

Review

Bibliometric Analysis of Supplier Management: The Theme and Cluster Perspectives

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Abstract: This paper conducted a bibliometric analysis based on 4687 papers on supplier management from 1997 to 2017. Through a comparative analysis of the four stages using Bibexcel and Ucinet6 software, this paper explores the evolution of supplier management from the theme and cluster perspectives. The results show that supplier management research has made breakthroughs in both breadth and depth. Representative research themes, such as “sustainable supply chain”, “corporate social responsibility”, “knowledge management”, etc., have gradually penetrated into the field of supplier management. Research related to “supplier selection” and “supplier relations” have always been of the highest strategic importance, and themes in “supplier relations” cluster such as “trust” and “commitment” have gradually attracted more and more researchers’ attention. The “inventory” cluster has also been a research focus, and the structural stability and maturity of the cluster have gradually improved. The “innovation” cluster is a relatively “open” cluster, and its impact on the entire research field of supplier management has been gradually increasing. More importantly, the “sustainability” cluster is an evolving cluster, research themes related to “sustainability”, such as “green supply chain”, “sustainable supply chain” and “green supplier selection”, will play an increasingly important role in the field of supplier management.

Keywords: supplier management; evolution; co-word analysis; cluster analysis; bibliometrics; strategic diagram

1. Introduction

In the 21st century, the operating environment of the supply chain shows the characteristics of globalization, rapid development of technological, and rapid change of customer demand. In the context of globalization, more and more companies have been trying to improve their competitiveness from the perspective of procurement and products that are closely related to suppliers [1]. As the basic unit of the supply chain, suppliers are considered to be an important part of the supply chain network and play an important role in business performance, responding to market competition, and improving customer satisfaction [2].

Another consequence of globalization is that it provides companies with more optional suppliers and increases the dependence of the company on suppliers [3]. At the same time, the mistakes of decision-making in supplier management may lead to significant negative impacts on companies. In 2000, Ericsson lost 400 million U.S. dollars and its competitive position in the mobile phone market which is due to its supplier’s failure to provide some key components on time [4]. Toyota recalled more than 20 million vehicles between 2004 and 2010, mainly due to the quality problems of parts and subassemblies produced by its suppliers, causing an estimated \$6 billion in losses [5]. Therefore, supplier management not only can influence whether the company could achieve sustainable competitive advantage, but also is vital for the survival of the company.

The important role of supplier management in practice has also promoted the development of related academic research. After decades of accumulation, research themes in the field of supplier management have been more and more abundant, and the relationship network of research themes has become more and more complex. Many researchers have adopted the literature review approach, which contributes to the construction of a research field and provides a background for its development [6], to better understand the development of the supplier management. In terms of research themes, literature reviews on sustainability and supply chain, such as sustainable supply chain, green supply chain and low-carbon supply chain, have attracted the most attention in recent years. These literature reviews are structured using the following different categories: definitions [7], framework [8], theme structure [9–11], research methods or theories [11–15], drivers or barriers [14–18], key elements [19], etc. There are also literature reviews focusing on the interaction of sustainability with other themes in the context of the supply chain, such as innovation [20], supplier selection, monitoring and development [21], supply chain performance measures [22] and circular economy [23]. Literature reviews on supply chain risk management mainly analyze the definitions [24], risk types [24–26], risk factors [24,27], and mitigation strategies [24,25]. Research on mathematical methods dominates the original studies on the theme of supplier selection [28], as well as the literature reviews. Literature reviews on supply chain collaboration mainly include two directions, one is the impact of supply chain collaboration on performance [29–31], and the other is the key themes of supply chain collaboration [32]. In addition, the application of emerging technologies such as big data, blockchain, Internet of things (IoT) in the supply chain [33–36] has become an important part of recent literature reviews in the field of supplier management.

Through a comprehensive analysis of the existing literature reviews related to the field of supplier management, it can be found that the literature reviews on supplier management are fragmented, and most of them are only for specific research themes. In terms of methodology, most of these literature reviews have mainly adopted the method of qualitative analysis, which is essentially based on the experience of researchers and will reduce the reliability of research results [37]. Even though there are a few literature reviews that adopted the method of bibliometric analysis, most of them are static analysis of literature within a certain research period, and comprehensive and dynamic bibliometric analysis for supplier management is missing. To fill this research gap, this paper conducts a bibliometric analysis of the literature in the field of supplier management from 1997 to 2017, and mainly intends to answer the following four questions:

- Q1: what are the hot research themes in the field of supplier management?
- Q2: what is the relationship between these hot research themes?
- Q3: What are the evolution trends in the field of supplier management?
- Q4: What are the main future research directions in the field of supplier management?

In order to answer these above questions, this paper conducts the bibliometric analysis from both theme and cluster perspectives. This paper is organized as follows: after the introduction (Section 1), the materials and methodology are presented and explained in Section 2. Section 3 conducts co-word analysis and discusses the hot research themes and evolution trends from the theme perspective, thus answering Q1 and Q3. Section 4 conducts cluster analysis from a different perspective and explores the interrelationship between the themes as well as the evolving trends in the field of supplier management, thus answering Q2 and Q3. Section 5 discusses the important findings, thus answering Q3. Section 6 summarizes the conclusions, and proposes suggestions for future research, thus answering Q4.

2. Materials and Methodology

2.1. Bibliometric Analysis Method

The method of bibliometrics analysis, which is the quantitative analysis of scholarly publication and citation data and intends to provide insight into the value and influence of published research,

is adopted in this paper. Compared with the traditional literature review method, bibliometrics analysis can handle a large number of articles more effectively, and visualization results of bibliometrics tools such as Bibexcel, Ucinet, CiteSpace and VOSviewer, makes it easier for readers to understand the development of a research field. More importantly, the bibliometrics analysis method enables us to obtain more comprehensive information through quantitative analysis [38].

Co-word analysis is a kind of bibliometrics method which can be used to track the evolution of a research field along consecutive time periods [39]. Co-word analysis can be divided into three steps: First, a word database should be created. It should be noted that in order to ensure the validity of the word database, words need to be processed, such as merging singular and plural words, unifying different expressions of the same word, combining abbreviations and full names, etc. Second, a co-occurrence matrix should be built based on the co-occurrence frequency of each two words, which can represent the strength of the connection between two words. Third, the results of the second step should be further processed through visualization tools to reveal the hot research themes and evolution trends of a research field. In this research, Bibexcel software is used to conduct the Co-word analysis.

The relationship between the research themes also has an important impact on the development of supplier management research. However, the relationship network among the themes has become more and more complex, so this paper combines cluster analysis and strategic graph together to conduct the analysis from a different perspective, which can provide valuable information that is helpful to explore the evolution trends of a research field from a different perspective. In this research, Ucinet6 software is used for cluster analysis.

2.2. Data Collection

In order to draw a comprehensive and valid picture of the evolutionary history of supplier management research, this paper collected all related literature from Web of Science Core Collection, which is an authoritative retrieval platform for scientific documents worldwide. On January 8, 2018, we used “Supplier” and “Vendor” as “Title”, and set the “Timespan” to “1997–2017”. In addition, the “Document Types” was limited to “Article” and the “Search Language” was limited to “English”. According to the above search algorithm, a total of 4687 papers were obtained, as shown in Figure 1.

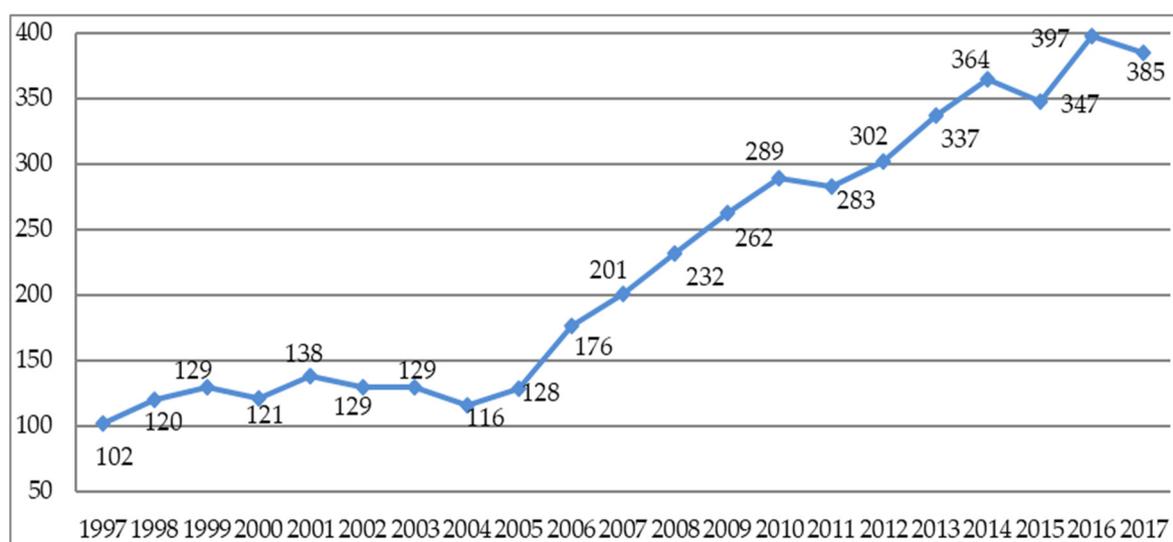


Figure 1. The number of papers from 1997 to 2017.

