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THE RIPPLE EFFECT - IMPLICATIONS AND CONSEQUENCES OF INCIDENTAL DISRUPTIONS AND BLACK SWAN PHENOMENA IN THE SUPPLY CHAIN

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Abstract

Global supply chains are one of the key components of the economy. Any disruption in their functioning can have implications for the global economic situation. Phenomena known as black swans have transformed supply chains. In addition, unforeseen incidental events have contributed to an increasing global ripple effect, the implications of which are unpredictable for all supply chain participants. Black swans have contributed to the increased use of digitalisation and automation processes, combined with algorithms to predict trends in an uncertain market. Models and concepts hitherto used to manage supply chains have become useless, and phenomena previously described as unlikely to occur have become part of reality. The intensification of the risks identified is related to the lengthening of supply chains, decreasing reliability of supply, lack of visibility and transparency of individual processes. New ways and methods of managing supply chains should provide a solution to these and identified problems. Supply chains have become more complex over recent years, becoming key elements of competitiveness for many companies. But their interconnected, global nature also makes them increasingly vulnerable to a range of risks and failures.Recent years have shown that the resilience of supply chains to global shocks and changes has been shaken. It is therefore important to examine how chains have changed, the implications of global shocks and what actions need to be taken to strengthen the resilience of new business models. The aim of this study is to analyse the scope, implications and possible consequences of these phenomena in supply chains. A bibliometric method will be used to realise this objective, using tools to support visualisation and inference within the phenomena under study).

Keywords: ripple effect, global supply chain, black swan, co-occurance analysis

1. INTRODUCTION

The ripple effect and black swans events, referred to in the literature as incipient disruptions, have increasingly become an issue for supply chain managers in recent years, with a huge impact on each company and the oprational, tactical and strategic decisions taken on a daily basis. Due to the global economy and interconnectedness, the negative impact of the indicated indicative events carries a high risk of being affected by events that until recently were described as theoretical, impossible to occur and the probability of their occurrence was described as negligible. Recent indirectional events that have had a ripple effect or black swan occurrence are the Covid-19

pandemic and the outbreak of war in Ukraine. Particularly the first event, which was unexpected and at the same time affected almost everyone on the globe, has shown the huge role that supply chains play in today's economies and the key role they play in international trade. Any disruption has serious economic, economic and social implications. Aware of the risks, it is therefore necessary to take measures to minimise the risk of their occurrence or to minimise the possible effects of, for example, ripple effects.

Building a supply chain resilience system must include many interlinked elements. The systems, tools and instruments used so far are not fully effective. Mechanisms should therefore be employed to offset ripple effects or to protect chains from black swans.

2. THESIS, RESEARCH GAPS AND METHODOLOGY

Using research methodologies related to scientometrics, especially in the context of visualisation and co-occurence mapping, specific analyses were carried out in relation to the identified research gap to investigate trends in scientific publications related to the emergence of ripple effects and black swans and their impact on the functioning and management of supply chains. Both of these phenomena have appeared in the literature relatively recently, so it is interesting from a scientific point of view to indicate whether and to what extent and in what area the interest of researchers in these topics is changing. In order to clearly and comprehensively show the changes taking place in science and, above all, in the number of scientific publications on this topic, the mapping of science in terms of bibliometric analysis is used in this article (Maia, et. al. 2019) with usin VOSviewer (Noyons, E. C., Moed, H. F., & Luwel, M. (1999). N.J. Van Eck, L. Waltman (2010). The tool used is not new, however, it shows changes and trends in the phenomenon under study in a very illustrative way, thanks to the science mapping system. The research was based on a systematic literature review (Tranfield, D., Denyer, D., & Smart, P. (2003).

The research gap detrmined the data for the study, its limitations and possible discussion. The myodolgy of the study was based on the criteria indicated by the Zhao, D., & Strotmann, A. (2015). In accordance with the methodology indicated there, four research steps were carried out, including:

- Definition of keywords
- Photomatisation and cleaning of data (from repetitive sources or sources that do not meet boundary conditions)
- Performing a preliminary analysis
- Performing the final analysis.

The research was based on the Scopus database, using a search covering: title, abstract, keywords. The selected database allows for citation analysis and includes journals from the Web of Science database (Falagas, M. E., Pitsouni, E. I., Malietzis, G. A., & Pappas, G. (2008). The survey was conducted in April 2023, the data for 2023 is therefore limited to 4 months of the year indicated. Reserach framework included: searching TITLE-ABS-KEY, scientific mapping analysis: Citation analysis, Co-authors analysis, Co-occurance analysis, performance analysis: The numer of publications, Types of research, Geographical position, Timeline analysis, Name of journlas, Author citation.

With regard to the analysis, selected bibliometric indicators were taken into account in relation to keywords, authors and the clusters created on this basis. Changes over time were also shown. In order to realise the research objectives, the following thesis was established. The research areas and the scope of the topics covered in supply chain management in recent years are increasingly linked to the ripple effect and black swans. This can be seen both in the increasing number of publications containing the indicated words chosen for analysis, as well as in the links between authors and the geographical locations in which the publications are produced. There is an upward trend, which can be interpreted as an increased interest in the phenomena concerned,

an increased incidence of their occurrence and the need to take action to find opportunities and ways of mitigating their risk.

The bibliometric analysis method is used in supply chain research in a variety of contexts (Anugerah i in. 2022; Cancino i in. 2019; Hashemi i in. 2022; Malacina, & Teplov, 2022; Majiwala & Kant, 2022; Montecchi i in., 2021; Martins & Pato, 2019), with regard to interference (Rinaldi i in., 2022; Simonetto i in., 2022; Nimmy i in., 2022 and to a limited extent to the ripple effect (Hosseini & Ivanov, 2020) and black swans (Manning, L., Birchmore, I., & Morris, W. (2020). Dengyuhui Li e. At. (2023), Zhang, Y., et. al. (2022). Zarghami, S. A., & Dumrak, J. (2021)..

The discussion will present an analysis related to the impact of incidental disruptions such as ripple effect and black swans on the supply chain in the context of building resilience and better and more efficient management of chains. The analysis allows conclusions to be drawn and further work and research directions to be identified in this area.

3. LITERATURE BACKGROUND

The unpredictable scaling of the simultaneous spread of disruption in supply chains through its many tiers is referred to as the ripple effect/disruption propagation, or ripple/wave effect (Ivanov & Dolgui, 2020; Dolgui & Ivanov, 2021, Mishra i in., 2021). Disruptions previously unaddressed and unidentified as supply chain risk factors have affected many organisations in recent years, complicating existing strategies and activities related to how to manage risk in supply chains. Such a sudden disruption, an incidental event not previously expected or considered when creating mechanisms to build resilience in chains, can significantly damage many elements and links in supply chains in the long term (Wang i in., 2021; Li i in., 2021). The ripple effect can contribute to the negative effects of disruption starting to spill over into other supply chains (Monostori, 2021; Scheibe & Blackhurst, 2018). Such an effect is identified when the impact of the disruption on upstream participants cannot be localised and, at the same time, the negative effects of the disruption spread throughout the chain and negatively impact downstream participants (Ivanov i in., 2019a; 2019b). In an operational context, it can be said that one operational failure causes operational failures in other entities (Li i in.; 2021). Their scope, area is increasing due to the complexity of the supply chain, time and efficiency pressures (Mishra i in., 2021). The impact of such actions can contribute to reduced revenue and income, profits, loss of profit sharing (Mishra i in., 2021), the disruption of supply chains, the need to reconfigure them and make changes to build a new management strategy. The context of black swans (Zarghami, S. A., & Dumrak, J. (2021) zaczyna odgrywać coraz większą role także w łańcuchach dostaw. A black swan is an 'unknown' whose existence cannot be recognised or anticipated (Manning, L., Birchmore, I., & Morris, W. (2020) . Black swans are future circumstances, events or outcomes that cannot be predicted, planned for, or even know where or when to look for them" (Gleadale, 2011, p.10). The concept of unknown unknowns, i.e. risks that are specifically recognised as unknown or unknown and unpredictable and have an impact on decision-making.

