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COMBINING PROBLEM STRUCTURING METHODS AND ANALYTICS IN OPERATIONAL RESEARCH: A SURVEY FROM 2015 TO 2021

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RESUMO

Em Pesquisa Operacional (PO), visamos apoiar o processo de tomada de decisão explorando diferentes abordagens, incluindo *analytics*, modelagem, estruturação de problemas, simulação, otimização, entre outras. Seu foco prático leva ao uso de estruturas multimetodológicas que podem envolver abordagens divergentes como a PO *Hard* e os Métodos de Estruturação de Problemas (PSM) / PO *Soft*. Ao combinar *PSM* às *ferramentas analíticas*, que misturam análises qualitativas e quantitativas, é possível oferecer soluções mais arredondadas a problemas diversos. Nesta pesquisa, fazemos um levantamento da combinação de métodos ocorrida entre 2015 e 2021. Focamos nas metodologias mais utilizadas em PO *Soft*: *Soft Systems Methodology* (SSM) e *Strategic Options Development and Analysis* (SODA). Nossos resultados sugerem que esta combinação ainda é muito escassa e diversificada, com discreto crescimento nos anos mais recentes. Além disso, nota-se um interesse crescente com ferramentas ligadas à interpretação e avaliação da linguagem verbal.

PALAVRAS-CHAVE. Métodos de Estruturação de Problemas, Inteligência Analítica, Multimetodologia.

Tópicos: OA – Outras aplicações em PO, BDA – Big Data e Analytics

ABSTRACT

In Operational Research (OR), we aim to support the decision-making process by exploring different approaches including analytics, modelling, problem structuring, simulation, optimization, amongst others. Its practical focus leads to the use of multi-methodological frameworks that may involve divergent approaches such as *Hard OR* and *Problem Structuring Methods* (PSM) / *Soft OR*. By combining *PSM* with *analytical tools*, that is by mixing qualitative and quantitative analysis, it is possible to offer much rounded solutions to different problems. In this research, we survey the combination of methods taking place between 2015 and 2021. We focused on the most used methodologies in *Soft OR*: *Soft Systems Methodology* (SSM) and *Strategic Options Development and Analysis* (SODA). Our results suggest that this combination is still very scarce and diverse, with a slight increase in recent years. In addition, there is a growing interest with tools related to the interpretation and assessment of verbal language.

KEYWORDS. Problem Structuring Methods, Analytics, Multimethodology.

Paper topics: OA – Other applications in OR, BDA – Big Data and Analytics

1. Introduction

Operational Research (OR) is a multidisciplinary research area with a strong practice-based identity [Ormerod 2002] focusing on real-world concerns searching to improve the design and performance of existing systems, but also involving users, stakeholders, decision-makers amongst other actors [Royston 2013]. In this regard OR has been driven by the drift of the world itself (and its clients), and the current movement includes opposite sometimes complementary directions beyond the traditional 'hard' OR approaches. One offering a range of sophisticatedly analytical tools that enable to work with the huge amount of data that organizations are currently making available [Ormerod 2021], [Liberatore e Luo 2010]. As result, this trend topic has been inspiring many operational researchers [Romero-Silva e Leeuw 2021]. Another direction deals with the complexity of the contemporary world with 'messy' problems involving multiple stakeholders and conflicting objectives [Ranyard *et al.* 2015] which can be considered real open-ended challenges. Both merits our attention, and it would not be adequate to segregate one or another decision-making process, nor to neglect one in favor of the other, thus limiting the way in which concrete problematic situations are addressed. The connection of these two streams appears to be relevant and a potential contribution to the OR practice [Burger *et al.* 2019]. Followed by an exploration on theoretical development of heterogeneous relationships involving human and technological contributions together, Burger *et al.* (2019) research proposes a framework baptized as 'Smart OR' for the 'combination of data-driven decision support and context-specific (human) resources', that means, people involved in the context together to their trackable data, to create new opportunities for enhancements in organizations and institutions. All this boost a discussion about how decisions are taken nowadays when technology together to ethical values, interests, and beliefs are at stake. Together to the lack of pragmatic cases that explores this blend in detail as reported in that study, we propose to explore qualitatively the multi-methodological relations between *Soft* OR (also known as Problem Structuring Methods – PSM) and analytic tools.

