logistics include but are not limited to real-time and full transparency of information across the supply chain, decentralized and interconnected processes, and self-governing management that includes automation [32].

### 3. Methodology

Figure 2 shows the schematic diagram of the methodology of this study. It illustrates the workflow of the conducted text mining analysis, which includes selecting articles, conducting statistical analysis, and the output figures. The next subsections explain the detailed steps in the schematic diagram.



**Figure 2.** Schematic diagram of the text mining workflow.

#### 3.1. Article Search

The Science Direct advanced search function was used to find articles published in journals that contain “logistics” in their title and that were published in the years 2016–2021. Citation information of these articles was downloaded in BibTex format. The BibTex citation data was parsed using the Python 3.7 and pybtex version 0.24.0. The R tm package was used to load the article abstract and metadata and to perform text mining. Article citation

data including article abstracts were retrieved and filtered on articles containing at least a title, abstract and doi. This amounted to 5098 logistics papers published in the period of 2016–2021. The 5098 papers represent all available literature in logistics and were used in the analysis to prevent bias. To support our aim of understanding the impact of the COVID-19 pandemic on trends and innovations in the logistics sector (regarding resiliency, sustainability, and digitalization), we divided articles into two periods: (1) 2016–2018, which represents the pre-COVID-19 period, and (2) 2019–2021, representing the COVID-19 period up to the date of writing.

### 3.2. Data Analysis Using Text Mining

We performed text mining using R 4.1.2, tm version 0.7–8 package, dplyr 1.0.7 and DataCombine 0.2.21. Visualizations were performed with ggplot2 version 3.3.5 and pheatmap version 1.0.12. Abstracts were loaded as text corpus, converted to lower-case and filtered on common English stop words, punctuation, and special characters. The cleaned-up corpus was used to build a Term-Document matrix. The Term-Document matrix was used to count the relative word frequency over all article abstracts.

To prepare the data for analysis, we first removed words that occurred infrequently. Hence, words with a relative word frequency below 0.01 were removed. Next, we calculated the relative frequency of words defined as  $relative\_freq\_periods = \log\left(\frac{relative\_freq\ Covid-19}{relative\_freq\ pre-Covid-19}\right)$  and ranked the words in descending order by their relative frequency. We then plotted the 50 words with the highest ranking, words most dominantly present during pre-COVID-19 period, and the 50 words with the lowest ranking, words most dominantly present during the COVID-19 period. Then, we calculated the Standard Deviation of the Word frequency as  $\frac{p*(1-p)}{\sqrt{N}}$ .

We used the 100 words we identified in the comparison of trends and performed a time-based analysis by counting for each publishing year the relative word frequency (Supplementary File S1). The outcome was supplemented with additional words associated to the three concepts, resilience, sustainability, and digitalization. Next, we fitted a trendline with 95% confidence interval to identify significant trends in word frequency. The objective of this analysis was to gain a more fine-grained understanding the trends with respect to the three concepts. By plotting the relative frequency of terms per year, we could see if the occurrence of terms were part of an ongoing trend independent of the COVID-19 period, or if these trends emerged or were accelerated during the COVID-19 period. Although a change in trend does not prove causality, it is an indication that the COVID-19 pandemic might have influenced the trend.

To obtain in-depth insights about the words that are dominantly occurring during the COVID-19 period, we perform a correlation analysis. We selected the 80 words with the highest relative frequency (most abundant) during the COVID-19 period as seed for a new Term Document Matrix to identify associated words. We plotted a heatmap of the Euclidian distance between terms, showing clusters of correlated words which have a lower Euclidian distance.

