



Problem Structuring Methods: A Review of Advances Over the Last Decade

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Abstract

The Problem Structuring Methods (PSMs) are a set of interactive and participatory modeling approaches for dealing with unstructured complex problems, which are characterized by the existence of multiple actors, with differing perspectives and conflicting interests, trying to identify alternatives for solving a problematic situation in an environment with uncertainties. In this paper, we provide a literature review about PSMs over the last decade (2010–2020), focusing on verifying the distribution of papers according to year, journals, countries, and authors; to identify the most frequent PSMs and areas of application; and to present methodological and theoretical advances, and emerging topics. The content analysis technique was used to analyze the papers. From 2015 on there was a significant increase in the number of studies that address the PSMs and the years 2018 and 2019 concentrate around one-third of the number of papers. Most of the papers present applications of PSM in different areas that were classified into five categories: business management; environmental management; healthcare sector; social issues; and other areas. Regardless of the application area, the Soft System Methodology (SSM) is the most frequently used PSM and a discussion is provoked about this finding. The paper also presents the theoretical and methodological advances and emerging topics in this discipline.

Keywords Problem structuring methods · Soft systems methodology · Group decision · Complex problems · Soft OR · System thinking

Introduction

Operational Research (OR) is a discipline that encompasses the development and/or application of analytical methods aiming to provide improved decision making in different

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contexts; traditionally, these methods are addressed to solve well-structured problems, that is, problems that can be expressed in terms of mathematical expressions (Mingers and Rosenhead 2004; Rosenhead 1996; 2006); the so called “Hard OR” search optimization and objectivity (Ackoff 1979). However, in various situations the nature of decisions is complex, making it difficult, or even impossible, to model the problems mathematically. According to Ackoff (1979), traditional OR’s methods and models are not meant for dealing with complex decisions, which the author called “messy problems” and (Rittel and Weber 1973) called “wicked problems”. Complex decisions are problems that involve multiple actors, with differing perspectives and partially conflicting interests, significant intangibles, and perplexing uncertainties (Rosenhead 2006). These situations, despite being extremely common, are strategic, not short-term, and narrowly focused (Mingers 2011a).

Since the late 1960s, specialists started debates about claims for objectivity of hard OR models and the limitations imposed on OR practice by its concentration in well-structured problems (Rosenhead 1996). This movement for a reevaluation of OR and their customer base was started in OR community in Britain followed by some American researchers, such as Russell Lincoln Ackoff, Charles West Churchman, and Hugh Jordan Miser (Kirby 2007). In his criticism, Ackoff (1979) pointed out that Hard OR approaches were no longer sensitive to the evolution of management needs. In this context, a new class of methods, named Problem Structuring Methods (PSMs), emerged, giving rise to a new branch in OR, which became known as “Soft OR” (Ackermann 2012; Mingers 2011a). As pointed out by Mingers (2011a), despite having existed for more than 50 years, efforts are still necessary to recognize Soft OR as a legitimate Operational Research discipline.

PSMs are a set of interactive and participatory modeling approaches that help groups of diverse actors to alleviate a common complex and problematic situation (Mingers and Rosenhead 2004; Mingers and White 2010). These methods offer a well-defined and an agreed upon structure, originating from differing perceptions of the situation, for this type of circumstances can help generate a consensus or to facilitate negotiations, that is, these methods help structuring the problem instead of solving them directly (Rosenhead 1996). Therefore, PSMs manage the complexity of these messy situations aiming actors to develop a comprehensive appreciation of the situation and thereby they are able to achieve a common understanding about it Ackermann (2012).

Smith and Shaw (2019) point out some characteristics of PSMs: they build models that are qualitative; they facilitate engagement and improve the participants’ learning about the problem; they seek to create a holistic understanding of the system, and their inputs are the participants’ subjective understandings of the world. Other characteristics of PSMs are: the credibility of the model is established by preserving the contribution of the participants; the rationality of the procedures aim to promote confidence; knowledge is structured through various stages of analysis; and there are distinct phases for convergent and divergent thoughts (Schramm and Schramm 2018), which help the group involved in the complex problem to negotiate a set of improvements and actions to resolve the situation (Ackermann 2012).

In a retrospective and prospective study about PSMs, Rosenhead (2006) presents some areas in which these methods can be useful: development planning, community operational research, large group interventions, information systems projects, and management of risks. Thirteen years after Rosenhead’s study, Harwood (2019b) points out areas in which research using PSMs can be fruitful: strategy development; change management; sustainable development; social enterprise; and teaching research methods. In the last decade, PSMs have been applied in diverse areas: business management (Abuabara et al. 2018; Damenu and Beaumont 2017; Davis et al. 2010; Hanafizadeh and Ghamkhari 2019; Savage et al. 2019);

environmental management (Hart and Paucar-Caceres 2014; Potts et al. 2015; Santos et al. 2019; Schramm and Schramm 2018; Watkin et al. 2012); healthcare sector (Cardoso-Grilo et al. 2019; Carter et al. 2019; Heyrani et al. 2012; Sinclair et al. 2014; Vandebroek et al. 2014); social issues (Brocklesby and Beall 2018; Capolongo et al. 2019; Laouris and Michaelides 2018; Rodríguez-Ulloa et al. 2011); among others (Armstrong 2019; Bell et al. 2017; Cloutier et al. 2015; Cronin et al. 2014; Eigbe et al. 2010).

The foremost PSMs are Soft Systems Methodology (SSM) (Checkland 2001), Strategic Choice Approach (SCA) (Friend 2001), and Strategic Options Development and Analysis (SODA) (Ackermann and Eden 2010; Eden and Ackermann 2001). SSM is a learning system that consists of the construction of a graphical description of the problem, construction of a conceptual model based on the perspective and interests of decision makers, comparison of both real and conceptual models, identification of changes that are culturally feasible and systemically desirable, and take action to solve the problem. SODA uses cognitive mapping to represent the perceptions of individuals about the situation, creating a holistic and common understanding about the problem and helping the group to find ways for mitigating it. SCA helps actors working together to make decisions by focusing their attention on possible modes of managing uncertainty; it is formed by a process with four complementary modes: shaping, in which decision-makers address the problems; designing, whose focus is formulating feasible actions to solve the problem; comparing, for comparing these actions with each other; and choosing, which is the stage to achieve an agreement in relation to the action the group will chose. Other PSMs that are cited by Rosenhead (2006) are: Hypergame Analysis; Interactive Planning; Metagame Analysis; Robustness Analysis; Strategic Assumption Surfacing and Testing. Other methods that are described in the literature as PSMs are: Viable System Model (VSM) (Beer 1984), Drivers, Pressures, State, Impact and Response (DPSIR) (Bell 2012), and Waste and Source-matter Analyses (WASAN) (Shaw and Blundell 2010).

