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Supply Chain Complexity – A Bibliometric Analysis

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

CAS	Complex adaptive system
GC	Global citation
GSCM	Global supply chain management
LC	Local citation
NAP	Number of articles published
SC	Supply chain
SCC	Supply chain complexity
SCM	Supply chain management
SCP	Supply chain performance
SCR	Supply chain risk
SJR	SCImago Journal Rank indicator
TGC	Total global citations
TLC	Total local citations
WoS	Web of Science

1 Introduction

Supply chain (SC) structures become more dynamic and complex with an increasing globality (Xu *et al.*, 2020, p. 3508; Hosseini *et al.*, 2019, pp. 300–301; Kamalahmadi and Parast, 2016, p. 116; Kim *et al.*, 2015, pp. 56–58). Complexity in SCs relates to three main dimensions. Spatial, horizontal, and vertical complexity are associated with higher uncertainty and missing transparency in Supply Chain Management (SCM) (Bode and Wagner, 2015, pp. 223–225). In modern SCM it is always assumed that the SCs are of global nature and reach across borders into different cultures (Vachon and Klassen, 2002, p. 219). This led to a competitive environment where company networks face each other instead of single firms (Kotzab *et al.*, 2015, pp. 525–526). As there are many definitions (Bode and Wagner, 2015, pp. 216–217; Serdarasan, 2013, pp. 533–534; Beamon, 1999, p. 275; Vachon and Klassen, 2002, pp. 219–223) of Supply Chain Complexity (SCC) that differ to some extent, the definition that underlines the basic approach of this paper is by (Bozarth *et al.*, 2009). In SCM, SCC is defined as a combination of product, process, and network complexity (Bozarth *et al.*, 2009, p. 80).

SCC management is a challenging task for SC managers all over the world. If a company is about to fail at SCC management, negative consequences will be generated. These consequences reach from inconsistent incoming material quality to higher transaction costs and a general inflexibility (Manuj and Sahin, 2011, p. 524). It is impossible for SC managers to eliminate complexity which establishes an importance to create an understanding of drivers in SCC, determine, evaluate, and implement strategies to reduce complexity. Higher complexity leads to an overall worse performance in SCM, forming an incentive to manage SCC (Serdarasan, 2013, pp. 537–538).

To review a research field, a method that is often applied is the bibliometric analysis. This is especially relevant in the environment of SCM (Xu *et al.*, 2020; Kotzab *et al.*, 2020; Mishra *et al.*, 2018; Fahimnia *et al.*, 2015; Georgi *et al.*, 2013). The bibliometric analysis should enable the creation of a comprehensive review in the scope of SCC by providing a holistic overview on the evolution of research.

The structure of the paper is as follows. For a theoretical background, the basic research about SCC and its interrelations to Supply Chain Performance (SCP), Supply Chain Risk (SCR) and Global Supply Chain Management will be reviewed. The next part explains the methodology and data source. This will build the basis of understanding the analysis of the literature data. The analysis brings forth the main achievement in answering the following research questions:

1. What is the intellectual foundation of SCC, i.e. the most impactful articles, authors, institutions, and journals as well as the academic output?
2. A. Does the bibliometric analysis give evidence on the interdisciplinary character of SCC?
2. B. Is the bibliometric analysis backing the assumptions made about the interrelations of SCC?

2   Theoretical Background

2.1   Supply Chain Complexity

SCC refers to the dynamic, multi-functional and global nature of SCs with multiple elements, flows, processes, and interactions being involved into the multifaceted and large-scale systems (Choi and Hong, 2002; Choi *et al.*, 2001; Mentzer *et al.*, 2001). One affecting dimension of SCC is the spatial complexity, which refers to the geographical spread of organizations and gives an explanation for SC disruptions. Moreover, horizontal complexity impacts SCC. Firms with many departments have more issues with complexity due to the high number of SCs. Finally, vertical complexity, in terms of firms with hierarchical levels, constitutes an affecting dimension for SCC. All three dimensions are associated with a higher level of uncertainty and missing transparency in a SC due to the increasing complexity (Bode and Wagner, 2015, pp. 223–225). The degree of SCC is determined by different drivers as for example uncertainty, in terms of the system's unpredictability and non-linearity, diversity of the elements that are involved or variability of the SC over time. Besides that, speed, structure, and size as well as a lack of synchronization or cooperation are important drivers, which determine the level of SCC. A high SCC can lead, inter alia, to a reduced financial and delivery performance, inflexibility, and difficulties in describing, understanding, and controlling the system. Furthermore, consequences of SCC may result in higher transaction costs, longer cycle times, a lower inventory turnover and an inconsistent incoming material quality (Serdarasan, 2013, p. 534; Leeuw *et al.*, 2013, p. 967; Manuj and Sahin, 2011, p. 524). Therefore, managerial effort is needed to understand and measure the complexity reduce it internally, externally, and interactively. Otherwise, a lack of understanding the SCC leads to poorly designed and executed strategies to address the complexity (Isik, 2010, p. 3685).