4. DATA ANALYSIS

The research process was performed according to the specified analysis steps. The SCOPUS database identified the keywords that were to be used in the analysis. Iteratively, data selection was performed. It was important to divide the study into two aspects: ripple effect and supply chain and black swan(s) and supply chain. Limitations of the study: peer-reviewed journals, texts written in English, The range of information needed was exported as plain text for bibliometric analysis. It included titles, abstracts and keywords (Ji i in., 2021).

Publications from 2011 to 2023 (until 30.04.2023) were selected. When searching for the data needed for the analyses, the following were taken into account: "title, abstract, keywords",

found in the already indicated SCOPUS database. Document types were limited to: "ar", "ch", "cp", "re", "bk". In terms of fields and areas of publication, after analysis of individual articles found there, due to the lack of links to the main topic of the study, this scope was limited and publications from subareas were excluded:

"CHEM","BIOC","IMMU","MEDI","EART","MATE","ARTS","PHYS","PSYC". Analizie TITLE-ABS-KEY the following keywords were subjected to: (TITLE-ABS-KEY (supply AND chain) AND TITLE-ABS-KEY (ripple AND effect)) AND (EXCLUDE (SUBJAREA, "IMMU")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p") OR LIMIT-TO (SRCTYPE, "k")) AND (EXCLUDE (PUBYEAR, 2011) OR EXCLUDE (PUBYEAR, 2010) OR EXCLUDE (PUBYEAR, 2009) OR EXCLUDE (PUBYEAR, 2008) OR EXCLUDE (PUBYEAR, 2007) OR EXCLUDE (PUBYEAR, 2006) OR EXCLUDE (PUBYEAR, 2005) OR EXCLUDE (PUBYEAR, 2003)).

The choice of keywords was based on an analysis of previous publications in this area. This search identified 188 papers in research area “ripple effect” and 38 in the area “black swan(s), there were directly related to the scope of this review.

4.1. Performance analysis – selected aspects

The next stage of the analysis was to examine the links between the 'supply chain' with: "black swans" and "ripple effect". The scope of the analysis in both cases was limited to the years 2012-2023, due to the fact that this year was the first time that both concepts occurred in association with the supply chain. Figure 1 shows the frequency of occurrence of the related concepts between 2012 and 2023.

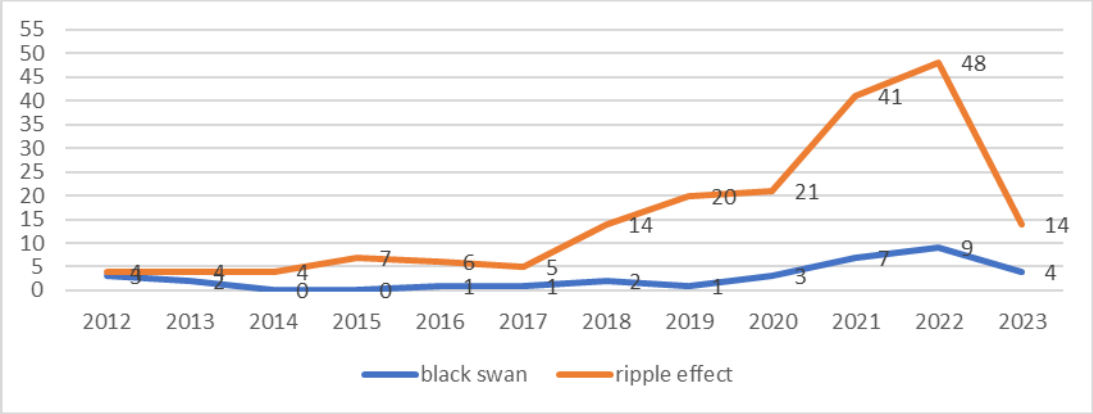

Figure 1 Change in the number of publications from 2012 to 2023 (2023 only until 30.04.2023)

Analysing Figure 1, it can be seen that the number of publications is changing, so there is definitely an increase in interest in both types of concepts on an annual basis. A definite increase can be seen from 2020 onwards, i.e. from the first significant incident that affected the entire global economy.

Another element of the analysis is the indication of the country of affiliation of the authors who deal with the indicated topics (Figure 2). In this analysis, it can be seen precisely that researchers from as many as 71 countries are interested in the indicated topic. Figure 2 shows the countries with at least four indications in one of the areas. The remaining countries are indicated in Table 1 (3 countries were identified as unidentified, in both areas)

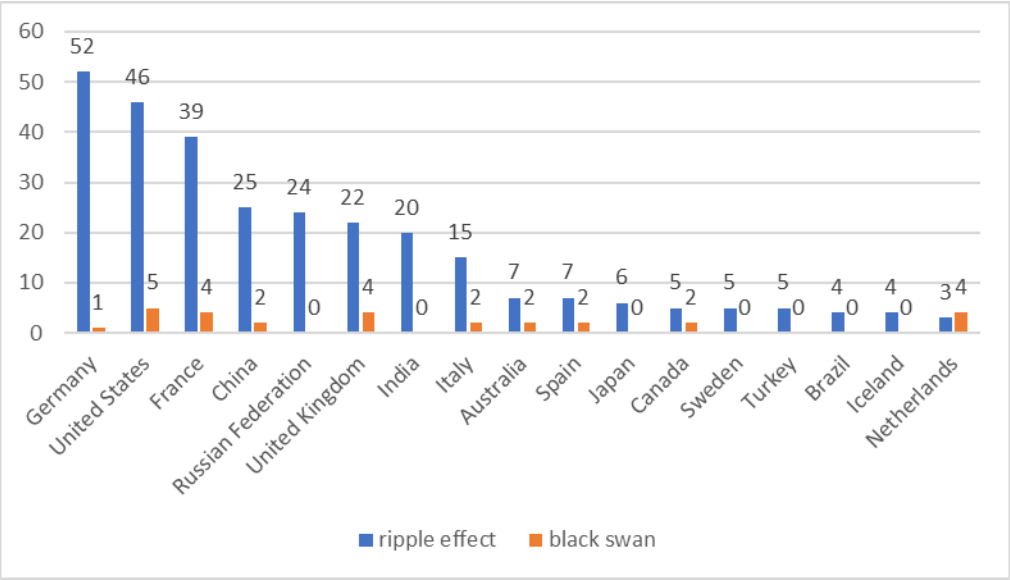

Figure 2 Number of articles in selected countries (min. 4 articles in one area)

To complete the analysis, other creations with fewer than 4 publications are also indicated (Table 1).

Table 1 Number of articles in selected countries number 3 and below

	Number of articles		
	3	2	1
ripple effect	Netherlands, Austria, Denmark, Iran, Ireland, Norway, Philippines, Poland, Saudi Arabia, Singapore, South Korea	Algeria, Bangladesh, Greece, Hong Kong, Hungary, Malaysia, Mexico, Pakistan, Portugal, Qatar, Slovenia, South Africa, Sri Lanka, Switzerland	Albania, Argentina, Chile, Croatia, Ecuador, Egypt, Faroe Islands, Finland, Ghana, Indonesia, Israel, Kazakhstan, Latvia, Mauritania, Morocco, Nepal, New Zealand, Thailand, Tunisia, Viet Nam
black swans		Italy, Australia, Spain, China, Canada	Singapore, Iran, Slovenia, Switzerland, Morocco, Austria, Kuwait, Malaysia, Nigeria, Pakistan, South Africa, Turkey, United Arab Emirates, Bangladesh

On the other hand, in figure no. 3 you can see the research centers from which the first author of the publication came. Subsequent institutions had only 2 or fewer articles. (pokazano tylko ripple effect). In terms of "black swans events", the leading institutes are: INSEAD, Europe and Tilburg University with 3 articles each, and Università Politecnica delle Marche, International University of Rabat and Tilburg School of Economics and Management with 2. The other institutions have 1 each.

