# ARTICLES

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# STRUCTURAL CARTOGRAPHY FOR LITERATURE REVIEW: REVEALING THE UNDERLYING STRUCTURE OF A LITERATURE THROUGH A BIBLIOGRAPHIC ATLAS

## *Cartografia estrutural para revisão de literatura: Revelando a estrutura subjacente de uma literatura por meio de um atlas bibliográfico*

## *Cartografía estructural para la revisión de literatura: Revelando la estructura subyacente de una literatura por medio de un atlas bibliográfico*

**ABSTRACT**

This paper presents the results of a methodological study that established a specific method for historical and bibliographic analysis known as structural cartography for literature review. Structural cartography is a rigorous and interdisciplinary method that reveals the structure of a literature knowledge domain through the methodological notions found in historical research, bibliographic investigation, citation network analysis and cartography. This paper intends to provide readers with a broad understanding of the method of structural cartography for literature review and how to apply it. Finally, this article presents twelve ways of approaching a literature structure by using the bibliographic atlas elaborated by means of structural cartography for literature review.

**KEYWORDS** | Structural cartography, mapping literature, citation index, bibliographic atlas, literature review.

*RESUMO*

*Este artigo apresenta os resultados de um estudo em metodologia que determinou um método específico de análise histórica bibliográfica, descrito como cartografia estrutural para revisão de literatura. O método de cartografia estrutural é rigoroso, interdisciplinar e revela a estrutura de uma bibliografia em estudo por meio dos conceitos metodológicos encontrados em pesquisa histórica, pesquisa bibliográfica, teoria dos grafos, análise de índices e redes de citações e cartografia. Pretende-se que o leitor tenha uma ampla compreensão sobre o que é e como se aplica o método de cartografia estrutural. Por fim, serão apresentadas 12 maneiras de se abordar a estrutura de uma literatura utilizando o atlas bibliográfico elaborado por meio da cartografia estrutural para revisão de literatura.*

***PALAVRAS-CHAVE*** */ Cartografia estrutural, mapeamento da literatura, índice de citações, atlas bibliográfico, revisão de literatura.*

*RESUMEN*

*Este artículo presenta los resultados de un estudio de metodología que ha determinado un método específico de análisis histórico bibliográfico, descrito como cartografía estructural para revisión de literatura. El método de cartografía estructural es riguroso e interdisciplinario y permite revelar la estructura de una literatura en estudio a través de los conceptos metodológicos encontrados en investigación histórica, investigación bibliográfica, teoría de los grafos, análisis de índices y redes de citas y cartografía. Se pretende que el lector tenga una amplia comprensión sobre qué es y cómo se aplica el método de cartografía estructural para la revisión de la literatura. Por último, se presentan las doce maneras de abordar la estructura de una literatura utilizando el atlas bibliográfico elaborado a través de la cartografía estructural para revisión de literatura.*

***PALABRAS CLAVE*** */ Cartografía estructural, mapas de literatura, índice de citas, atlas bibliográfico, estudio bibliográfico.*

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## INTRODUCTION

This article presents an original, accurate, new method of historical bibliographic analysis described as structural cartography for literature review. This method enables understanding the historical thematic structure of a subject through a visual and figurative model that familiarizes academic researchers with the theoretical framework of their literature.

Many academic papers in Business Administration research depend on bibliometric studies, providing through a literature review a descriptive analysis of theoretical references of a knowledge domain in a certain historical period to map their bibliography (Zhao & Strotmann, 2015). However, many of these studies do not necessarily contain visual maps of the relations between references, just a list categorized according to a conceptual taxonomy or ordered according to quantitative indicators (Caldas & Tinoco, 2004; Mascena, Figueiredo, & Boaventura, 2013; Siegler, Biazzin, & Fernandes, 2014). When presenting a network mapping their field of knowledge, these studies do not directly deal with relations among the references in the literature. Rather, they illustrate networks associating authors, education institutions, or keywords (Favaretto & Francisco, 2017; Oliveira, Shibao, & Godinho, 2016).

In addition, conducting bibliographic reviews to provide theoretical contents for academic research is hindered by the fact that the nature of academic literature is becoming increasingly fragmented, mainly in the Business Administration field, as Siegler et al. (2014) point out. Unsurprisingly, in 1969, Ziman presaging this time claimed there was "no glory for reviewers" in his criticism of the practice of fragmented publications in Science, indexation of scientific journals, and contempt for review studies. It is well known that a sophisticated literature review is essential in substantiating constructive research. Thus, the structural cartography method enables researchers to familiarize themselves with the historical development of the literature of their interest, allowing them to transform it contextually into an intelligible chain of thoughts that can argue, criticize, and summarize this information into reliable, relevant, and rigorous public knowledge (Ziman, 1969).

By applying structural cartography, it is possible to establish a chronology among literary works and objectively reveal the main relations among them using a citation index and bibliographic atlas composed of maps and diagrams. This literature review method differs from the usual bibliometric studies focused on quantifying the data on publications (Favaretto & Francisco, 2017; Siegler et al., 2014), and offers maps of the structure of the literature.

The objective of this article is to present an interdisciplinary methodological study on the structural cartography method by showing readers the preliminary notions extracted from the areas of (i) bibliographic research, (ii) historical research, and (iii) analysis of citation indexes and their respective networks. The definitions of new principles and notions applied to the structural cartography method for literature review are established based on the Mutual Methodological Critique analysis proposed by Abbott (2004, pp. 75-79).

Thus, in the first part of this article, the theoretical framework of the structural cartography method is discussed. In the second part, the maps composing the bibliographic atlas are presented, followed by guidelines for preparing a citation index using the study of the emergence of Problem Structuring Methods (PSM) from 1950 to 1989 in the literature on Operational Research as example (Georgiou & Heck, 2017). As such, readers will be able to broadly understand the meaning and application of this new method.

## METHODOLOGICAL STUDY OF THE STRUCTURAL CARTOGRAPHY METHOD

The structural cartography method for literature review has been discussed for exploratory mapping citation networks to find the underlying structure of an ideal bibliography composed of classical texts and documents, as well as other contributions supporting a knowledge domain. The underlying structure of literature is the one defined in the representation of the citation networks that originate from bibliographic references. These expose the connections between them and reveal conceptual borrowings, cross-references, or parallel formulations appropriate to ensuring cohesion in the knowledge domain.

The proposed methodological study aims to understand the structure of the thematic history of a specific subject of literature by elaborating a bibliographic atlas based on the analysis of citation networks. Thus, defining the elements composing a citation network should comply with a preliminary notion pertaining to (i) the nature of the bibliographic research, (ii) propositions for a historical approach, and (iii) visual representation of the structural parts of the maps constituting a bibliographic atlas. Therefore, the methodological procedures of the structural cartography method were defined according to these three features.

The first feature deals with the bibliographic analysis proposed in the area of Educational Research (Boote & Beile, 2005; Hart, 1998) as a complementary element for using the

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information contained in texts. The second feature refers to using a historical approach based on the concept of thematic history proposed by Holton (1996a, 1996b). Finally, the third feature is a longitudinal exploratory map of citation networks based on the mathematics area known as Graph Theory (Harary, 1969) and on Information Organization, called analysis of citation indexes, as suggested by Garfield (1979).

## First feature: Context of bibliographic research in the academic environment

Bibliographic research is one of the oldest ways of research, especially for literature reviews. Noteworthy is that the Greek philosopher Aristotle stated that a historical-critical examination of the thoughts of the philosophers who lived before him was needed to render the theoretical basis of his *sophis*, the "science that investigates the first principles and causes." In other words, a literature review is essential in establishing the theoretical bases of a knowledge domain.

Therefore, a literature review is the most important task in an academic researcher's theoretical and empirical research process (Boote & Beile, 2005; Combs, Bustamante, & Onwuegbuzie, 2010; Onwuegbuzie, Leech, & Collins, 2012). Boote and Beile (2005) noted, "A thorough, sophisticated literature review is a foundation and inspiration for substantial, useful research" (p. 3). A literature review is usually understood as a core phase of research on the theme being studied.

However, since the beginning of the 1990s, Educational Research scholars have recognized an imbalance in the contents of doctorate theses in Social Sciences, where the emphasis on empirical research supersedes that on academic theoretical studies (Boote & Beile, 2005). Specifically, studies show that postgraduate research strongly concentrates on data collection and the subsequent analysis of information related to the study's problem, thus neglecting theoretical studies in the field of knowledge being analyzed (Alton-Lee, 1998; Grant & Graue, 1999).

However, why are theoretical studies being disregarded, for example in post-graduate research, in favor of empirical studies? Many of these studies are exclusively based on bibliographic research and an analysis of documents collected, such as a literature review, and, according to Ziman (1969), take a long time and demand a high level of rigor and devotion to review and critically summarize the knowledge domain. Indeed, in the absence thereof, the definition of the research problem, exploration of arguments for analysis, and organization of the ideas to be discussed, will remain unclear and unrefined (Hart, 1998; Hjorland, 1988; Holbrook, Brouke, Faibairn, & Lovat, 2007).

This phenomenon is not limited to post-graduate research. It includes publications of academic articles in which the literature supporting the theoretical foundation is insufficient, chronologically limited, or anachronistic and dissociated from the empirical study (Alton-Lee, 1998). Thus, conducting empirical research as a solution for using a shallow and deficient bibliography has become a common characteristic in academic studies. Data and hypotheses set *a priori* have become the basis of the definition of the study's theoretical question. Instead of studying the area of interest in depth to establish a relevant research question, academic researchers glimpse in the set of data available the possibility of defining hypotheses to be tested by applying a quantitative or qualitative method to prove these previously defined hypotheses. This is understood as placing theory on top of the data collected, because a deeper discussion of theoretical perspectives is lacking (Alton-Lee, 1998).

In this context, Boote and Beile (2005) contended that "doctoral students must be scholars before they are researchers" (p. 11) once "less-successful researchers have perhaps never learned to develop productive research questions because they have superficial understanding of the problems of their field" (p. 11). With few exceptions, the bibliographic method, which is supposed to extract a research problem from the literature, is limited to a chapter or less in reference books on methodological studies (Boote & Beile, 2005; Onwuegbuzie et al., 2012). In this sense, the area of Educational Research has constantly warned that in-depth and more sophisticated literature reviews provide the foundation and inspiration for more substantial research (Alton-Lee, 1998; Boote & Beile, 2005; Hart, 1998).