The articles from Choi *et al.* (2001) and Vachon and Klassen (2002) represent two fundamentally important articles in the research domain of SCC. Choi et al. argued to compare supply networks to complex adaptive systems (CAS). They explained the underlying dynamics of CASs, internal mechanisms, the environment, and co-evolution, and applied this to the context of supply networks. They conclude that supply networks should be recognized as CAS which supports the process of understanding the internal relations and patterns of evolution in supply networks. In their article Vachon and Klassen (2002) discuss the impact of SCC on delivery performance through an exploratory study. They propose a framework to explain the sources of SCC complexity with the two dimensions technology and information processing. Especially the technology dimension that was separated into product/process complicatedness and management systems uncertainty had an empirically significant impact on the delivery performance.

2.2 Interrelations of Supply Chain Complexity (SCC)

Besides the importance of being familiar with the significance of SCC as such, it is essential to understand the interrelations to the concepts of SCP and SCR, as they are strongly linked to each other. SCP refers to the SC's activities meeting requirements in a responsive manner regarding e.g. delivery times and quality (Arzu Akyuz and Erman Erkan, 2010, p. 5147). The circumstance of SCs becoming more complex in a globalized world negatively influences the performance. The drivers of SCC also affect the performance, which again confirms the significance of an efficient system of complexity measurement and management. Managers can strongly improve the performance through managing the complexity (Beamon, 1999, pp. 275–290).

Apart from the interrelation to SCP, complexity is also connected to SCR. Risks arise more frequently and with greater speed in more complex systems which is why it is easier to manage risks in a less complex SC. A lower complexity is the precondition for the successful implementation of risk management strategies to achieve a desired performance (Tang and Nurmaya Musa, 2011; Manuj and Mentzer, 2008, p. 197).

Furthermore, SCC is also in a strong dependence to Global SCM (GSCM). The increasing global interconnectedness leads to several changes in management practices. Since the term *complexity* is inherent in SCM even if there was no globalization, the complexity is further increasing regarding a SC in a global context (Vachon and Klassen, 2002, p. 219). It becomes more complex to manage a SC across borders and cultures since every country has its own culture which is important to include in global management practices (Mussa, 2003, p. 15; Hofstede, 1984). Flows of materials, funds, and information are more intense, higher, and deeper in international systems and networks. However, especially networks are a very important and relevant instrument when managing a global SC regarding e.g. managing interconnected flows and building up supplier relationships (Rudberg and Olhager, 2003, p. 29). This is in common with the fact that one of the main requirements of a SC is a fast delivery which is a challenging and increasing complex challenge in a global view (Manuj and Sahin, 2011, p. 512). Moreover, there are several key factors in SC-literature which are also dependent on a SC's complexity because those key factors can differ intensively in another culture. One important factor is e.g. the information technology since this creates and improves competitive advantages, especially when the firm has chosen a unique technology. Nevertheless, even information technologies can differ extensively in another country because of different development steps (Manuj and Sahin, 2011). This is only one of several key factors influencing an efficient SC, which gets further complex in a global context.

Since challenges in SCM are very high and will further be complicated in a global context it is of high importance that decision makers calculate different components such as the culture,

management practices, organizational systems, and technological development levels sufficiently in order to manage SCC and to reduce SC disruptions (Mussa, 2003, p. 17; Vachon and Klassen, 2002, p. 221).

3 Methodology and data source

The previous statements are derived from academic literature about SCC. To approve them and to gain deeper insight into the research field, a bibliometric analysis was conducted. This approach is of systematic nature and allows to create an unbiased and objective overview over the intellectual foundation of SCC.

The underlying literature data of the bibliometric analysis was collected from Web of Science (WoS). WoS is a website that contains literature data and citation data. The proceeding of the search process can be seen in Table 1 below.

Table 1: Refinement Steps to get dataset for bibliometric analysis

Refinement Step	Results
1. Search: "Supply Chain Complexity" in TOPIC in Web of Science	3431
2. Refined by articles	2277
3. Refined list of Journals based on mandatory requirements and Harzing list	768

The final data set consists of 768 articles. To conduct the analysis, 30 journals were chosen, because of two different reasons (Appendix 1). The first 15 journals were mandatory and predetermined by the professorship Global SCM. The other 15 journals, the articles have been published in, are selected based on the Harzing List (Harzing, 2020). The Harzing List uses different ratings to assess the quality of the various academic journals. Within the Harzing List only journals that received at least the 2nd highest rating in 9 out of the 12 rankings were considered. They also had to be assigned to the subject area: "Operations Research, Management Science, Production & Operations Management".