In this work we aim to verify how the main PSMs have been combined with analytical tools. The PSMs evaluated were the two most reported and, thus practiced in the literature: *Soft Systems Methodology* (SSM) and *Strategic Options Development and Analysis* (SODA) [Abuabara e Paucar-Caceres 2021]. Based on a qualitative assessment of multi-methodological frameworks, this study focused on the decision context, the purpose of the combination of tools and, the way one approach complemented the other including the limitations of the cases, if any.

The article is divided in the following sections beyond this introduction: in Section 2, we address the purpose of PSMs, analytics tools and the multi-methodological frameworks originated from these associations. In Section 3, we expose the methodology proposed in this study. In Section 4, we present the results together to a discussion on our findings. In Section 5, we conclude our study exhibiting some limitations and future avenues.

2. Literature Review

In this section, three main topics are short addressed. We start by describing the purpose of PSMs and analytic tools followed by discussing reasons to associate both in a pluralist methodology.

Problem Structuring Methods (PSM)

The purpose of a PSM is to address unstructured complex problems which are distinguished by embodying stakeholders in a participatory modelling process that exhibit different perspectives and conflicting interests. Also known as *Soft* OR, there are a range of methodologies. Just to list some of them: *Soft Systems Methodology* (SSM), *Strategic Options Development and Analysis* (SODA), *Strategic Choice Approach* (SCA), *Drama Theory*, *Robustness Analysis*, amongst others. They have been applied from more than 40 years in many fields from business to social issues [Gomes Junior e Schramm 2021]. The methodologies are mainly qualitative (but not

exclusively) with a rigorous structure and employ diagrammatic procedures such as cognitive/causal maps, rich picture, influence diagram and so on [Dyson *et al*. 2021] in the modelling process.

SSM and SODA are the two most relevant PSMs considering their huge number of reported cases in the literature [Mingers e Taylor 1992] [Abuabara e Paucar-Caceres 2021]. Probably this achievement is likely because both methodologies offer means for a systems view of the problematic situation [Reynolds e Holwell 2020]. These methodologies were selected to be

Analytic Tools

Analytics is a growing field that has also found its room together to operations research [Mortenson *et al.* 2015]. Its central point is related to the extensive use of the burgeoning amount of (structured and unstructured) data generated especially by the Internet, social media, and computerized transactions [Chiang *et al.* 2012], in statistical and quantitative analysis with explanatory and predictive models to drive human or automated decisions [Davenport e Harris 2007]. Important disciplines particularly focused on the manipulation and analysis of data are encompassed by analytics such as data management, database systems, data warehousing, data mining, machine learning, natural language processing, network analysis, optimization, econometrics, statistical analysis, and visualization [Chiang *et al.* 2012]. Despite being a prominent area of research, the volume of studies published in journals associated to OR is still not very expressive [Mortenson *et al.* 2015].

Associating methodologies in hybrid cases

By combining different methodologies (or part of them), we are able to supplement or enhance them and thus achieve better results for a given problematic situation through a new design [Rosenhead e Mingers 2001]. In the literature this association can receive different labels such as *multimethodology* (of partitioned methodologies) or *combination* (of whole methodologies) [Mingers e Brocklesby 1997] or *mixing methods* [Howick e Ackermann 2011].

In the present research, we are surveying beyond the combination of methodologies. We are also evaluating the mingle of traditional (considering that the toolsets of OR and business analytics overlap considerably even knowing that OR emerged at a time when not much data was available) and alternative paradigms in OR. The methodological framework derived from these technology-rich and data-driven environments evolving human values in decision processes was recently called Smart OR [Burger *et al.* 2019]. There is already a discussion on the boundaries between identifying patterns, easily identified by analytical tools, and creating actionable knowledge.

3. Methodology

This section presents the methodology adopted in this research. For the two PSMs evaluated (SSM and SODA), we followed the steps shown in Figure 1 and detailed as follows.