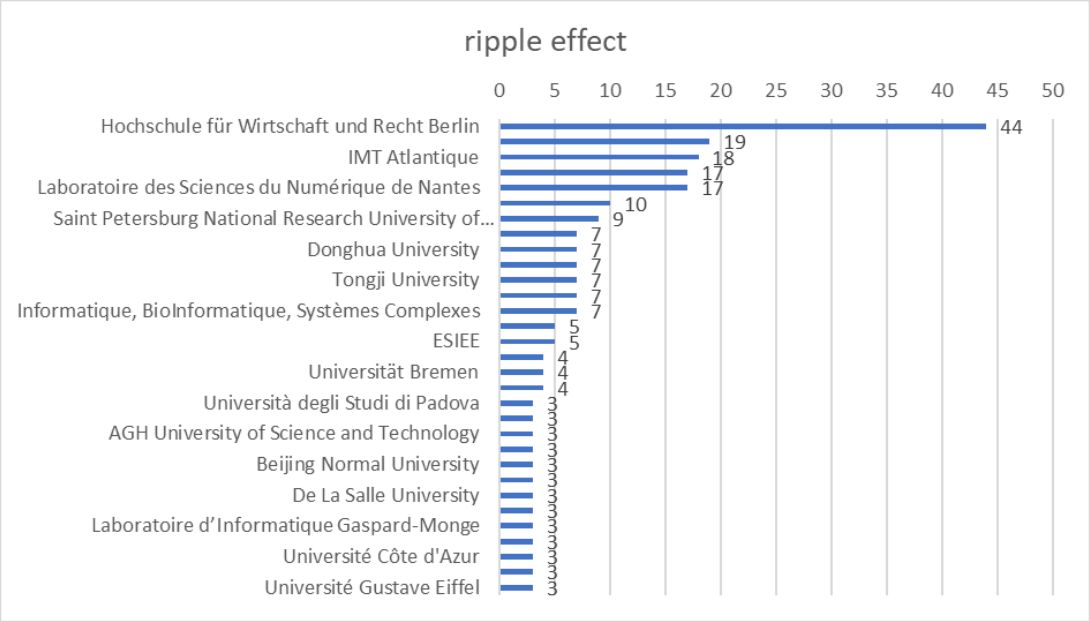

Figure 3 Articles from selected institutions (ripple effect).

An interesting element of the analysis is the number of publications in terms of number and percentage, but including the type of publication source, whether it is an article, a conference publication (indexed) or a book chapter. A visualisation can be found in Table 2

Table 2 Distribution of document types

Document type	Number of publications Black swans	Percentage	Number of publications Ripple effect	Percentage
Article	24	73%	137	73%
Conference Paper	9	27%	36	19%
Book chapter	0	0%	15	8%

Table 3 presents the16 most productive journals (excluded conference papers) that have published articles connecting supply chain with ripple effect and black swans.

Table 3 Journals – most productivity

	Supply Chain ripple effect	black swans
1	International Journal Of Production Research	International Journal Of Production Research
2	International Series In Operations Research And Management Science	Annals Of Operations Research
3	Annals Of Operations Research	Asia Pacific Journal Japan Focus
4	International Journal Of Production Economics	Benchmarking
5	International Journal Of Integrated Supply Management	Circuit World
6	Journal Of Cleaner Production	Communications In Computer And Information Science
7	Omega United Kingdom	Emerald Emerging Markets Case Studies
8	Transportation Research Part E Logistics And Transportation Review	Frontiers In Pharmacology
9	European Journal Of Operational Research	Industrial Marketing Management
10	International Journal Of Disaster Risk Reduction	International Journal Of Diplomacy And Economy
11	International Journal Of Environmental Research And Public Health	International Journal Of Emerging Markets
12	International Journal Of Physical Distribution And Logistics Management	International Journal Of Operations And Production Management
13	Plos One	International Journal Of Quality And Reliability Management
14	Process Integration And Optimization For Sustainability	Journal Of Supply Chain Management
15	Supply Chain Forum	International Journal Of Quality And Reliability Management
16	Sustainability Switzerland	Journal Of Supply Chain Management

4.2. Analiza ripple effect - knowledge maps

Given the limitations to the indicated 188 related publications in the ripple effect and 38 associated with the black swan(s), in-depth bibliometric analyses were performed using VoSviewer software creating Knowledge Maps.

a) Analysis of Co-occurance - all keywords

For better visualisation and readability of the maps in terms of the selected publications, a minimum number of occurrences of 10 was set, resulting in 1445 phrases with 19 keywords combined with others. Figure 4 shows the map along with identified clusters, for the most frequent keywords meeting the analysis boundary conditions. The words related to the broad scope of ripple effect, supply chain and their connections (risk, disruption, decision-making and various ripple effect and supply chain bifurcations understandably appear).

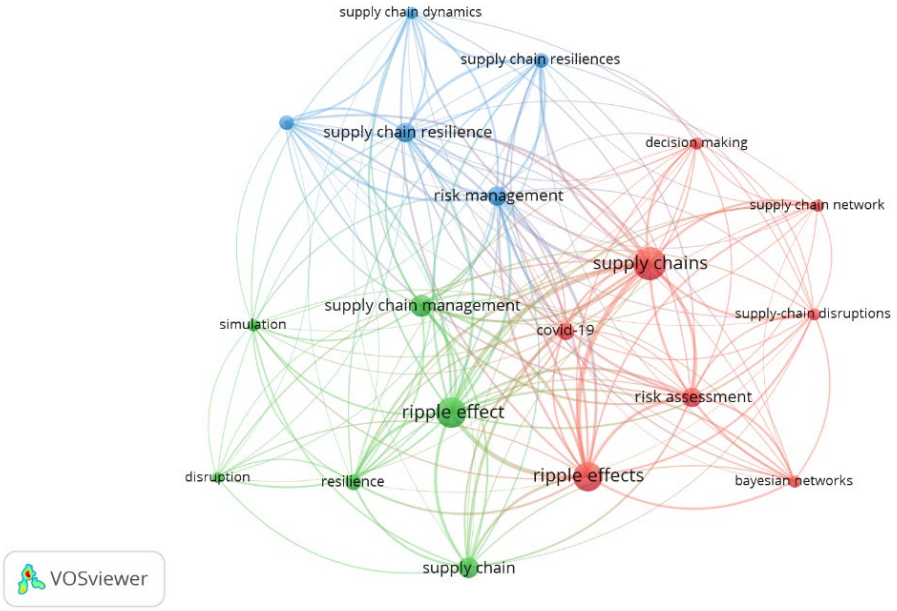

Figure 4 Ripple effect – co-occurance-all keywords analysis

All the keywords presented in the map that are part of the 3 clusters have connections, reflecting groups of emerging research themes in the area indicated

The temporal dynamics of this area are presented in Figure 5.

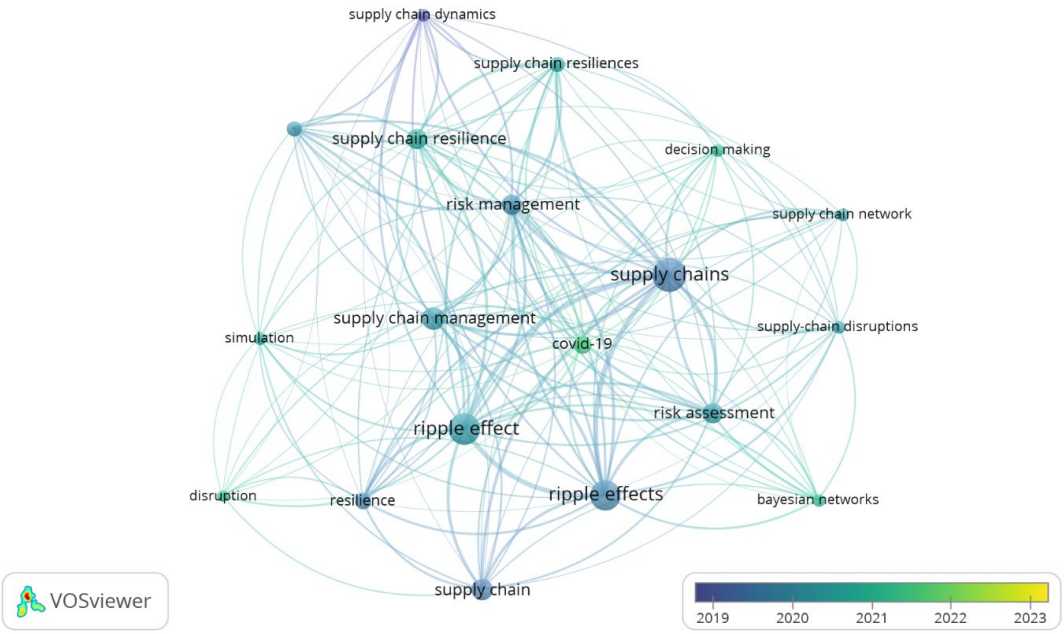

Figure 5 Ripple effect – co-occurance-all keywords – timeline analysis

Within the scope of this analysis, the 5 minimum number of occurance of a keyword is already 62 keywords related in 6 clusters, having 856 links.