To analyse the literature data, different bibliometric analysis tools were used. These enable the presentation of meaningful results regarding the field of SCC. First, Histcite (Garfield, 2009) was employed to examine the intellectual foundation of SCC. Histcite supports the process of identifying the most impactful academic actors in the research field. Second, VOSviewer – a visualization tool – was used to create a keyword-cluster and to employ a content analysis. VOSviewer was introduced by (van Eck and Waltman, 2010).

4 Analysis

4.1 Academic output in the SCC research domain

Figure 1 shows the academic output and the citations of the research field of SCC between 1994 to 2020. The number of articles published (NAP) refers to the total amount of articles that were published in the data set. In the graph, this is represented by the dotted line. The total global citation (TGC) score refers to the actual amount of citations the observed articles received each year. TLC stands for the total local citations, i.e. citations within the 768 selected articles.
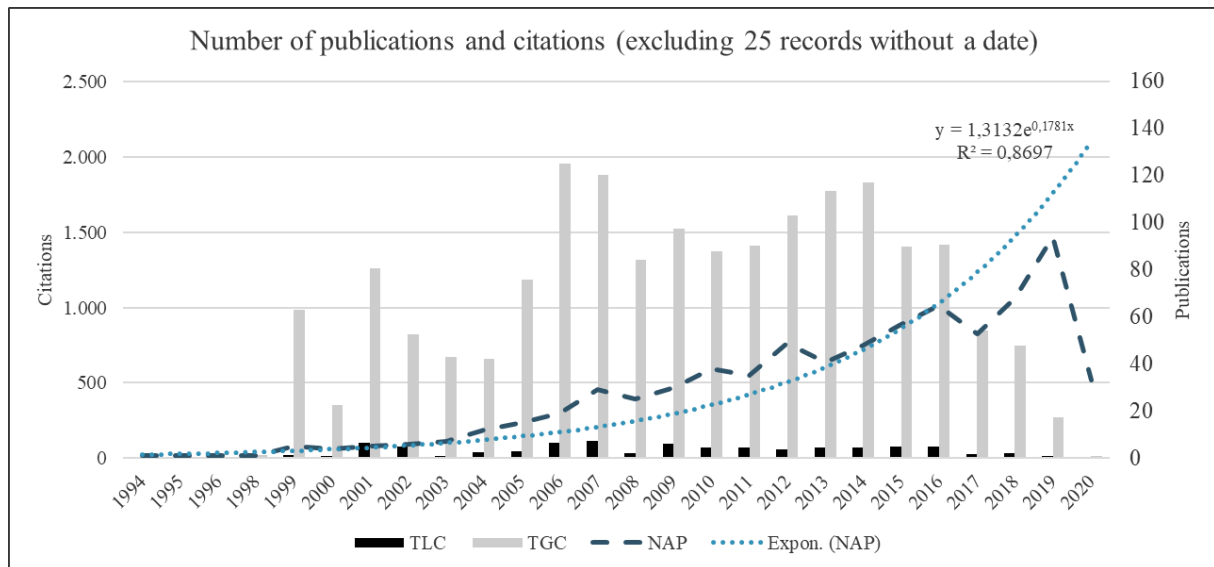

Figure 1: Number of publications and citations in SCC from dataset

Overall an increasing attention towards SCC is visible. With mathematical calculation the trend line of the NAP shows an exponential growth ($y = 1{,}3132e^{0{,}1781x}$; $R = 0{,}8697$). Besides the drops (compared to the output of the previous years) in 2008, 2011, 2013, and 2017 the number of articles published has steadily risen. The drop in 2020 is caused by the time the research was conducted at, as the underlying data was extracted from WoS on May 25th, 2020. The years with the highest citation scores, locally and globally, are 2006 and 2007. The articles published in 2006 received 105 local citations (LCs) and 1950 global citations (GCs) and the ones from 2007 received 112 LCs and 1888 GCs, respectively.

Table 2 gives insight on the most important journals used to examine SCC. They are ranked based on the number of local citations they received.
On rank one resides the *Journal of Operations Management* with a very high LC-number compared to the output volume. The *Journal of Operations Management* is publishing articles within the research area of operations management research and provides relevant output for academic and practical audiences.

On rank two with 146 LCs, there is the *International Journal of Production Economics*. It is an interdisciplinary journal dealing with the relation between engineering and management. Their goal is to consider whole cycles of activity.

On the third position, there is the *International Journal of Production Research*, mainly focussing on manufacturing, operations research, and logistics. The resulting articles are of high practical applicability trying to solve real-life problems.

The 10 journals presented in Table 2 make up about 59% of the whole academic output observed in this analysis. Their total NAP is 452 articles.