3. Results of Co-Word Analysis: From the Theme Perspective

In order to summarize the evolution trends in the field of supplier management, this paper divides the research period into four stages: 1997–2001 (stage 1), 2002–2006 (stage 2), 2007–2011 (stage 3) and 2012–2017 (stage 4).

3.1. The Establishment of Word Database

Keywords can clearly and intuitively reflect the core content of the literature. Therefore, this paper takes keywords as the input of the word database. It is worth noting that the preliminary processing of keywords is crucial to the establishment of word database. In addition to the unified rules as mentioned above, data purification is also necessary. Since the main purpose of this paper is to reveal the hot research themes, theme clusters and revolution trends in the field of supplier management, keywords that cannot represent the research theme need to be deleted from the database, as shown in Table 1.

Table 1. Data processing rules.

Rule	Example	
	Before	After
1. Unify the singular and plural forms of keywords	supplier, suppliers	supplier
2. Unify the different expressions of the same word	supplier, vendor	supplier
3. Unify the abbreviation and full writing of the same word	VMI, Vendor managed inventory EOQ, Economic Order Quantity JIT, Just in Time PSO, Particle Swarm Optimization	VMI EOQ JIT PSO
4. Unify different expressions of the same meaning	supplier selection, supplier selection problem	supplier selection
5. Delete keywords that cannot represent the research theme	keywords representing regions, countries, industries, etc.	deleted

After preliminary processing of keywords, this paper conducts statistical analysis on the keywords, and sorts them in descending order of frequency. Due to the large number of keywords, only the top 20% of keywords with high frequency are selected according to the “80/20 rule” as input to establish the word database. Therefore, these keywords selected in the database represent the hot research themes in the field of supplier management.

The word database for the four stages is shown in Table 2.

Table 2. Word database for the four stages.

Stage 1	Stage 2	Stage 3	Stage 4
Supplier Relations	Supplier Relations	Supplier Selection	Supplier Selection
Purchasing	Inventory	Supplier Relations	Supplier Relations
Inventory	Supplier Selection	Inventory	Inventory
Product Development	Purchasing	Purchasing	VMI
Supplier Selection	Quality Management	VMI	Purchasing
Outsourcing	Product Development	Trust	Trust
Logistics	Supplier Evaluation	Supply Chain	Outsourcing
JIT	Trust	Coordination	Supplier Risk
Supplier Involvement	Supply Chain	Supplier Evaluation	Supplier Evaluation
Production	Coordination	Supplier Risk	Supply Chain
Supplier Cooperation	Supplier Network	Outsourcing	Coordination
Supply Contract	VMI	Supply Chain Integration	Product Development
Product Design	Supplier Development	Product Development	Innovation
Quality Management	Supplier Involvement	Supplier Development	Green Supply Chain
Lead Time	Outsourcing	Supplier Involvement	Supply Chain Contract
Technology Transfer	Innovation	Innovation	Supplier Development
Supplier Rating	Retailing	Supplier Performance	Sustainability
Supply Chain	Commitment	Delay in Payment	Supplier Performance
Coordination	EOQ	Supply Chain Contract	Supply Chain
Satisfaction	Production Planning	Order Allocation	Collaboration
Distribution	Environmental	Logistics	Green Supplier Selection
Information System	Management	Lot Sizing	Supplier Network
VMI	Supply Chain	Pricing	Power
	Collaboration	Relationship Marketing	Quality Management
	Lead Time	Channel Relationship	Supplier Competition
		JIT	Quantity Discount
		Transaction Cost	Sustainable Supply
		Economics	Chain
		Supplier Network	Information Sharing
		Supply Chain	Order Allocation
		Collaboration	Asymmetric Information
			Supplier Involvement
			Supply Chain Integration
			Lot Sizing
			Consignment Inventory
			Commitment
			Trade Credit
			Supplier Cooperation
			Pricing
			Transaction Cost
			Economics
			Decision Support System
			PSO
			Corporate Social
			Responsibility
			Knowledge Management
			Customer

3.2. The Establishment of Co-Occurrence Matrix

The co-occurrence matrices of high-frequency keywords for the four stages are calculated using Bibexcel. The element of the co-occurrence matrix represents the co-occurrence frequency of keywords, and diagonal elements indicate the self-frequency of keywords. Table 3 shows part of the co-occurrence matrix of keywords for stage 4.

Table 3. The co-occurrence matrix of high-frequency keywords (Part) ¹.

	Supplier Selection	Supplier Relations	Inventory	VMI	Purchasing	Trust	...
Supplier Selection	314	2	10	0	8	0	...
Supplier Relations	2	171	0	0	7	12	...
Inventory	10	0	88	11	2	0	...
VMI	0	0	11	63	0	0	...
Purchasing	8	7	2	0	56	1	...
Trust	0	12	0	0	1	47	...
...

¹ The co-occurrence matrices of all high-frequency keywords for the four stages were established, this table shows only partial data for example.

3.3. Visualization of Hot Research Themes

In order to better understand the evolution of hot research themes in the field of supplier management at different stages, this paper draws the quadrant diagram of keywords for each stage on the basis of the co-occurrence matrix. Specifically, the frequency of the keyword itself and its co-occurrence frequency with other keywords are taken as the vertical axis and the horizontal axis respectively, and the mean value of all keywords at this stage is taken as the origin. The frequency of the keyword itself can reflect the degree of researchers’ attention or enthusiasm for this research theme, while the co-occurrence frequency can reflect the strength of interaction or connection between the research theme and other themes. The position of the keyword in the quadrant diagram indicates its strategic position in the research field. If the occurrence frequency and co-occurrence frequency of a keyword is high, it is obvious that this research theme plays an important role in the field of supplier management.

The quadrant diagrams of hot research themes for the four stages are shown in Figures 2–5.

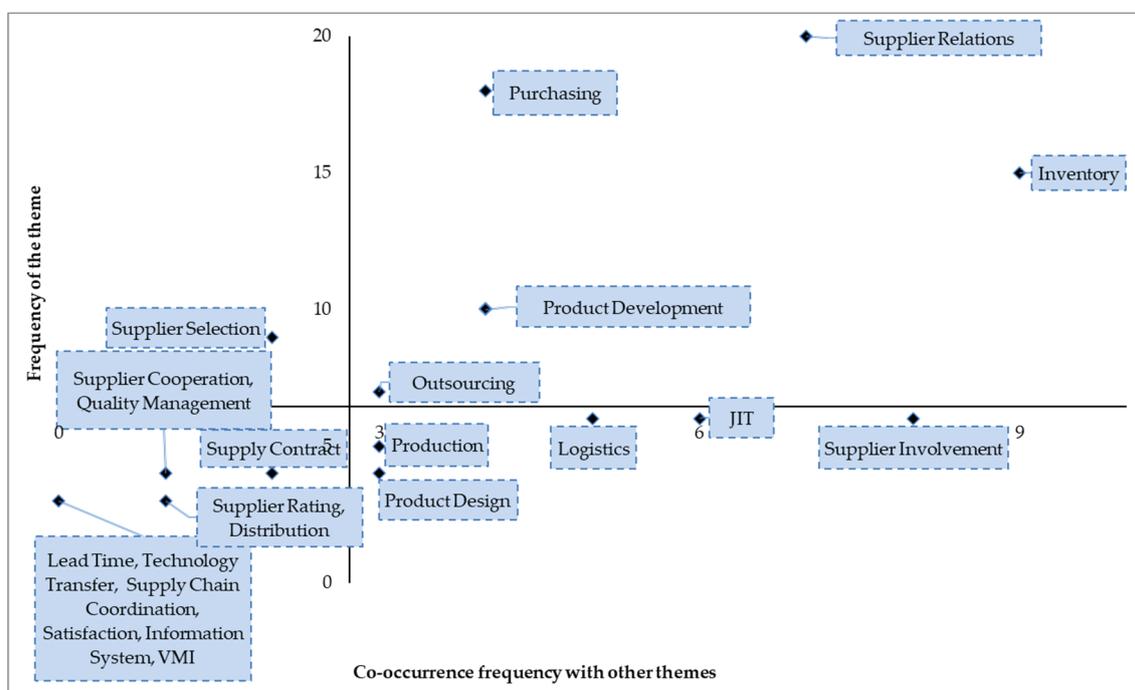


Figure 2. Quadrant diagram of hot research themes for stage 1.

