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# THE EVOLUTION OF THE SUPPLY CHAIN MANAGEMENT AND THE ANALYSIS OF RESEARCH TRENDS

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Abstract

The purpose of this study was to identify the evolution of the intellectual structure of supply chain management (SCM) studies. Bibliometric analysis, multivariate analysis and social network analysis were used to trace the development path of SCM research. By analyzing 67,007 citations of 1,091 articles published in SCI and SSCI journals in SCM area between 2009 and 2018, this study maps the intellectual structure of SCM studies. The results suggest that contemporary SCM research is organized in two different concentrations of interest: sustainable SCM and green SCM. Future SCM studies will probably continue to center on these topics. The results help to profile the invisible network of knowledge production inSCM and provide important insights with implications for current and future research directions of SCM studies for management scholars and practitioners.

Key words: supply chain management, sustainable supply chain management, green supply chain management

## Introduction

Globalization and recent economic trends have created highly complex supply chains (Varma, Wadhwa, & Deshmukh, 2006) and the design, organization, interactions, competences, capabilities and management of these supply chains have become key issues (Gold, Seuring, & Beske, 2009). Supply chain management (SCM) is therefore highly relevant both to successfully competing in today's market and in addressing responsible behaviour at all stages of the supply chain. It represents a potentially important discipline for establishing how to integrate environmental and social considerations and practices, to achieve the goal of sustainability (Ashby, Leat, & Hudson-Smith, 2012). Global warming, ozone depletion, and climate change have been considered as important issues for global environmental sustainability (Canan et al., 2015). The concept of environmental sustainability for firms has increasingly gained importance in academic and business fields in recent years (Masocha, 2018). For organizations to compete in the global markets, they need a well-integrated supply chains (Attia, & Essam Eldin, 2018). Traditionally, some researchers believe that there is an intrinsic conflict between environmental sustainability and business performance (Eiadat et al., 2008). Therefore, in order to produce win-win solutions that facilitate both economic benefits and environmental sustainability simultaneously, firms have begun to place great emphasis on innovation, especially environmental innovation capability.

Using the network approach, the current paper chronicles the results of SCM research journals from a database developed from the Sciences Citation Index (SCI) and Social Sciences Citation Index (SSCI) over a 10 years period, 2009–2018. The principal methods used are citation and co-citation analysis, social network analysis, plus a factor analysis which is performed to identify the invisible network of knowledge generation underlying the SCM literature. The author co-citation analysis (ACA) method is commonly used to group authors of reference papers. This study use an ACA analysis method, which groups complete author sets of reference papers into clusters and thus finds authors who may have expertise in more than one area. Based on the ACA analysis of these data in SCM, this study first reports the relative academic importance of authors, articles, and journals (in terms of number of citations) in the SCM literature, and then points out the historical stages in the field development. This study further maps the co-citation networks and reveals the top 31 authors in the

past 10 years and predicts the future directions of this field.

## Review of the Academic Literature on Author Co-citation Analysis

Author co-citation analysis (ACA) is a widely applied technique that uses a matrix of co-citation frequencies between authors as its input (McCain, 1990). ACA, which uses seminal authors in a discipline as the units of analysis, based on the idea that the conceptual similarity in the works of such authors would increase the likelihood of their being cited together regularly (McCain, 1990). The frequency of co-citation is therefore a measure of the proximity between authors (White & Griffith, 1981). Generally speaking, the formal and informal communications that authors engage in are systematically chronicled in journals that publish their works. Authors working in a stream of research often cite one another author as well as draw on common sources of knowledge. Further, their works are likely to be frequently co-cited by other authors working on intellectually similar themes. The upshot of this process is an intricate web of relationships between authors established through the creation and dissemination of knowledge. Thus, co-citations of seminal authors provide a basis for unraveling the complex patterns of associations that exist among them as well as trace the changes in intellectual currents taking place over time.