Comparing the output of Table 2 to the respective impact factors of the journals, it appears that there is no relation between the impact factor and the LCs. Considering the SCImago Journal Rank indicator (SJR) from 2019 the top three Journals are: First *Management Science*, second *Journal of Operational Research* and third the *International Journal of Physical Distribution & Logistics Management*. Based on the H Index (2019) the *European Journal of Operational Research* would rank first followed by *Management Science* and then the *Journal of Operations Management*. Only the *Journal of Operations Management* appears to be highly accolated in all three categories (LC, SJR, and H Index).

Table 2: 10 most locally cited Journals in SCC

Rank	Journal	NAP	<u>LC</u>	GC	SJR
1	Journal of Operations Management	33	339	3.763	3,96
2	International Journal of Production Economics	105	146	3.566	2,38
3	International Journal of Production Research	102	116	2.285	1,78
4	International Journal of Operations & Production Management	44	110	2.451	2,19
5	Decision Sciences	19	81	1.091	1,30
6	IEEE Transactions on Engineering Management	9	60	229	1,07
7	European Journal of Operational Research	56	57	2.281	2,36
8	Supply Chain Management - an International Journal	45	48	1.078	1,68
9	International Journal of Physical Distribution & Logistics Management	31	45	649	2,75
10	Management Science	8	40	680	5,44

4.2   Citation Analysis

Table 3 shows the most contributing authors to SCC literature. Tiwari and Wagner both published eight articles and are on top of the chart. Blackhurst, Huatuco, Sarkis, and Wu each brought out seven papers.

Table 3: 10 most contributing authors in SCC

Rank	Author	NAP	LC	GC
1	Tiwari MK	8	4	203
2	Wagner SM	8	50	333
3	Blackhurst J	7	78	970
4	Huatuco LH	7	27	134
5	Sarkis J	7	18	638
6	Wu T	7	25	275
7	Blome C	6	33	456
8	Nair A	6	34	362
9	O'Grady P	6	25	275
10	Wiengarten F	6	15	227

Comparably more interesting is Figure 2 displaying the most impactful articles based on their LC score and the citation relations between them. This allows to also give a more meaningful statement about the most important authors contributing to the SCC domain. Choi is the most cited author in the dataset with 137 LCs. His articles are present twice in the cluster with very high LC scores. Following at second and third place are Blackhurst (78 LCs) and Krause (71 LCs). Krause is a co-author of Choi. In the fourth place, there are four authors: Bozarth, Flynn B., Flynn E., and Warsing that have merely published one article.

Overall, Figure 2 shows 30 nodes (most locally cited articles) with 80 links between them (Appendix 2). At a minimum, an article has been locally cited 9 times and at a maximum 71 times. The arrows indicate that article x has cited article y (article y being the cited one). The timespan of this particular set of articles ranges from 1999 to 2016. There appears to be one main cluster revolving around the article from Choi and Krause (2006) that simultaneously is the most locally cited publication in the data set. There is an exception for the second most important article from Bozarth et al. (2009) which was cited 69 times within the dataset, because it does not cite Choi's work from 2006. This article itself is related to the research from Choi *et al.* (2001) and Vachon and Klassen (2002) that can be identified as the foundation in the research domain of SCC. The articles from Prater et al. (2001) and Hall/Potts (2003) are isolated in the histography.
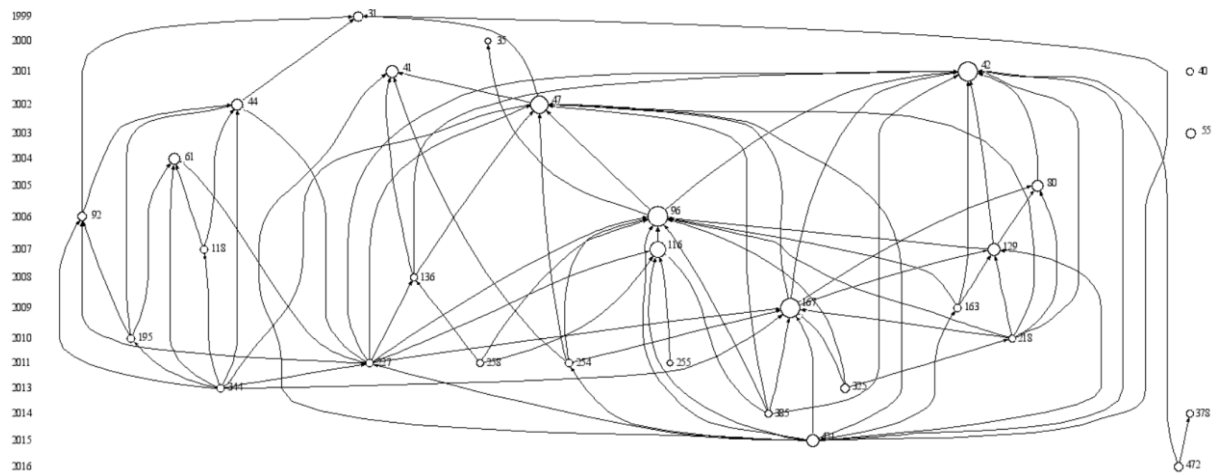
Figure 2: Citation relation histography of the 30 most locally cited articles in SCC