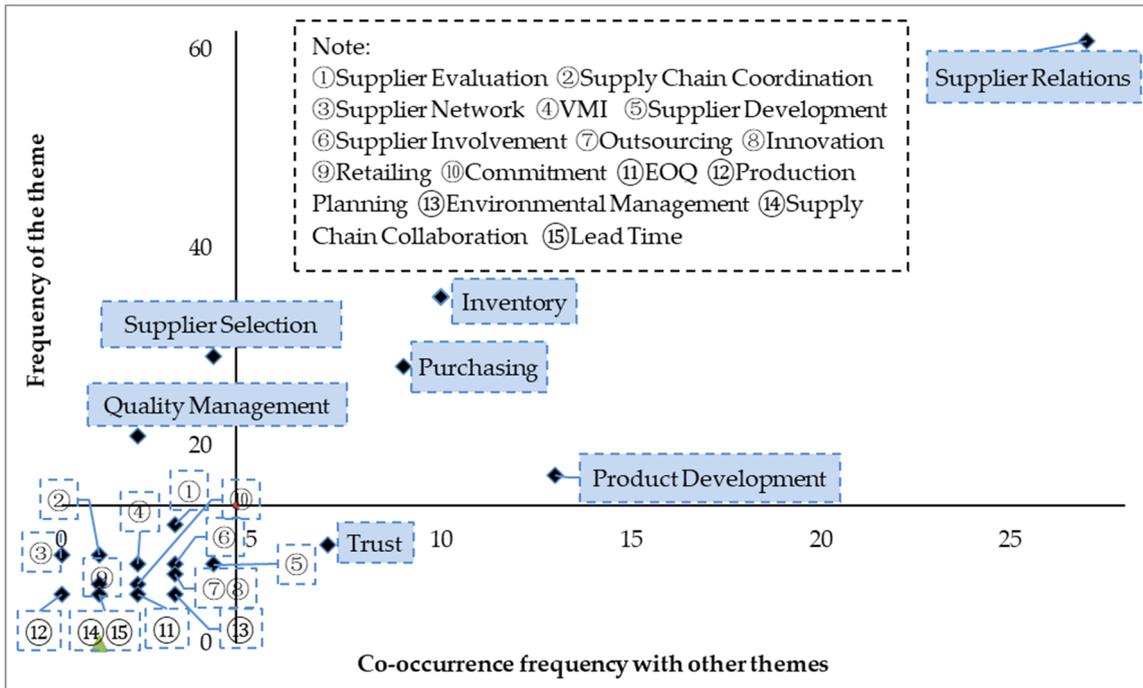


Figure 3. Quadrant diagram of hot research themes for stage 2.

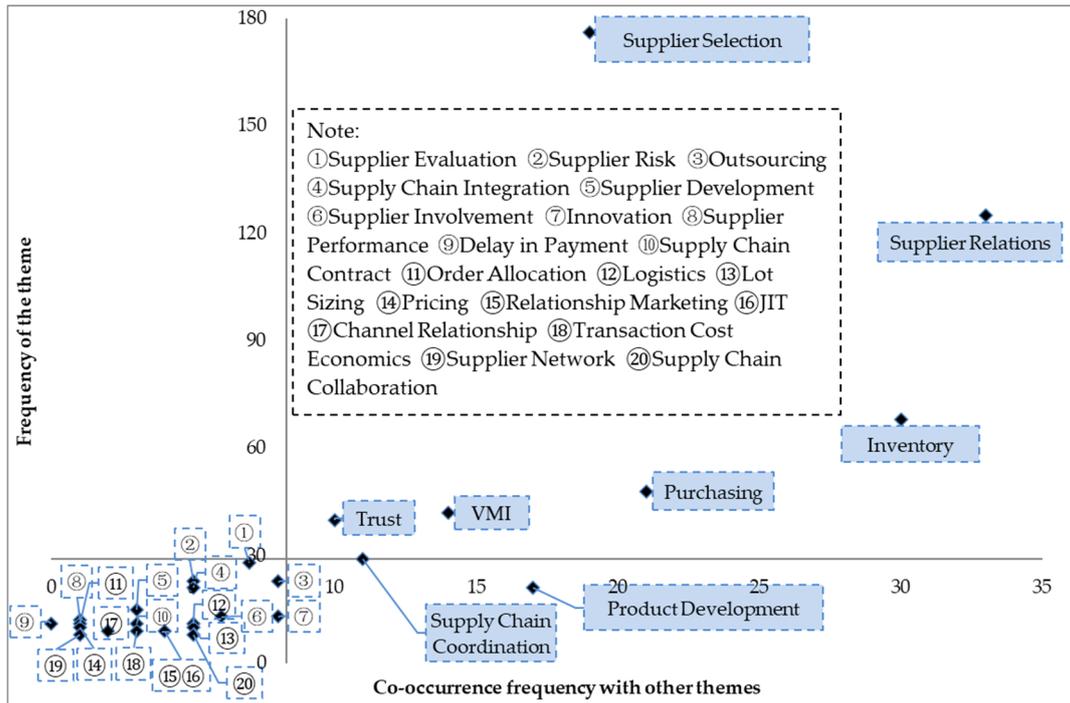


Figure 4. Quadrant diagram of hot research themes for stage 3.

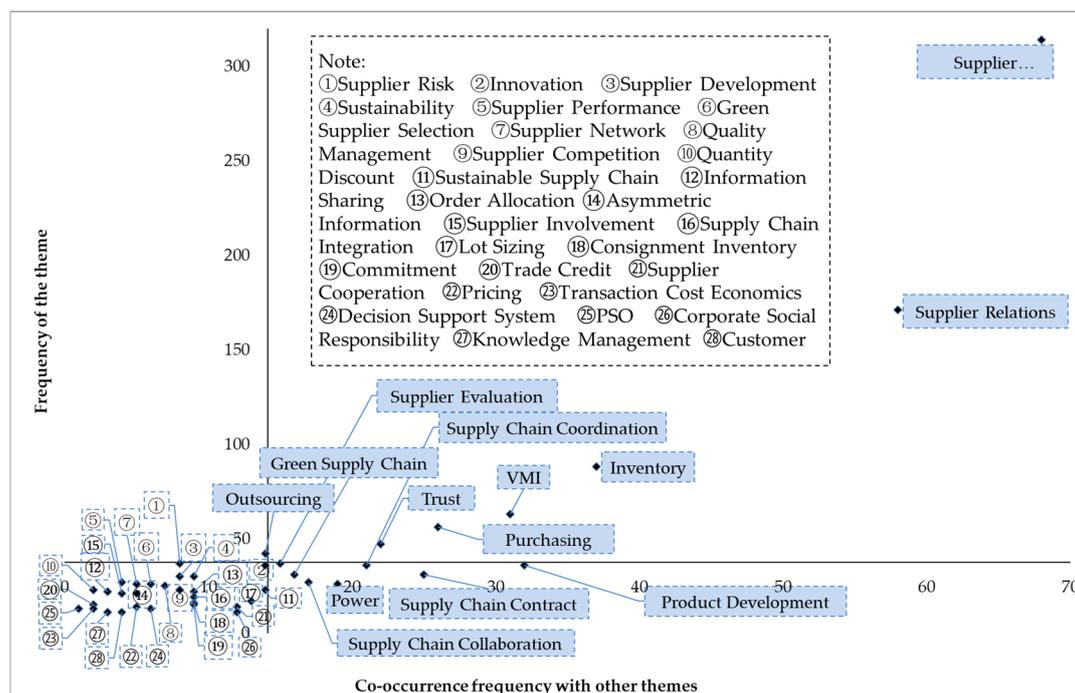


Figure 5. Quadrant diagram of hot research themes for stage 4.

According to the four-quadrant rule, research themes in the first quadrant are characterized by high self-frequency and high co-occurrence frequency, themes in the second quadrant are characterized by high self-frequency and low co-occurrence frequency, themes in the third quadrant are characterized by low self-frequency and low co-occurrence frequency, and themes in the fourth quadrant are characterized by low self-frequency and high co-occurrence frequency. In order to make the data more intuitive, the annual self-frequency and co-occurrence frequency of the hot research themes at each stage are calculated as a supplement to the quadrant diagrams, so as to better understand the evolution of hot research themes in different stages. The calculation results and the quadrant changes of the themes are shown in Table 4. Due to the large number of themes, only the themes in the first, second and fourth quadrants are shown in Table 4.

Table 4. The numerical changes of hot research themes.