In ACA, cited and co-cited authors are the unit of analysis (McCain, 1990). ACA's unit of analysis is an individual author rather than a specific paper or journal. It is must be noted that the name of author is merely a label for the central conceptual theme or idea that he or she represents (Culnan, 1986; 1987). The intellectual map is thus a representation of ideational interactions among authors established through the frequency of co-citation and overall distribution of co-citations that they share with one another (White & McCain, 1998; McCain, 1990). This makes ACA eminently suitable for explicating the subfields that fall within the overall disciplinary domain of SCM. More specifically, ACA's ability to reveal patterns of association between authors based on their co-citation frequency makes it a potentially useful methodology for understanding the evolution of an academic discipline (White & McCain, 1998). Moreover, the versatility of the technique and its acceptance by many different disciplines make it appropriate for this study.

## Method

This study used citation data, including journal articles, authors, publication journals, publication date, and cited references to explore the intellectual structure of SCM research between 2009 and 2018. This time period was chosen because the SCM studies in this period represent the most updated and probably also the most important research in the field of SCM (up to the date when the data were collected for this study). This time period was further divided into two stages, the first five years from 2009 to 2013 and the second five years from 2014 to 2018 in order to better reveal the changes in key research themes in the last ten years. Citation and ACA was the main method for this study. With citation and ACA, the invisible knowledge network of SCM literature was mapped to describe the knowledge distribution process in SCM studies. Citations are considered to be an authentic and reliable indicator of scientific communication (Small, 1978; Garfield, 1979a) and a basis for the identification of "invisible colleges," i.e., research networks that refer to each other in their documents without being linked by formal organizational ties (Price, 1965; Crane, 1972; Lievrouw, 1989). A citation is taken to be a valid and reliable indicator of scientific communication (Small, 1978; Garfield, 1979b).

The number of co-citations determines the proximity of any two publications or authors, and is generally used to uncover intellectual structure. Using block modeling of data from sociometric questionnaire, Mullins et al. (1977) have shown that the co-citation structure of a research field is a fair representation of how it is perceived by its members. McCain (1986) confirmed these findings. Co-citation is frequency with which two documents or authors are cited together by more recent papers (Alger, 1996). The basic assumption behind co-citation is that documents that are frequently cited together by succeeding works are related in subject matter. The essential notion is that the more frequently the two publications are co-cited, the stronger is their linkage. As discussed in the literature review, SCM discourse has been vigorous in many managerial disciplines, including environment, social, economic, strategic, management, marketing, customer relationship, and information technology among more obvious, so data used in this study were not drawn from journals chosen by the peer researchers (Acedo & Casillas, 2005; Holsapple et al., 1993; Walstrom & Leonard, 2000). Instead, the entire databases of SCI and SSCI from 2009 to 2018 served as the universe for conducting the analysis. In order to choose sample articles, this study used "key

words" method which utilizes the SCI and SSCI databases key word search in article's title. Using "supply chain management" as key words, this study included 1,091 journal articles which cited 67,007 other publications as references. The cited publications in these papers include both published books and other journal articles. Therefore, the results reported in this study are not limited to any specific field or area, which confirm the true interdisciplinary nature of the SCM field.

With citation and ACA, this research proceeded in four stages, each stage required different approaches to examining the evolution of SCM studies. In the first stage, databases were identified as the sources of SCM publications. Then data collection and analysis techniques were designed to collect the desired information about the topics, authors, and journals on SCM research. In the second stage, citation analysis was tabulated for each of the 67,007 source documents using the MS *Excel* software. After a series of operations, key nodes which are the most cited authors in the knowledge network in SCM studies were identified and the structures developed.

The third stage was to perform a co-citation analysis based on the most cited authors of each sub-period, in order to trace relationships between them and identify schools of thought and prevailing topics of research.

Co-citation analysis also was tabulated for each of the source documents using the MS *Excel* software. Co-citation analysis is based on the distribution frequencies obtained from the citations count, by forming the pairs possible from the 31 most frequently cited authors and counting all the articles that cite both authors. Based on the total number of citations in the selected authors, the top authors were identified, and then a co-citation matrix was built before a pictorial map was drawn to describe the correlations among different authors. In the final stage, ACA was conducted to carry out social network analysis and factor analysis in order to map the intellectual structure of SCM studies and to explore the invisible knowledge nodes that have contributed most to such studies and their possible evolutionary patterns.