In the past ten years, some literature reviews about PSMs and related topics were published in specialized literature. Mingers and White (2010) reviewed the contribution of Systems Thinking to Operational Research in the first decade of the 2000s. Franco and Montibeller (2010) discussed the facilitated modeling as an intervention tool and offered a formal definition for it. Paucar-Caceres (2010) performed a review of papers to verify paradigmatic changes in Management Science; the review was limited to papers that were published in OMEGA, International Journal of Management Science, from 1973 to 2008. Mingers (2011b) provided a discussion about the recognition of Soft Operational Research as a legitimate Operational Research discipline. Howick and Ackermann (2011) reviewed the mixing of methods in Operational Research. Paucar-Caceres and Pagano (2011) explored the differences between trends in Operational Research, a research developed in England and the United States. Khadka et al. (2013) performed a literature review of PSM use in participatory forest planning. Davis et al. (2015) reviewed Systems Thinking's application to organizational performance in higher education and healthcare. Ranyard et al. (2015) discussed the influences of Business Analytics and PSM in the future of Operational Research.

More recently, Patrício et al. (2016) reviewed the use of DPSIR in ecosystem management. Marttunen et al. (2017) reviewed the combination of Multi-Criteria Decision Analysis and PSMs. Powell and Mustafee (2017) presented a study about the use of SSM in the health care sector. Renzi and Leali (2017) reviewed decision-based design methods in engineering design contexts. Hanafizadeh and Mehrabioun (2018) reviewed the use of SSM in papers that were published between 2000 and 2015. Scott et al. (2016) reviewed the literature about Group Model Building. From a literature review, Smith and Shaw (2019) provided a frame-

work to determine which approaches can be considered PSMs. Warren et al. (2019) provided a bibliometric meta-analysis of the use of SSM. Wright et al. (2019) performed a review about the use of scenarios from the Intuitive Logics School to address wicked problems.

The motivation for this work stems from the need to analyze the relevant empirical and theoretical literature about PSMs. In this paper, a literature review about PSMs is provided, focusing on verifying the distribution of papers according to year, journals, countries, and authors; to identify the most frequent PSMs and areas of application; and to present methodological and theoretical advances, and emerging topics. The reviewed database is comprised of 322 papers that were published in peer-reviewed journals over the last decade (2010–2020). This paper is organized as follows: Section “[Research Methodology](#)” presents the methodology used in this study; Section “[Descriptive and Bibliometric Analysis](#)” presents the descriptive and bibliometric analysis; Section “[Applications and Methodological and Theoretical Advances](#)” presents applications as well as methodological and theoretical advances; Section “[Discussion](#)” shows the discussion, and the conclusion is presented in Section “[Conclusion](#)”.

Research Methodology

Literature reviews aim to describe, summarize, evaluate, clarify, and/or integrate the literature from a research field without collecting or analyzing any primary data (Cooper 1988; Paré et al. 2015). The reviewed papers may be empirical, theoretical, critical/analytic, or methodological in nature (Cooper 1988; Flick 2019). In this paper, a review of the relevant empirical and theoretical literature about PSMs that were published in peer-reviewed journals between 2010 and February 2020 is provided. To this, the process suggested by Creswell (2010) was followed, which involved preparing, conducting different analyses, understanding, representing, and performing an interpretation of the data (Fig. 1).

In order to verify the quality of the selected documents, the criteria informed by Flick (2019) were adopted: (i) authenticity that corresponds to the verification of the document’s genuineness; (ii) credibility that refers to the search for errors and distortions in documents; (iii) representativeness that refers to the typicality of the document, that is, whether the documents found have the typical characteristics of documents of the type, in this case papers; and (iv) significance that refers to the clarity of the document. This verification was performed during the first three phases of the research process: data collection, reading the papers; and papers encoding. Papers that do not meet these criteria were excluded from the database.

Data Collection: Delimitations and the Search for Literature

The data collection phase included the establishment of the limits for the study, the collection itself, and the protocol for recording information (Creswell 2010). First, we chose the keywords for the research: “problem structuring method*” or “soft systems methodology” or “strategic choice approach” or “strategic options development and analysis”. With this, it was assured that the returned papers refer to the main PSMs (that is SSM, SODA, and SCA) and papers that refer to other techniques that are PSMs or used as a PSM.

The database used was the Web of Science™ Core Collection (WoS) and the following indexes were considered: Science Citation Index Expanded (SCI-EXPANDED), Social Science Citation Index (SSCI), and Emerging Sources Citation Index (ESCI). This database

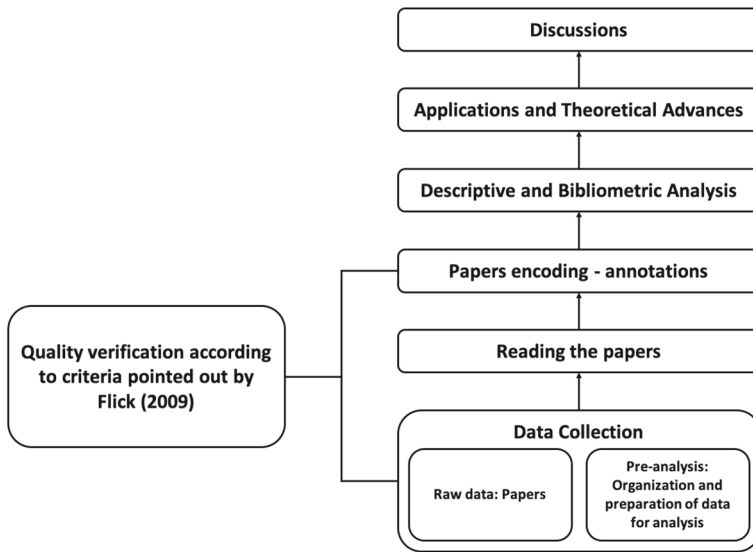


Fig. 1 Research process (adapted from Creswell (2010))

was chosen because it is the most reputable and comprehensive in the most diverse areas of knowledge (Bhardwaj 2016), with over 1.7 billion references cited from more than 159 million records (Clarivate 2020). The search was performed by topic, the keywords were searched in the following fields of the paper: title, abstract, authors’ keywords, and keywords plus. English publications were searched between 2010 and 2020 in peer-reviewed journals. Table 1 shows the parameters of the search, which was performed in February 2020.

Firstly, the database search returned 347 documents. Then, the criteria document type and language were applied, resulting in 332 papers. These documents were submitted to a preliminary analysis, taking into account the criteria pointed out by Flick (2019). After that, ten papers were excluded, and 322 papers were submitted for analysis.

Table 1 Web of Science™ search parameters

Database	Web of Science™ core collection
Indexes	Science Citation Index Expanded (SCI-EXPANDED); Social Sciences Citation Index (SSCI); and Emerging Sources Citation Index (ESCI).
Search type	Basic search
Field Labels	Topic
Keywords	“problem structuring method*” or “soft systems methodology” or “strategic choice approach” or “strategic options development and analysis”
Document Type	“Article” or “review”.
Period	2010-2020
Language	English

Data Analysis

The data analysis technique adopted in this study was the Content Analysis. This technique is mainly used to analyze textual data and it comprises two aspects: mechanical and interpretive. The first aspect involves organizing and subdividing the data. The second aspect involves the conceptual process of determining what categories are meaningful (Brewerton and Millward 2001), that is, extracting meaning from the data (Creswell 2010).

Both quantitative and qualitative content analysis was conducted. The first analysis type was used to generate numerical values, such as frequencies, presentations, or indexes, from the collected data, while the second emphasizes the meaning of that data (Brewerton and Millward 2001).