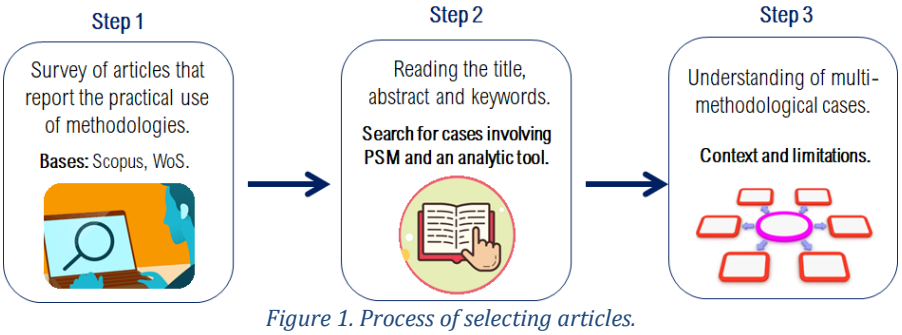


Figure 1. Process of selecting articles.

Step 1

The information was extracted from two bibliographic databases: *Scopus* and *Web of Science* and considered the period from January 2015 to March 2022. Only articles published in English language were included. Thus, book chapters and conference papers were not part of the research. Each PSM had a particular strategy in terms of searched keywords to have a reasonable result as presented in Table 2.

Table 1. Search and filtering criteria Information consulted for the literature review.

Search query information	Databases:	*Scopus* and *Web of Science*
	SSM terms:	"soft systems methodology" OR "SSM" AND "case"
	SODA terms:	"SODA" AND "operation* research" "SODA" AND "cognitive map*" "SODA" AND "strategic options development and analysis" "SODA" AND "Eden" "SODA" AND "Ackermann" "cognitive map*" AND "Eden" AND "Ackermann" "cognitive map*" AND "operation* research"
	Fields:	Publication title, abstract, or keywords
Filtering criteria	Type:	Journal articles
	Language:	English
	Time:	2015 to 2021

SSM is the most popular PSM, and we needed to include the term 'case' to isolate the practical cases involving the methodology, otherwise the number of articles to be analyzed would be extensive from a qualitative perspective. On the other hand, SODA even being the second most popular PSM had to combine a set of keywords to compose the search for its set of articles. In this case we followed Abuabara and Paucar-Cáceres [2021] search criteria. The focus of this research is not exactly to scan the literature, but to have a sample of these hybrid methodologies.

Step 2

By reading the title, abstract, keywords and, when necessary, consulting the entire text, we identified the articles in which a multi-methodological structure was present, involving an analytical tool that is usually dedicated to large volumes of data.

Step 3

Once identified these cases, we analyzed the context of application and the limitations in which analytics helped to overcome. The analysis was made by reading the articles and understanding the practice. We expect to have an exclusive case in each article.

We end this section concluding that although we used the same criteria for selecting the articles that would be evaluated, we had to use different strategies for surveying them according to the PSM in question. This was the result of a series of attempts until reaching the ideal strategy.

4. Results and Discussion

In this section we present and discuss the results of our research. In relation to SSM, our survey detected 68 exclusive works while in the case of SODA, 90 exclusive works were identified. Surprisingly, after reading title, abstract and keywords, we identified just two cases eligible for a more detailed assessment in case of SSM while six cases (three times more) among SODA's cases.

Table 2 summarizes SSM's cases. In Sibevei *et al*. [2020], the Social Network Analysis (SNA) replaced a supposed use of a multicriteria method to deal with the large volume of risks identified during SSM process as stated by the authors. In Cadzow [2019], the study took place in a Socio-Technical Environment (STE), not exactly with an analytical tool but in an analytical context.

Table 2. SSM hybrid cases related to analytics: contributions and limitations.

Reference	Approach/Methods	Contributions	Limitations
[Sibevei *et al.* 2020]	SSM, Social Network Analysis (SNA), Interpretative Structural Modelling (ISM) and Cross-Impact Matrix Multiplication Applied to Classification (MICMAC)	SSM generated a large number of risks which importance degree were evaluated through SNA. Then ISM was used to examine the relationship among key risks.	The multimethodological framework combined **four** different techniques to identify and evaluate risks associated with blood supply chain.
[Cadzow 2019]	SSM and a modified version of the Event Analysis of Systemic Team-work (EAST)	Verify the online sextortion in the digital society from a cybersecurity perspective.	Despite proposing a participatory methodology, the article is based on published surveys.