## Results

### *Citation Analysis*

To identify the key publications and scholars who have laid down the ground-work of SCM, citation data were tabulated for each of the 67,007 source documents using *Excel*. The citation analysis produced some interesting background statistics, as shown in

the following tables. Tables 1 list the top 10 most cited journals in SCM studies in the last decade. Additionally, the 31 most highly cited authors in two different periods, 2009-2013 and 2014-2018, were selected, as shown in Tables 2 and 3, respectively. The authors of these papers were then used as key nodes before conducting social network and factor analyses, following the procedures recommended by White and Griffith (1981).

Table 1. Top 10 Most Cited Journals in SCM Literature

| 2009-2013 | | 2014-2018 | |
|---|---|---|---|
| Journal | Citation | Journal | Citation |
| Journal of Operations Management | 963 | International Journal of Production Economics | 2214 |
| International Journal of Production Economics | 675 | Journal of Cleaner Production | 2201 |
| Supply Chain Management | 606 | Supply Chain Management | 1560 |
| International Journal of Operations & Production Management | 589 | Journal of Operations Management | 1556 |
| European Journal of Operational Research | 520 | International Journal of Operations & Production Management | 1166 |
| Journal of Business Logistics | 386 | International Journal of Production Research | 994 |
| Journal of Supply Chain Management | 377 | European Journal of Operational Research | 877 |
| Journal of Cleaner Production | 361 | Journal of Supply Chain Management | 876 |
| Management Science | 349 | International Journal of Physical Distribution & Logistics Management | 846 |
| International Journal of Production Research | 317 | Journal of Business Logistics | 672 |

Table 2. Top 31 Cited Authors Selected for Co-citation Analysis (first authorship only): 2009-2013

| Author | No. Cit. | Author | No. Cit. | Author | No. Cit. | Author | No. Cit. |
|---|---|---|---|---|---|---|---|
| Zhu, Qing-Hua | 172 | Lee, Hau L | 56 | Li, Su-Hong | 36 | Min, H | 25 |
| Carter, CR | 114 | Gunasekaran, A | 52 | Beamon, BM | 35 | Podsakoff, PM | 25 |
| Vachon, S | 94 | Rao, P | 50 | Frohlich, MT | 33 | Fisher, ML | 24 |
| Lambert, DM | 65 | Handfield, RB | 47 | Bowen, FE | 29 | Burgess, K | 23 |
| Seuring, S | 65 | Tan, Keah-Choon | 45 | Eisenhardt, KM | 29 | Simpson, D | 23 |
| Mentzer, JT | 61 | Srivastava, SK | 41 | Barney, J | 28 | Hall, J | 22 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Sarkis, J | 57 | Christopher, M | 37 | Pagell, M | 27 | Linton, JD | 22 |
| Chen, Injazz J | 56 | Porter, ME | 37 | Hervani, A | 25 | | |

Table 3. Top 31 Cited Authors Selected for Co-citation Analysis (first authorship only): 2014-2018

| Author | No. Cit. | Author | No. Cit. | Author | No. Cit. | Author | No. Cit. |
|---|---|---|---|---|---|---|---|
| Zhu, Qing-Hua | 773 | Walker, H | 119 | Lee, Su-Yol | 76 | Chen, Injazz J | 62 |
| Seuring, S | 314 | Srivastava, SK | 104 | Mentzer, JT | 76 | Gimenez, C | 62 |
| Carter, CR | 310 | Tseng, Ming-Lang | 102 | Lambert, DM | 73 | Beamon, BM | 61 |
| Sarkis, J | 252 | Green Jr, KW | 94 | Luthra, S | 73 | Handfield, R | 58 |
| Vachon, S | 182 | Gunasekaran, A | 89 | Mathiyazhagan, K | 72 | Kannan, D | 54 |
| Govindan, K | 150 | Diabat, A | 88 | Linton, JD | 66 | Porter, ME | 54 |
| Pagell, M | 137 | Beske, P | 85 | Klassen, RD | 64 | Eisenhardt, KM | 53 |
| Rao, P | 124 | Ahi, P | 84 | Gold, S | 63 | | |