However, what is a more sophisticated literature review? According to Alton-Lee (1998), academic authors should first question and criticize the bibliographic documents of their literature review and clarify possible conceptual confusions that may exist in their theoretical framework. Boote and Beile (2005) highlight that, despite the difficulties, developing "more sophisticated literature reviews" means sharing the methodologies able to generate knowledge from other fields of knowledge. An example is using research methods from History to strictly comprehend the historical context of the literature under study. In this case, citation networks would be analyzed to deepen understanding of the structural relations of that literature. It is worth emphasizing that one of the difficulties in bibliographic research, and especially in literature reviews, is mapping (Hart, 1998). By assessing the practices of a literature review, the structural mapping of that review can be defined as

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1 of the 11 activities listed by Hart (1998) called "understanding the subject structure" (p. 27). However, almost 20 years after Hart's proposed list, Boote and Beile (2005) observe that this activity is "too ambiguous to be operated and assessed" (p. 13).

There are two reasons for this ambiguity. The first is semantics. Here, the literature on bibliographic research uses the words "map" and "mapping" with metaphoric meanings, which do not usually refer to the cartographic definition of the physical and visual representation of the object "map." The second, which is more practical, refers to the choice of which map or maps would represent the structure of a bibliography. Thus, understanding the activity of "understanding the subject structure" has not been able to be operationalized, and no consensus has been reached in the academic world regarding the criteria thereof. Thus, the application of the structural cartography method for literature review aims to operationalize this activity.

## Second feature: On the perspective of historical research

Historical research is frequently conducted to explain specific characteristics of some area of knowledge, describe how it was developed, and determine its origins. Thus, it is important to understand how historical research could be used to determine a structural cartography method. Usually, the historical narrative is characterized as a simple chain of ideas or facts. However, a historical analysis of the construction of a theoretical framework demands rigorous methods. Although there are several methodological approaches to history, in his seminal book "History: Professional Scholarship in America," Higham (1989) suggests that "those who want to learn and study history have to trace the participation of professional historians in the whole historical movement and in the difficulties that movement has encountered" (p. 5). Thus, historian Holton's historical research stance was selected to support this methodological study based on thematic history or "Themata" (Holton, 1996a, 1996b).

In the 1960s, thematic analysis was introduced as a historical research method in the sciences to understand the success or failure of scientific studies (Holton, 1996a, 1996b). According to Professor Gerald Holton (1996a), science development is motivated by the basic thematic role or presuppositions when defining scientific research.

To understand the motivation leading scientists to develop their research, it is necessary to study the events in the period in which their work was conducted. Thus, a thematic analysis identifies the map of several themes and/or events, which "like fingerprints, can characterize an individual scientist or a part of the scientific community at a given time" (Holton, 1996a, p. 457). Therefore, the thematic approach as a historical method becomes the first feature of the method, namely "understanding the structure" of the literature. According to Holton (1996b), to understand the history of science, one must: (a) fully understand the main individual events in the history of a science, and (b) find the links/interconnections among these main events.

Events are not understood as constructs or speculative constructions, but as a scientific publication or seminal statement, such as that stated in Niels Bohr's speech on the Principle of Complementarity at the Seminar of Como, Italy, in 1927, an event that influenced the whole area of Quantum Mechanics (Beller, 1999). For this reason, it is important to strictly stick to the contents of scientific publications (i.e., these events) to avoid the mistake of conceiving concepts or ideas that do not represent the theoretical basis of a knowledge domain.

How can mapping a knowledge domain define the events composing its history? Some bibliographic papers such as those by Price (1965) and Goodman (1971), with some technical differences, use citation analysis as a tool to set a methodological approach for historical studies. In the structural cartography method, the main "events" are documents such as scientific articles, and the "connections" are their citations. Therefore, one can use an analysis of citation indexes and their bibliographic network as tools for a historical study of the method.

## Third feature: General characteristics of citation indexes and networks

The concepts and characteristics of the theory of citation indexes and their application in bibliographic networks were elaborated by the theory of Information Organization by the American scientist and linguist Eugene Garfield in the 1960s and 1970s. Garfield realized the usefulness of citation indexes as a new approach to classify the scientific literature (Garfield, 1973, 1979). Holding this vision, he noted the several aspects of citation analysis in his work "Citation indexing: Its theory and application in science, technology, and humanities" (Garfield, 1979). Therein, he showed that bibliographic networks are appropriate tools for conducting bibliographic research in a field of scientific study, and serve as models for studying the structure of science.

Citation indexes connect important individual events that occurred at different moments in a certain field of study. Thus, an

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analysis of the relations between references and citations has a chronological characteristic intrinsic to the index, which reveals the events related to an idea inside a historical perspective characterized by a bibliographic network (Garfield, 1973). Studies using a bibliographic network of the relations between citations demonstrate different visions of science, graphically presenting a historical design of scientific development (Garfield, 1973). Thus, the bibliographic network is a concise, figurative, readily analyzed model. The structure of historical events is understood in full and rigorously because of the objectivity required by the techniques of Graph Theory and network analysis. Mapping networks is a more sophisticated attempt to use citation analysis to define the structure of the science at an important scale and at the level of detail required for determining policies in scientific research and development (Garfield, 1979). An example here is the Small and Griffith study (1974).

This study tests two hypotheses. The first is that science comprises structures of specialties. The second is that a particular citation measures the common intellectual interest between two documents (source reference and cited reference). The measure used to verify these hypotheses was co-citation, an inversion of Kessler's (1963) concept of bibliographic coupling. Another common analysis method used in studies to map scientific structure is the main path analysis, initially defined by Hummon and Doreian (1989). This analysis identifies within a bibliographic network a concise list of documents among all the references comprising the core of the knowledge of the area under study by going through the entire network.

Finally, another aspect of the characteristics of citation indexes and networks is that both do not say anything about the contents of the cited references. It is therefore important that academic researchers consider selection criteria for referencing the contents of a cited document as the basis of their arguments. In the current scenario, using algorithms to prepare citation indexes (and as a result, the construction of bibliographic networks) has become prevalent. These algorithms promote a keyword search on databases without employing selection criteria to extract basic source references according to their contents. The consequences are serious: interpretation mistakes and abuses are common and significant, mainly in areas such as the Social or Human Sciences (Cronin & Sugimoto, 2014). In this context, the structural cartography method presupposes that the analysis of source and cited references for the preparation of the index should be elaborated manually without using algorithms, through studious reading of the contents of every article. Therefore, academic researchers should be familiar with the bibliography of their knowledge domain.

## STRUCTURAL CARTOGRAPHY FOR LITERATURE REVIEW

The three features characterizing a methodological study (bibliographic research, historical approach, and analysis of citation indexes and networks) do not only define the structural cartography method as a set of maps but also give it completeness by providing:

- a chart of the literature according to a schematic structure;
- a means through which can be explained not only events but also their relations; not only the facts but also the nature of their evolution by means of conceptual borrowings, cross-references, and parallel formulations;
- a unity of visual maps to interpret and clarify a literature;
- in other words, a bibliographic atlas.

An atlas organizes the documents composing an area of knowledge to clarify its principles, thoughts, general concepts, and new ideas. It associates two notions, one of encyclopedia and one of exposition, depending on the structural schema in which the maps were created, designed, and organized. Therefore, an atlas is understood here as more than a collection of maps. It is an organized way of interpreting and elucidating a knowledge domain, registering its collection and incorporating the activities of design, both artistic in terms of visual exposition and intellectual regarding the documental arrangement (Akerman, 1991).

In this regard, the structural cartography method for literature review does not produce only maps. This method results in a bibliographic atlas organized by several charts and composed of three parts accompanied with tables and diagrams. As such, this method maps the structures of the literature as an atlas maps the structure of world cartography.

In the first part, the bibliographic atlas presents a panoramic coverage of the "mappa mundi" of the literature, exposing its macrostructure from a historical and thematic perspective. This part also provides descriptive statistics with matrix tables. In the second part, the bibliographic atlas includes particular maps about the source and cited references. Finally, in the third part, it presents maps of scientific journals and their respective authors. Thus, the exploratory analyses of the network of relations between author and journal enable visualizing the dissemination of concepts and ideas in the literature and clarify which authors influenced its propagation.

### Longitudinal exploratory citation network mapping

Exploratory mapping of citation networks is performed by building networks, which are mathematical structures of directed graphs or digraphs in which the direction of the relation between two


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vertices is represented with an arc (Harary, 1969). In addition to these networks being directed graphs, they are acyclic, meaning they do not have directed cycles, because a scientific article published after another one cannot be cited in the latter.

The first stage of building these networks is elaborating a citation index based on the source and cited references. The second stage is structuring the pieces of information obtained from the index in a Microsoft Excel worksheet to ensure they can be handled in network construction software programs such as Pajek, a free specialized network software (De Nooy, Mrvar, & Batagelj, 2011). Structuring the data aims to encode the vertices (documents/articles), arcs (citations), authors, and scientific journals. In addition, temporal indicators are encoded. Following that, the main network (or master network) and author-journal bipartite network are constructed. From these two networks, sub-networks can be extracted for longitudinal analyses (Georgiou & Heck, 2015). Finally, in the third stage, exploratory analyses are conducted based on the maps and diagrams obtained in the mapping.

Operating and cartographical procedures are presented and illustrated for didactic purposes using an example from the elaboration of a citation index and bibliographic atlas of a study on the conceptual unity of PSM from 1950 to 1989 in the literature on Operational Research (Georgiou & Heck, 2017).

## First stage: Elaborating a citation index

Elaborating a citation index comprises two steps: (i) searching and collecting source references to compile an index of them, and (ii) linking them to their respective cited references to compile an index of cited references.

In the first step, the preliminary searching of source references should be defined by subject and by means of a list of well-known authors in the area of study (Garfield, 1979). The scope of the preliminary search for basic source references in the study of PSM was defined on the basis of the following criteria:

- Only scientific articles evaluated by a peer review were selected.
- The word or set of words considered to collect the documents were defined: (i) by topic as Problem Structuring Methods (PSM), Soft Systems Methodology (SSM), Strategic Options Development and Analysis (SODA), Strategic Choice Approach (SCA), and Robustness Analysis (RA); and (ii) by the main authors in the PSM areas: Checkland, Eden, Friend, Rosenhead, and Mingers.
- The external digital databases used in the search were EBSCO, Scopus-Elsevier, Thomson Reuters, and Google Scholar as a search tool specialized in scientific documents.
- The temporal threshold defined in the search was from 1950 to 1989, the initial period of the PSM that ended with the publication of the seminal work on the subject, Rational Analysis for a Problematic World (Rosenhead, 1989).

The outcome of this step is a list of articles constituting the index of source references. This index is then encoded for identification (ID and label) and segmented into categories such as author, year of publication, title, journal, and complementary attributes (Table 1). The category "complementary attributes" aims to qualitatively enhance the information on the documents. Here, complementary conceptual attributes were categorized as TP ("theoretical precedent") for articles acting as theoretical precedents for the formation of PSM, PSMG (or "PSM in General") for those in which PSM is presented in general terms, SSM for articles about Soft System Methodology, SODA for articles about Strategic Options Development and Analysis, SCA for articles about Strategic Choice Approach, RA for articles about Robustness Analysis, and NA for articles that are "not applicable" because they do not meet the scope of the document search (Table 1 ).