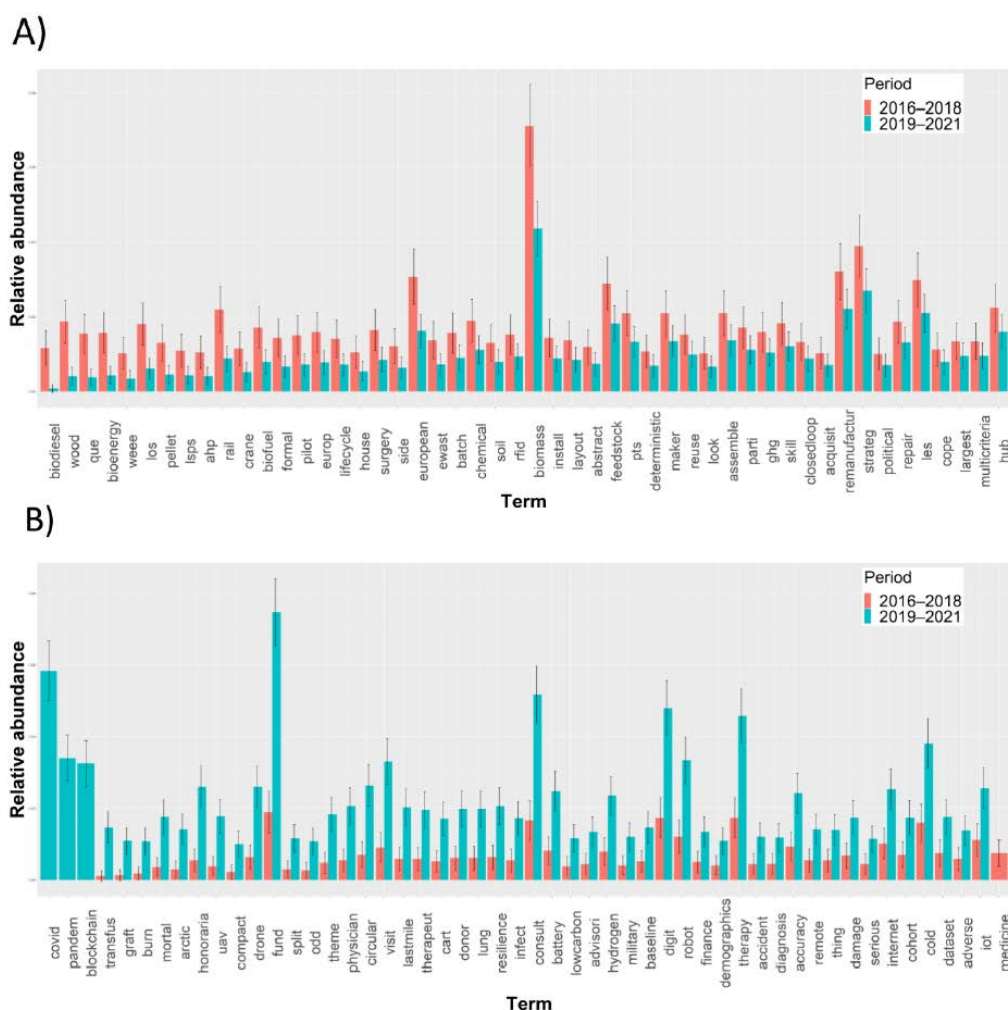
## 4. Results

The results are divided into three sections. First, we compare the relative word frequency in the two periods to show the pre-COVID-19 and COVID-19 trends and innovations in logistics. Second, we present the outcome of the time-based analysis to evaluate the significance of the trends and innovations identified before and after the COVID-19 pandemic. Third, we present the terms that cluster together in the COVID-19 period based on a correlation analysis of the abstracts.

### 4.1. Comparison of Trends and Innovations in Logistics before and during COVID-19

Figure 3 presents the 100 words with the largest difference in relative abundance between before and during COVID-19 pandemic time frame. The red color in the figure indicates the before-COVID-19 years (2016–2018) while the blue color represents the

during-COVID-19 years (2019–2021). The relative word frequency shows a clear difference between words trending before and after the start of the COVID-19 pandemic. In Figure 3A, word frequency indicates a strong focus before COVID-19 on (1) sustainability via “bioenergy”, “biomass”, “bio-fuel”, “wood”, “lifecycle”, “e-waste”, “closed-loop”, “remanufacturing” and “reuse”; (2) single market and logistics of “soil”, “feedstock”, “chemical”, and (3) Logistics Service Provider (LSP) such as “rail” and “crane”. There is also a strong focus on “medicines” due to the global shortage of medicine in years 2016–2017; see, for example, [36,37].