Research Theme	Freq./Year	Co-Occurrence Freq./Year	Quadrant
	Stage: 1→2→3→4	Stage: 1→2→3→4	Stage: 1→2→3→4
Supplier Relations	4.0→12.2→25.0→28.5	1.4→5.4→6.6→9.7	1st→1st→1st→1st
Supplier Selection	1.8→5.8→35.2→52.3	0.4→0.8→3.8→11.3	2nd→2nd→1st→1st
Inventory	3.0→7→13.6→14.7	1.8→2.0→6.0→6.2	1st→1st→1st→1st
Purchasing	3.6→5.6→9.6→9.3	0.8→1.8→4.2→4.3	1st→1st→1st→1st
VMI	0.6→1.6→8.4→10.5	NA→0.4→2.8→5.2	3rd→3rd→1st→1st
Trust	NA→2.0→8.0→7.8	NA→1.4→2.0→3.7	NA→4th→1st→1st
Outsourcing	1.4→1.4→4.6→7.0	0.6→0.6→1.6→2.3	1st→4th→4th→2nd
Product Development	2.0→3.4→4.2→6.0	0.8→2.6→3.4→5.3	1st→1st→4th→4th
Supply Chain Coordination	0.6→1.8→5.8→6.0	NA→0.2→2.2→3.5	3rd→3rd→4th→4th
Supplier Evaluation	NA→2.4→5.6→6.2	NA→0.6→1.4→2.5	NA→3rd→3rd→4th
Supply Chain Collaboration	NA→1.0→1.6→4.5	NA→0.2→1.0→2.8	NA→3rd→3rd→4th
Green Supply Chain	NA→NA→NA→5.2	NA→NA→NA→2.7	NA→NA→NA→4th

3.4. Results of Theme Analysis

Through the above comparative analysis of the four stages from the theme perspective, it can be found that studies on supplier management from 1997 to 2017 mainly presents the following development trends:

- The research on supplier management has made breakthroughs in both breadth and depth. As can be seen from Figures 2–5, representative research themes, such as, “sustainability”, “corporate social responsibility”, “knowledge management”, etc., have gradually penetrated into the field of supplier management. In addition, it can be seen from Table 4 that the self-frequency and co-occurrence frequency of most hot research themes show an increasing trend, which to some extent indicates that these hot research topics continue to make breakthroughs in depth.
- Researchers have always been very enthusiastic about the research themes, such as “supplier selection”, “supplier relations” and “inventory”, which are always in the first quadrant of the quadrant diagrams for the four stages, see Figures 2–5. This conclusion can also be confirmed in Table 4, from which it can be found that the frequency of these three themes has been always in the top three.
- The research themes of “VMI” and “trust” are attracting more and more researchers’ attention. As can be seen from Figures 3 and 4, the theme “VMI” moved from the third quadrant to the first quadrant, and “Trust” from the fourth quadrant to the first quadrant, indicating that the number of studies on these two themes increased significantly. Figure 5 shows that these two themes are still in the first quadrant at stage 4, indicating that these two themes are of great strategic importance in the field of supplier management.
- It can be predicted from the trends that research themes, such as “green supply chain”, “supply chain collaboration”, will become more and more important in the field of supplier management. “Supply chain collaboration” appears in the word database at stage 3, and “green supply chain” appears in the word database at stage 4. It can be found in Figure 5 that they are all in the fourth quadrant and are very close to the first quadrant. According to the calculation results in Table 4, the self-frequency and co-occurrence frequency of these two themes are of great potential, and it can be predicted that they will likely move to the first quadrant in the future.

4. Results of Cluster Analysis: From the Cluster Perspective

In fact, the development of a research theme depends not only on the theme itself, but also on those themes that are closely related to it. Through the elements in the co-occurrence matrix, it is easy to find that the connection strength between different research themes is different. More specifically, some themes are closely related, while some are not related. Frequently interacting research themes can form theme clusters, which can provide valuable information that is helpful to explore the evolution trends of a research field from a different perspective. Therefore, this paper combines cluster analysis and strategic graph together to conduct the analysis of research themes which can explore the interrelationship between the themes as well as the evolution trends in the field of supplier management.

4.1. The Establishment of Similarity Matrix

Since the elements in the keyword co-occurrence matrix are the values of the co-occurrence frequency, it is difficult to accurately reflect the correlation between the research themes. Therefore, the Ochiai coefficient is used to codify the co-occurrence matrix and a similarity matrix of the co-occurrence matrix is generated [40], as shown in Table 5.

Table 5. The similarity matrix (Part) ¹.

	Supplier Selection	Supplier Relations	Inventory	VMI	Purchasing	Trust	...
Supplier Selection	1	0.008631	0.060158	0	0.06033	0	...
Supplier Relations	0.008631	1	0	0	0.071533	0.133855	...
Inventory	0.060158	0	1	0.147734	0.02849	0	...
VMI	0	0	0.147734	1	0	0	...
Purchasing	0.06033	0.071533	0.02849	0	1	0.019492	...
Trust	0	0.133855	0	0	0.019492	1	...
...

¹ The similarity matrices of all high-frequency keywords for the four stages were established, this table shows only partial data for example.

4.2. Cluster Analysis of the Research Themes

Ucinet6 software is used for cluster analysis. Hierarchical clustering is selected as the clustering method. As for the parameter settings, “Similarities” is selected between “Similarities” or “Dissimilarities”, and “WTD_AVERAGE [average between all pairs]” is selected as the distance calculation method. The tree diagram of theme clusters for the four stages generated by Ucinet6 software, which clearly illustrates the relationship between the themes and clusters, are shown in Figures 6–9.

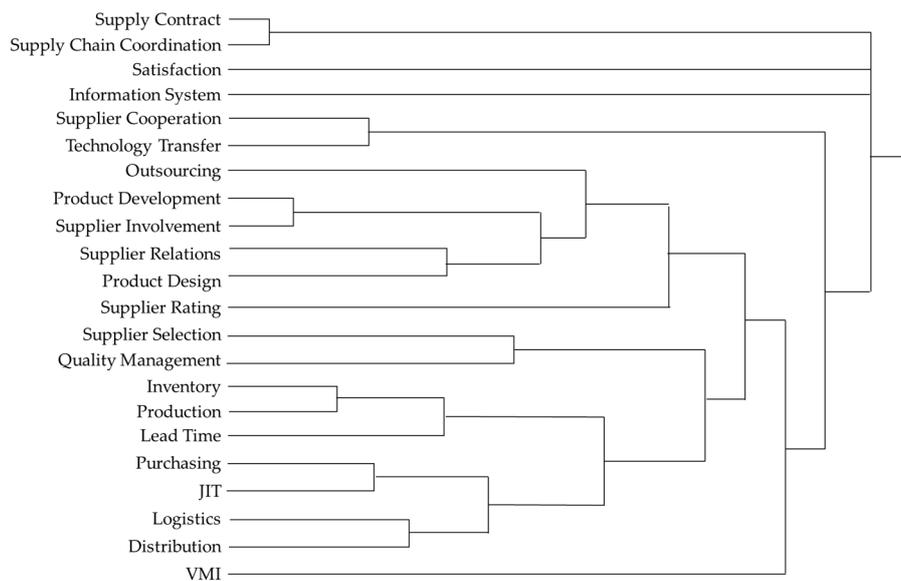


Figure 6. Tree diagram of theme clusters for stage 1.

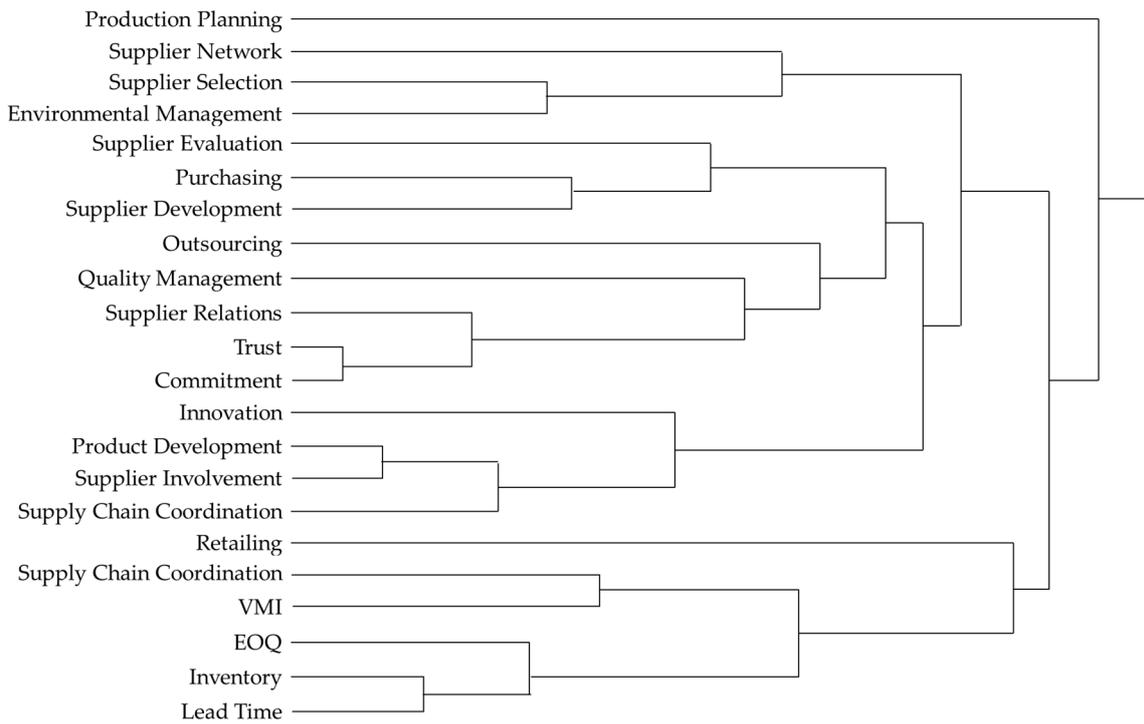


Figure 7. Tree diagram of theme clusters for stage 2.