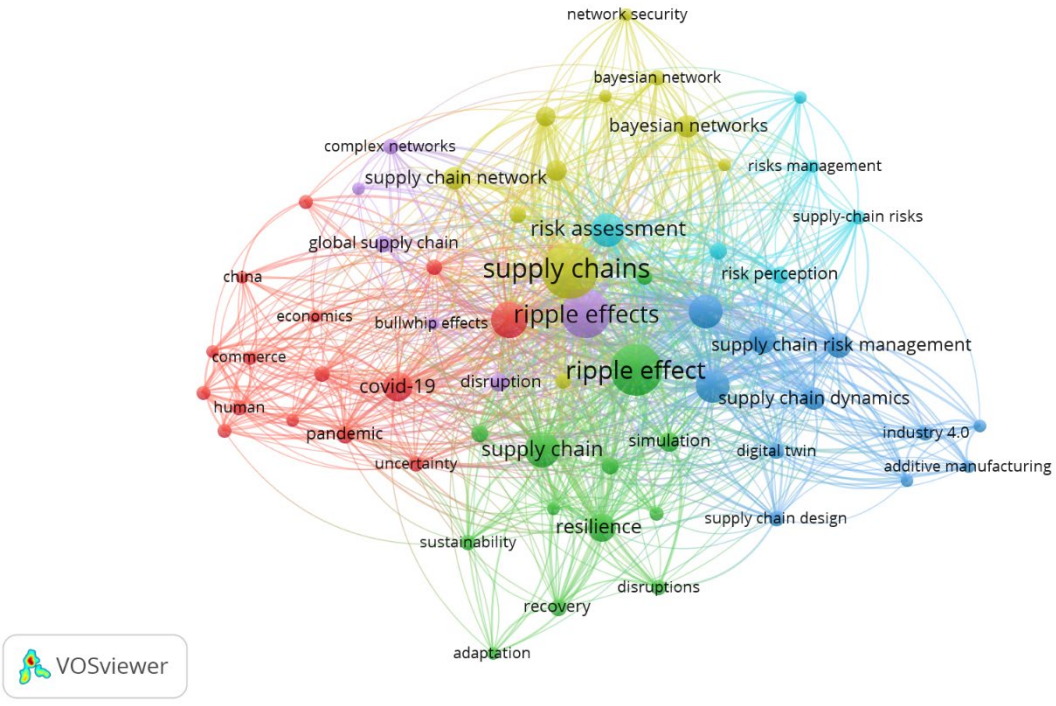

Figure 6 Ripple effect – co-occurance-all keywords analysis (5 minimum numer of occurance of a keywords)

The analysis presented in Figure 6 already clearly shows a higher density and not only a higher number of keywords, but also their connections. This clearly indicates the wide range of interest in the research topic.

b) Analisys of co-occurance and index keywords

Within the scope of this analysis, 1065 words were found, the analysis was limited to a minimum number of occurance of a keyword of 10 and 14 keywords were found that met the requirements and boundary conditions. (Figure 7).

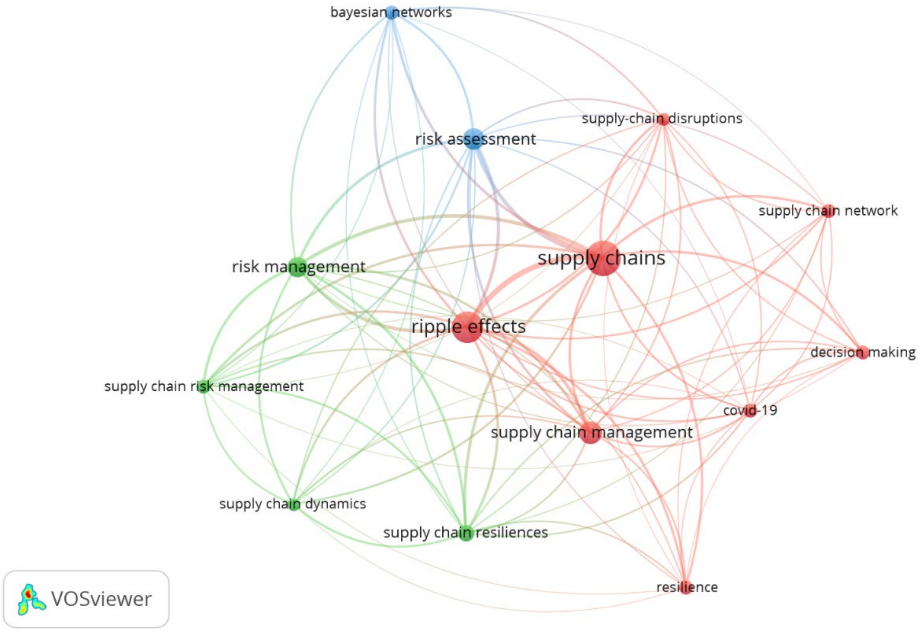

Figure 7 Co-occurance and index keywords – (first analysis)

This restriction proves to be too detailed, very limiting, but on the other hand it clearly shows that the "ripple effect" is linked to the supply chain, its resilience, decision-making or risk management.

When reducing the restriction to 5 minimum number of occurance of a keyword, there are already 45 keywords related in 5 clusters, having 471 links (Figure 8)

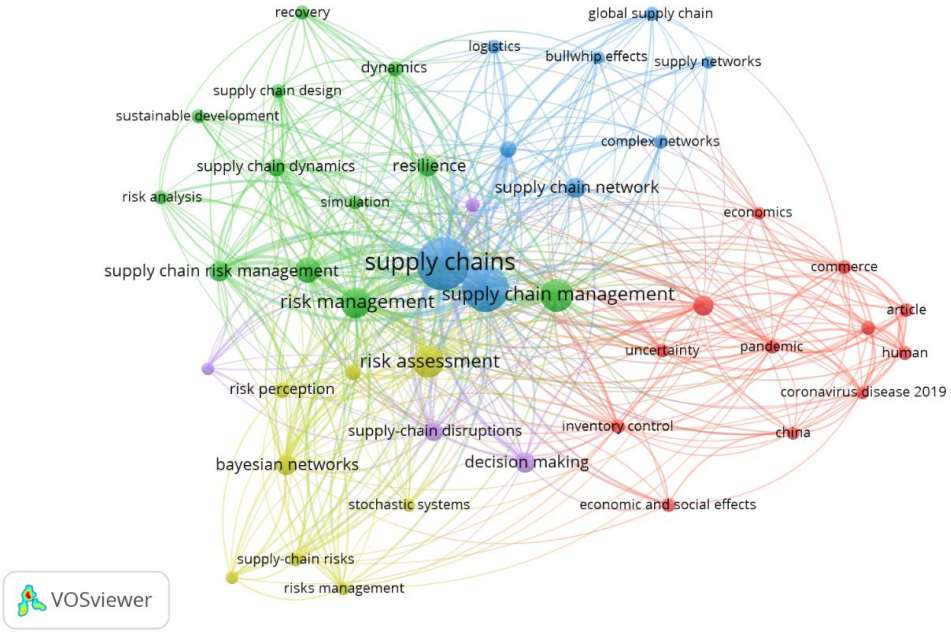

Figure 8 Ripple effect - Co-occurance and index keywords – (second analysis)

c) Analysis of co-occurance and author keywords

In this limittions, the analysis indicates 558 keywords, with 24 words remaining limited to the 5-word linkage, occurring in 5 clusters with a linkage count of 126. (Figure 9)