The analysis was separated into three parts: (i) descriptive analysis; (ii) bibliometric analysis; and (iii) qualitative analysis. In the descriptive analysis, the distribution of reviewed papers according to publication year, journals, countries, authors was verified, as well as the research methodologies applied in the papers. In the qualitative analysis, the papers were analyzed in terms of which areas they were applied, the most used PSMs, and we presented the methodological and theoretical developments.

In the bibliometric analysis, both the keyword co-occurrence network and the co-citation of authors network were created, using the VosViewer version 1.6.14 tool (Van Eck and Waltman 2010). The keyword co-occurrence network is a set of interconnected keywords used in the papers, in which the frequency of occurrence of these words and the relationship between them are represented (Van Eck and Waltman 2017). The co-citation network shows the frequency in which two papers are cited together by other papers; the closer authors are in the graph, the more co-citations their papers received.

Moreover, the Citation Network Explorer (CitNetExplorer) version 1.0.0 tool was applied to aggregate the publications, where each node represents a publication, based on a citation relationship. The vertical location of the paper was determined by the year of publication and the horizontal location was determined by the proximity of the citation relationship between the papers (Van Eck and Waltman 2014).

Descriptive and Bibliometric Analysis

Distribution of Papers According to Year, Journals, Countries, and Authors

In order to present the distribution of the papers per year, we removed the 5 papers that were published in 2020, to consider only completed years. Therefore, Fig. 2 presents the distribution of 317 papers that were published from 2010 to 2019.

In the first five years, ~20 papers were published per year. The graph shows an upward trend in number of publications from 2015 onwards, with ~32% having been published in 2018 and 2019. However, in 2017, the number of publications decreased significantly, perhaps because of the European Journal of Operational Research, which is the journal with highest number of publications related to PSMs in the period, it had published only one paper on this topic in that year. In 2018, this same journal published 16 papers related to PSMs, provoking an increase of 86% in the number of papers in relation to 2017.

The reviewed papers were published in 128 different journals, but five of them were responsible for 47% of the publications: European Journal of Operational Research (58 papers, ~18%); Journal of the Operational Research Society (31 papers, ~9.6%); Systemic Practice and Action Research (31 papers, ~9.6%); Systems Research and Behavioral

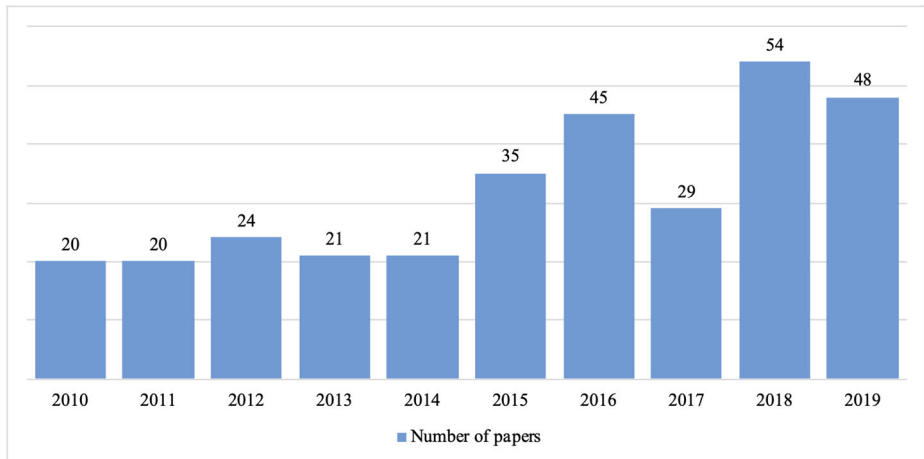


Fig. 2 Distribution of papers per year (2010–2019)

Science (23 papers, $\sim 7\%$); and Group Decision and Negotiation (9 papers, $\sim 2.8\%$). Figure 3 shows the distribution of papers by journal.

Regarding the origin of the papers, they were produced by authors from 61 countries. England is the country of origin with the most papers: 117, followed by Australia with 41 publications, US with 37 publications, Italy with 21 publications, New Zealand with 20 publications and Brazil with 19 publications. The leadership of British publications can be explained by the high level of criticism and dissatisfaction with the traditional Operational Research paradigm in this country. Another important information that we can extract from the data is that, given the importance of the USA in the world, a small number of publications in this country may reveal some resistance of North American researchers to the Soft paradigm of Operational Research, in particular the PSMs, as observed in the studies of Paucar-Caceres (2010) and Paucar-Caceres (2011). Regarding Brazil, most of papers ($\sim 89\%$) were published from 2015 onwards, which indicated that the interest about this topic by academics and practitioners in the country is recent and growing, being lead authors of 5.6% of publications; in a previous review carried out by Mingers (2011a), lead authors of the papers from Brazil were responsible for only 2% of publications on PSMs.

The total number of authors is 797 and the ten authors that have the highest number of publications are: Yearworth, M. (12 papers), White, L. (9), Paucar-Caceres, A. (9), Mingers, J. (8), Franco, A. (7), Tavella, E. (7), Midgley, G. (7), Sauser, B. (6), Cavana, R (5), and Hanafizadeh, P (5). These 10 authors are responsible for $\sim 23\%$ of publications. We can say that they are PSM thinkers.

Research Methodologies Applied

Five research methodologies were differentiated (Fig. 4): 212 papers ($\sim 66\%$) are case studies; 49 papers ($\sim 15\%$) aim to develop the theoretical assumptions of PSMs; 25 papers ($\sim 8\%$) propose new approaches to structure problems, but without presenting its applications; 18 papers ($\sim 5.6\%$) are surveys that seek to investigate characteristics of PSM interventions; and 18 papers ($\sim 5.6\%$) are literature review papers. It is important to note that we did not assess the methodological rigor of these papers.

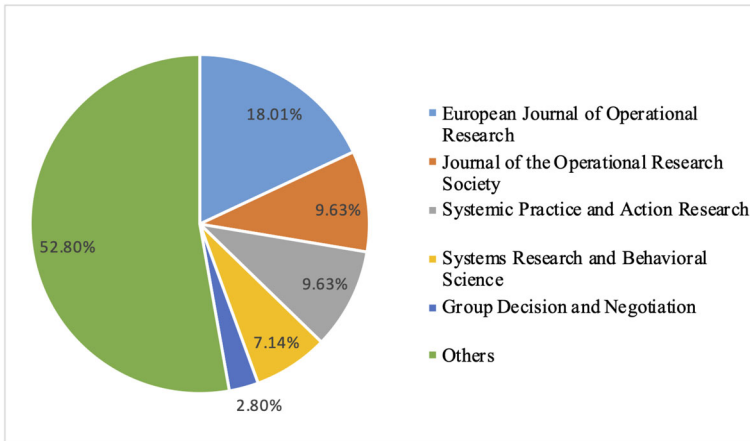


Fig. 3 Distribution of papers per journal

Analysis of Keywords Co-occurrence

The total keywords in papers is 997. To create a well-defined bibliographic map, we have defined that a minimum of five occurrences per keyword. In addition, synonyms were removed, resulting in 30 keywords that were aggregated into two clusters in the keywords co-occurrence network (Fig. 5): soft system methodology (green) and problem structuring methods (red). In this map, the nodes represent the keywords - the larger the node the greater the relevance of the item is in the network; the length of the arcs represent the strength of the link between the keywords - the closer they are the stronger the link is.