In the second step, the association between the source references and their citations is prepared. Based on this link, the index of cited references is established, enabling the determination of the structure of a bibliographic network (i.e., the relation between the two vertices by means of an arc) (Table 2).

The citation index includes the indexes of source and cited references. Once the citation index is defined, source references can be found as citations in the cited references. As such, the most appropriate terminology to define a document in a citation network is "citee" for a document/author cited by another, and "citer" for a document/author citing another (Georgiou, 2014). Based on the citation index, a list of vertices (i.e., the list containing all documents present in the index), list of arcs (i.e., the list of all "citee" ⇢ "citer" relations), and list of all scientific journals in which the documents were published are defined.

Of the 381 articles obtained in the database search published in the period under analysis on PSM, only 126 met the criteria for building a network. These 126 articles were identified in the first step, and belong to the index of source references. They enabled the determination of 1,690 cited references in the second step, 542 of which were content analyzed. In this set of cited references, some articles already recorded in the first and second steps were repeated. After analyzing those documents, 155 scientific articles and 406 citation links among them were selected for inclusion in the citation network.


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Table 1. **Example of encoding for an index of source references**

| Id | Label | Author | Year | Reference | Journal | Attribute |
|---|---|---|---|---|---|---|
| 1 | "Hurni 1954" | Hurni | 1954 | Hurni ML (1954) Observations on operations research. *Journal of the Operations Research Society of America* 2(3): 234-248 | Journal of the Operations Research Society of America | TP |
| 2 | "Hitch 1955" | Hitch | 1955 | Hitch C (1955) An Appreciation of Systems Analysis. *Journal of the Operations Research Society of America* 3(4): 466-481 | Journal of the Operations Research Society of America | TP |
| 3 | "Ackoff 1956" | Ackoff | 1956 | Ackoff RL (1956) The development of operations research as a science. *Operations Research* 4(3): 265-295 | Operations Research | TP |
| 4 | "Checkland and Davison 1956" | Checkland and Davison | 1956 | Checkland, PB, and Davison, WH (1956) 'Infra-red spectrum of rubber hydrochloride'. *Transactions of the Faraday Society*, 52, 151-156 | Transactions of the Faraday Society | NA |
| 5 | "Koopman and Hitch 1956" | Koopman and Hitch | 1956 | Koopman BO, Hitch C (1956) Fallacies in operations research. *Operations Research* 4(4): 422-430 | Operations Research | TP |
| 6 | "Simon 1957" | Simon | 1957 | Simon, H (1957) 'Background of Decision Making'. *Naval War College Review*, 3, 1-24 | Naval War College Review | TP |
| 7 | "Wanty 1957" | Wanty | 1957 | Wanty J (1957) Thoughts on the conference. *Operational Research Quarterly* 8(4): 194-197 | Operations Research | TP |
| 8 | "Lindblom 1958" | Lindblom | 1958 | Lindblom, CE (1958) 'Tinbergen on Policy-Making'. *Journal of Political Economy*, 66(6), 531-538 | Journal of Political Economy | NA |
| 9 | "McEachron 1958" | McEachron | 1958 | McEachron WD (1958) Prediction and Feedback in Business Planning. *Operations Research* 6(4): 560-572 | Operations Research | TP |
| 10 | "Simon and Newell 1958" | Simon and Newell | 1958 | Simon H, Newell A (1958) 'Heuristic Problem Solving: The Next Advance in Operational Research'. *Operations Research*,6(1), 1-10 | Operations Research | TP |

Table 2. **Example of encoding for an index of cited references**

| Id | Label | Author | Year | Id2 | Id | Label2 | Author2 | Year2 | Reference2 | Journal2 | Attribute |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 85 | "Elton et al 1973b" | Elton et al | 1973 | 1315 | 78 | "Rosenhead et al 1972" | Rosenhead et al | 1972 | Rosenhead J, Elton M, Gupta SK (1972) Robustness and optimality as criteria for strategic decisions. *Operational Research Quarterly* 23(4): 413-431 | Operational Research Quarterly | RA |
| 85 | "Elton et al 1973b" | Elton et al | 1973 | 1316 | 84 | "Dyson 1973" | Dyson | 1973 | Dyson RG (1973) Robustness. *Operational Research Quarterly* 24(2): 317-318 | Operational Research Quarterly | RA |
| 86 | "Elton et al 1973a" | Elton et al | 1973 | 1317 | | | Friend and Jessop | 1969 | Book | Book | NA |
| 86 | "Elton et al 1973a" | Elton et al | 1973 | 1318 | | | Robinson | 1972 | Book | Book | NA |

(continue)

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Table 2. **Example of encoding for an index of cited references** (conclusion)

| Id | Label | Author | Year | Id2 | Id | Label2 | Author2 | Year2 | Reference2 | Journal2 | Attribute |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 86 | "Elton et al 1973a" | Elton et al | 1973 | 1319 | 100 | "White DJ 1973a" | White DJ | 1973 | White DJ (1973) Robustness and optimality as criteria for decisions. *Operational Research Quarterly* 24(2): 311-313 | Operational Research Quarterly | RA |
| 89 | "Lee 1973" | Lee | 1973 | 1320 | 13 | "Lindblom 1959" | Lindblom | 1959 | Lindblom CE (1959) The science of "muddling through". *Public Administration Review* 19(2): 79-88 | Public Administration Review | TP |
| 99 | "White DJ 1973b" | White DJ | 1973 | 1321 | 86 | "Elton et al 1973a" | Elton et al | 1973 | Elton M, Gupta SK, Rosenhead J (1973) Reply to Professor D. J. White. *Operational Research Quarterly* 24(2): 313-316 | Operational Research Quarterly | RA |
| 100 | "White DJ 1973a" | White DJ | 1973 | 1322 | 78 | "Rosenhead et al 1972" | Rosenhead et al | 1972 | Rosenhead J, Elton M, Gupta SK (1972) Robustness and optimality as criteria for strategic decisions. *Operational Research Quarterly* 23(4): 413-431 | Operational Research Quarterly | RA |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1323 | 63 | "Checkland 1971" | Checkland | 1971 | Checkland P (1971) A systems map of the universe. *Journal of Systems Engineering* 2(2) | Journal of Systems Engineering | TP |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1324 | 74 | "Checkland 1972" | Checkland | 1972 | Checkland P (1972) Towards a systems-based methodology for real-world problem-solving. *Journal of Systems Engineering* 3(2) | Journal of Systems Engineering | SSM |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1325 | 76 | "Foster 1972" | Foster | 1972 | Foster M (1972) An Introduction to the Theory and Practice of Action Research in Work Organizations. *Human Relations* 25(6): 529-556 | Human Relations | TP |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1326 | 47 | "Jenkins 1969" | Jenkins | 1969 | Jenkins GM (1969) The systems approach. *Journal of Systems Engineering* 1(1) | Journal of Systems Engineering | TP |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1327 | 50 | "Checkland 1970" | Checkland | 1970 | Checkland P (1970) Systems and science, industry and innovation. *Journal of Systems Engineering* 1(2) | Journal of Systems Engineering | TP |
| 103 | "Checkland and Jenkins 1974" | Checkland and Jenkins | 1974 | 1328 | 51 | "Checkland and Griffin 1970" | Checkland and Griffin | 1970 | Checkland P, Griffin R (1970) Management information systems: a systems view. *Journal of Systems Engineering* 1(2) | Journal of Systems Engineering | TP |

## Second stage: Elaborating exploratory maps

To elaborate the bibliographic atlas, a main citation network and an author/journal bipartite network must be constructed. Building these networks begins with enumerating the vertices and arcs. Using the encoded list of vertices and arcs, an entry data worksheet is prepared so that Pajek, the network building software, can be used (De Nooy et al., 2011). Structuring the entry data comprises three sections: (i) Network data, (ii) Indexes, and (iii) Author-Journal arcs. Each section is composed of several sets of encoded data totaling eight subsections (Georgiou & Heck, 2015) (Table 3).

Table 3. **Example of data entry structure for building a master network**

| | NETWORK DATA | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1.Master Network | 2. Year | 3. Author | | | 4. Journal | 5. PSMs Attribute |
| | | | 1st Name | Name Code | Journal Code | | |
| *Vertices | 155 | | | | | | |
| 1 | "Hurni 1954" | 1954 | Hurni | 50 | 145 | JORS | TP |
| 2 | "Hitch 1955" | 1955 | Hitch | 48 | 145 | JORS | TP |
| 3 | "Ackoff 1956" | 1956 | Ackoff | 1 | 152 | Oper. Res. | TP |
| 4 | "Koopman and Hitch 1956" | 1956 | Koopman | 57 | 152 | Oper. Res. | TP |
| 5 | "Wanty 1957" | 1957 | Wanty | 104 | 152 | Oper. Res. | TP |
| 6 | "McEachron 1958" | 1958 | McEachron | 69 | 152 | Oper. Res. | TP |
| 7 | "Drucker 1959" | 1959 | Drucker | 26 | 148 | Manag. Sci. | TP |
| ... | ... | ... | ... | ... | ... | ... | ... |
| 150 | "Davies 1988" | 1988 | Davies | 23 | 163 | Syst. Practice | SSM |
| 151 | "Dunn 1988" | 1988 | Dunn | 28 | 158 | Policy Stud. Rev. | PSMG |
| 152 | "Eden 1988" | 1988 | Eden | 30 | 123 | Eur. J Oper. Res | SODA |
| 153 | "Eden and Huxham 1988" | 1988 | Eden | 30 | 144 | JORS | SODA |
| 154 | "Friend et al 1988" | 1988 | Friend | 38 | 144 | JORS | SCA |
| 155 | "Bulow 1989" | 1989 | Bulow | 16 | 136 | J Appl. Syst. Anal. | SSM |
| *arcs | | | | | | | |
| 1 | 121 | | | | | | |
| 2 | 36 | | | | | | |
| 2 | 53 | | | | | | |
| 2 | 75 | | | | | | |
| 2 | 127 | | | | | | |
| 3 | 121 | | | | | | |
| ... | ... | | | | | | |
| 140 | 148 | | | | | | |
| 142 | 150 | | | | | | |
| 144 | 146 | | | | | | |
| 147 | 151 | | | | | | |
| 148 | 155 | | | | | | |
| 149 | 155 | | | | | | |

(continue)