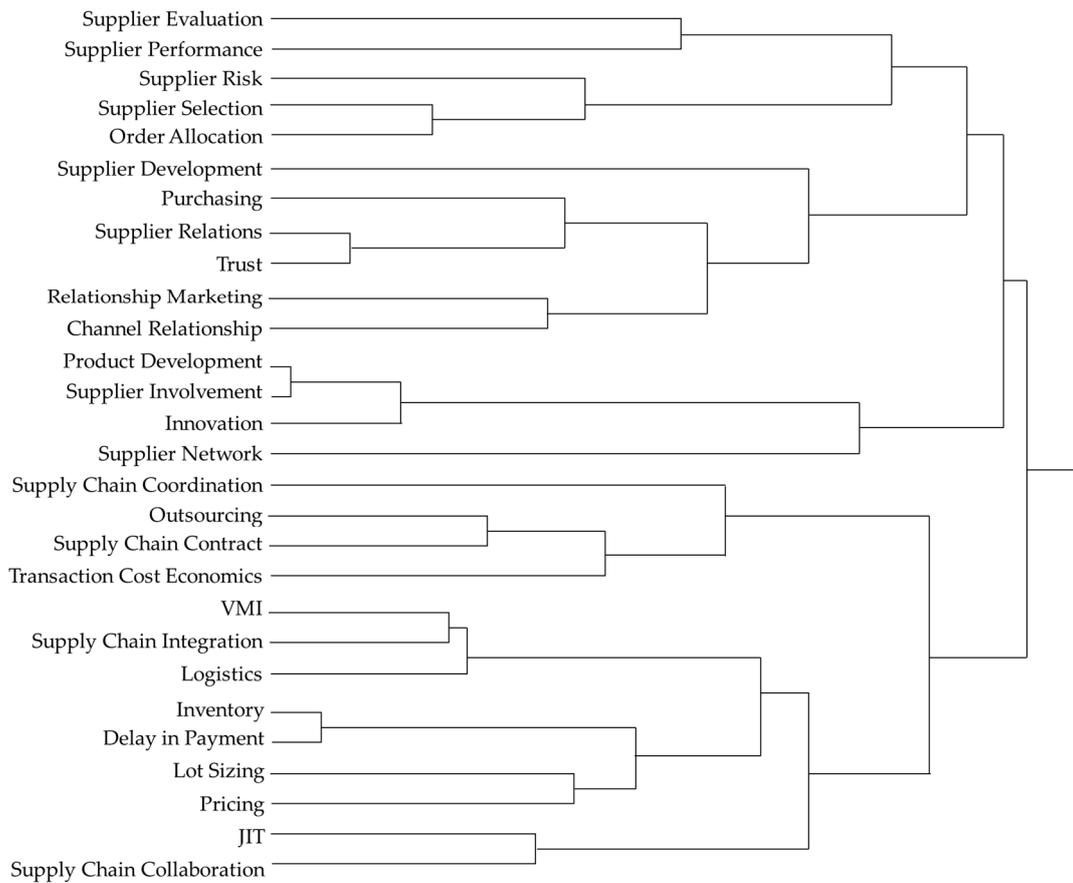


Figure 8. Tree diagram of theme clusters for stage 3.

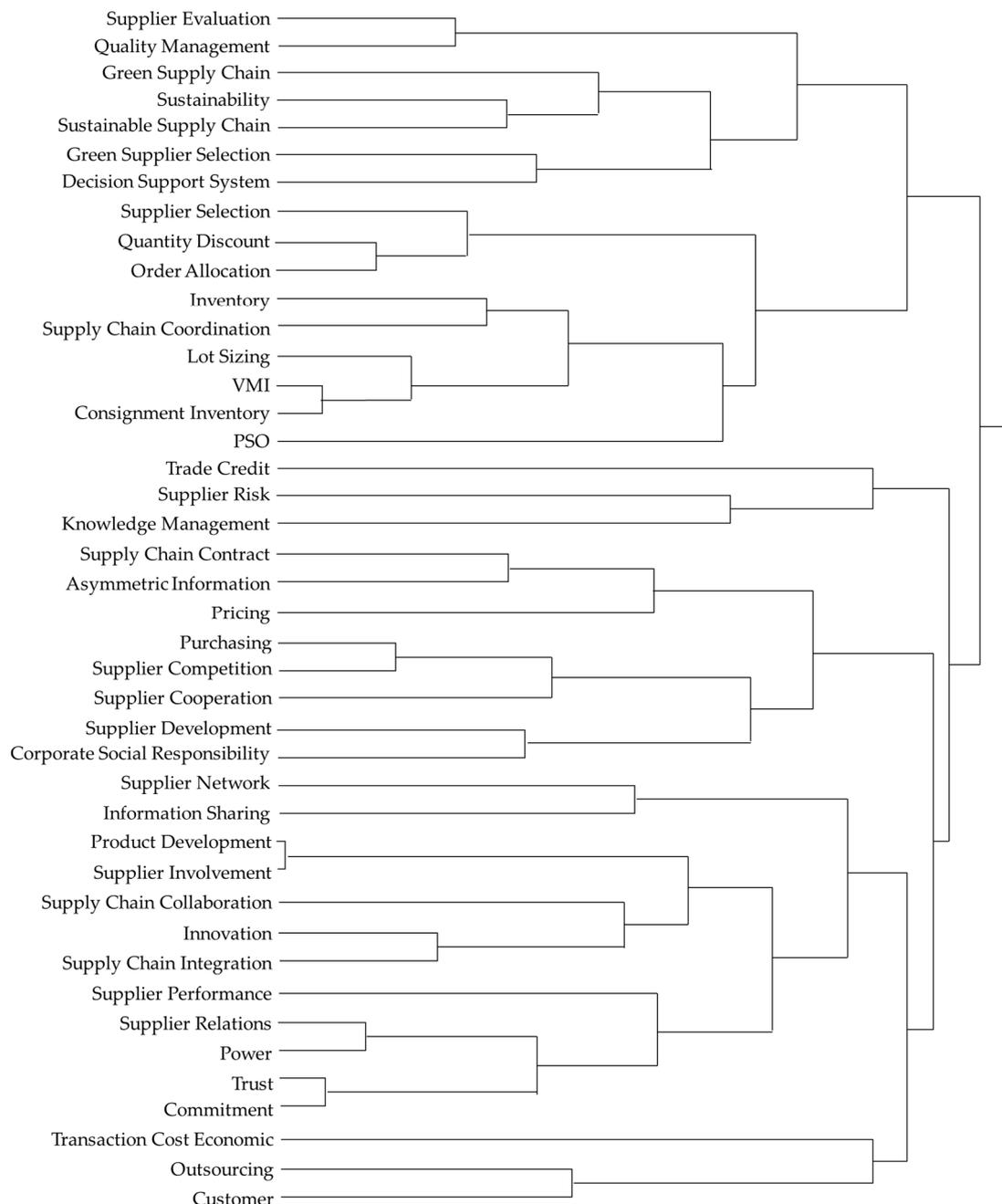


Figure 9. Tree diagram of theme clusters for stage 4.

Each cluster consists of multiple themes, and different themes contribute differently to the entire cluster. The nature of the cluster is generally determined by several core themes with the highest adhesion. Adhesion can be calculated by the mean value of a theme’s internal links with other themes within the cluster (represented by the elements of the similarity matrix) [40]. Actually, adhesion is an index that reflects the average connection strength between one theme and other themes of the same cluster. Therefore, it can also reflect the influence of one theme on the whole cluster in which it is located. In addition, the external linkage which can indicate the strength of a theme’s link to other clusters’ themes at the same stage is also calculated. The external linkage of one theme is equal to the sum of similarity matrix elements between this theme and other clusters’ themes [40].

Details of the theme clusters at each stage are shown in Table 6. It should be noted that the clusters with less than three keywords are removed since the cluster with less than three members does not have statistical significance.

Table 6. Theme clusters for the four stages.

Cluster	Theme	Adhesion	External Linkage
Cluster 1.1	Product Development	0.219273	0.074536
	Supplier Involvement	0.338644	0.192450
	Supplier Relations	0.152105	0.345719
	Product Design	0.210618	0.235702
Cluster 1.2	Inventory	0.454547	0.539341
	Production	0.230940	0.182574
	Lead Time	0.223607	0.000000
Cluster 1.3	Purchasing	0.308604	0.729813
	JIT	0.345522	0.393393
	Logistics	0.297410	0.182574
	Distribution	0.303744	0.149071
Cluster 2.1	Supplier Network	0.061898	0.085358
	Supplier Selection	0.144944	0.353582
	Environmental Management	0.083045	0.186359
Cluster 2.2	Supplier Evaluation	0.105586	0.299069
	Purchasing	0.121370	0.576599
	Supplier Development	0.117846	0.090536
Cluster 2.3	Quality Management	0.066949	0.256129
	Supplier Relations	0.170502	0.604400
	Trust	0.296143	0.240828
	Commitment	0.297132	0.235098
Cluster 2.4	Innovation	0.105657	0.118580
	Product Development	0.276339	0.429758
	Supplier Involvement	0.240164	0.000000
	Supply Chain Collaboration	0.125015	0.084515
Cluster 2.5	Supply Chain Coordination	0.057635	0.303391
	VMI	0.074284	0.000000
	EOQ	0.087796	0.000000
	Inventory	0.167484	0.174544
	Lead Time	0.106695	0.084515
Cluster 3.1	Product Development	0.247634	0.232191
	Supplier Involvement	0.238317	0.122865
	Innovation	0.137446	0.212236
	Supplier Network	0.025717	0.031623
Cluster 3.2	Supplier Evaluation	0.051980	0.171947
	Supplier Performance	0.013639	0.119126
	Supplier Risk	0.053074	0.246429
	Supplier Selection	0.072960	0.401387
	Order Allocation	0.089662	0.036564
Cluster 3.3	Supplier Development	0.030548	0.107676
	Purchasing	0.043002	0.561042
	Supplier Relations	0.138244	0.586022
	Trust	0.068073	0.217986
	Relationship Marketing	0.061193	0.061898
	Channel Relationship	0.046074	0.000000

Table 6. Cont.