The green cluster contains 13 keywords: Soft Systems Methodology (93 occurrences), Systems Thinking (29 occurrences), Action Research (12 occurrences), Community Operational Research (12 occurrences), Strategic Choice Approach (8 occurrences), Behavioral

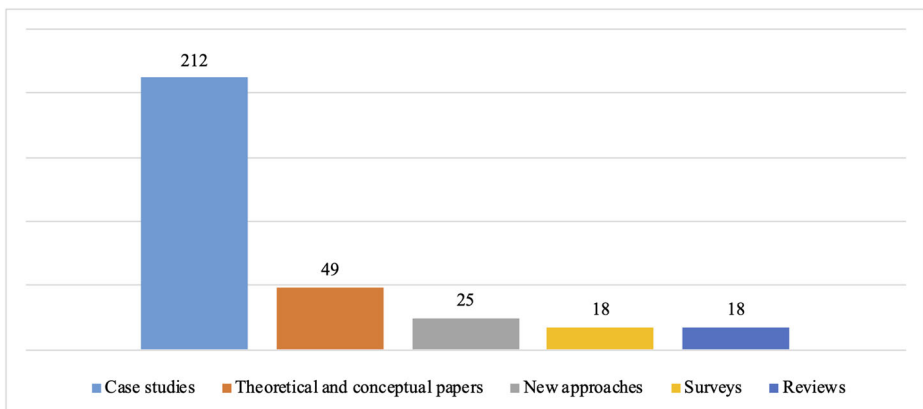


Fig. 4 Categories of research methodologies

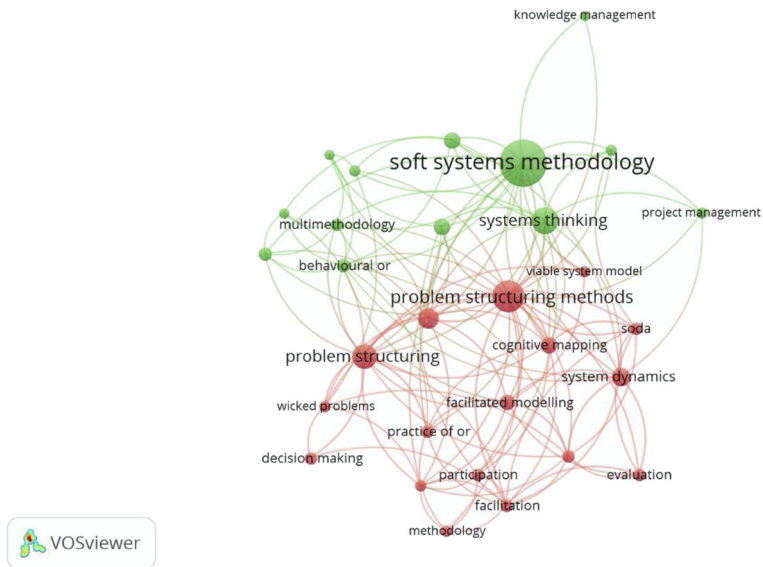


Fig. 5 Keywords co-occurrence network

Operation Research (8 occurrences), Multimethodology (7 occurrences), Boundary Critique (6 occurrences), Project Management (6 occurrences), Sustainability (6 occurrences), Critical Systems Thinking (5 occurrences), Decision Process (5 occurrences), and Knowledge Management (5 occurrences).

Analyzing this cluster, we observed that the SSM is the most frequently used and studied PSM. The theoretical and methodological bases of this method also appear in the clusters: Systems Thinking, Action Research, Boundary Critique, and Critical Systems Thinking. Moreover, we can conclude that SSM appears in emerging areas of Operational Research, as indicated by the presence of the keywords “Community Operational Research” and “Behavioral Operation Research”. The presence of the keywords “Strategic Choice Approach” and “Multimethodology” indicates that SSM is being applied combined with other methods. In addition, the cluster shows the area in which SSM is being applied (Knowledge Management, and Project Management). Finally, we observed the presence of words that indicate the objectives of applying this method, which are support for the “Decision process” and the “Sustainability” of decisions.

The red cluster contains 17 keywords: Problem Structuring Methods (41 occurrences), Problem Structuring (26 occurrences), Soft Operational Research (17 occurrences), System Dynamics (14 occurrences), Cognitive Mapping (11 occurrences), Facilitated Modeling (10 occurrences), Decision Making (7 occurrences), Evaluation (7 occurrences), Facilitation (7 occurrences), Group Model Building (7 occurrences), Participation (7 occurrences), Practice of Operational Research (7 occurrences), SODA (7 occurrences), Methodology (6 occurrences), Simulation (6 occurrences), Viable System Model (6 occurrences), and Wicked Problems (6 occurrences). This cluster is broader, with the presence of several methods and techniques and the presence of keywords that refer to PSMs interventions, such as: Facilitated Modeling, Decision Making, Facilitation, Participation, and Practice of Operational Research.

Analysis of Co-citation of Authors

Regarding the co-citation authors' network, 9952 authors were cited in the reviewed papers. To present a well-defined bibliographic map, we have defined a minimum number of 20 citations per author. Applying this criterion, a co-citation network was constructed with 68 authors who were distributed into four clusters (Fig. 6): red, blue, green, and yellow. In this map, the nodes represent the authors in the reviewed papers - the larger the node the greater the relevance the item in the network is. The length of the arcs represents the strength of the link between the authors - the closer they are the stronger the link is.

The red cluster is the largest one with 30 authors: Eden, C. (350 citations), followed by Rosenhead, J. (204), Franco, L. A. (197), Ackermann, F. (191), and White, L. (136). The former is the creator of SODA and has a lot of work developed in collaboration with Ackermann, F., who also studies the benefits of PSMs. Rosenhead, J is an editor of books on PSMs, and Franco, L.A. works with aspects related to facilitated modeling.

The blue cluster is the second largest with 17 authors: Mingers, J. (489), followed by Checkland, P. (476), Ackoff, R. (106), Churchman, C. (52), and Lane, D. (42). This cluster contains the authors with the highest number of citations in the entire network: Mingers, J. and Checkland, P. The former is a book editor about PSMs, and the latter is the creator of the SSM, which according to our analysis is the most applied PSM. Ackoff, R. and Churchman, C. are System Thinking academics and were precursors of criticism directed at traditional methods of Operational Research. Lane, D. develops research on Systems Dynamics.