Table 3. **Example of data entry structure for building a master network**

(conclusion)

| INDICES | | | | | | | |
|---|---|---|---|---|---|---|---|
| 6. Author Index | | 7. Journal Index | | Time Index | | | |
| Author | Code | Title | Code | Period | Bin | 8.TPC | 9.TIC |
| Ackoff | 1 | Administrative Science Quarterly | 115 | 1950-1959 | 1950 | 1 | 156 |
| Adelson M | 2 | American Economic Review | 116 | 1960-1969 | 1960 | 2 | 157 |
| Adelson RM | 3 | Annual Review of Psychology | 117 | 1970-1974 | 1970 | 3 | 158 |
| Armstrong | 4 | Artificial Intelligence Review | 118 | 1975-1979 | 1975 | 4 | 159 |
| Atkinson | 5 | Business Horizons | 119 | 1980-1984 | 1980 | 5 | 160 |
| Ball | 6 | Cybernetics and Systems | 120 | 1985-1989 | 1985 | 6 | 161 |
| Bardie | 7 | Design | 121 | | | | |
| ... | ... | ... | ... | | | | |
| White SH | 109 | Social Science and Medicine | 162 | | | | |
| Wiedermann | 110 | Strategic Management Journal | 163 | | | | |
| Wilson | 111 | Systems Practice | 164 | | | | |
| Wiltshire | 112 | Technological Forecasting and Social Change | 165 | | | | |
| Woolley | 113 | The Antioch Review | 166 | | | | |
| Young | 114 | Town Planning Review | 167 | | | | |

| AUTHOR - JOURNALS ARCS | | |
|---|---|---|
| | 10. Author - journals Arcs | |
| Name | Author | Journal |
| Ackoff | 1 | 152 |
| Ackoff | 1 | 151 |
| Ackoff | 1 | 148 |
| Ackoff | 1 | 126 |
| Ackoff | 1 | 123 |
| Ackoff | 1 | 144 |
| Ackoff | 1 | 162 |
| ... | ... | ... |
| Wiedermann | 110 | 144 |
| Wilson | 111 | 136 |
| Wiltshire | 112 | 137 |
| Woolley | 112 | 144 |
| Woolley | 113 | 131 |
| Young | 114 | 156 |


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Table 4. **Example of data entry structure for building an author-journal bipartite network**

| **Author - Journal Bipartite Network** | | |
|---|---|---|
| *Vertices | 165 | 114 |
| 1 | "Ackoff" | |
| 2 | "Adelson M" | |
| 3 | "Adelson RM" | |
| 4 | "Armstrong" | |
| 5 | "Atkinson" | |
| 6 | "Ball" | |
| 7 | "Bardie" | |
| ... | ... | |
| 109 | "White SH" | |
| 110 | "Wiedermann" | |
| 111 | "Wilson" | |
| 112 | "Wiltshire" | |
| 113 | "Woolley" | |
| 114 | "Young" | |
| 115 | "Administrative Science Quarterly" | |
| 116 | "American Economic Review" | |
| 117 | "Annual Review of Psychology" | |
| 118 | "Artificial Intelligence Review" | |
| 119 | "Business Horizons" | |
| 120 | "Cybernetics and Systems" | |
| 121 | "Design" | |
| ... | ... | |
| 160 | "Social Science and Medicine" | |
| 161 | "Strategic Management Journal" | |
| 162 | "Systems Practice" | |
| 163 | "Technological Forecasting and Social Change" | |
| 164 | "The Antioch Review" | |
| 165 | "Town Planning Review" | |
| *Arcs | | |
| 1 | 124 | |
| 1 | 127 | |
| 1 | 135 | |
| 1 | 136 | |
| 1 | 149 | |
| ... | ... | |
| 112 | 140 | |
| 113 | 132 | |
| 113 | 135 | |
| 114 | 155 | |


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In the Network Data section, for every vertex, a sequential identification number and defined label are attributed in the citation index. The arcs are defined with the identification numbers of the vertices, with the first number of the arc referring to the article cited ("citee") and the second number to the article that cites ("citer"). The codes for authors' names and journals are defined on the basis of the indexes of authors and journals in the Indexes section, and transcribed for their respective authors and journals in the subsection Author and Journal.

The second section, Indexes, defines the indexes of the author, journal, time period code (TPC), and time indicator code (TIC). The subsection Time Index defines the time intervals for each longitudinal period. This example has six periods of interest; therefore, the TPC is encoded from 1 to 6 in a chronological order, which can also be used as attributes. The TIC establishes a time indicator of the vertices of the master network to enable extracting longitudinal sub-networks. Encoding the TIC follows a numerical sequence beginning with the subsequent number of the code of the vertices. In this example, the last vertex of the master network is 155, so the first TIC code will be 156.

Finally, the Author/Journal Arcs section structures the data to determine the arcs of the author-journal bipartite network to associate the codes of the authors' names with those of the journals defined in the subsection "Author" of the Network Data section. Every author/journal pair is organized in increasing order, and any duplication removed. In this example, the total number of vertices is 165, and the number separating the group of the authors' vertices from that of journals is 114 (Table 4).

Based on these entry data worksheets, the maps and diagrams of the bibliographic atlas are constructed. The procedures for building citation networks with Pajek software are presented step-by-step in the flowcharts of the document Longitudinal Exploratory Citation Network Analysis: An Atlas-Based Methodology, as suggested by Georgiou and Heck (2015).

## Third stage: Exploratory analyses of the bibliographic atlas

As mentioned, the bibliographic atlas consists of three parts determined in the three exploratory analyses of (i) panoramic coverage, (ii) references, and (iii) journals (Exhibit 1).

A panoramic coverage analysis is the broadest exploratory analysis and covers the longitudinal analysis of the master network by enabling visualization of the synchronology, longitudinally arrayed adjacency matrix, longitudinal sub-networks, and sub-networks aggregated per attribute. The synchronology is the map of the master network organized by time period such as decades and visually presented horizontally from the oldest period, on the left, to the most recent period, on the right (Figure 1).

Thus, synchronology is a chart showing the chronological dynamics of the publications of the documents being studied. Although it does not render precise visual information about the connections between events, this analysis enables observing the most intense periods of academic production.

From the synchronology, the longitudinally arrayed adjacency matrix of the master network can be determined. This enables presenting measures related to the number of edges directed in a vertex, or "indegree," and number of edges directed out the vertex, or "outdegree" of the network, which enables checking the dynamics and production of research activities (Table 5) (Harary, 1969).

The longitudinally arrayed adjacency matrix is a triangular matrix providing information on the number of articles published per period, number of articles cited ("outdegrees" data per line), and number of articles that cite other articles ("indegrees" data per column). For example, Table 5 shows that 16 articles were published in the 1960s. In the respective line, these 16 articles were cited 47 times from 1960 to 1989. On the other hand, in the respective column, these 16 articles cited articles from previous periods 9 times. Moreover, the published articles were most cited from 1975 to 1979 (153 times). From 1980 to 1984, the articles more often cited previous articles (207 times). This shows the dynamics of the publication of the PSM literature.

The main longitudinal network is visually similar to the master network, but differs in that for each vertex, a TIC is defined to enable the longitudinal extraction of sub-networks for a specific period. These sub-networks clarify what was previously published only if it was cited by the articles published in this period. This analysis is similar to a historical geographical atlas (Figure 2). In this example, the sub-network represents a structure with two separate components: one with the PSM and the other only with the Dunn article (1988) and its "citees." This suggests an apparent absence of cohesion in that literature.

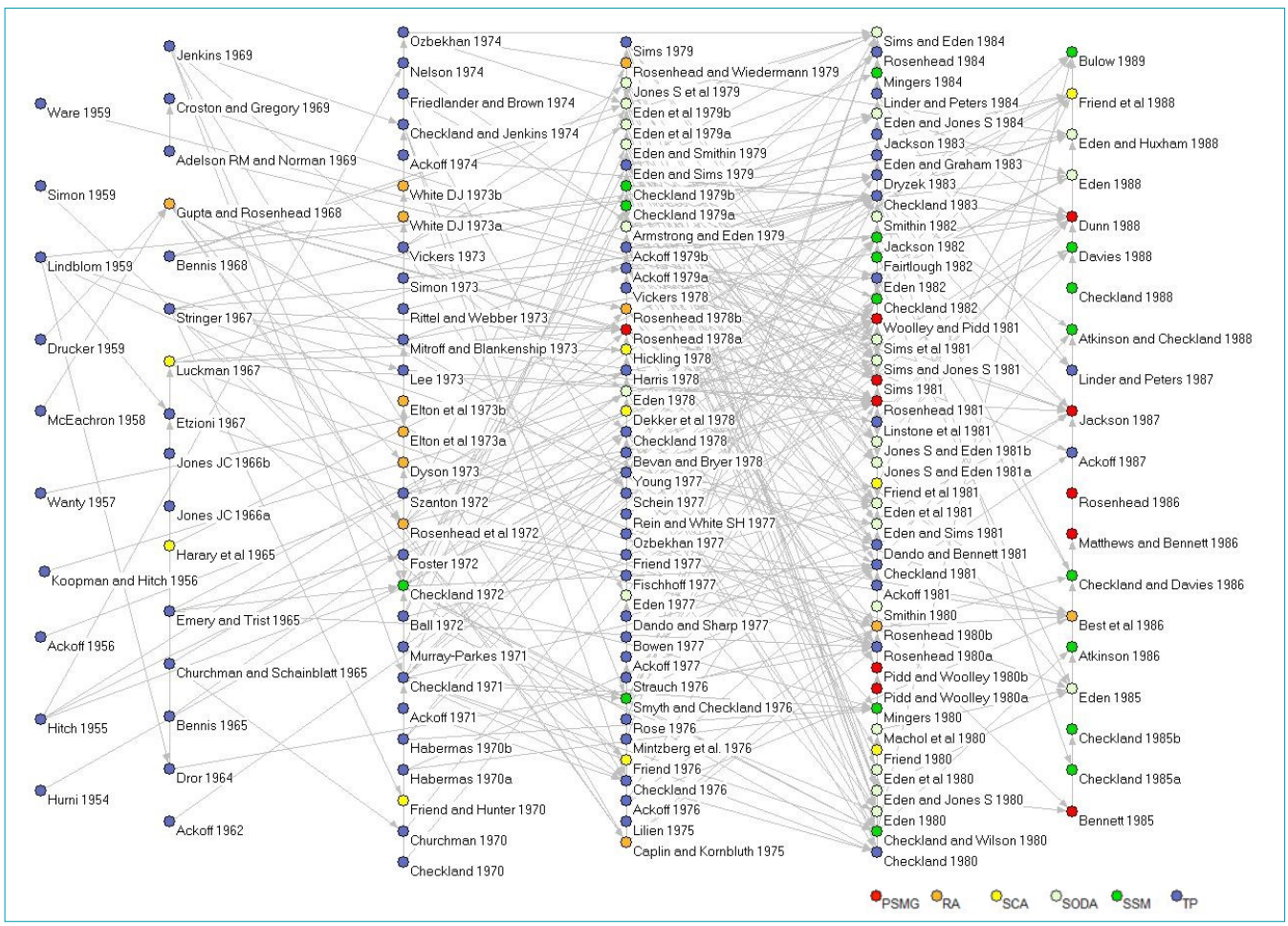
Finally, from the master network or longitudinal sub-network it is possible to extract a sub-network aggregated per attribute by reducing all the articles of one attribute to just one vertex (Figure 3). This type of sub-network enables identifying the cross-references, conceptual borrowings, or parallel formulations common to each PSM category. In this example, of the 81 articles categorized as theoretical precedents (TP), only 5 are common with other PSMs. It is interesting that for the four PSMs considered complementary in the literature (Rosenhead, 1989), only five articles associate them. Thus, it can be inferred that the association of their theoretical bases, supported by these cross-references, is weak and limited.