4.3 Affiliation analysis

With the help of Histcite, it was possible to identify the top ten universities sorted by the NAP in the field of SCC. 60 percent of the institutions are located in the USA. At the same time the Table 4 provides information about the countries that contribute the most to the research domain. Based on articles published the USA (269) would rank first, followed by the UK (134).

The top five universities are the *Arizona State University* followed by the *Michigan State University,* the *Politecnico di Milano,* the *Hong Kong Polytech University* and in fifth place the *Penn State University.*

Furthermore, a few important actors researching SCC are representing the universities, listed in Table 4. For example, the most locally cited author Choi is representing the *Arizona State University*, implying that the university is both active in publishing articles and important due to their citation scores.

Table 4: 10 most contributing institutions in SCC

Rank	Institution	NAP	LC	GC	Country
1	Arizona State University	20	172	2.033	USA
2	Michigan State University	19	29	695	USA
3	Politecnico di Milano	17	53	476	Italy
4	Hong Kong Polytech University	15	16	597	Hong Kong
5	Penn State University	15	40	837	USA
6	Ohio State University	13	24	422	USA
7	University Leeds	12	28	252	UK
8	University Tennessee	12	42	1.001	USA
9	Cranfield University	11	9	353	UK
10	MIT	11	55	727	USA

4.4   Interdisciplinarity of SCC

This part aims to answer the research question 2.A. Does the bibliometric analysis give evidence on the interdisciplinary character of SCC? To answer this question, it is necessary to first define what is meant by an interdisciplinary character of a research field. Interdisciplinarity is derived from the word discipline which stands for the security and consistency where interdisciplinarity is the counterpart and indicates a diverse and adaptable research field (Miller, 2010, pp. 5–6).

In scientific research, the disciplines are the base unit of knowledge structure that were laid out chronically by the building up of departments for research (Miller, 2010, pp. 5–6). Therefore, the definition that will be used to answer the research question will focus on these basic units of knowledge in research and if more than one is contributing to the theoretical foundation of SCC.

The interdisciplinary nature of SCC needs to be addressed as it is common for SCM to be viewed as an interdisciplinary research field (Stindt *et al.*, 2016; Sanders *et al.*, 2013; Sahamie *et al.*, 2013; Kühnle and Dekkers, 2012). The future of SCM research lies in the combination of disciplines. The combination is necessary to deal with current and future SCM challenges (Sanders *et al.*, 2013, pp. 413–414).

To get to the bottom of this question, it is necessary to review the disciplines which contribute to the research field of SCC by having a look into different categories as well as Journals and even authors that normally would not publish in the field of SCM and thus, bring an interdisciplinarity character with them.

First, the categories in WoS will be analysed to see if there are various disciplines to be found. The categories in WoS are clustered into five broad categories called research areas. These consist of Arts & Humanities, Life Sciences & Biomedicine, Physical Sciences, Social Sciences and Technology (Clarivate Analytics, 2020). All the categories (Table 5) that can be found in the dataset that is analysed are placed in the research area of Social Sciences. This is at first glance a reason to not expect a high level of interdisciplinarity.

A closer look into the data reveals that there are twelve different categories in the dataset. This can be seen in Table 5. As the data only contains articles as explained in chapter 3 all the records are of this literature type. An article can be assigned to more than one category at once. Thus, the percentages in the third column come together. This indicates that the research field of SCC has its origins in Operations Research & Management Science with a majority of 61.46 percent of all published articles assigned to this category.

Table 5: WoS categories in the field of SCC

Web of Science Categories	Records	% of 768
Operations-Research & Management Science	472	61,46%
Management	370	48,18%
Engineering Industrial	351	45,70%
Engineering Manufacturing	276	35,94%
Computer Science Interdisciplinary Applications	86	11,20%
Business	58	7,55%
Economics	11	1,43%
Engineering Civil	11	1,43%
Transportation	11	1,43%
Transportation Science Technology	11	1,43%
Computer Science Artificial Intelligence	4	0,52%
Computer Science Information Systems	4	0,52%

A clustering of the twelve categories can be easily achieved by grouping them into four topics, the result can be seen in Table 6. Taking a closer look, this indicates a form of interdisciplinarity as the four topics generally have different departments in research institutes. In a historic view, this led to the creation of interdisciplinarity (Miller, 2010, pp. 5–6).