The green is the third cluster with 17 authors: Midgley G. (274), followed by Jackson, M. (256), Ulrich, W. (109), Beer, S. (81), and Flood, R. (72). The first author of this cluster develops research on Systemic Interventions. Jackson, M. develops research related to Critical Systems Thinking. Ulrich W. develops research on Critical Heuristics of Social Planning, which has served as the basis for Midgley's work about Systemic Interventions

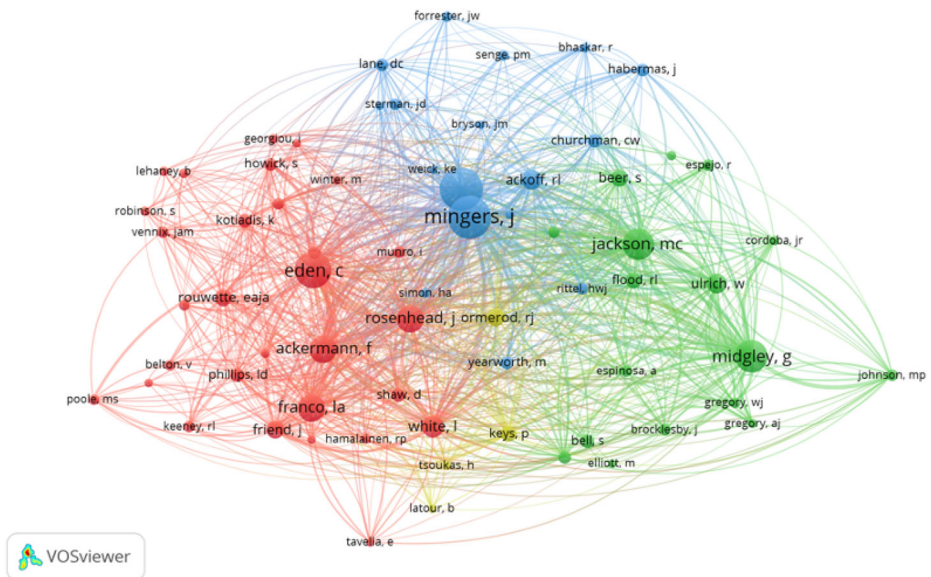


Fig. 6 Co-citation of authors network

and Theory of Boundary Critique. Beer, S. studies the relationship between Cybernetics and Management. Flood, R. developed a methodology for choosing appropriate methods for interventions. Finally, the yellow, a secondary cluster, with four authors: Ormerod, R (82), Keys, P (66), Latour, B (20), Tsoukas, H. (20). The first author studies the use of PSMs in organizations and in Information Systems. Keys, P. studies the design of interventions, more specifically on the issue of expertise. Latour, B developed the Actor-Network-Theory. Tsoukas, H. studies topics related to Complex Thinking. This map of co-citations presents us with the theoretical basis of the methods used in the reviewed papers and the basis for structuring problems.

Analysis of the Network of Citations

The citation network analysis of 316 papers was performed using the CitNetExplorer Software. Six papers were not considered for this analysis because they are classified as “early access” in the Web of Science database, that is, documents that are still in process of publication, and the software does not process this type of document. To construct the network, a minimum number of five citation links per paper has been established as an exclusion criterion. With this, a network with 62 publications was constructed (Fig. 7).

Note that there is a concentration of these publications between the years 2015 and 2016. The ten most important publications and their respective citation score are summarized in Table 2.

The most important publication of the analyzed period is “Soft OR comes of age — but not everywhere!” from John Mingers, in which the author presents the main PSMs, argues about the success of PSMs both in theory and in practice, and comments on their invisibility in literature, trying to promote the Soft Operational Research as a legitimate Operational Research discipline. With a very close number of citations, Franco and Montibeller (2010) perform a literature review on facilitated modeling, a traditional tool in PSM interventions; and Ackermann (2012) discusses arguments in favor of and against the use of PSMs.

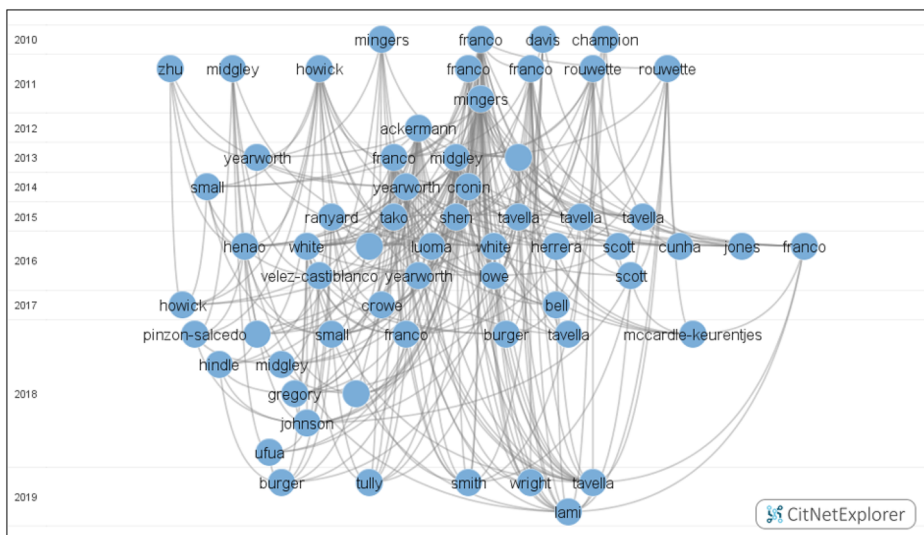


Fig. 7 Main publications about PSM in the period from 2010 to 2020

Table 2 Ten most influential publications in the citation network

Nº	Paper Title	Cit. Score
1	Soft OR comes of age-but not everywhere! Mingers (2011a)	43
2	Facilitated modelling in Operational Research (Franco and Montibeller 2010)	42
3	Problem structuring methods ‘in the Dock’: Arguing the case for Soft OR (Ackermann 2012)	42
4	Towards a new framework for evaluating systemic problem structuring methods (Midgley et al. 2013)	35
5	A review of the recent contribution of systems thinking to Operational Research and management science (Mingers and White 2010)	31
6	Rethinking soft OR interventions: Models as boundary objects (Franco 2013)	20
7	Mixing OR methods in practice: Past, present and future directions (Howick and Ackermann 2011)	19
8	Understanding multi-methodology: Evaluating the perceived impact of mixing methods for group budgetary decisions (Franco and Lord 2011)	17
9	Decision development in facilitated modelling workshops (Franco and Rouwette 2011)	17
10	The non-codified use of problem structuring methods and the need for a generic constitutive definition (Yearworth and White 2014)	15

Applications and Methodological and Theoretical Advances

PSMs in Practice

To present the areas in which the PSMs were applied in the case studies, the papers were classified into five categories: business management; environmental management; healthcare sector; social issues; and other areas.

PSMs in Business Management

From 212 case studies, 67 of them (~32%) applied PSMs in business management. These papers use PSMs to structure problems about different themes of business management, such as supply chain management, knowledge management, innovation management, organizational strategy, information security, cost management, stakeholder management, support decision-making, change management, and other issues related to business management. Most of the papers (~66% or 44 papers) used SSM, applied individually, or integrated with other methods. Table 3 presents the themes in which the PSMs were applied in business management and the corresponding papers.