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## Exhibit 1. **Elements composing a bibliographic atlas**

| |
|---|
| **Panoramic range** |
| 1. Synchronology |
| 2. Longitudinally arrayed Adjacency matrix |
| 3. Longitudinal sub-networks |
| 4. Sub-networks aggregated by attributes |
| **Exploring references** |
| 5. Sub-network of *top citees* |
| 6. Sub-network of *top citers* |
| 7. "Radar" sub-network |
| 8. Bibliographic coupling sub-network |
| 9. Co-citation sub-network |
| 10. Sub-network of the main path analysis |
| **Exploring journals** |
| 11. Author-journal bipartite network |
| 12. Journal sub-network |

## Figure 1. **Synchronology of a master network defined by attributes**




Source: Adapted from Georgiou and Heck (2017).


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Table 5. **Longitudinally arrayed adjacency matrix of a master network**

| Time periods | | 1950-1959 | 1960-1969 | 1970-1974 | 1975-1979 | 1980-1984 | 1985-1989 | Time Period Aggregate Outdegrees Results | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Papers Published | 10 | 16 | 28 | 40 | 41 | 20 | Outdegree | Average Outdegree/ Papers | % of network Outdegrees |
| 1950-1959 | 10 | 0 | 4 | 4 | 1 | 8 | 0 | 17 | 1.70 | 4.19% |
| 1960-1969 | 16 | | 5 | 9 | 15 | 12 | 6 | 47 | 2.94 | 11.58% |
| 1970-1974 | 28 | | | 18 | 27 | 36 | 8 | 89 | 3.18 | 21.92% |
| 1975-1979 | 40 | | | | 41 | 94 | 18 | 153 | 3.83 | 37.68% |
| 1980-1984 | 41 | | | | | 57 | 27 | 84 | 2.05 | 20.69% |
| 1985-1989 | 20 | | | | | | 16 | 16 | 0.80 | 3.94% |
| Time Period Aggregate Indegree Results | Indegree | 0 | 9 | 31 | 84 | 207 | 75 | | | |
| | Average Indegree/ Papers | 0.00 | 0.56 | 1.11 | 2.10 | 5.05 | 3.75 | | | |
| | % of network Indegrees | 0.00% | 2.22% | 7.64% | 20.69% | 50.99% | 18.47% | | | |

| Total Papers | Total Arcs |
|---|---|
| 155 | 406 |

Source: Adapted from Georgiou and Heck (2017).

Therefore, for panoramic coverage, the bibliographic atlas in structural cartography offers four analyses: (i) synchronology (a panoramic map), (ii) longitudinally arrayed adjacency matrix, (iii) longitudinal sub-networks, and (iv) sub-networks aggregated per attribute.

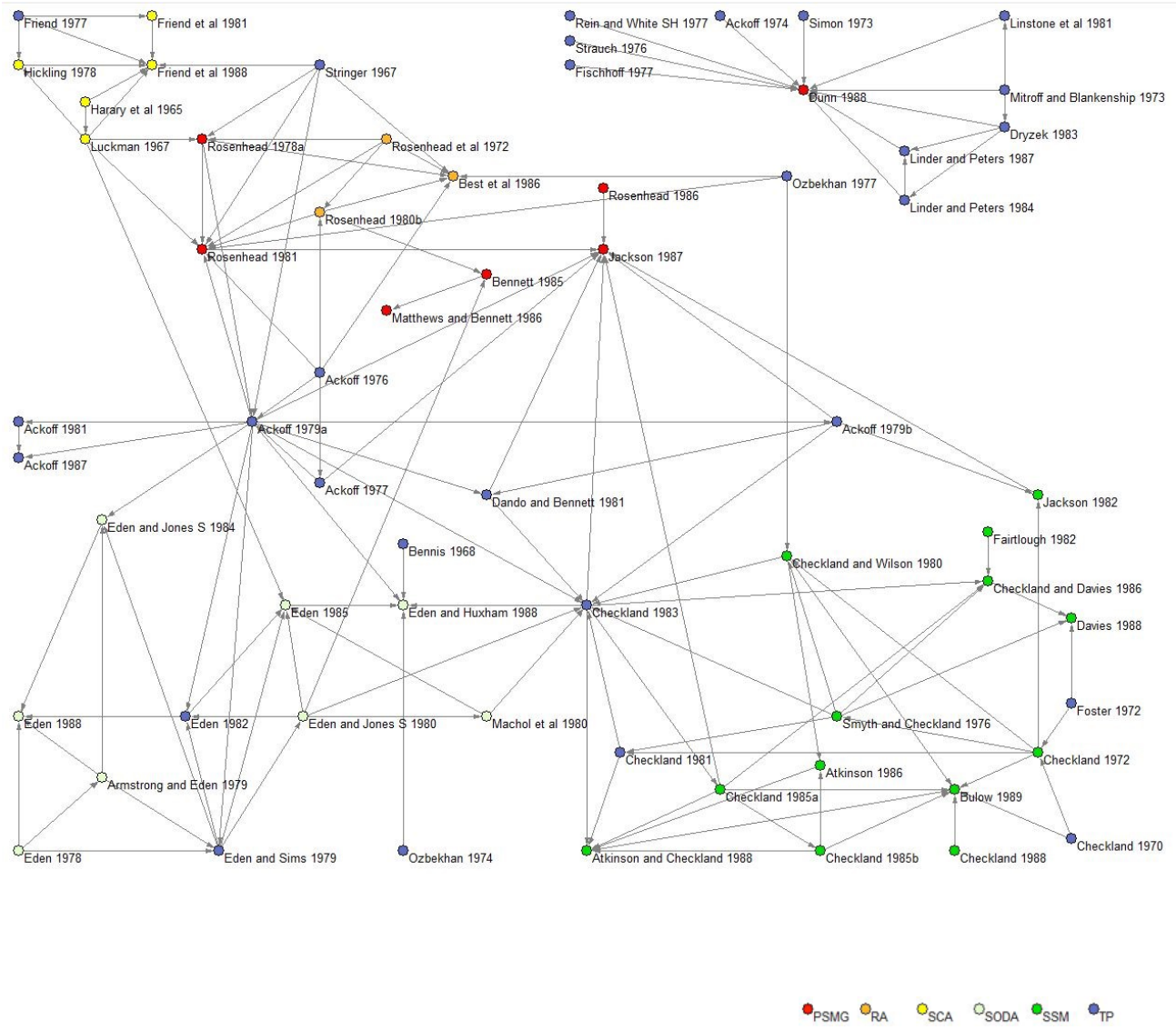
The second exploratory analysis in the bibliographic atlas is that of documents. Here, sub-networks of the most cited articles in the network are examined, the so-called "top citees" (Figure 4), as are those of the articles citing other articles the most, the so-called "top citers" (Figure 5). Analyzing the "top citees" reveals which authors conceptualized new ideas and what documents are useful in understanding the subject under study. An examination of the "citers" indicates which articles add the most to previous knowledge inside a field of study and which can be considered syntheses of the literature.

Two facts emerged in the sub-network. First, only SODA articles are represented as "top citers," together with TP and general PSM articles (PSMG). The other PSMs such as SSM, SCA, and RA are absent. Second, the Dunn article (1988), which was not directly mentioned in the other PSM articles (Figure 7), is one of the "top citers" (Figure 10). This confirms the necessity of clarifying the context of the existence of an article such as this, which was ignored in the PSM literature.

Another analysis of the exploration of references to be considered is the sub-network "radar," which condenses the fundamental structure based on "top citees," integrates the "citers" of the "top citees," and includes their "citees." Thus, the "radar" sub-network is a microcosm inside a field of knowledge (Figure 6). This "radar" sub-network is one of the most relevant and innovative maps in the bibliographic atlas of the structural cartography method. It was originally defined by Georgiou (2014).

Moreover, it is possible to explore the network by analyzing cohesive groups in citation networks using two complementary measurements: (i) bibliographic coupling and (ii) co-citation (Figures 7 and 8). The difference between these two measures is that in the bibliographic coupling method, the content of a pair of articles is characterized by past knowledge, and in the co-citation method it is influenced by the knowledge of future periods. Therefore, the possibility of longitudinal extraction from bibliographic coupling and co-citation enables the structural cartography method to perform a diachronic analysis in addition to the longitudinal analysis.

Figure 2. **Longitudinal sub-network extracted for the period 1985 to 1989**



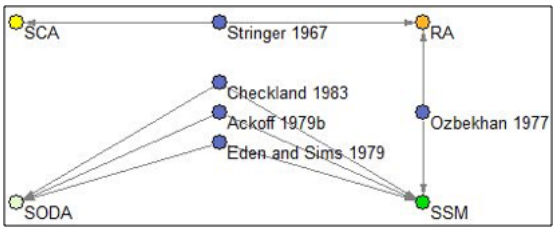

Source: Adapted from Georgiou and Heck (2017).