Table 6 The four main categories of SCC

Engineering	Management & Economics	Transportation	Computer Science
Engineering Industrial	Management	Transportation	Computer Science Interdisciplinary Applications
Engineering Manufacturing	Business	Transportation Science Technology	Computer Science Artificial Intelligence
Engineering Civil	Economics		Computer Science Information Systems
	Operations Research & Management Science		

The ten most contributing authors in SCC (Table 3) are all only contributing to the broader research area that consists of the aforementioned categories from Table 5 and Table 6. The same statement can be made regarding the Journals (Appendix 1) contributing the dataset on which this paper is based.

For these reasons, SCC cannot be defined as a highly interdisciplinary research field. This finding needs to be addressed cautiously as it heavily depends on the literature that was selected

respectively excluded (Chapter 3Methodology and data source). Especially the Journal selection contributes to this fact, but with that said, some assumptions about an interdisciplinarity nature can be made. Inside the area of Social Sciences, it includes the four different topics of Engineering, Management & Economics, Transportation, and Computer Science (Table 6) which indicates a form of interdisciplinarity.

4.5   Interrelations to SCP, SCR and GSCM

The second part of the research question (2.B) is the bibliometric analysis backing the assumptions made about the interrelations of SCC, and it will be answered in this chapter. To answer this, it is necessary to investigate the assumptions that were taken in the first place. In chapter 2.2 the interrelations between SCC, SCP, SCR, and GSCM were derived from current literature from these fields. This chapter aims to connect the literature review from chapter 2 with findings from the bibliometric analysis. The bibliometric analysis is therefore presented upfront with the combination of the literature review and the bibliometric data analysis following to form a content analysis.

The following network analysis consists of all the keywords that occurred more than 35 times in the dataset of 768 articles. This left the network with 29 keywords, therefore, an analysis of the network is possible. The information loss must be accepted because the totality of 3,494 keywords or even a lower threshold of 2 occurrences (Appendix 3) would go beyond the scope of this paper. The different measures portrayed in this cluster analysis are the link strength between keywords and the occurrences. The link strength is indicated by the thickness of connections between keywords and the number of occurrences is indicated by the size of the dot behind the keyword and the font size. The link strength is defined by the intersection of articles that a keyword appears in (van Eck and Waltman, 2010).
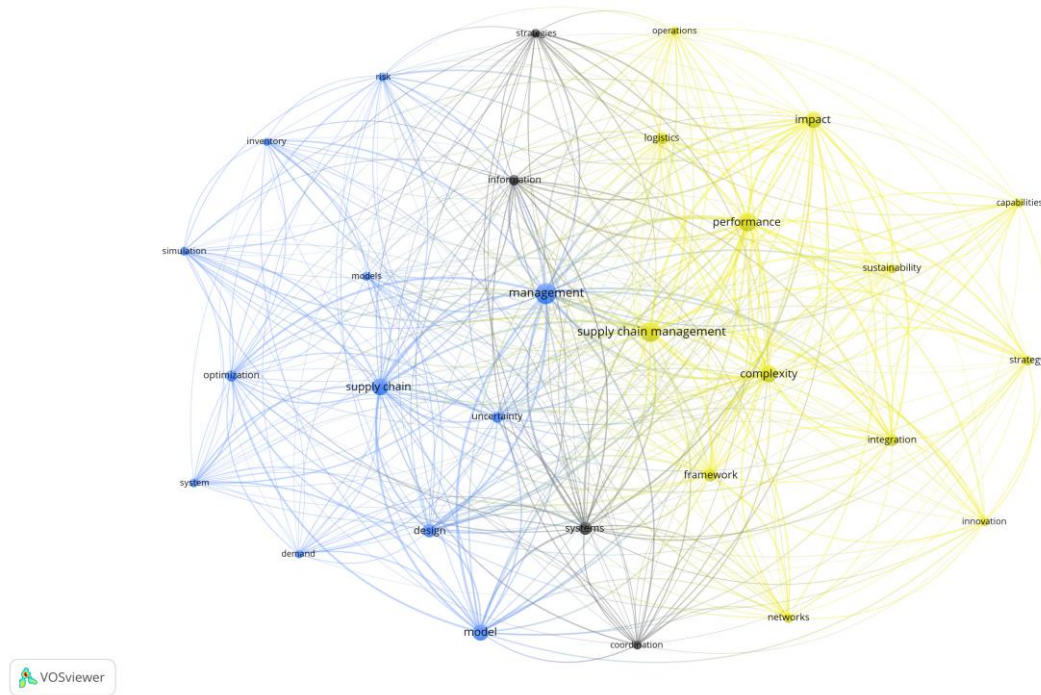
Figure 3: Keyword network analysis SCC threshold: min. number of occurrences 35