Table 3 PSMs in business management

Theme	Reference
Supply chain management	Behera et al. (2015), Davis et al. (2010), Erkoyuncu et al. (2016), Guarnieri et al. (2016), Hanafizadeh and Vali Zadeh (2015), Hildbrand and Bodhanya (2017), Irani et al. (2018), Mello et al. (2017), Sharif et al. (2014), Shoushtari Darivandi (2013), and Tavella and Hjortsø (2012)
Knowledge management	Hanafizadeh and Ghamkhari (2019), Jianmei (2010), Klappalová (2019), Preece and Shaw (2019), and Somerville et al. (2019)
Innovation management	Burnett (2012), Savage et al. (2019), Scozzi et al. (2017), Sjögren et al. (2018), Sossa et al. (2016), Tura et al. (2017), Turner et al. (2017), and Zahedi et al. (2018)
Organizational strategy	Abuabara et al. (2018), Bryant et al. (2011), Espinosa et al. (2015), Houghton (2013), Houghton and Tuffley (2015), Liboni et al. (2015), Liu et al. (2012), and Sauser et al. (2011a)
Information security	Damenu and Beaumont (2017) and Schatz and Bashroush (2018)
Cost management	Ameyaw and Alfen (2018), Erkoyuncu et al. (2014), Fregonara et al. (2016), Urquhart and Whyte (2018), and Wang and Chen (2012)
Stakeholder management	Andayani (2017), Broadhurst (2018), Dias et al. (2016), Eskafi et al. (2019), Phi et al. (2014), Proches and Bodhanya (2015), and Wang et al. (2015)
Support decision-making	Cristofaro (2017), Damart (2010), Ngai et al. (2012), and Schotten and Morais (2019)
Change management	Donaires and Martinelli (2019), Harwood (2012), and Scholz et al. (2020)
Other issues related to business management	Bernardo et al. (2018), Burger et al. (2019), Carlucci et al. (2018), Castellini and Paucar-Caceres (2019), Nakakawa et al. (2013), Niu et al. (2011), Jalal and Shoar (2019), Paucar-Caceres et al. (2016), Rodriguez-Ulloa (2018), Small and Wainwright (2014), Stadt (2015), Walworth et al. (2016), Wang and Chen (2014), and Yu and Hong (2016)

PSMs in Environmental Management

Among the case studies, 36 papers (~17%) apply PSMs in the area of environmental management, particularly in marine ecosystem management, water resource management, environmental conflict, climate change, floods, forest management, waste management, and other environmental issues. Most of these studies (41.2% or 15 papers) used SSM and its variations applied individually or integrated with other methods. Another PSM that is often used in the environmental management context is the DPSIR and its variations, applied individually or integrated with other methods. Table 4 presents the applications of PSMs in environmental management.

PSMs in Healthcare Sector

32 papers (~15%) applied PSMs in healthcare sector to improve the service in health organizations, to support the formulation of public health policies, and other issues related to management in healthcare sector. In only four cases other PSMs instead of SSM were used

Table 4 PSMs in environmental management

Theme	xReference
Marine ecosystem management	Alexander et al. (2015), Baldwin et al. (2016), Gregory et al. (2013), and Potts et al. (2015)
Water resource management	Dolbeth et al. (2016), Gomes et al. (2018), Harwood (2018), Hassenforder et al. (2015), Hosseini and Rezaei (2013), Jafary et al. (2018), López et al. (2019), Pereira and Morais (2020), Robinne et al. (2018), Sani et al. (2019), Schramm and Schramm (2018), Unalan (2013), and Zare et al. (2019)
Environmental conflict	Hart and Paucar-Caceres (2014), Slotte and Hämäläinen (2015), and Watkin et al. (2012)
Climate change	Beall and Brocklesby (2017), Freeman and Yearworth (2017), Grant et al. (2019), Hu and He (2018), and Nolan and Crowe (2010)
Floods	Giordano et al. (2017), Santoro et al. (2019), and Suriya and Mudgal (2013)
Forest management	Santos et al. (2019) and Tikkanen et al. (2016)
Waste management	Sankaran et al. (2015), Shaw and Blundell (2010), and Souza et al. (2015)
Other environmental issues	Kish et al. (2016), Nathwani et al. (2019), and Nguyen et al. (2019)

(Duryan et al. 2015; Lins et al. 2019; Rees et al. 2018; Robinson et al. 2014). The majority (87.5%) used SSM and its variations applied individually or integrated with other methods. A recent study presents arguments for the use of PSM in healthcare sector (Augustsson et al. 2019b) and another argue the need to conduct a review of PSM interventions in this sector (Augustsson et al. 2019a). Table 5 presents the applications of PSMs in healthcare sector.

Table 5 PSMs in healthcare sector

Theme	Reference
Improve the service	Carter et al. (2019), Crowe et al. (2017), Dalkin et al. (2012), Duryan et al. (2015), Emes et al. (2017), Emes et al. (2019), Hayward et al. (2019), Heyrani et al. (2012), Hodges et al. (2012), Keffe and Ormsby (2015), Kotiadis et al. (2013), Kotiadis et al. (2014), Lamé et al. (2019), Newell et al. (2017), Pentland et al. (2014), Price (2016), Price and Lau (2013), Rees et al. (2018), Robinson et al. (2014), Schwartz et al. (2017), Sinclair et al. (2014), Small and Wainwright (2018), Thomas et al. (2014), Torlak and Müceldili (2014), and Železnik et al. (2017)
Public policies of health	Lins et al. (2019) and Vandenbroeck et al. (2014)
Other issues related to management the health sector	Cardoso-Grilo et al. (2019), Hales and Chakravorty (2016), Sephehrirad et al. (2017), Sharma et al. (2019), and Zheng et al. (2019)

PSMs in Social Issues

30 papers (~14%) were identified in which PSMs were used for addressing social issues: teenage pregnancy, insecurity, democracy, small farming, access to food, promoting peace; urban planning, community development, among other social issues. Eight of these studies make mention of the term “Community Operational Research”, which Midgley et al. (2018) defined their characteristics. As for the method, SSM is the most frequently used but other traditional PSMs appear such as SCA and cognitive mapping techniques. Table 6 presents the applications of PSMs in social issues.

Other Areas

Other areas that appeared in the case studies were public management, military management, non-profit organizations, teaching and research, systems design, among other issues. In this category, there are a total of 47 articles (~22%). As in other categories, SSM is the most frequently applied PSM. Table 7 presents the application of PSMs in other areas.

Methodological and Theoretical Advances

To present the methodological and theoretical advances, the analysis was separated into five topics: development of new approaches, aspects of interventions, multimethodologies, community operational research, and recognition of PSMs.

Development of New Approaches

Recent advances were made in the development of new approaches for dealing with complex problems. Fountas et al. (2015) proposed an SSM-based conceptual model to analyze

Table 6 PSMs in social issues

Theme	Reference
Teenage pregnancy	Franco and Lord (2011)
Insecurity	Rodríguez-Ulloa et al. (2011)
Democracy	Laouris and Michaelides (2018) and Weaver et al. (2018)
Promoting peace	Pinzon-Salcedo and Torres-Cuello (2018)
Access to food	Wang et al. (2018)
Small farming	Setianto et al. (2014)
Urban planning	Capolongo et al. (2019), Coelho et al. (2010), Howick et al. (2017), Jeppesen (2011), Konsti-Laakso and Rantala (2018), Lopes et al. (2015), Phillips and Natarajan (2019), Paucar-Caceres et al. (2020), Picchianti (2019), Todella et al. (2018), and White et al. (2016)
Community development	Brocklesby and Beall (2018), Espinosa and Walker (2013), Henao and Franco (2016), Hindle and Vidgen (2018), McLellan and Blanchard (2018), Taylor et al. (2012), Trutnevte et al. (2012), Ufua et al. (2018), and Xing et al. (2013)
Other social issues	Hardjosoekarto (2012), Nakagawa et al. (2010), and Tavella and Papadopoulos (2015b)