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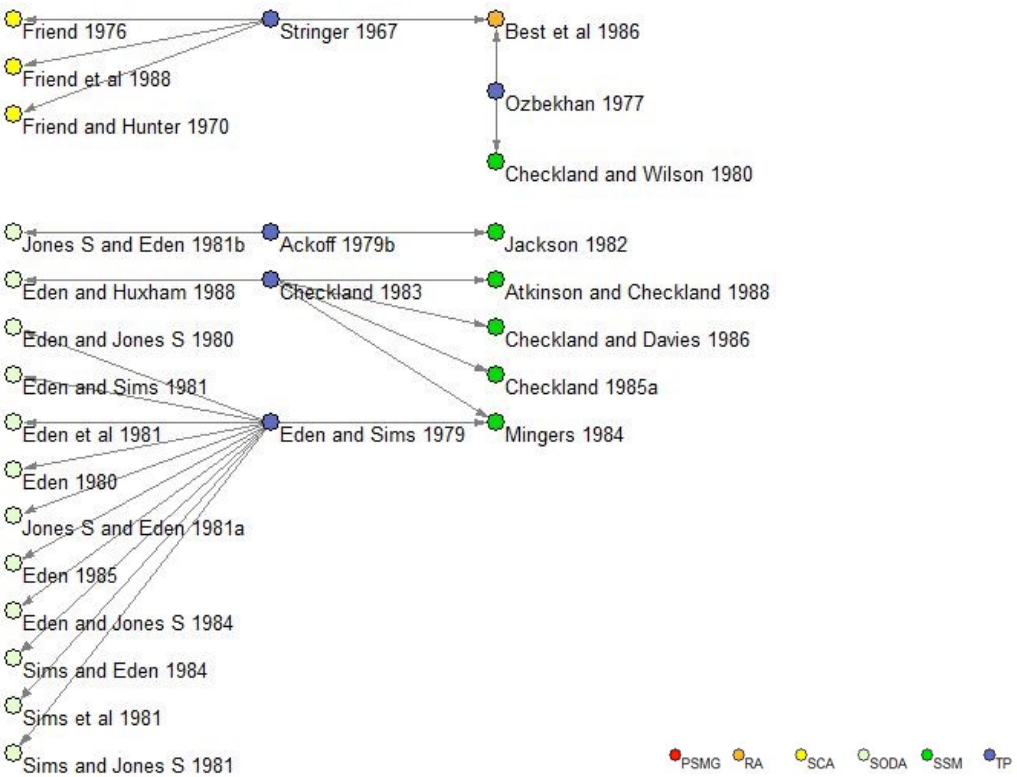
ISSN 0034-7590

## Figure 3. Sub-network of theoretical precedents (TP) cited in the PSM

Aggregated sub-network

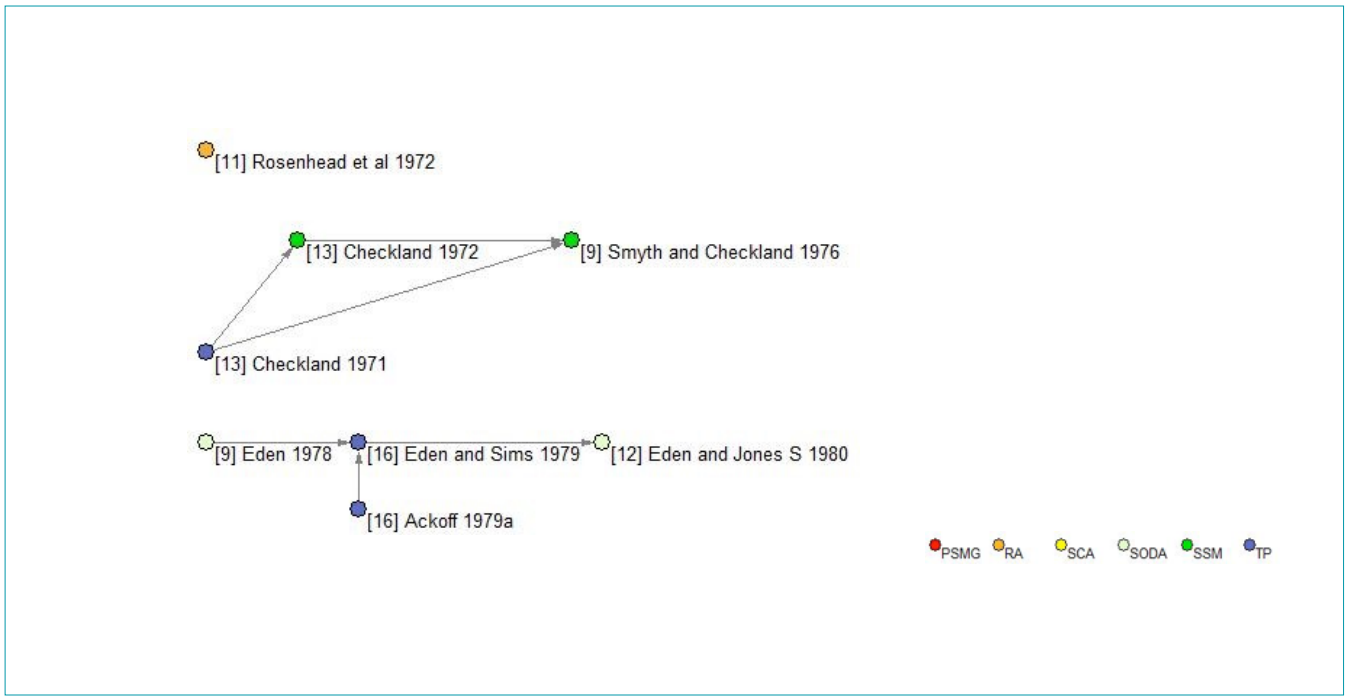



Detailed sub-network



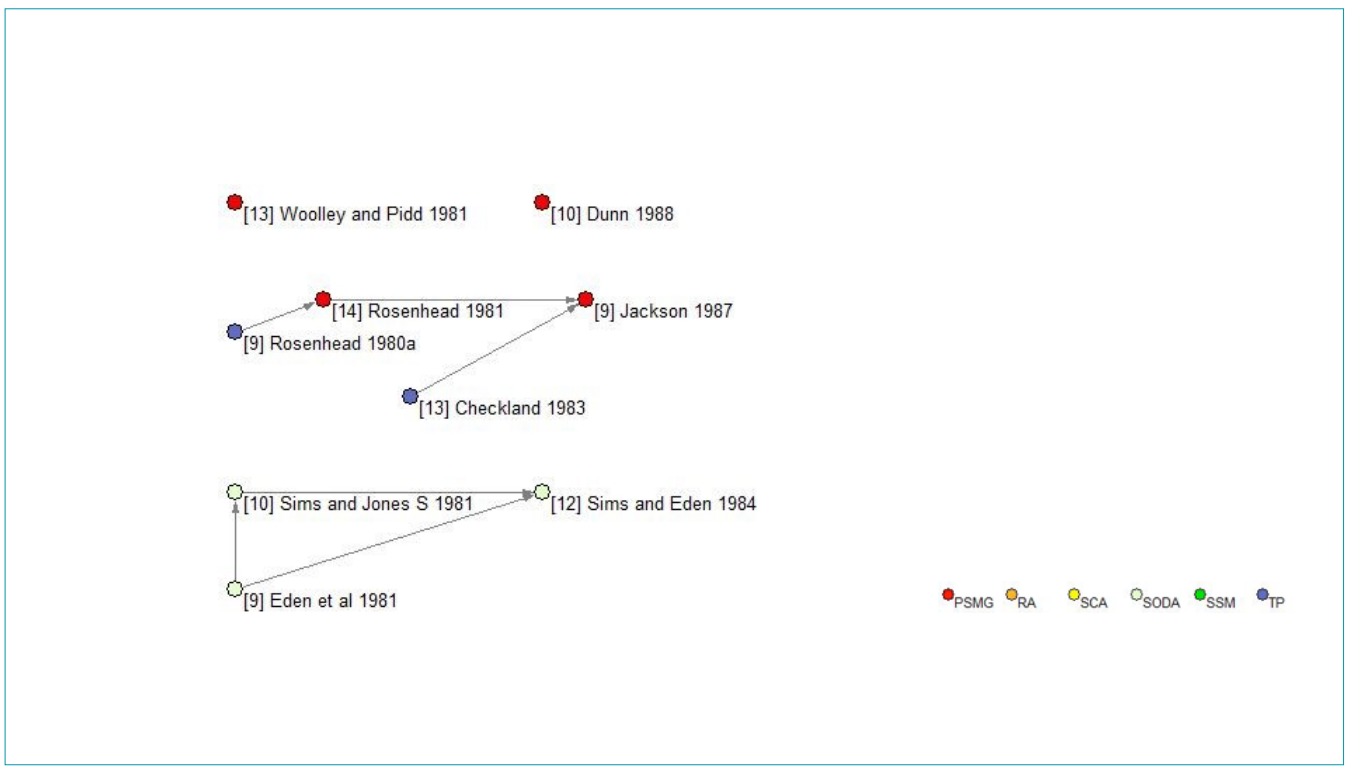

Source: Adapted from Georgiou and Heck (2017).

Figure 4. **Sub-network of top citees with more than nine references**




Source: Adapted from Georgiou and Heck (2017)

Figure 5. **Sub-network of top citers citing more than nine references**

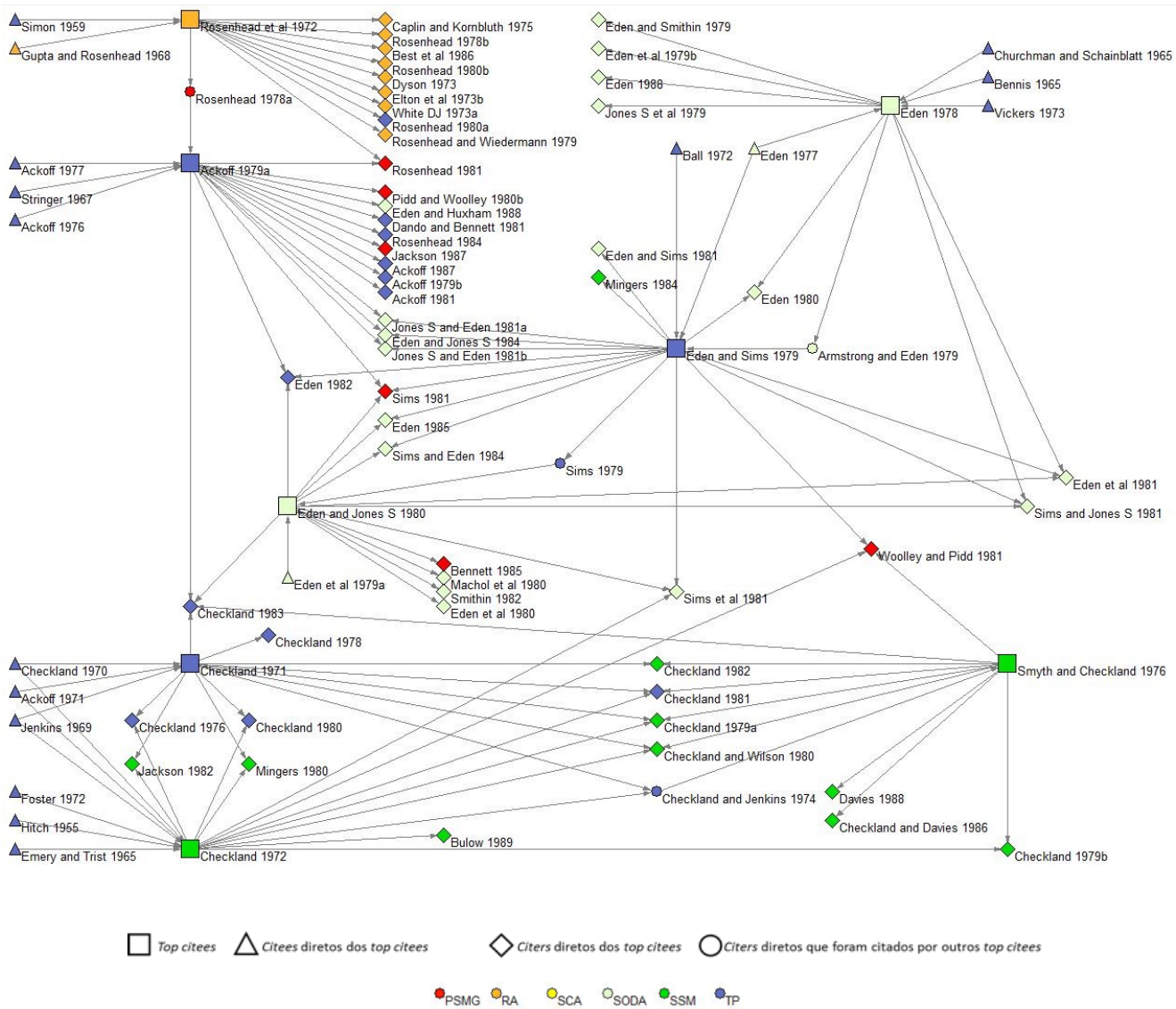



Source: Adapted from Georgiou and Heck (2017).