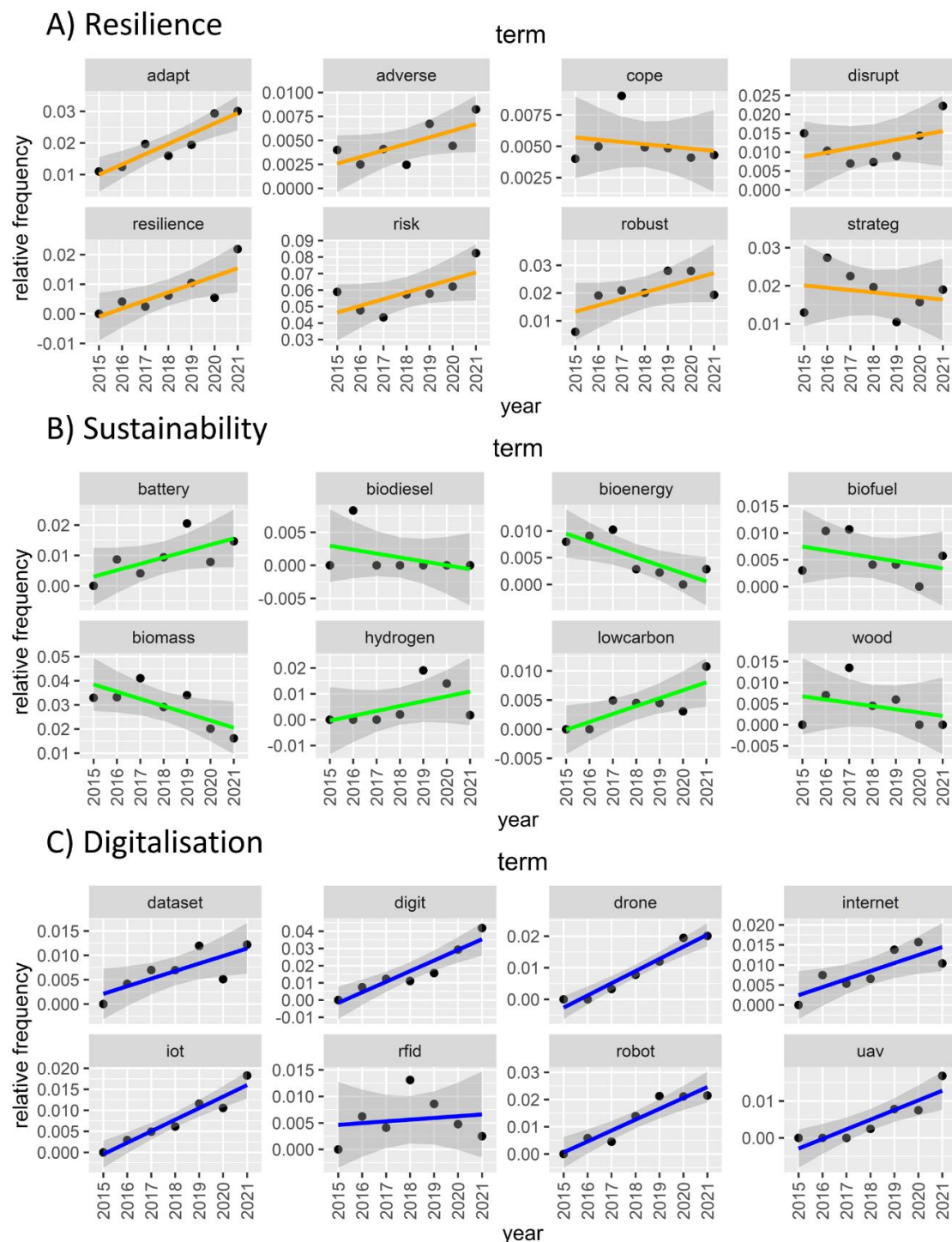
**Figure 3.** The relative word frequency of 50 words with the largest difference in relative abundance in the pre-COVID-19 (A) and 50 words with the largest difference in relative abundance during the COVID-19 period (B). The error bars show the 95% confidence interval.

Looking at the resulting key terms during COVID-19 pandemic (2019–2021) in Figure 3B, three main categories were identified. The first is related to sustainability, which is indicated by strong focus on keywords such as “low carbon”, “hydrogen”, and “batteries” (electric). The second is related to digitalization in logistics, which is related to keywords such as “blockchain”, “dataset”, “IoT”, “internet”, and “digit”. The third is related to automation and last mile logistics based on keywords such as “robot”, “remote”, “drones”, “uav” (Unmanned Aerial Vehicle) and “last-mile”.

#### 4.2. Time-Based Analysis of Trends in Terms

Figure 4 shows the trends in the terms of resiliency (Figure 4A), sustainability (Figure 4B), and digitalization (4C). The lines represent the linear trend lines with the gray

areas representing the 95% confidence interval. A complete overview of the time-based analysis of all the 100 terms can be found in the Supplementary File S1.