Table 7 PSMs in other areas

Theme	Reference
Public management	Eigbe et al. (2010, 2015), Fitch et al. (2012), Ison et al. (2014), Jetha et al. (2019), Norese et al. (2015), Rouwette et al. (2011), and Sauser et al. (2011b)
Military management	Cloutier et al. (2015), Lowe et al. (2016), Van Antwerpen and Curtis (2016), and Veldhuis et al. (2015)
Non-profit organizations	Armstrong (2019), Moore et al. (2017), and Strang (2019)
Teaching and research	Bell et al. (2017), Booton (2018), Carr et al. (2010), Cezarino et al. (2016), Hardman and Paucar-Caceres (2011), Holland and Garfield (2016), Houghton and Stewart (2017), Mirijam-dotter et al. (2018), Radfar et al. (2019), Siddiqui et al. (2016), Taylor et al. (2015), de Almeida et al. (2019), Wallis (2020), Wang and Wang (2016), Wilkin and Underwood (2016), and Yearworth and Edwards (2014)
Systems design	Emes et al. (2012), Fountas et al. (2015), Hanafizadeh and Alihyaei (2011), Paes de faria et al. (2020), and Rose and Saifullah (2012)
Science and technology conflict	Cronin et al. (2014)
Buddhist organizations	Shen and Midgley (2015)
Eldercare	Sommer and Mabin (2016)
Rocket Launch	Caruzzo et al. (2015)
Dressage	West and de Bragança (2012)
Mass Media	Hardjosoekarto et al. (2014)
5G technology	Jones et al. (2016)
Tourism	Yeoman et al. (2016)
Crisis management	Grunnan and Fridheim (2017)
Service-Dominant Logic	Glassburner et al. (2018) and Nowicki et al. (2018)

the development of an agricultural information management system. Tako and Kotiadis (2015) proposed a multimethodology model that combines optimization techniques with SSM to support discrete-event simulation in the health care sector. Yearworth and White (2013) described a method for exploring the creation of causal loop diagrams from coding trees that are developed through a Grounded Theory approach. Jun et al. (2011) provided a tool to support healthcare managers comparing and choosing appropriate simulation and modeling techniques. Georgiou (2012) shows how SODA can be integrated with SSM and applied in a more broad way. Midgley and Pinzón (2011) argue that the Theory of Boundary Critique is useful for conflict prevention and presents a model to reinforce their arguments. Han and Laiô (2011) presented an approach for planning analysis based on the combination of the garbage-can model, SCA and decision tree. Fregonara et al. (2013) showed an SCA-based approach for selecting, designing, and evaluating sustainable building solutions. Müller et al. (2012) proposed an approach to guide the setting up of groups in collaborative research involving social problems. Cunha et al. (2016) presented a procedure to support analysts in aggregating cognitive maps.

Scattoni (2018) describes an approach based on SCA to construct urban planning rules. Keršulienė et al. (2010) feature a method, named Step-Wise Weight Assessment Ratio Analysis – SWARA, for solving disputes. Ganzert et al. (2012) presented an approach

based on VSM and SSM to prospect, select, and distribute information across organizations. Michnik (2013) describes a method for dealing with complex situations (Weighted Influence Non-linear Gauge System- WINGS). Dortmans and Durrant (2013) presented an approach based on SSM to address the issue of successful changes in complex organizations. Shaw and Blundell (2010) developed a methodology (WASAN) that aims to support industry managers to develop recommendations for waste reduction. Mota-Hernández et al. (2015) proposed an SSM-based approach to identify and examine the dynamics of global financial and economic markets. Paucar-Caceres and Jerardino-Wiesenborn (2019) presented a framework with the objective of refining and improving the understanding of the SSM application process. Other approaches that aim to structure complex problems are described in the following papers: Ferreira (2013); Grant and Elliott (2018); Hanafizadeh et al. (2018); Lauttamäki (2016); Lombardi (2018); Pepper et al. (2016); and Torres (2018).

Methodological issues of PSMs are also addressed in some review papers: Franco and Montibeller (2010) discussed facilitated modeling as an intervention tool and offer a formal definition for it; Ranyard et al. (2015) discussed the influences of Business Analytics and PSM in the future of Operational Research.

Aspects of Interventions

In the last ten years, some studies have examined how facilitated modeling environments work in practice: Rouwette (2011); Bell and Morse (2013); and Tavella and Franco (2015). Cunha and Morais (2016, 2019) analyzed the implications of PSM intervention in group decision-making processes. Franco and Rouwette (2011) examined the dynamics of facilitated modeling workshops. Franco et al. (2016) sought empirical evidence for the influence of cognitive factors in interventions. White (2016) provided a framework for understanding behavior in Operational Research interventions. Tavella and Lami (2019) explored how negotiations evolve in a PSM intervention. Zec and Matthes (2018) offered insights about virtual interventions. Yearworth and Cornell (2016) presented a framework to make the modeling process more effective.

Others explore the role of facilitators (McCardle-Keurentjes and Rouwette 2018; Tavella and Papadopoulos 2015a; Tully et al. 2019) and the experiences of participants in PSM interventions (Rouwette et al. 2016; Scott et al. 2013; 2016). Velez-Castiblanco et al. (2016) used the Boundary Game theory to understand the social dynamics underlying the design of an intervention. Other aspects of the interventions are studied in Franco and Greiffenhagen (2018); Lami and Tavella (2019). According to White et al. (2016), on a practical level, the study of interventions has been done through the lens of the Behavioral Operational Research.

Multimethodology

An important area of discussion about PSMs is mixing methods, the so-called multimethodology. Herrera et al. (2016) can be quoted, who presented insights on the benefits and drawbacks of multimethodology. Zhu (2011) discusses multimethodology. Howick and Ackermann (2011) reviewed the mixing of methods in Operational Research. Marttunen et al. (2017) reviewed the combination of Multi-Criteria Decision Analysis and PSMs. In addition to these theoretical papers, the wide application of multimethodologies in case studies and in the new approaches presented above can be noted.

Community Operational Research

Rosenhead (2006) pointed out that a fruitful application area for PSMs would be the Community Operational Research. In 2018, the European Journal of Operational Research dedicated an edition to Community Operational Research, in which this area is presented in theory and in practice. Some examples of papers that address Community Operational Research are Espinosa and Walker (2013); Gomes et al. (2018); Midgley et al. (2018); and Ufua et al. (2018).

Recognition of PSMs

Although PSMs have been discussed in literature for more than 50 years, we observe that efforts are still being applied to increase the recognition and acceptance of PSMs in the Operational Research community. Ackermann (2012) discusses arguments in favor of and against the use of PSMs. Champion and Wilson (2010) discussed contingency factors that influence the validation of PSMs. Franco (2013) discusses the benefits related to knowledge creation in Soft Operational Research interventions. Dodd (2019) addresses the difficulty of Operational Research to adopt more relational forms of modeling. Midgley et al. (2013) described a methodological framework that aims to evaluate and compare PSMs interventions. Mingers (2015) discussed how Operational Research and Management Science can contribute to solving real problems and concludes that structuring problems can contribute a lot to this. Mingers and White (2010) reviewed the contribution of Systems Thinking to Operational Research in the first decade of the 2000s. Mingers (2011a) provided a discussion on the recognition of Soft Operational Research as a legitimate Operational Research discipline. To define what constitutes a PSM, Smith and Shaw (2019) present a framework for determining which approaches can be considered PSMs.