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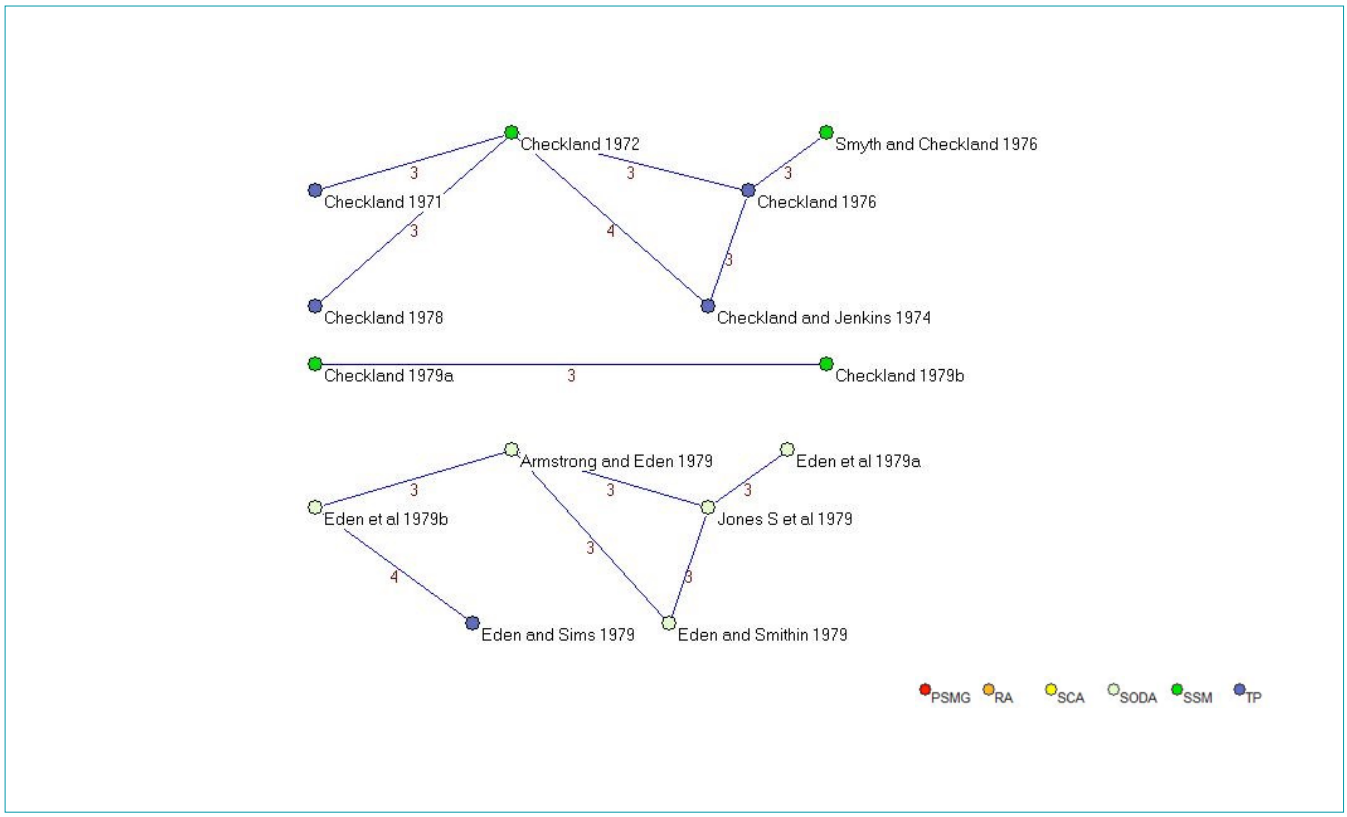
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Figure 6. **"Radar" sub-network**



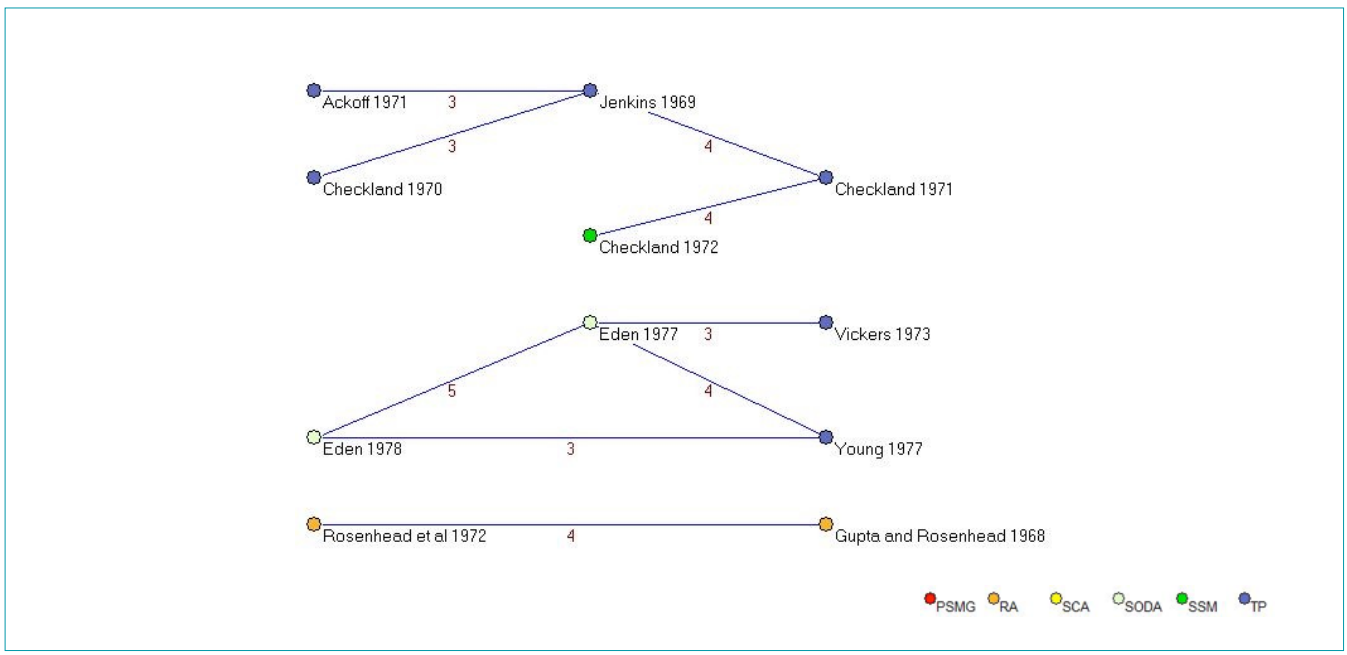

Source: Adapted from Georgiou and Heck (2017).

Figure 7. **Sub-network of bibliographic coupling (citers with three or more citees in common)**




Source: Adapted from Georgiou and Heck (2017).

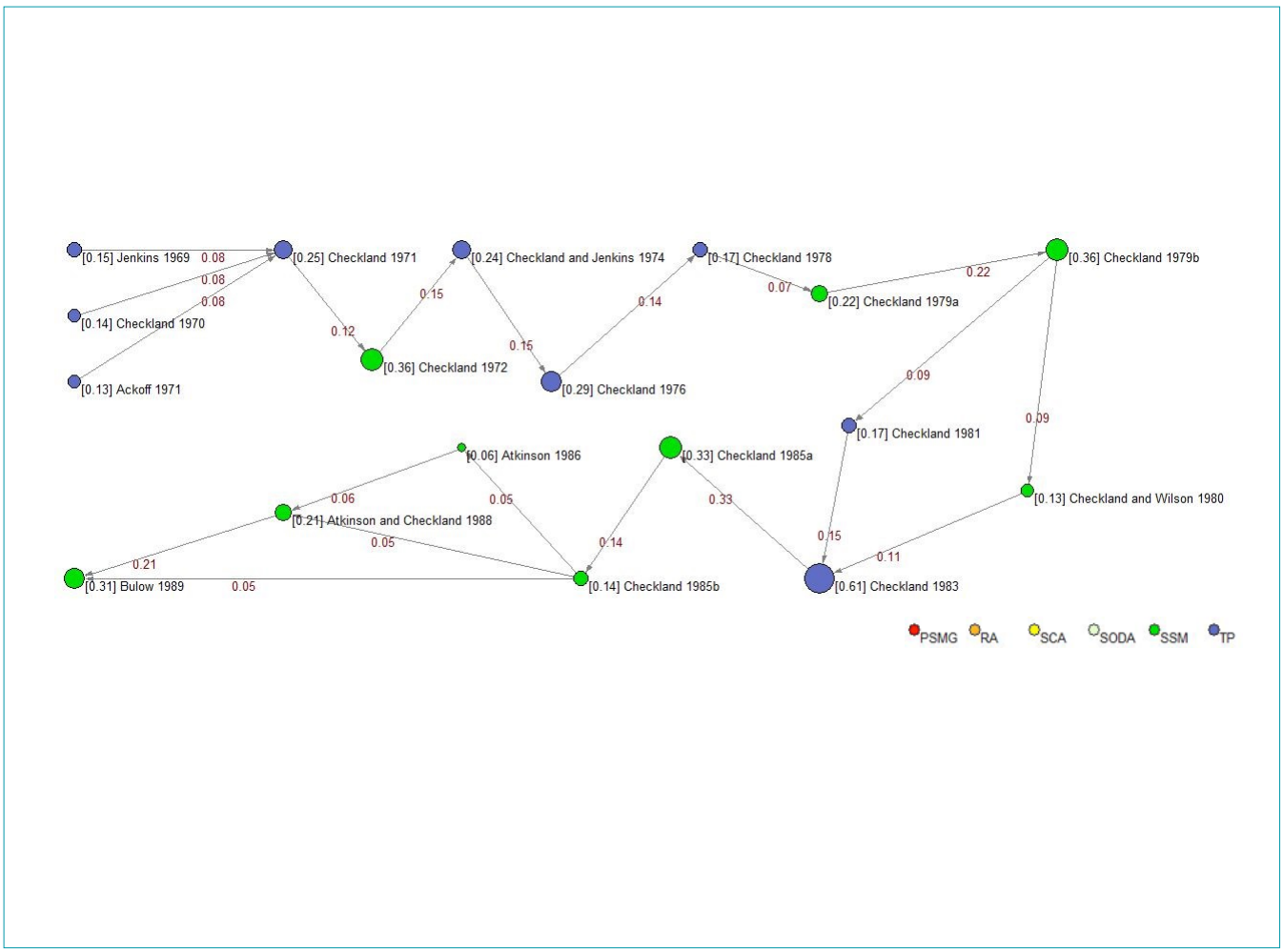
Figure 8. **Co-citation sub-network (citees with three or more citers in common)**




Source: Adapted from Georgiou and Heck (2017).