**Figure 4.** Time-based analysis of terms representing (A) resilience keywords (orange trend line), (B) sustainability keywords (green trend line), and (C) digitalization keywords (blue trend line).

When it comes to resiliency (Figure 4A), our results show that there is an increase in logistic disruption as indicated by the keywords “disrupt”, “adverse” and “risk”. At the same time, there is an increase in occurrence of keywords associated to resilience such as “adapt”, “robust”, and “resilience”. More loosely associated keywords such as “cope” and

“strategy” are not showing a clear pattern. The “disrupt” keyword is hyperbolic, with peak in 2016 and 2021.

Regarding sustainability (Figure 4B), there is a shift in attention from wood, biofuel, bioenergy, biodiesel and biomass towards battery and hydrogen powered and a focus on low-carbon emission in logistics. However, we see that this trend is not clearly linear, nor can we see a change in trends since the onset of COVID-19. The increased focus on sustainability and a shift towards battery and hydrogen power might therefore be independent of COVID-19.

If we look at the terms associated to digitalization (Figure 4C), we do, however, see indications that this trend is accelerated by the onset of COVID-19. Keywords such as “dataset”, “digit”, “drone”, “internet”, “iot”, “robot”, and “uav”, which did not occur before COVID-19 as indicated by zero frequency, have dramatically increased, and show linear trends. Only the “rfid” keyword has a hyperbolic trend.

#### 4.3. Correlation and Clustering of Terms

Figure 5 shows the analysis of the correlation between words in abstracts. Due to the limited size of the abstracts, only small correlation clusters can be identified. Looking at the right side (or bottom) keywords, the first main cluster of words of interest is logistics digitalization, which start from keywords “internet” to “transform”. The second cluster is the last mile logistics automation, which include keywords such as “rapid”, “drone”, “uav”, and “compact”. The third cluster is related to global developments, specifically in medical field. This is illustrated by clustering of keywords such as “treat”, “consult”, “physician”, “COVID” “donor”, “graft”, “lung”, etc. Finally, the fourth cluster of keywords is related to sustainability, with words such as “arctic”, and “hydrogen”.