Cluster	Theme	Adhesion	External Linkage
Cluster 3.4	Supply Chain Coordination	0.050233	0.447835
	Outsourcing	0.077988	0.338943
	Supply Chain Contract	0.112740	0.129612
	Transaction Cost Economics	0.056670	0.280984
Cluster 3.5	VMI	0.075304	0.258587
	Supply Chain Integration	0.064856	0.139876
	Logistics	0.054955	0.229620
	Inventory	0.106196	0.275574
	Delay in Payment	0.041134	0.000000
	Lot Sizing	0.065394	0.106395
	Pricing	0.040385	0.000000
	JIT	0.047106	0.103053
Cluster 4.1	Supply Chain Collaboration	0.036554	0.241484
	Green Supply Chain	0.083354	0.173655
	Sustainability	0.053899	0.187043
	Sustainable Supply Chain	0.081321	0.124722
	Green Supplier Selection	0.072789	0.104530
Cluster 4.2	Decision Support System	0.054108	0.237223
	Supplier Selection	0.131158	0.642830
	Quantity Discount	0.141863	0.344860
Cluster 4.3	Order Allocation	0.167116	0.327421
	Inventory	0.100741	0.213843
	Supply Chain Coordination	0.109194	0.390706
	Lot Sizing	0.113048	0.340296
	VMI	0.167466	0.109706
Cluster 4.4	Consignment Inventory	0.176077	0.000000
	Purchasing	0.101449	0.444194
	Supplier Competition	0.167184	0.224176
Cluster 4.5	Supply Chain Cooperation	0.101449	0.397488
	Product Development	0.184216	0.233889
	Supplier Involvement	0.119608	0.108746
	Supply Chain Collaboration	0.069649	0.466321
	Innovation	0.091144	0.305743
Cluster 4.6	Supply Chain Integration	0.087510	0.112703
	Supplier Performance	0.067757	0.298894
	Supplier Relations	0.119160	0.654365
	Power	0.136367	0.125993
	Trust	0.191583	0.245327
	Commitment	0.121623	0.293105

As can be seen from Table 6, some themes are always assigned to the same cluster, which means that the interrelationship between them is close. Specifically, there are three groups of themes: (1) “product development”, “supplier involvement” and “innovation”; (2) “supplier relations”, “trust” and “commitment”; (3) “inventory”, “VMI” and “lead time”.

4.3. Visualization of Theme Clusters

In this section, a visual analysis using a strategic diagram is conducted to gain a more intuitive understanding of the strategic position and evolution of the theme clusters.

The horizontal axis and the vertical axis of the strategic diagram represent the clusters’ centrality and density individually. Centrality reflects the strength of the link between one cluster and other clusters. The centrality of a cluster, which can be expressed as the sum of the external linkage of each

theme member, is positively correlated with its impact on the entire research filed or research network. Density, which can be expressed as the mean of each theme’s adhesion within the cluster [40], reflects the strength of the linkages between keywords within a cluster; it can explain the strength of internal linkages, structural stability, and research maturity of research theme clusters.

The centrality and density of these clusters are calculated based on the themes’ adhesion, and the strategic diagrams for the four stages are shown in Figures 10–13.

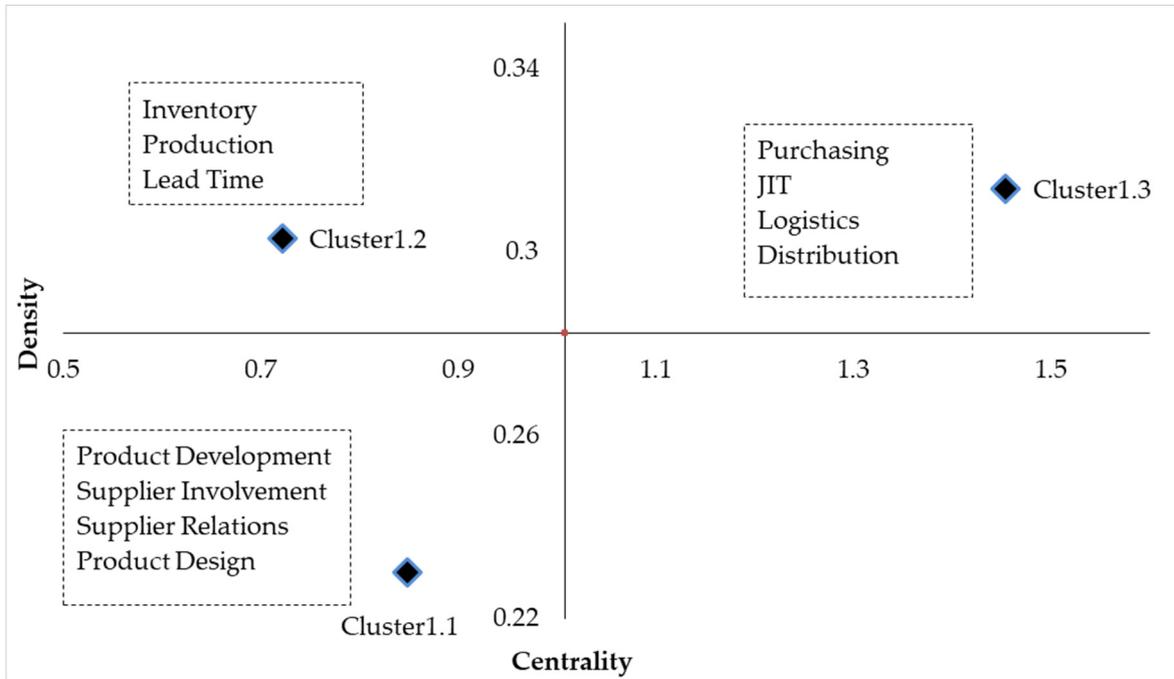


Figure 10. Strategic diagram for stage 1.

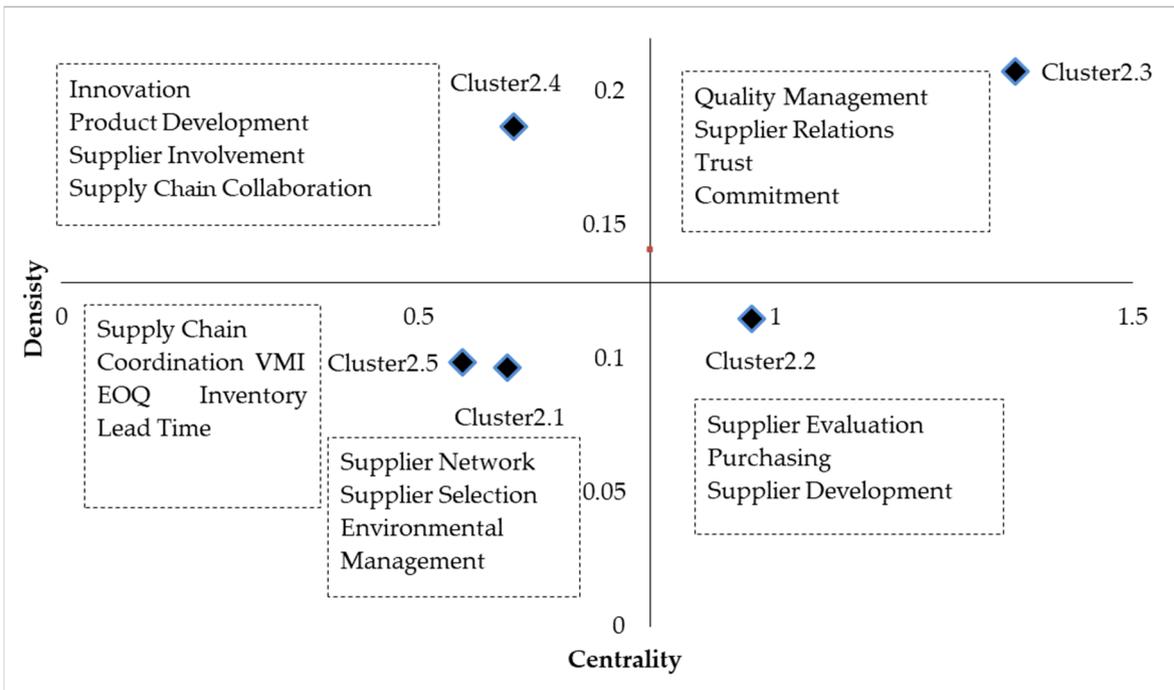


Figure 11. Strategic diagram for stage 2.