### *Co-citation analysis*

Social network analysis tools can be used to graph the relations in the co-citation matrices, and thus identify the strongest links and core areas of interest in SCM (Pilkington & Teichert, 2006). Figures 1 and 2 show the core areas in the co-citation network map for the 31 authors examined in this study with links of greater than or equal to zero co-citation shown in the network, and with factor loadings greater than or equal to 0.7, in order to keep the diagram relatively uncluttered and easier to interpret. The figures were produced using the *UCINET* software (Borgatti, Everett & Freeman, 2002). The different shapes of the nodes result from a faction study of the authors. This method seeks to group elements in a network based on the sharing of common links to each other. Whilst Figures 1 and 2 provide a clear picture of the data, they only focus on the very core areas of interest, and a limited amount of the data available. Using the co-citation matrix and grouping the authors using factor analysis of the correlation between the entries can determine which authors are grouped together and share a common element. Based on this, the closeness of author points on such maps is algorithmically related to their similarity as perceived by the citers. R-Pearson was used as a measure of similarity between author pairs, because it registers the similarity in shape of the co-citation count pro-

files among all the authors in the set (White & McCain, 1998). The co-citation correlation matrix was factor analyzed using varimax rotation, a commonly used procedure, which attempts to fit (or load) the maximum number of authors on the minimum number of factors. The diagonals were considered as missing data, and the criterion of omitting the two cases (pairwise deletion) was applied (McCain, 1990).

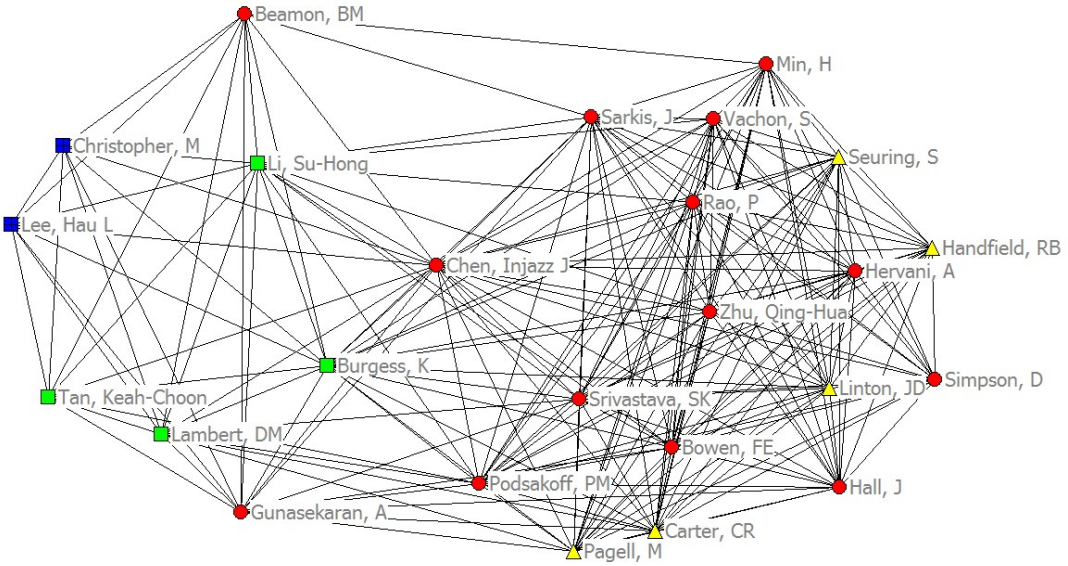


Figure 1. Top 31 of Authors the Co-citation Map (2009-2013)