Discussion

In this section, the main findings of this research are presented and some directions for future work on this topic.

Evolving Research on PSM

It was observed that the number of publications on PSMs has been increasing annually and are widely distributed in a large number of journals that encompass issues on different knowledge areas: in the first years of the decade (2010 to 2014), the average of publications per year was ~ 21 and in the last years of the decade this number jumped to ~ 40 , a growth of $\sim 100\%$ in the number of publications spread throughout 128 different journals.

However, most of the publications come from studies that were developed in Europe, particularly England where the movement for a reevaluation of OR started. While, there are 117 papers coming from England, the United States, which is giant in scientific research, are responsible for only 37 papers of the sample. From the list of ten authors with the highest number of publications in the reviewed papers, seven are affiliated to European universities, six from in Universities in the United Kingdom: Mike Yearworth, Leroy White, Alberto Paucar-Caceres, John Mingers, L. Alberto Franco, and Gerald Midgley. Besides these authors, the chief PSMs have been developed by researchers affiliated at UK Universities: SSM was developed by Peter Checkland, a Professor at Lancaster University; SODA,

which initially was developed by Colin Eden and colleagues at Bath University; and SCA, which initially was developed by John Friend and colleagues at the Tavistock Institute of Human Relations.

Among these main PSM researchers, Alberto Paucar-Caceres has been collaborating with Brazilian academics, which appears in the list of the six countries that have the highest number of publications, with 19 publications of the sample of the reviewed papers. Besides England, United States and Brazil, Australia also appears in this list with 41 publications, Italy with 21 publications, and New Zealand with 20 publications. In Australia, Fran Ackerman was highlighted who is co-author of the SODA PSM. Most of the papers (~53%) were published in the *European Journal of Operational Research* that is one of the most important peer-reviewed journals on the area of OR, founded by the Association of European Operational Research Societies (EURO), and whose editor in chief is Roman Stowiński from the Poznan University of Technology, Institute of Computing Science, in Poland.

Applications

Most of the reviewed papers present applications of PSMs addressing business management problems, encompassing issues on supply chain management, knowledge and innovation, organizational strategy, information security, costs, etc.

However, the review showed us PSMs are powerful tools for solving unstructured problems from different nature, such as environmental management, healthcare management, social issues, and others.

The PSM SSM (by itself or in combination with other methods) is the most frequently used PSM in these applications. Moreover, SSM is the most referenced PSM of all the types of studies concerning this topic. This is shown in the keyword co-occurrence network, in which the most cited keyword is Soft Systems Methodology, and in the co-authorship network, where Peter Checkland, its creator, appears as the second most cited author in the sample of reviewed papers.

The SSM consists of a process with seven stages, for which a small set of requirements is given, offering high practitioner freedom. This makes the application of SSM very simple and easy and so attractive to be used. However, it is important to note that SSM is a framework that integrates individuals, usually conflicting with each other, to construct a common understanding about a complex situation aiming to solve it. Thus, the simplicity of its requirements contrasts with the complexity of the issues that can emerge in each of its stages. A consequence of this is to ensure effective results, we should have a very experienced analyst moderating the application of the SSM; otherwise, the results can be questionable, putting the effectiveness of the PSMs at risk.

The high popularity of SSM among the PSMs might induce the mistake of thinking that PSMs and SSM are the same things. Moreover, despite the efforts that are applied to give the desired position to PSMs in the Operation Research area, it is also observed that “PSMs club” is very closed, including basically only three methods (SSM, SODA, and SCA). Meanwhile, various other methods and techniques are being developed and successfully applied for structuring complex problems. In this sense, OR community should come together to answer the question “What is a PSM?”.

Attempts to answer this question have been made: Smith and Shaw (2019) proposed a framework to determine what approaches can be considered PSM and according to them only SSM, SCA, and SODA are PSMs. Using the framework proposed by Smith and Shaw (2019), Harwood (2019) states that VSM is a PSM. Bell (2012) discusses whether the DPSIR is a PSM and argues that, although limited, when DPSIR is used in combination with

other methods it can perform as a PSM. Therefore, we understand that the lack of a definition for PSMs, that incorporates the philosophy underlying of the structuring of problems, ends up limiting the progress of these methods, but it is not necessary a consensual definition. A kickoff was done by Yearworth and White (2014) that developed a set of testable propositions to recognize PSMs even when this method is not classified as such.

Theoretical and Methodological Advances and Emerging Topics

Some of the reviewed papers aim to provide methodological and theoretical advances in approaches for dealing with complex unstructured problems. In this sense, we noted that the combination of a PSM with other techniques and methods, the so called multimethodology, is an emerging topic. In contrast to Hard-OR methods, these PSM-based multimethodologies aim to adapt the method to the problems and not the contrary. Therefore, it can be concluded that the motivation that gave rise to these methods more than 50 years ago still remains the same, that is, the focus must be on the problem and not the method or technique.

It was also observed that efforts are still being applied to reduce the negative perception that OR community has about PSMs. For example, papers were found that examine modeling environments, implications of PSM intervention in the group decision-making processes, the role of facilitators and the experiences of participants. Finally, it was observed that the studies involving the development and applications of PSMs have a close connection to Behavioral Operational Research, which is a new area of specialization whose focus is to study human behaviors and emotions when facing complex decision problems and that have sparked interest in academic and practitioners from OR as well as from other disciplines.

Conclusion

The goal of this paper was to analyze the relevant empirical and theoretical literature about PSMs published over the last decade (2010–2020) aiming to verify the distribution of papers according to year, journals, countries, and authors; to identify the most frequent PSMs and areas of application; and to present methodological and theoretical advances, and emerging topics.

It can be concluded that PSMs have gained popularity worldwide, but studies are still mainly concentrated in the community of OR in Europe, particularly in the United Kingdom. Efforts are necessary to propagate PSMs into the United States and Asia's OR communities as well as in other disciplines since complex problems are commonplace in human and social relations. Regarding the application of PSMs, it can also be concluded that PSMs are powerful tools for solving problems from different areas, particularly the ones related to environmental and social systems.

As far as methodological and theoretical advances are concerned, we encourage OR community to apply effort to review the definition of PSM, aiming to make it wider in order to include other existing methods and techniques for structuring complex problems. Moreover, it can be observed that multimethodology approaches for dealing with complex unstructured problems is a trendy topic and that this can help to increase the interest of OR's academics and practitioners on PSMs. Finally, the consolidation of the Behavioral Operational Research area may have positive impacts on PSMs since both areas are closely connected.

Thus, the development and applications of PSMs is a research topic that is in a growth stage with a large quantity of opportunities to be explored and this paper can be used as a starting point to new development in this field.

Our review did not aim to evaluate the performance of PSMs in the analysis of complex problems, neither to evaluate the quality of the reviewed studies themselves, although we think that this is necessary and relevant in order to advocate (or not) for using these type of analysis tools in the context of group decision making. Other limitation is that only papers available on the Web of Science™ Core Collection were reviewed, potentially overlooking valuable publications that are not available on this base. In this sense, for future work we suggest including other bases and performing an evaluation of the outcomes provided by PSMs.

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Conflict of Interests The authors declare that they have no conflict of interest.

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