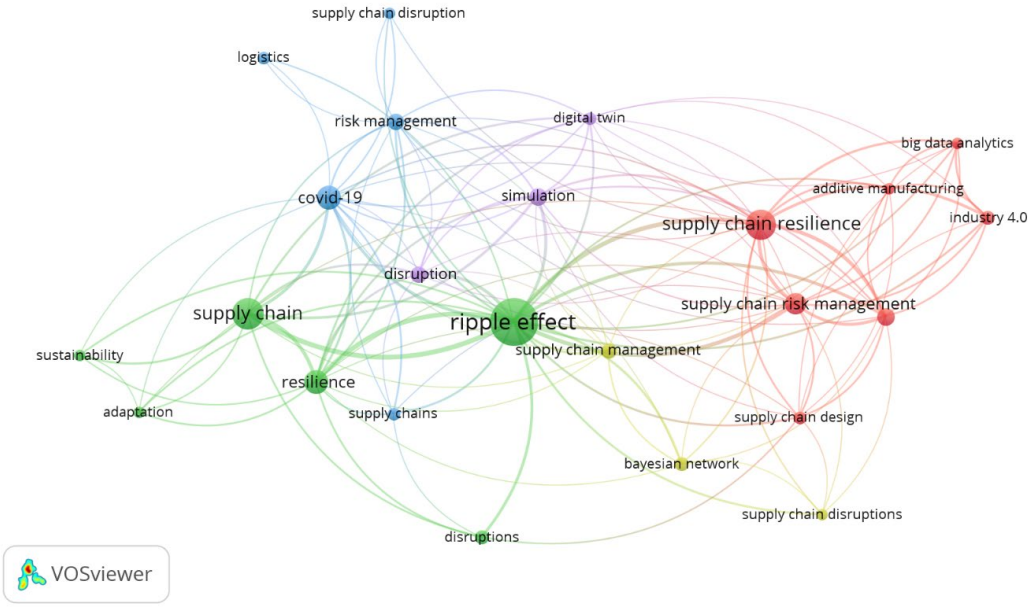

Figure 9 Ripple effect - Co-occurance and author keywords

d) Analysis of co-authorhips - author

Given the limitation to the indicated 188 publications, keywords were selected for the individual maps and analyses, which formed the lexical map in the next step. For co-author-author analyses, a minimum number of occurrences of 2 was set, in terms of minimum number of documents of an author, withouth corelation between citation, resulting in 451 authors, of which 55 were linked. The analysis shows that some of the authors have no links. The largest set of conected items consist of 27 items. Figure 10 shows only authors with related

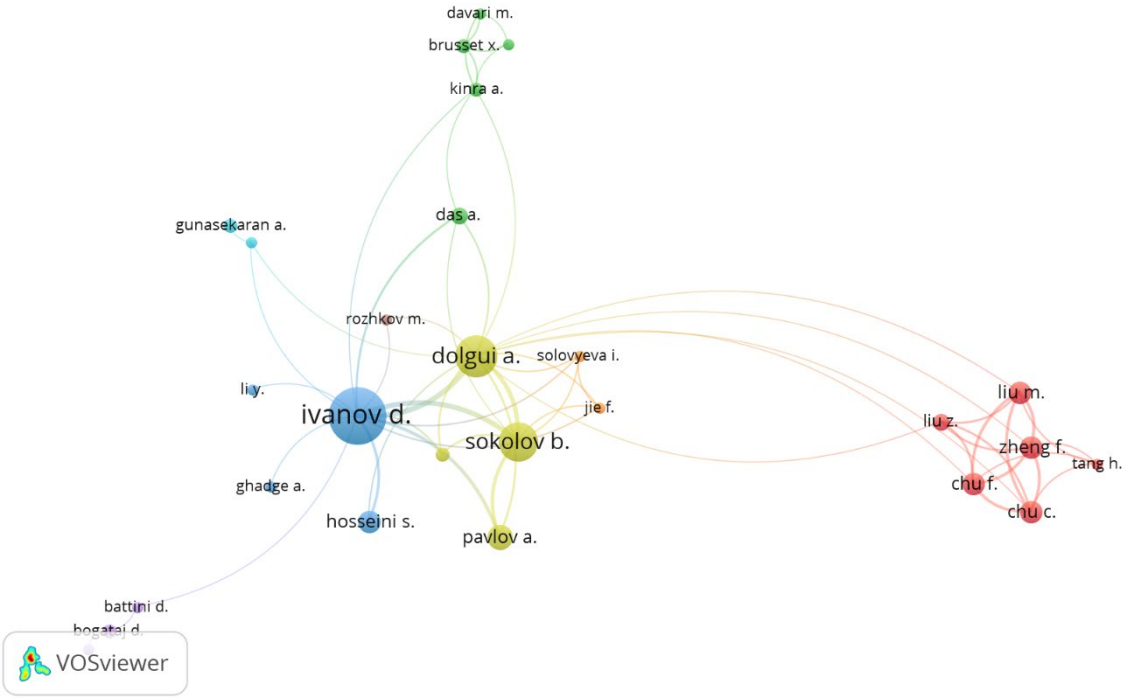

Figure 10 Ripple effect - Co-authorhips - author

e) Analysis of co-authopship and countries

The next analysis will address issues related to co-authorship and countires. The analysis shows that the authors working on this topic come from 67 countries, the analysis was limited to the presence of at least 2 articles from a given country, and 42 links were found in this area. The visualisation is presented in Figure 11. The resulting clusters show that researchers from the USA, Germany, France, the Russian Federation, India and the United Kingdom have the highest number of links and therefore interest.

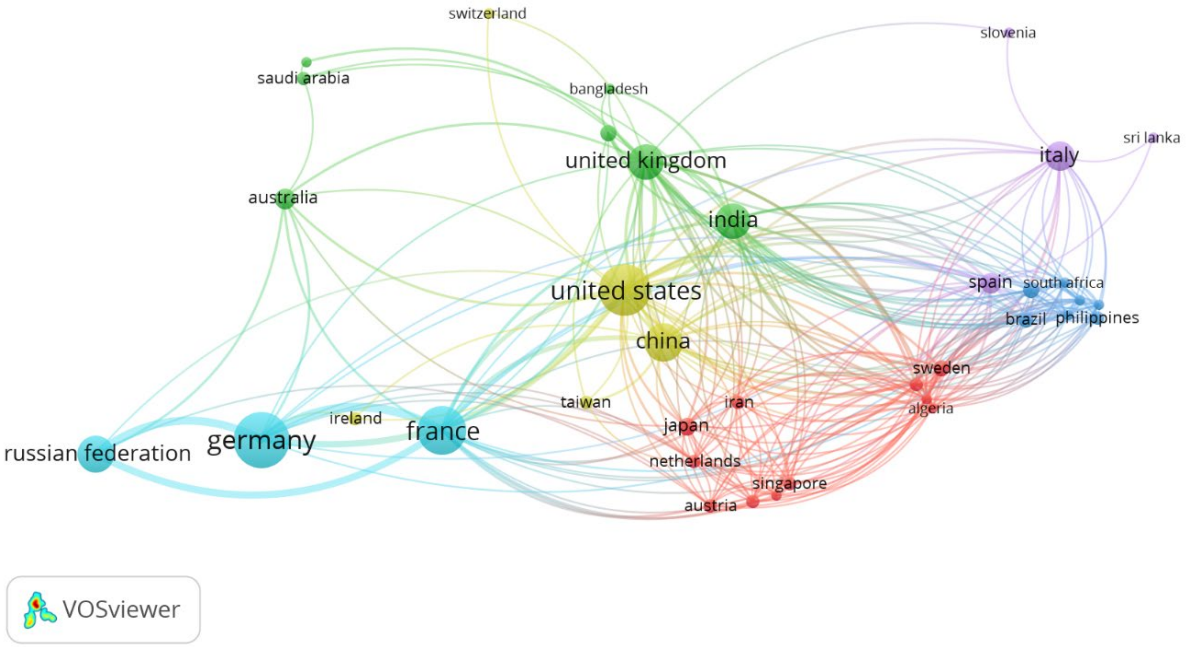

Figure 10 Ripple effect - Co-authorhips - countries

4.3. Analysis of black swan(s) – knowledge maps

An identical analysis to that for the 'ripple effect' was carried out for the links 'supply chain' and 'black swan(s) event'. Within the scope of this analysis, 38 articles meeting the requirements (from the Scopus database) were selected.