Finally, another way to explore references is through a main path analysis. In this analysis, the backbone of the citation network map is constructed, providing a list of articles representing the core of the knowledge in the area under study (Georgiou, 2014) (Figure 9). In the example of the study on PSMs, the analysis shows only the presence of TP and SSM articles. This fact raises a question regarding the conceptual unity of that literature.

Figure 9. **Sub-network of the main path analysis**



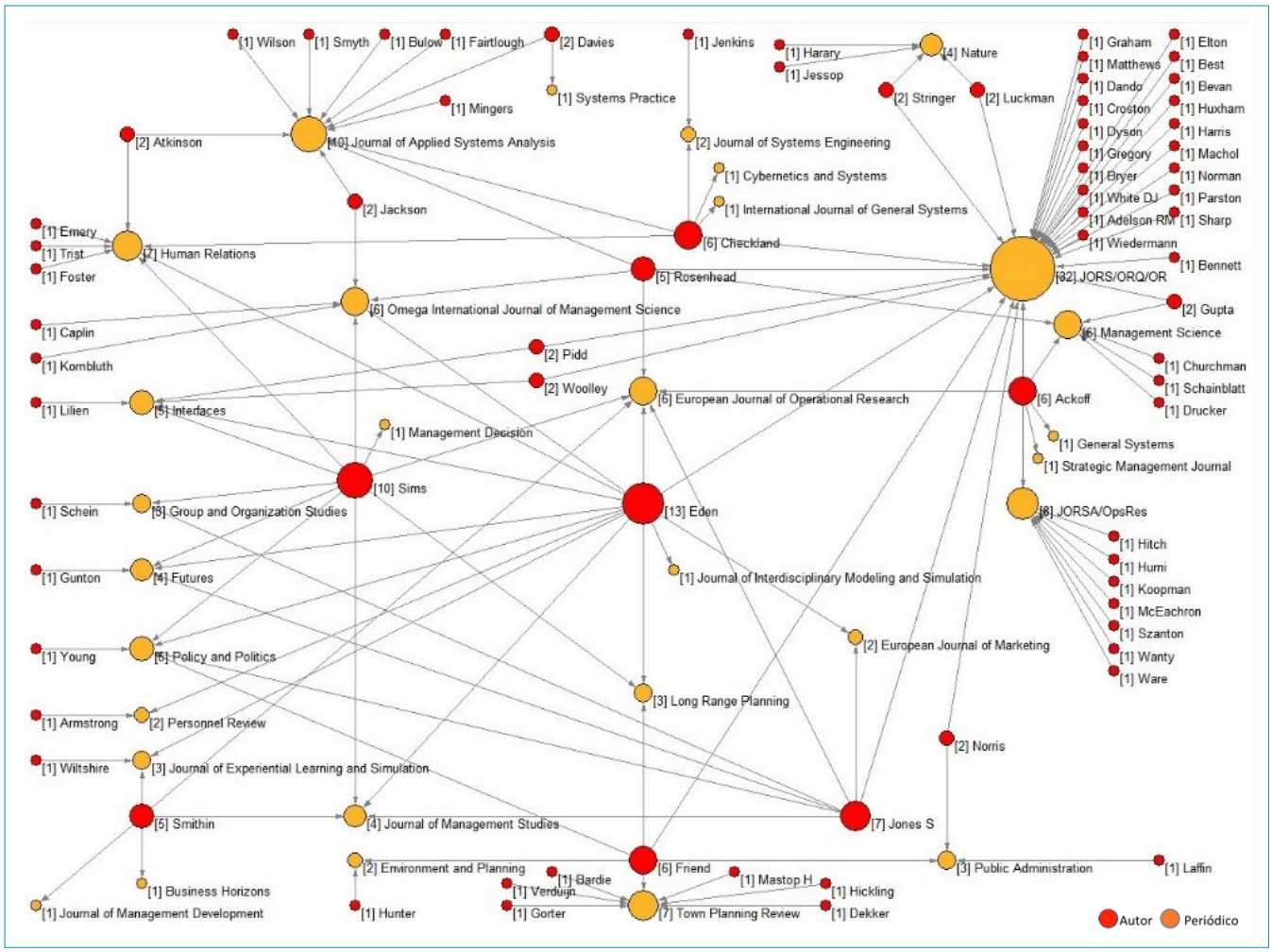

Source: Adapted from Georgiou and Heck (2017).

Thus, to explore references, the bibliographic atlas in structural cartography offers six analyses: (i) sub-network of "top citees," (ii) sub-network of "top citers," (iii) "radar" sub-network, (iv) sub-networks of bibliographic coupling, (v) sub-networks of co-citation, and (vi) main path analysis.

The third and last exploratory analysis of the structural cartography method is conducted through an author-journal bipartite network, which maps the authors of each article with the respective scientific journals in which they were published (Figure 10). This network shows whether a concentration exists among scientific journals and which authors disseminate the knowledge in the field under study. Note that the primary elements of the bipartite network are authors and scientific journals, not articles.

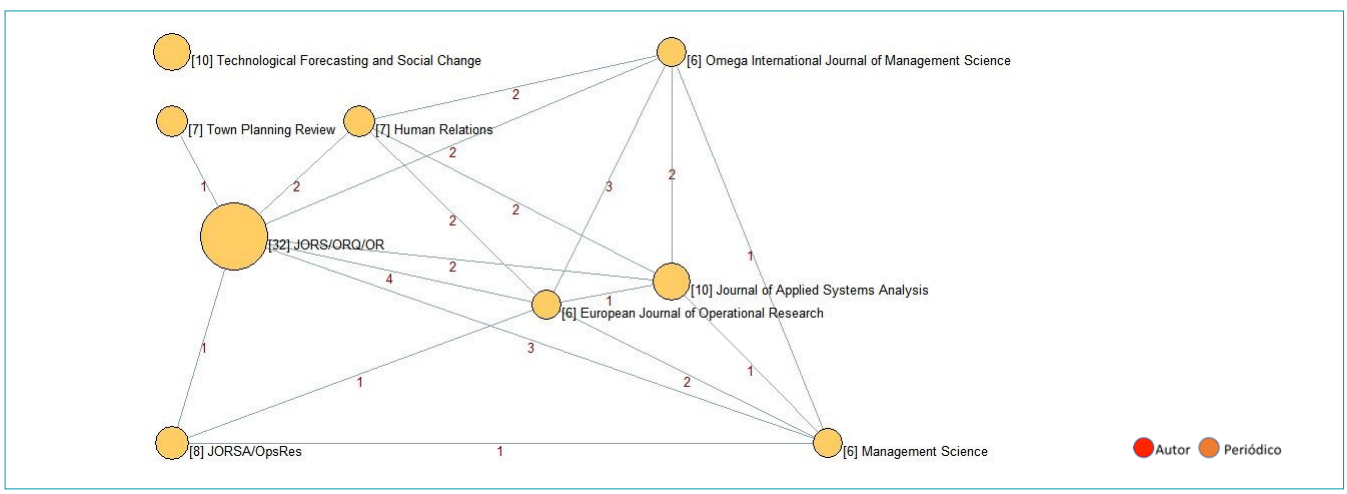
The journal sub-network is also analyzed, which is determined only by the scientific journals for which the relation among those journals is defined based on the criterion of sharing the same authors (Figure 11). In the study on PSMs, the "Journal of the Operational Research Society" (JORS/ORQ/OR) is the preferred journal in which to publish. The journal has published the articles of 32 authors, i.e., 28% of all authors in the network, highlighting the hegemony of that journal in the literature.

## Figure 10. Author-journal bipartite network




Source: Adapted from Georgiou and Heck (2017).

## Figure 11. Journal sub-network




Source: Adapted from Georgiou and Heck (2017).

Thus, for exploring journals, the bibliographic atlas in structural cartography offers two approaches: (i) the author-journal bipartite network and (ii) journal network.

The results of using the structural cartography method are represented by the 11 maps comprising the bibliographic atlas, which exposes the underlying structure of the literature.

## CONCLUSION

The structural cartography method for literature review offers an organized, repeatable, and self-correcting procedure for research that ensures valid results are obtained. This method outlines rigorous basic rules to build a bibliographic atlas of the literature. The results of using the structural cartography method provide 12 ways to approach the literature in a specific field (see Exhibit 1).

Through this visual and figurative model, it is possible to establish a chronology of papers, objectively showing the main associations between them and analyzing the thematic history of an area of knowledge. Bibliographic atlas maps organize and record the bibliographic "collectanea" of a literature and expose the structural cohesion of that bibliography, which will be used to substantiate a thesis or academic study.

In the study of the literature on PSM, known for its conceptual unity (Rosenhead, 1989), the underlying structure found through the structural cartography method does not provide evidence of cohesion, since there are few cross-references, conceptual borrowings, and parallel formulations. Therefore, the use of the method confirms that the idea of unity in the PSM field is not supported by the structure of references revealed in the exploratory analyses of the bibliographic atlas. In addition, it revealed references such as that of Dunn (1988), which was ignored by academics in the area. Thus, using the structural cartography method for literature review enables conducting sophisticated theoretical research in Business Administration (Georgiou & Heck, 2017).

However, the application of this method requires that academic researchers manually elaborate the citation index and study in depth the content of every document in the bibliographic atlas to identify gaps in the theme under study and advance knowledge.

Finally, structural cartography is a unique interdisciplinary method for conducting comprehensive and sophisticated literature reviews theoretically grounded in bibliographic research, historical research, the theory of the citation index, mapping bibliographic networks, and cartography. This method enables mapping the underlying structure of a subject, as suggested by Hart (1998), and operationalizes this activity, which has been considered too ambiguous and whose resolution has remained pending until now.

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