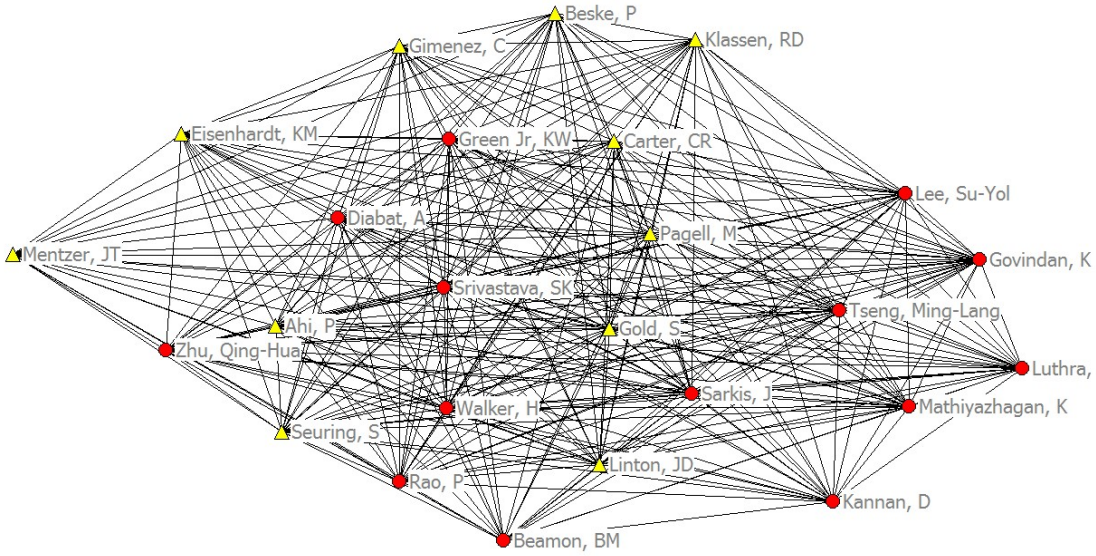


Figure 2. Top 31 of Authors the Co-citation Map (2014-2018)

Following the example of previous studies (Acedo & Casillas, 2005; Culnan, 1986; Rowlands, 1999; White & Griffith, 1981), a work was included in a particular research trend when its loading was equal to or greater than 0.4, and if the loading was greater than 0.7 then, the work was considered as making a significant contribution to the corresponding paradigm. Tables 4 and 5 show the results of this analysis. Significantly, most of the authors' works are loaded with a weight greater than 0.7, indicating the relevance of these works within their respective paradigms. Moreover, these works are of even greater interest, as they represent bridges between paradigms and allow us to observe a broader spectrum of influences among those works that belong to different research fronts, helping us to understand their evolution and the links that have been forming between the different research trends.

Table 4. Top 31 Cited Authors Factor Loadings at 0.40 or Higher (2009-2013)

| Rank | Factor 1: Green SCM | | Rank | *Eigenvalues*: 13.75 | *% Variance*: 43.8 |
|---|---|---|---|---|---|
| 7 | Sarkis, J | 0.97 | 14 | Srivastava, SK | 0.80 |
| 1 | Zhu, Qing-Hua | 0.95 | 30 | Hall, J | 0.75 |
| 11 | Rao, P | 0.94 | 29 | Simpson, D | 0.75 |
| 20 | Bowen, FE | 0.90 | 3 | Vachon, S | 0.73 |
| 24 | Hervani, A | 0.88 | 16 | Porter, ME | 0.67 |
| 25 | Min, H | 0.83 | | | |
| Rank | Factor 2: SC integration | | Rank | *Eigenvalues*: 6.18 | *% Variance*: 19.7 |
| 17 | Li, Su-Hong | 0.81 | 19 | Frohlich, MT | 0.68 |
| 28 | Burgess, K | 0.75 | 22 | Barney, J | 0.61 |
| 13 | Tan, Keah-Choon | 0.74 | 27 | Fisher, ML | 0.56 |
| 4 | Lambert, DM | 0.73 | 6 | Mentzer, JT | 0.53 |
| 8 | Chen, Injazz J | 0.70 | | | |
| Rank | Factor 3: Sustainable SCM | | Rank | *Eigenvalues*: 2.35 | *% Variance*: 7.5 |
| 23 | Pagell, M | 0.85 | 12 | Handfield, RB | 0.77 |
| 2 | Carter, CR | 0.81 | 31 | Linton, JD | 0.75 |
| 5 | Seuring, S | 0.80 | | | |
| Rank | Factor 4: ASC strategy | | Rank | *Eigenvalues*: 1.75 | *% Variance*: 5.6 |
| 15 | Christopher, M | 0.86 | 21 | Eisenhardt, KM | 0.61 |
| 9 | Lee, Hau L | 0.70 | | | |