a) Analysis of co-occurance and all keywords

Figure 11 presents the results of the study, with the following boundary conditions: a minimum number of occurrences of 2, resulting in 312 keywords of which 37 were co-related. For 37 keywords, the total strength of co-occurence links with the other keywords was calculated. The keyword with the greatest total link strength will be selected. All of the keywords presented on the map are part of 5 clusters that have 142 links to each other, reflecting groups of emerging research topics within the scope indicated. It is evident that the black swan event itself, although evident from the limitations of the analysis, does not occur as frequently as it did in the previous analysis. This is probably the result of a kind of "discovery" of this phenomenon for the supply chain theme. Instead, words related to disruption, dissasters and Covid 19.

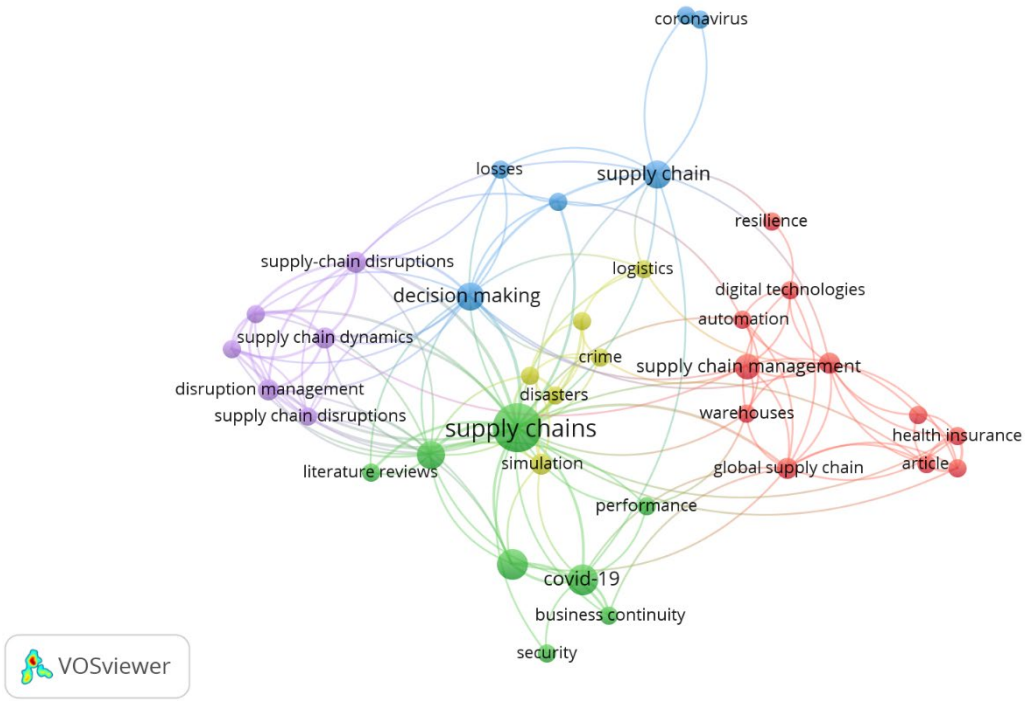

Figure 11 Black swans - co-occurance and all keywords

b) Analysis of co occurance – index keywords

W zakresie tej analizy wyselekcjonowano 208 słów kluczowych, zastosowano ogranicznie do 2 słów co-oocurance, wyselekcjonowano 23 słowa kluczowe, połączone w 6 klastrów, mających 75 linków. Zdecydowanie widać powiązanie z zarządzaniem łańcuchem dostaw, globalnymi łancuchami dostaw, ale także disruptions, Covid-19, disasters i risk management.

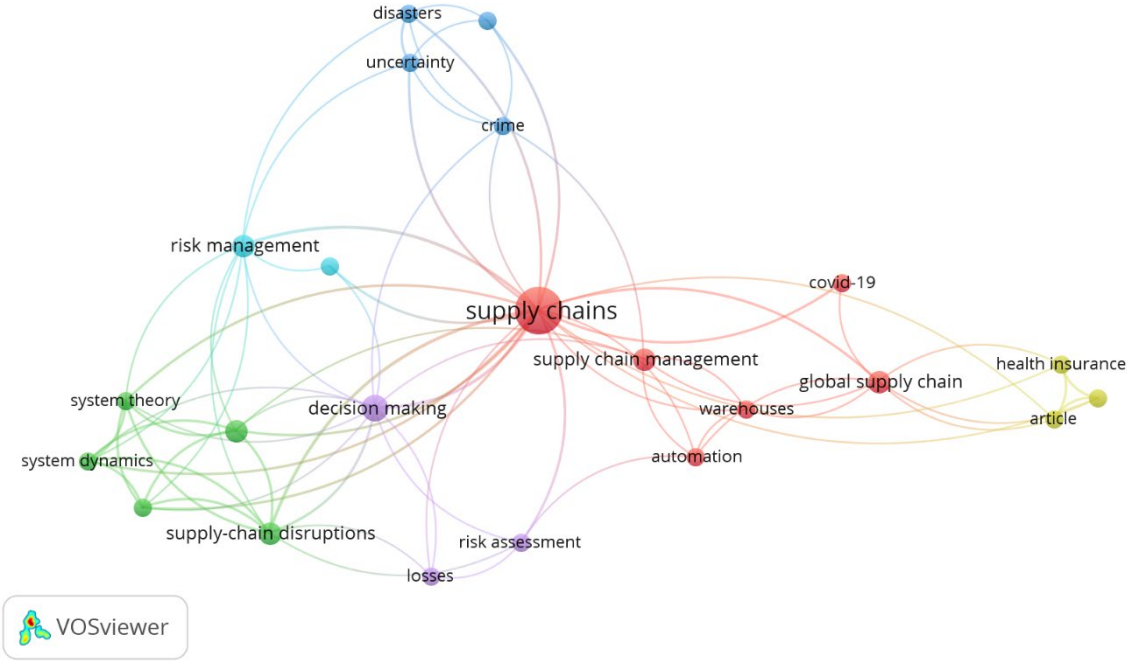

Figure 12 Black swans - Co occurance – index keywords

c) Analysis of co-oocurance - authors keywords

In terms of the analyses concerning links to authors' keywords, 154 keywords were found, 18 keywords were selected linked in 4 clusters and 34 links. (Figure 13)