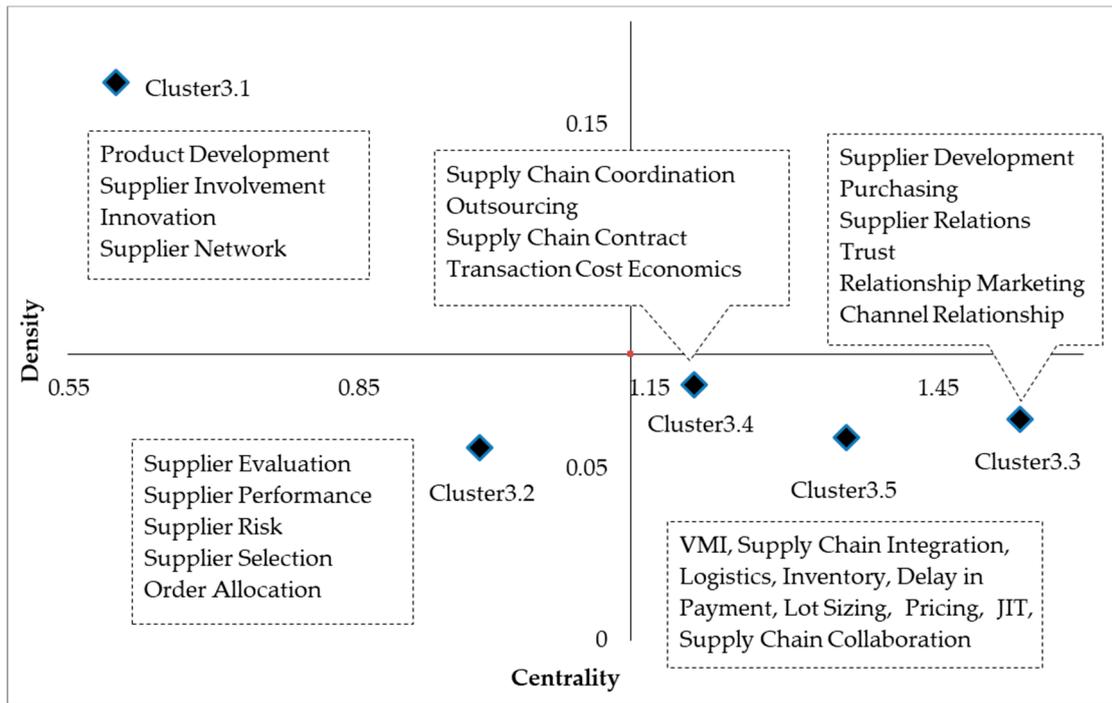


Figure 12. Strategic diagram for stage 3.

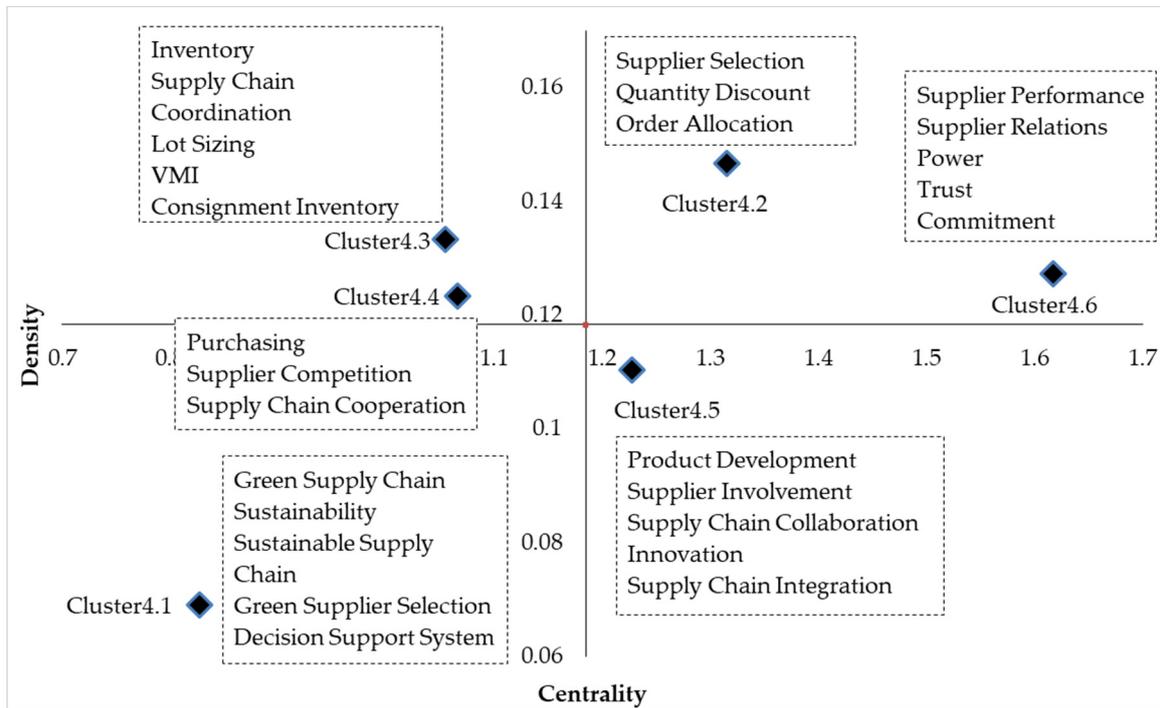


Figure 13. Strategic diagram for stage 4.

The strategic diagrams show that clusters 1.3, 2.2, 4.2 and 4.6 are all of high centrality and density, and are in the first quadrant of their respective stage. This means that both the external connection strength and internal connection of these clusters are relatively high, and these clusters are the core of the research theme networks of their respective stages. Similarly, clusters 1.1, 2.1, 2.5, 3.2 and 4.1 are in the third quadrant of their respective stage, which means that both the external connection strength and internal connection of these clusters are relatively low. Clusters 1.2, 2.4, 3.1, 4.3 and 4.4 are in the

second quadrant of their respective stage, which means that the external connection strength of these clusters is relatively low, while the internal connection strength is relatively high. Clusters 2.2, 3.3, 3.4 and 4.5 are in the fourth quadrant of their respective stage, which means that the external connection strength of these clusters is relatively high, while the internal connection strength is relatively low. The strategic importance of clusters in the second and fourth quadrants is higher than clusters in the third quadrant, but lower than those in the first quadrant.

4.4. Evolution Analysis of Theme Clusters

The strategic diagrams of different stages present different characteristics, and theme members of each cluster in different stages are not exactly the same. This phenomenon is easy to understand, because the development of supplier management research is a dynamic process, with new research themes constantly emerging and the importance of different research themes constantly changing.

Although there are many differences among theme clusters at different stages, it can be found that three groups of clusters that have high similarity and run through multiple stages, which can be used to analyze the evolution of supplier management research. Specifically, group 1, mainly related to “inventory”, consists of clusters 1.2, 2.5, 3.5 and 4.3; group 2, mainly related to “innovation”, consists of clusters 1.1, 2.4, 3.1 and 4.5; group 3, mainly related to “supplier relations”, consists of Clusters 2.3, 3.3 and 4.6. The evolution paths and quadrant changes of the three cluster groups are shown in Table 7.

Table 7. Evolution paths and quadrant changes of cluster groups.

Group	Evolution Path	Quadrant
Inventory	Cluster 1.2→Cluster 2.5→Cluster 3.5→Cluster 4.3	2nd→3rd→4th→2nd
Innovation	Cluster 1.1→Cluster 2.4→Cluster 3.1→Cluster 4.5	3rd→3rd→2nd→4th
Supplier Relations	Cluster 2.3→Cluster 3.3→Cluster 4.6	1st→4th→1st

4.5. Results of Cluster Analysis

From the perspective of the cluster, the above comparative analysis indicates the interrelationships between the hot research themes and explores the development trends in the field of supplier management. The important findings are as follows:

- As can be seen from the strategic diagram for stage 4 (Figure 13), the “supplier relations” cluster (cluster 4.6), is in the first quadrant, indicating its high strategic importance in the field of supplier management. In addition, from the comparative analysis of theme clusters for the four stages, it can be found that the centrality of “supplier relations” cluster at different stage is always high, which indicates that “supplier relations” clusters have always been playing a significant role in the field of supplier management. These results are consistent with the results of co-word analysis, which show that the self-frequency and co-occurrence frequency of theme members in the “supplier relations” cluster is always high, and present a rapid growth trend during the research period.
- The “supplier selection” cluster is also in the first quadrant of strategic diagram for stage 4 (Figure 13), indicating its importance in the field of supplier management. It should be noted that the “supplier selection” cluster is not stable because its theme members are always changing. As can be seen from Figures 6–9, there are only two theme members at stage 1, “supplier selection” and “quality management”; three members at stage 2, “supplier network”, “supplier selection” and “environmental management”; five members at stage 3, “supplier evaluation”, “supplier performance”, “supplier risk”, “supplier selection and “order allocation”; and three members at stage 4, “supplier selection”, “quantity discount” and “order allocation”. This shows that the “supplier” selection cluster is not focused on a specific topic, and the theme of “supplier selection” is not very closely related to other themes.