Furthermore, the network data was analysed to get numerical values behind the clusters and networks. This was done by extracting the data as two .txt documents of which one is building the connections between the keyword and one is building the positioning of the keywords and the sizing of them. The two documents were imported into Microsoft Excel to create a matching list were the link strength of different connections can be seen. Before, the link strength was only connected to the ID which makes it complicated to understand and present. In Table 7, this was done for the keywords that will contribute to this chapter. In the set of 3,494 keywords VOSviewer assigns each keyword an ID based on an alphabetical order. Before the matching, the tables for the network and the map look like the tables in the Appendix 4 and Appendix 5. There, it can also be seen how the matching worked (Appendix 6).

Table 7: Matched map and network file of Keyword analysis for risk, performance, and complexity

ID 1	ID 2	Label 1	Label 2	Link strength
494	2329	complexity	performance	49
494	2731	complexity	risk	12
2329	2731	performance	risk	17

Based on chapter 2.2 and the data portrayed in Figure 3 and Table 7 , research question 2.B is going to be answered.

The interrelations of SCC and SCP established in the last century (Beamon, 1999). This article is also referenced multiple times in the dataset that was found on SCC. With a better management of SCC the SCP will rise (Bozarth *et al.*, 2009, pp. 89–90). The difficulty in managing SCC to maintain the desired SCP will increase with higher SCC (Serdarasan, 2013, pp. 537–538). It is interesting to consider the driver of SCC in relation to SCP (Chapter 2.2). The eight drivers of SCC also affect the SCP in various ways (Leeuw *et al.*, 2013, p. 969). The driver uncertainty can also be found in the keyword cluster in Figure 3. Other drivers as the structure and the lack of cooperation can be identified by combining knowledge and fall under keywords as integration. As SC integration is defined as the level of cooperation that SC actors engage in and in what way the SC processes are collaboratively managed (Kotzab *et al.*, 2020, p. 288). The link between complexity and performance has the second highest link strength with 49 articles sharing both keywords. Both words define the yellow cluster in the network analysis. SCC and SCP are both closely linked to SC integration which is another topic of SCM at the ravages of time (Kotzab *et al.*, 2020).

The interrelations of SCC and SCR are shaped by spatial complexity (Chapter 2.2). A SC that is globally connected is more prone to disruptions, bankruptcies, breakdowns, and political changes. The risks rise with a more complex SC. In global SCs, the speed and frequency of risks is more significant (Manuj and Mentzer, 2008, p. 196). As there are different risk management strategies, one of them is the hedging strategy. To reduce risk the hedging strategy applies measures. To reduce risk the hedging strategy applies measures by spreading the risk into a portfolio. In the finance sector, this means buying different assets, in the SCM context, this means to avoid single sourcing. The wide array of faculties of the suppliers will reduce the risk but will increase complexity and thus reduce the performance (Tang and Nurmaya Musa, 2011, p. 1450). Nevertheless, it is vital to conclude the right risk management strategies in complex SCs (Sofyalıoğlu and Kartal, 2012, p. 1456). The link between SCR and SCC is well established in the literature but less significant in the bibliometric analysis than the interrelations between SCC and SCP. The link strength of 12 compared to 49 and the belonging to different keyword cluster further emphasize that finding. The linkage is still the 83. highest link strength of 380 links in total. Therefore, the interrelations are not found to be very strong but still important.

Regarding the interrelations to GSCM, some very interesting results of the bibliometric analysis can be found. Inside the dataset the keyword global SC is only linked once with the term complexity. The reason for this gives (Vachon and Klassen, 2002) paper on *Supply Chain Complexity and delivery performance*. Most of the authors dealing with SCM already think of a global SC when using the terms SCM or SC, meaning that there can be a real interrelation as indicated in pertinent literature. In the complete dataset of 768 records, 22 articles have the word "global" in their title and 25 of the 3,494 keywords are either global or have the term global inside the article. The most prominent global keywords are Global Sourcing, Global

Supply Chain and Global Optimization (5, 4 and 4 occurrences). Both indicate a relationship of SCC and GSCM in the dataset. On the other hand, the interrelations between SCC and GSCM are well documented in literature. The spatial complexity of a SC is directly linked with the global aspects of SCM. Information transfer is of great value and necessity when trying to manage global SCC. It is no longer possible to regard to SCC without viewing it in a global context (Bode and Wagner, 2015; Vachon and Klassen, 2002). Also there are studies trying to link GSCM with SCP, SCR, and SCC (Kinra *et al.*, 2020; Ivanov and Dolgui, 2020; Reinerth *et al.*, 2018). Cultural aspects from different countries further increase the complexity and risks and make it more difficult to reach the needed performance. Another deciding factor in complexity are the information systems that are split in the keyword analysis in the black cluster.