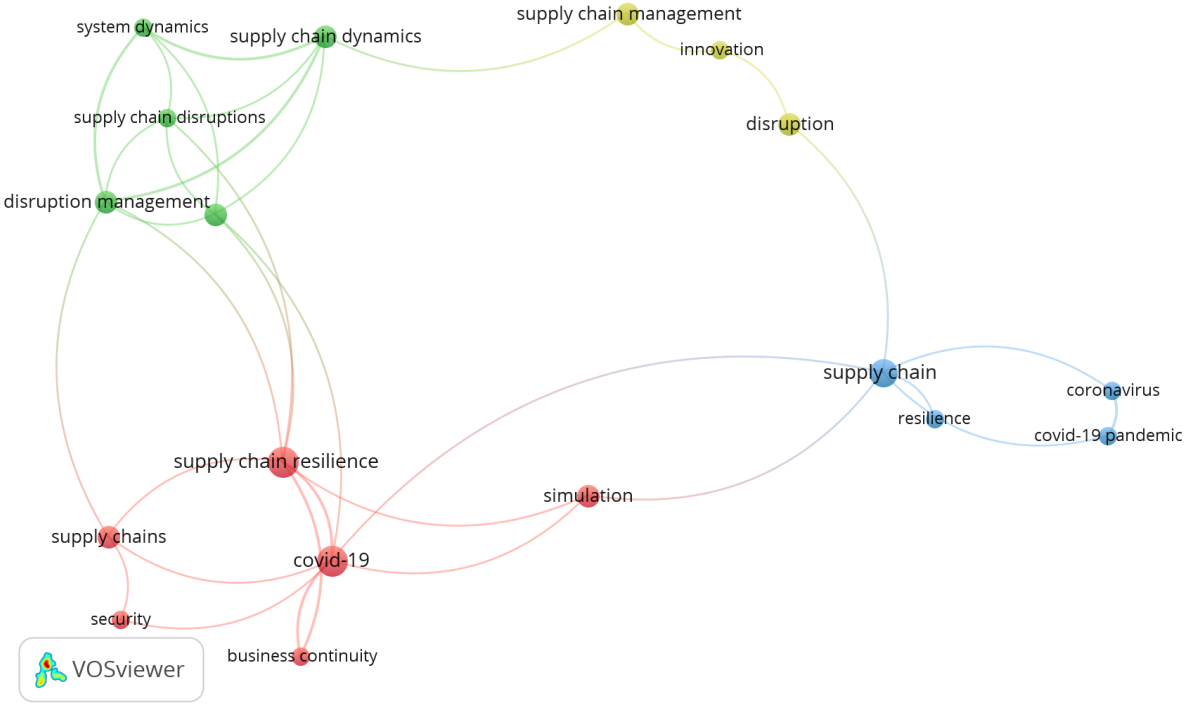

Figure 13 Black swans - Co-oocurance authors keywords

d) Analysis of co-authorship and author

Due to the small number of articles to be analysed, the first analysis considered a minimum number of author papers of 2. With a total of 105 authors, only 5 related papers were found (Figure 14) .

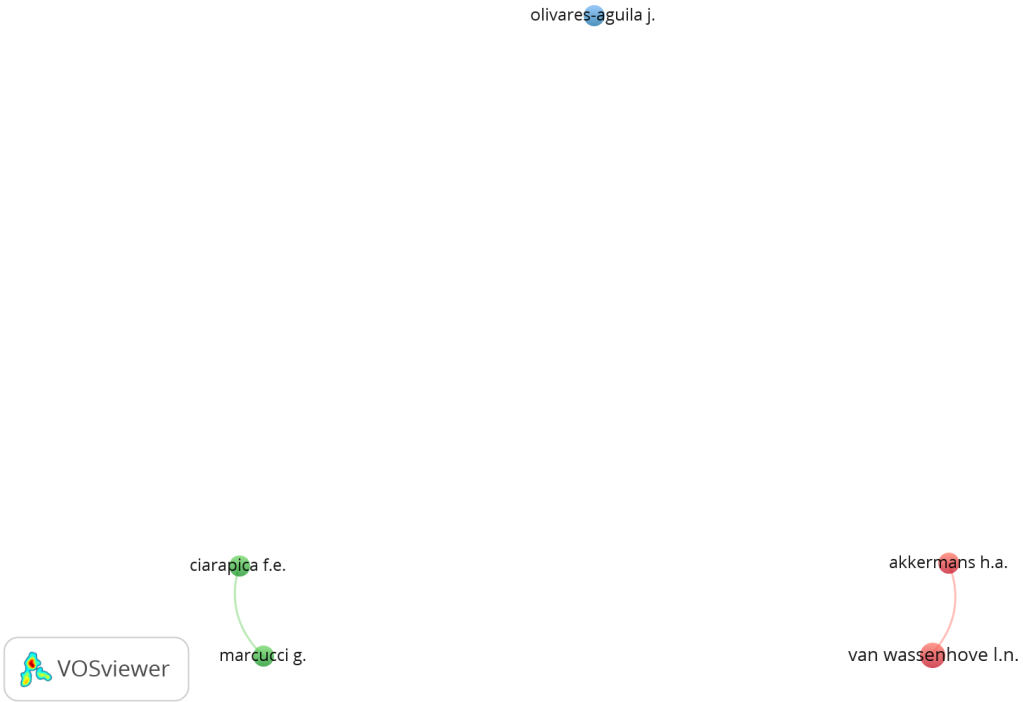

Figure 14 Black swan(s) - Co-authorship – author (minimum 2 articles)

With such a small number of publications, it was decided to change the boundary conditions - 1 rarticle was taken under the wuage and the fascination was examined. A total of 34 clusters were created showing the collaboration of authors in the preparation of the publication. In this respect, 145 links appeared. (Figure 15)

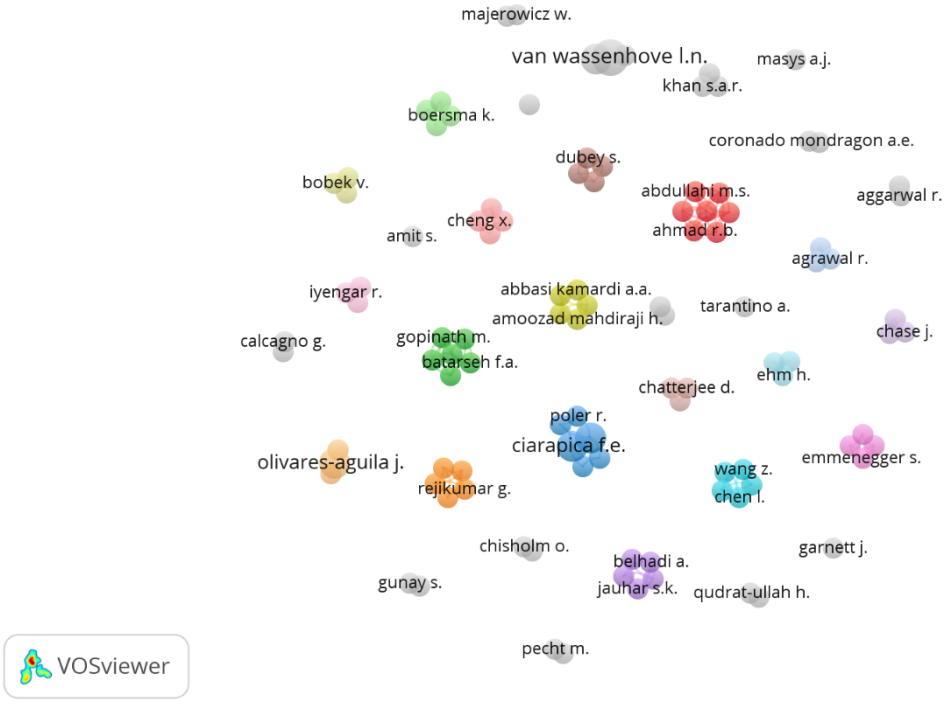

Figure 15 Black swan(s) - Co-authorship – author (minimum 1 articles)

e) Analysis of co-author and countires

Within the scope of this analysis, a minimum of 2 papers from a given country were uploaded, with a total of 29 countries represented. 11 countries show links within the scope of the analysis, with the highest number of publications from the USA. Within the scope of this analysis, 4 clusters and 15 links were found (Figure 16)