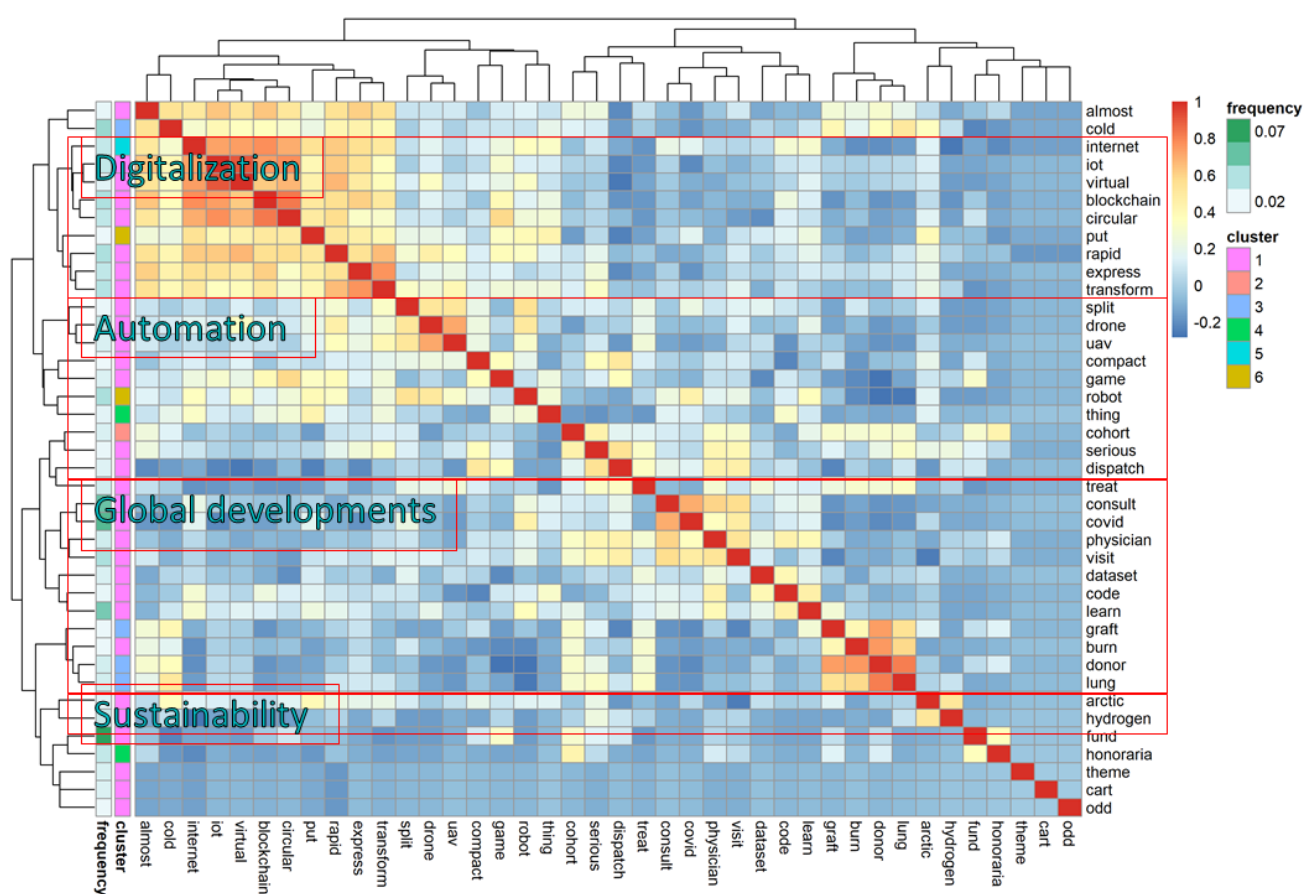


Figure 5. Heatmap of the correlation of 80 most abundant words in the 2019–2021 COVID-19 period.

## 5. Discussion

Below the results of the analysis are discussed in relation to the concepts of resiliency, sustainability, and digitalization in logistics.

### 5.1. Resiliency in Logistics

Consistent with the study of Ivanov [9], our results show that resilience is an ongoing theme in logistics based on the outcome of the linear trends before and during the COVID-19 pandemic. The focus on resiliency-based keywords such as “disrupt” is more prominent in certain years, which could be explained by macro-economic factors and worldwide events. For instance, supply chain disruptions in the years 2015–2016 have been very high due to a number of natural disasters such as earthquakes and big typhoons that hit Southeast and East Asia [38]. At that same time, catastrophic event such as the explosion of the port in Tianjin, which is considered as the top 10 busiest ports in the world, impacted and caused disruptions to the supply chains of many multinational corporations [39]. The focus on supply chain resiliency has further increased in years of COVID-19 due to the disruptions and risks that the pandemic brought to logistics operations.

### 5.2. Changing Sustainability Focus and Last Mile Logistics

The results do not indicate a significant change in sustainability trends before and during the COVID-19 pandemic. The primary focus on biobased renewable fuels before the pandemic decreases after the onset of COVID-19 pandemic, while there is a shift towards low-carbon, battery powered (electric), and hydrogen vehicles as alternative to fossil fuels in logistics during the COVID-19 pandemic. These results could probably be explained by two reasons.

Firstly, relevant factors such as policies and research interests on sustainability have already been existing before the arrival of COVID-19 pandemic. Therefore, they could also be the influencing factors for the change in the sustainability trends. For example, the transport sector is known to be one of the main contributors of carbon emission so the European Commission introduced the Green Deal to move the transport sector towards zero emission strategies by 2050 [40]. Part of the Green Deal policies include the use of shared mobilities, the low-carbon, electric, and hydrogen vehicles and the use of city hubs to reduce CO<sub>2</sub> emissions of the transport sectors, e.g., [41–43]. Policy makers, transport industries, and academic institutions have been collaborating to address the sustainability issues in logistics related to climate change (CO<sub>2</sub> emission) and inefficient use of energy resources [44].

Secondly, the COVID-19 lockdowns have also shown positive sustainability effects due to less air, land, and water travels. Improvements in air quality due to less environmental pollution, traffic, and CO<sub>2</sub> emissions have been observed during the COVID-19 pandemic [45]. Moreover, there has been a rapid growth of online retailers during the COVID-19 lockdowns worldwide. This resulted in innovation in last mile logistics, such as the use of electric bikes and drone deliveries, to enable transportation of goods and services to consumers [8]. This move towards digitalization in last mile logistics during the COVID-19 period is also identified in our correlation analysis (Cluster 1) and goes together with automation of last mile logistics (Cluster 2). Cluster 1 contains, in addition to digitalization keywords, words such as “circular”, “rapid”, “express” and “transform” which indicate the rise of these technologies is linked to sustainability and is rapidly transforming the sector. The second cluster contains in addition to automation keywords “split”, “compact” and “thing”, indicating the automation and use of drones is mostly linked to last mile logistics of compact cargo where delivery can be split and to the use of Internet of Things.