Global demand is increasingly homogenous, global competition intensifies, and companies search for competitive advantages, taking risks as SCs get more complex while this makes it harder to achieve the desired performance (Sofyalıoğlu and Kartal, 2012, p. 1449). This last statement also answers the research question 2.B as SCC, SCP, SCR, and GSCM have interrelations and are influenced by each other.

4.6   Further Findings – Agency Theory

Regarding the article's research, there was found a research field, which seems to be of high importance. Merely two articles about the field "agency theory and asymmetric information" were found in a totality of 60 articles (LC). Those two articles from (Wilhelm *et al.*, 2016) and (Kalkanci *et al.*, 2011) are four and nine years old and therefore still relatively new which is another reason to look into the connections of SCC and agency theory. There was only found a very limited number of papers dealing with the agency theory in the context of international SCC earlier than in the last decade. The reason for that could be an increased international interconnectedness especially within the last decade (Auer *et al.*, 2017, p. 3). Therefore, also the trade across borders has risen constantly which does imply a rising amount of information in a SC's environment. This rising amount of information does also increase the risk of asymmetric information between the principal and the agent. Including the rising globalization, further pushing environmental complexity and uncertainty, more information is available with which SC managers must deal with. Therefore, it is not surprising that several authors outline that the agency theory and asymmetric information problem field will further increase, leading to significant coordination problems and SC disruptions (Wilhelm *et al.*, 2016; Kalkanci *et al.*, 2011; Mussa, 2003, p. 17). Conversely, increased agency problems will further increase SCC. Therefore, the topic has not been that relevant earlier – due to a lower global interconnectedness – and is even more relevant now.

Due to the importance of the connection between the agency theory and SCC, this could be an interesting research field for further papers, taking a closer look to possible consequences for SCs.

5 Conclusion

Through providing an overview over the academic output, the most contributing authors, the most impactful articles and the affiliation of the research, the theoretical foundation of the research field SCC was examined. The most influential paper was written by Choi and Krause (2006) with 71 LCs and the most relevant articles were published in the *Journal of Operations Management*.

Regarding the interdisciplinarity of SCC, the considered data set appears to be insufficient, since the considered Journals are published in the field of Social Sciences. Therefore, the implications must be perceived cautiously. The findings imply that SCC is interdisciplinary within the research domain of Social Sciences. The preliminary statements about the interrelations of SCC to SCP and SCR can be validated. The results of the content analysis establish a strong relation inside the research field of GSCM linking SCC, SCR, and SCP.

The findings of this paper result in a positive outcome for researchers dealing with SCC. The identified intellectual foundation with the contribution of authors, journals, articles, and keywords increases the accessibility to SCC. Based on these results, researchers are able to evaluate their findings. Additionally, the paper revealed two interesting topics for further research.

However, there are some limitations in the paper. First of all, the analysis process with Histcite has generated a few errors. Some of the articles, as noted in Figure 1, do not have a publishing date assigned to them. This caused some errors in the calculated trend line of the NAP. Furthermore, one article had a wrong citation score. There remains a possibility that this is not the only error of this kind. This might have led to some biases in the citation analysis.

For a more holistic analysis, more data sources in addition to the core collection of WoS could be considered. The investigated journals all publish in the Social Science domain. Accordingly, the interdisciplinary nature of SCC outside the research domain cannot be reviewed in the dataset.

To address this issue, one could observe an extended set of Journals. E.g. before refining the literature and citation data the *Journal of Cleaner Production* by Elsevier contributed 56 records to the research field of SCC. Based on the NAP it would rank at a joint fourth place.

The findings to the agency theory embedded into SCC present an interesting finding. The agency theory originates in the new institutional economics. The application of the agency theory in the field of SCC offers a new perspective and assist managers in further dealing with SCC.

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Appendix

All documents of the Appendix can be found in the attached document.

Table of Contents

Appendix 1: Full List of Journals in the Dataset

Appendix 2: 30 most locally cited articles in dataset (basis for: Figure 2)

Appendix 3: Keyword cluster SCC dataset (Threshold: 2 occurences)

Appendix 4: First three rows of map.txt file for Figure 3

Appendix 5: First three rows of network.txt file for Figure 3

Appendix 6: Example for matched table (capabilities and complexity)

Affidavit

We hereby declare that we have produced the present work independently and without the use of any aids other than those specified. All passages that have been taken literally or analogously from published or unpublished writings are marked as such. The paper has not yet been submitted in the same form or in extracts in the context of other examinations.

Bremen, 09.06.2021

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Paul Mäder

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_____

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