Table 5. Top 31 Cited Authors Factor Loadings at 0.40 or Higher (2014-2018)

| Rank | Factor 1: Sustainable SCM | | Rank | *Eigenvalues*: 21.18 *% Variance*: 67.7 | |
|---|---|---|---|---|---|
| 15 | Beske, P | 0.95 | 3 | Carter, CR | 0.87 |
| 24 | Gold, S | 0.95 | 2 | Seuring, S | 0.81 |
| 7 | Pagell, M | 0.91 | 18 | Mentzer, JT | 0.81 |
| 23 | Klassen, RD | 0.91 | 22 | Linton, JD | 0.80 |
| 26 | Gimenez, C | 0.89 | 25 | Chen, Injazz J | 0.69 |
| 31 | Eisenhardt, KM | 0.88 | 13 | Gunasekaran, A | 0.58 |
| 16 | Ahi, P | 0.87 | | | |
| Rank | Factor 2: Green SCM | | Rank | *Eigenvalues*: 5.38 *% Variance*: 17.2 | |
| 14 | Diabat, A | 0.95 | 12 | Green Jr, KW | 0.79 |
| 29 | Kannan, D | 0.94 | 8 | Rao, P | 0.76 |
| 6 | Govindan, K | 0.93 | 9 | Walker, H | 0.75 |
| 20 | Luthra, S | 0.93 | 4 | Sarkis, J | 0.75 |
| 21 | Mathiyazhagan, K | 0.92 | 10 | Srivastava, SK | 0.75 |
| 17 | Lee, Su-Yol | 0.89 | 1 | Zhu, Qing-Hua | 0.73 |
| 27 | Beamon, BM | 0.88 | 5 | Vachon, S | 0.63 |
| 11 | Tseng, Ming-Lang | 0.87 | | | |

In the Stage 1, based on the results of factor analysis shown in Figure 1 and Table 4, the author identified four factors, although some of them have a close relationship with each other. As can be observed, all of the information is summarized in four factors that explain 76.6% of the variance. Significantly, most of authors are loaded with a weight greater 0.7, corroborating the relevance of these works within their respective paradigms.

Figure 1 and Table 4 clearly indicates that the most influential research on SCM clustered together around four core research themes in the period 2009–2013. The first group of studies focused on the green SCM (e.g. Sarkis, 2003; Zhu & Sarkis, 2004; Rao & Holt, 2005. The second group of studies focused on supply chain integration (e.g. Li et al., 2006; Chen & Paulraj, 2004; Tan, Lyman, & Wisner (2002). The third group of studies focused on the sustainable SCM (e.g. Carter & Rogers, 2008; Pagell & Wu, 2009; Seuring & Müller, 2008). The fourth group of studies focused on the agile supply chain strategy (e.g. Christopher, 2000; Lee, Padmanabhan, & Whang, 1997).

In Stage 2, based on the results of

factor analysis shown in Figure 2 and Table 5, the author identified two factors, although some of them have a close mutual relationship. As can be observed, all of the information is summarized in two factors that explain 84.9% of the variance.

Figure 2 and Table 5 present the results for the period 2014–2018, and two major research clusters were extracted from the SCM literature. The first group of studies also focused on the sustainable SCM (e.g. Seuring & Müller 2008; Gold, Seuring, & Beske, 2010; Beske, Land, & Seuring, 2014; Klassen & Vreecke, 2012). The second group of studies also focused on green SCM (e.g. Diabat & Govindan, 2011; Kannan, de Sousa Jabbour, & Jabbour, 2014; Govindan et al., 2014; Luthra et al., 2011).

## Conclusions

The past decade has seen extensive research on SCM. This study investigates SCM research using citation and co-citation data published in SCI and SSCI journals between 2009 and 2018. With the help of social network analysis tools and a factor analysis of the co-citation data, this study maps the intellectual structure of SCM over the past decade. A factor analysis of the co-citations suggested that the field is organized into four different concentrations of interest in Stage 1 (2009-2013): green SCM, SC integration, sustainable SCM, and ASC strategy. In addition, the field is organized into two different concentrations in Stage 2 (2014-2018): sustainable SCM and green SCM. Future SCM studies will probably continue to focus on sustainable SCM and green SCM. These results help to profile the invisible network of knowledge production in SCM and provide important insights with implications for current and future research paradigms of SCM studies for both management scholars and practitioners.

This paper presents the most influential scholars, identifies the links among them, and confirms the status of each scholar with regard to contributions to the SCM field. This paper also have profiled the major themes, concepts and relationships discussed within each domain, and the results show the scope of SCM research has been broad, and that many research opportunities are now emerging in the field. The contributions of this paper are thus that it provides valuable research directions for scholars investigating SCM, and also proposes an objective and systematic means of determining the relative importance of different knowledge nodes in the development of this field.

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