### 5.3. Digitalization for Innovation in Logistics

Consistent with several studies, e.g., [46,47], this study shows an acceleration in adoption of digitalization in logistics during the COVID-19 pandemic. Even though the era of digitalization started to arise before the COVID-19, the limitation of face-to-face contact

and transactions as well as the inefficiency and increasing costs in logistics operations have intensified the need for digitalization during the COVID-19 pandemic. Many industries have reported the need to implement digitalization such as blockchain, Internet of Things (IoT), Artificial Intelligence, and Big Data to adapt to COVID-19 pandemic. These include, for example, the (1) use of digital application to optimize logistics and capacity planning for vaccination during COVID-19 [48]; (2) use of blockchain in shipping and ports to trace goods, reduce inefficiencies due to long paper works, and reduce disputes in logistics of goods [49], and (3) use of Artificial Intelligence and Big Data to identify passengers including their health conditions and luggage controls to facilitate efficiency in human logistics in urban railways and airports [11,50]. Big firms can more rapidly adapt to digitalization, while SMEs still find it challenging to completely adopt digitalization due to limitations in financial and human resources [51]. This is exemplified by the six biggest global companies which all have digital technology at the heart of their business model [34]. The needs for SMEs to be digitally ready are twofold. Firstly, SMEs are an important backbone of the economy. For instance, approximately 36% of employment in the European Union comes from the SME's, therefore making them important for domestic economic growth. Secondly, many big firms are dependent on SMEs, and as such are also dependent on their adaptation of digitalization; otherwise, they will be in danger of being outcompeted by companies that do have SMEs in their supply chain that adopted digitalization [52]. Therefore, digitalization of SMEs is important for competitiveness and future proofing of the whole industry. The digitalization trends that were observed could stay for either short- or long-term time horizon. According to DHL [53], trends that are relevant in less than five years horizon include big data, IoT, Omni-channel logistics, and cloud logistics while trends that are relevant in more than five years horizon include unmanned vehicles, self-driving vehicles, self-learning systems and grey power logistics.

## 6. Conclusions

This study analyzed 5098 logistics articles from the three years before and the three years after the start of the COVID-19 pandemic. Some major changes in logistics trends have been identified such as (1) a move from biofuel and bioenergy towards battery and hydrogen-powered energy, (2) a move to digitalization of logistics using blockchain, IoT, datasets, and (3) a move towards automation using drones, robots, and unmanned vehicles, especially in last-mile logistics. Furthermore, the results show that the attention for resiliency is steadily increasing through time, especially during the COVID-19 pandemic. The results also indicate a significant acceleration of digitalization in logistics during the COVID-19 pandemic. This is in contrast to sustainability in logistics. Clearly, digitalization is a worldwide trend that logistics companies cannot ignore if they want to remain competitive and to survive in the sector. Similarly, resiliency and sustainability are trends that cannot be evaded, especially due to macro-economic factors such as climate change, Ukrainian–Russian war, and shifting consumers and political demands for more sustainable production and supply chains.

Based on our findings, we urge companies to analyze their readiness to adopt the three ongoing trends of resilience, sustainability and, in particular, digitalization, which is an accelerating trend. Especially Small and Medium Enterprises (SMEs) must make sure that they remain competitive and future-proof, e.g., by performing a maturity scan regarding of their digital readiness. Policy makers can provide support to these SMEs by providing information, funding, and template solutions.

Further research might include the text mining analysis of the full text of the 5098 logistics papers analyzed. A full text analysis could be used to find more correlations between terms and to provide context of the trends identified by this study. Further research might also include separating articles on the GEO location, continent, country, or the specific logistics sector being discussed. Such an analysis, although daunting, might provide an even more fine-grained picture of which countries and which logistics sectors are spearheading these new logistics trends.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/pr10122667/s1>, Figure S1: Time-based analysis of 100 words with the largest relative word frequency different between pre-COVID19 and during the COVID-19 period.

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