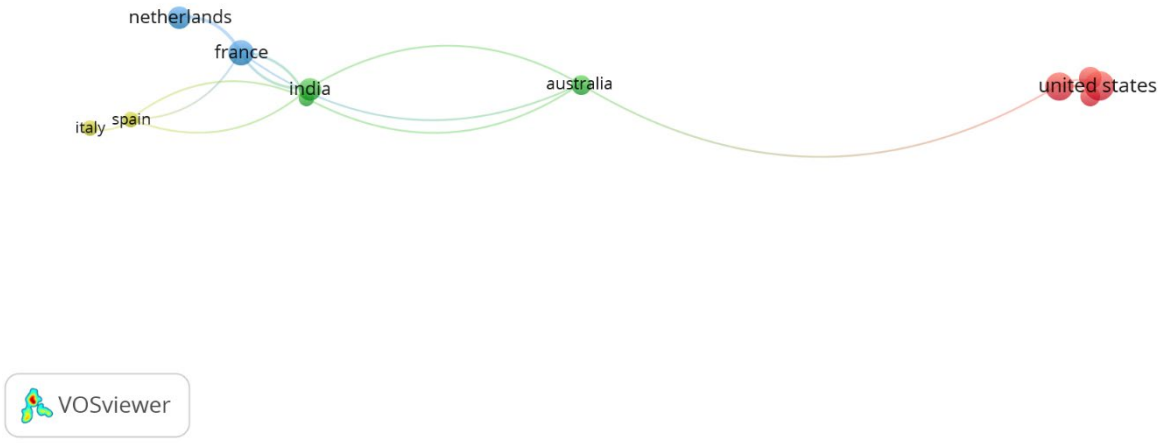

Figure 16 Black swan(s) – co-authorship-countries (2 minimum)

An analysis taking into account co-authors and countries, with a limitation to a minimum of two documents from a given country of affiliation, shows that the highest number of appearances is in the USA, linked to Autraslia. This country in turn is linked to India, followed by France, the Netherlands, Spain and Italy

When the links of 1 country and co-authors are taken into account, the analysis of figure 17 is a bit different - here there are16 items, 6 clusters 23 links.

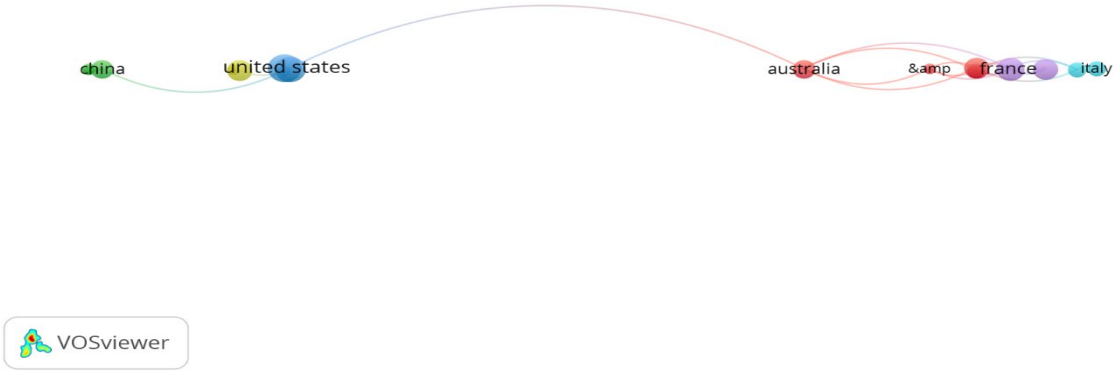

Figure 17 Black swan(s) – co-authorship-countries (1 minimum)

Limiting the occurrence of links to only one document per country shows greater fragmentation, although in fact the conclusions are the same as for Figure 16. There are no major changes, links and countries are the same.

Other countries without links are shown in Map 18 (entirety) 29 countries 15 calsters 26 links

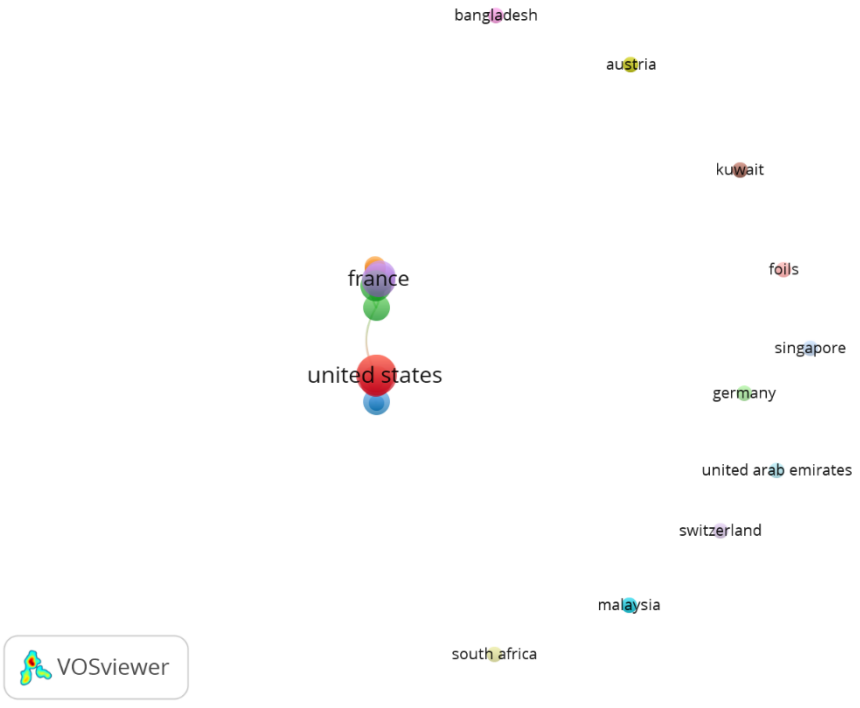

Figure 18 Black swan(s) – co-authorship-countries (all countries)

The last figure, 18, shows a visualisation without restrictions and connections, which shows which countries, or rather researchers from which countries, are involved in the indicated topics. Here, one can see more fragmentation, but countries such as Germany, Sıngapur, Banglaswesh,

Kuwait, Malaysia and Switzerland also appear. These do not show links to other countries, but complete the analysis by indicating which countries and which researchers are affiliated to which countries in the field of research.

5. LIMITATION, DISCUSSION AND CONCLUSION

The bibiometric analysis used in the analysis and preparation of the article is an excellent method to show how the interest of researchers in the topics under study is changing. Furthermore, with it, it is possible to show which areas, methods and research fields are of interest to researchers worldwide. It is perfectly possible to show the connections between not only the keywords occurring in the texts, but also between the authors, to distinguish the scientific units involved in the research of the indicated topic, as well as to distinguish the country in which the research takes place. This type of analysis: a combination of perforce analysis and visual knowledge maps is an excellent way to identify themes and undertake further, more detailed research into them. The method is of course limited in scope (only to keyword analyses, indexes and abstracts, despite the systematic literature review), but nevertheless contains many interesting analyses from which conclusions can be drawn about the scope of research, area, research methods, authors, countries and the most frequently used keywords. Unfortunately, limitations also arise from the fact that the descriptions and use of individual words are very fragmented. Furthermore, authors often treat abstracts without due attention to detail and indicate the most relevant elements from the content of the articles. This element is most relevant when automating data retrieval for bibliometric analyses. Therefore, in order to accurately assess the scope of the research area, it is necessary to read the entire texts in order to accurately analyse the phenomena studied or to draw universal conclusions. Also, the multiplicity of keywords and their fragmentation results in a lack of precision and accuracy in defining the object of analysis, a lack of clarity facilitating the identification of the area or the scope of re-examination concerning the specificity of the indicated study.

For the analyses, the article takes the SCOPUS database to examine issues related to phenomena that have had a great impact on supply chains in recent years, but which have not previously been considered with such intensity, and have not been studied in terms of their great impact on the effective functioning of the supply chain.

The main conclusions that emerge from the analysis indicate that interest in the topic is definitely increasing, in both areas. In terms of both phenomena under study, a visible increase is noticeable from 2020 onwards. This is probably the result, firstly, of the outbreak of the Covid 19 pandemic and, in 2022, of the outbreak of war in Ukraine. Research is definitely easier in the field of the 'ripple effect', as more publications allow it, in the field of the 'black swan(s)' the number of publications is still small, but is steadily increasing, which means that the phenomenon is starting to have an increasing impact on the functioning of the supply chain. This topic is therefore becoming an increasingly interesting element and area of research, and should be explored, not only to perform bibliometric research in the future, but to find, through it and other research tools and methods, ways to solve supply chain problems and prevent its destruction.

Exploring research areas also allows for building better protection systems and increasing the resilience of supply chains.

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