- As can be seen from Table 7, the evolution path of the “inventory” cluster is: cluster 1.2→cluster 2.5→cluster 3.5→cluster 4.3, and the quadrant changes of these clusters in the strategic diagram are: 2nd→3rd→4th→2nd. It can be summarized from Table 6 that the density of “inventory” cluster shows a trend of decreasing first and then increasing. Due to the addition of new theme members, such as “VMI” and “EOQ”, the density of “inventory” clusters decreased significantly from stage 1 to stage 2. However, the density increased significantly from stage 2 to stage 4, indicating that the strength of the linkages between themes within the cluster has been increasing, and the structural stability and maturity of the cluster have gradually improved.
- It can be seen from Table 7 that the quadrant changes of the “innovation” clusters (cluster 1.1→cluster 2.4→cluster 3.1→cluster 4.5) in the strategic diagram are: 3rd→3rd→2nd→4th, indicating that the strategic importance of “innovation” cluster in the study of supplier management is gradually increasing. It can also be summarized from Table 6 that the density of “innovation” cluster has gradually decreased during the research period, while the centrality has increased significantly from stages 2 to 4, indicating that the cluster is a relatively “open” cluster, and its impact on the entire research field of supplier management has been gradually increasing.
- As can be seen from the strategic diagram for stage 4 (Figure 13), the “sustainability” cluster has become the new favorite of researchers, which is consistent with co-word analysis results. The “sustainability” cluster at stage 4 mainly includes five research themes: “green supply chain”, “sustainability”, “sustainable supply chain”, “green supplier selection”, and “decision support system”. However, it is worth noting that the density of “sustainability” cluster is relatively low, indicating that the relationship between themes within the cluster is relatively weak, and the stability and maturity of the structure need to be further improved.

5. Discussion

This paper conducts a bibliometric analysis of the literature in the field of supplier management from the theme and cluster perspectives. Through the interaction of these two perspectives, the present study findings show that the research on supplier management mainly presents the following trends: first, the research on supplier management has made breakthroughs in both breadth and depth during the research period. Representative research themes, such as, “sustainable supply chain” [24–26], “corporate social responsibility” [27–29], “knowledge management” [30–32], etc., have gradually penetrated into the field of supplier management. Corporate social responsibility in supplier management has received increasing attention in recent years. Feng et al. (2017) conducted a literature review of 628 articles on corporate social responsibility in the supply chain and found that this research theme has been dominated by theoretical and conceptual research. In addition, the results also showed that the theme was closely related to the theme of sustainable development [41]. Knowledge management appears to be an effective response to the challenges posed by globalization and sustainability in the supply chain. Although the amount of literature on knowledge management in the supply chain is gradually increasing, some research problems still need to be further explored, such as key factors affecting knowledge management practices, obstacles to implementing knowledge management practices, and the impact of knowledge management practices on supply chain performance [42].

Second, research themes such as “supplier selection” and “supplier relations” have always been of the highest strategic importance in the field of supplier management, both from theme and cluster perspectives. However, the “supplier selection” cluster and “supplier relations” cluster present very different characteristics. The “supplier selection” cluster is not stable because its theme members are always changing, and the theme of “supplier selection” is not very closely related to other themes. The reason for this phenomenon may be that although there are a large number of studies on “supplier selection”, most of these studies focus on the application of mathematical methods in supplier selection. In addition, research on sustainable, green and strategic-oriented supplier selection is in the early stage of the research cycle and may evolve into hot research themes in the future [28].

The centrality of the “supplier relations” cluster at different stages is always high, indicating that “supplier relations” clusters have a significant impact on the field of supplier management. In addition, more and more researchers pay attention to the “supplier relations” cluster members such as “trust” and “commitment”. Many studies highlight the importance of “trust” and “commitment” to client–supplier relationship [43–46]. In addition, there are also studies show that “trust” has a significant positive effect on “commitment” [46,47].

Third, researchers have always been very enthusiastic about the research related to “inventory”, the strength of the linkages between themes within the cluster has been increasing, and the structural stability and maturity of the cluster have gradually improved. The theme members of these clusters cover some important inventory models, such as “VMI”, “consignment inventory” and “JIT”. The self-frequency and co-occurrence frequency of these themes gradually increased during the research period, while the self-frequency and co-occurrence frequency of “EOQ” gradually decreased. In addition, important factors affecting inventory management, such as “lead time”, “pricing”, and “logistics”, have also attracted the attention of many researchers.

Fourth, the “innovation” cluster is a relatively “open” cluster, and its impact on the entire research field of supplier management has been gradually increasing. The co-word analysis results show that theme members such as “product development”, “supplier involvement” and “innovation” have always been hot research themes. In addition, the results also show that “supply chain collaboration”, which has been proved to improve the collaborative advantage and have a significant impact on enterprise performance [48], is an important research background for research related to “innovation” in the field of supplier management. There are also studies indicating that “supply chain collaboration” has a positive effect on improving sustainability [49]. Wong et al. (2019) conducted a literature review of 155 literatures on supply chain innovation and found that most of the research samples on supply chain innovation are manufacturing companies [50]. Innovation in the supply chain is expected to achieve sustainable results. Therefore, sustainable supply chain innovation has also become an important research direction. Tebaldi et al. (2017) found that the number of papers on innovation and sustainable development increased by seven times in ten years, so they predicted that the rapid growth stage of sustainable supply chain innovation research was coming [20].

Fifth, the “sustainability” cluster is an evolving cluster, research themes related to “sustainability”, such as “green supply chain”, “sustainable supply chain” and “green supplier selection”, will play an increasingly important role in the field of supplier management. Both co-word analysis and cluster analysis results show that themes related to “sustainability” have become the new favorite of researchers. In fact, the integration of sustainability into business practice is one of the most dynamic research themes in the field of supplier management, and publications on this research theme presents a sharp growth in recent years [14,15,51]. The discussion above shows that some hot research themes, such as “corporate social responsibility”, “knowledge management”, “supplier selection”, “innovation”, and “supply chain collaboration”, are increasingly related to “sustainability”. In addition, it can be also found from the “Introduction” Section that literature reviews on sustainability and supply chain, such as sustainable supply chain, green supply chain and low-carbon supply chain, have attracted the most attention in recent years. However, it should be noted that despite the large number of studies on sustainability in the supply chain, most of these studies focus on environmental considerations, while less attention has been paid to social considerations [21]. In addition, the present findings show that the density of the “sustainability” cluster is relatively low, indicating that the stability and maturity of the structure need to be further improved. It is mainly because that research themes such as “green supply chain”, “sustainability” and “sustainable supply chain” are evolving concepts [52], which leads to the “sustainability” cluster being an evolving cluster. What’s more, it also illustrates that “sustainability” will interact deeply with more traditional and emerging themes in the context of the supply chain.

6. Conclusions

This paper conducted a bibliometric analysis based on 4687 papers on supplier management from 1997 to 2017. Through a comparative analysis of the four stages using Bibexcel and Ucinet6 software, this paper explores the evolution of supplier management from the theme and cluster perspective.

6.1. Theoretical Contributions and Management Implications

This paper contributes to the existing literature in two aspects. First, through the bibliometric analysis of a large amount of literature, this paper provides a comprehensive insight into the field of supplier management, including hot research themes and their relationship, evolution trends and future research directions. The present research finding can theoretically extend the research in the field of supplier management. In addition, this study is carried out from the theme and cluster perspectives, which will provide inspiration for similar studies in the future. The second contribution is to future research agenda. Based on the study of the existing literature in the Discussion section, we suggest that the following research directions should receive more attention in the future:

- Knowledge management in supply chain, such as key factors affecting knowledge management practices, obstacles to implementing knowledge management practices, and the impact of knowledge management practices on supply chain performance.
- Sustainable, green and strategic-oriented supplier selection.
- Supply chain innovation in industries other than manufacturing, such as healthcare, hospitality, construction, retail, etc.
- Quantitative research on sustainable supply chain and corporate social responsibility in supplier management.
- Social considerations in sustainable supply chain research.
- Cross-research on sustainability and other research themes, such as integration of corporate social responsibility and sustainability in the supply chain, sustainable supply chain innovation, supply chain cooperation and sustainability, green/sustainable/low-carbon supplier selection, etc.

The above research suggestions can not only contribute to the existing literature, but also provide management implications for practitioners. Enterprises should break through the traditional supplier-customer relationship, further explore the influence of the key factors such as corporate social responsibility, green, sustainability, knowledge management, innovation, etc., and integrate these factors in the supply chain to reduce supply chain risks and achieve sustainable development.

6.2. Limitations

One limitation of this research is the data. Using “Supplier” and “Vendor” as search keywords may not be incomplete. Since the batch exporting keywords function of the Web of Science database have been turned off, the data cannot be updated. In future research, the list of keywords used for search should be further expanded, and databases other than Web of Science, such as Scopus, can also be considered to get complete data. A second limitation is the word database in co-word analysis. Due to the large number of keywords, only the “vital few” keywords are included in the word database, while the “trivial many” keywords are ignored, which may lead to the exclusion of some potential keywords from the word database. Future research could widely apply methods such as database analysis and social network analysis which can cover all keywords to reveal the revolution history of supplier management research more comprehensively. In addition, research on specific themes with great development potential, such as green supply chain and sustainable supply chain could be conducted in the future to further explore the future directions in supplier management.

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