Table 3 summarizes SODA's cases which are quite varied. In Hoseini and Nikabadi [2021], they used text-mining and clustering techniques to identify key factors of outsourcing success from 1,000 published articles which was followed by an interpretive structural modeling technique. Yet, in Martins *et al.* [2020], the use of cognitive mapping jointly to Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) had the purpose to facilitate the development of an empirically robust artificial intelligence-based system, in this way, an indirect link and contribution to analytics. In the research developed by Tikkanen *et al.* [2020], they reported the desire and difficulties of working with huge groups in an equally way. The solution proposed was to combine cognitive mapping to another adapted method called 635, a sort of cyclic brainstorming (6 people, 3 ideas, 5 minutes). In Lima-Filho *et al.* [2021], SODA was used to evaluate pilots' behavior in a missile launch time in the context of a Beyond Visual Range (BVR) combat. Information resulted during causal mapping process was the starting point to select the desirable features in the Artificial Neural Networks (ANN), beyond the ones already recorded in the on-board systems during missile launching to develop an automated short time decision making system. Another interesting and atypical way of build a cognitive map was used by Lupetti *et al.* [2019] to evaluate the interaction of children with novel interactive systems in a Human-Robot Interaction (HRI) which used self-assessment and behavioral observational methods (video recorded-based) in addition to the verbal language. In Wang *et al.* [2019], the Soft OR technique of cognitive mapping stimulated the development of future-oriented (prospective) sense-making (although the most common studies are made with a retrospective approach) of emerging blockchain technology in supply chain management contributing to its diffusion.

Table 3. SODA hybrid cases related to analytics: contributions and limitations.

Reference	Approach/Method	Context	Limitations
[Hoseini e Nikabadi 2021]	Text-mining, interpretive structural modeling (ISM), SODA and dynamics modelling.	Text-mining (through a miner software) of 1,000 articles used to identify repeated factors in outsourcing. SODA was used as a social and participative interaction technique among experts to achieve consensus on factors relationships.	The multimethodological framework combined four different techniques to achieve a model for key factors of outsourcing. Experts were consulted during the stages of the process.

[Lima-Filho *et al.* 2021]	SODA and Artificial Neural Networks (ANN)	Although ANN is a machine learning technique, SODA (a human-oriented technique) provided features to the predict model, beyond the ones available from the on-board sensor systems.	Limited actual data available to evaluate a highly complex and risky problem.
[Martins *et al.* 2020]	SODA and MACBETH	Multimethodological use of SODA together to a multicriteria decision aid approach to create new insights to include them in an AI-based system to be developed.	The methodological framework is **not directly** related to analytics.
[Tikkanen *et al.* 2020]	Causal mapping and adapted 635-Method.	Multimethodological use of an adapted 635 method followed by SODA. The first enabled that a large group equally participated.	The map included the large qualitative data produced, which was difficult for a visual analysis, for instance. Also, some ideas produced by the adapted 635 method looked too broad.
[Lupetti *et al.* 2019]	Cognitive mapping and multicriteria structure	Cognitive map construction included additional knowledge elements such as physical and emotional expressions in addition to verbal expressions, based on the assessment of video/audio recorded experiments.	An unstructured test in real environment especially with children makes difficult to follow rigorous rules than lab studies.
[Wang *et al.* 2019]	Cognitive mapping and narrative analysis	Diffusion of blockchain technology through sensemaking process by using cognitive map as an intervening device towards strategy changes and innovation.	Benefits of blockchain technology are mostly speculative, lacking empirical evidence.

In SODA's case, beyond the articles exploring the use of text-mining [Hoseini e Nikabadi 2021] and narrative analysis [Wang *et al.* 2019] already discussed above, two articles [Shaw *et al.*, 2019; Shaw *et al.*, 2017] have direct concern to large volume of textual information. These articles did not deal with analytics, but they could, as these studies involved a considerable number of interviews in the build of individual cognitive maps [Shaw *et al.*, 2019] while Shaw *et al.* [2017] used criteria to select the debates to be mapped. Here, we have the use of media data (televised public interviews with leading politicians) in the context of Britain exiting the European Union (so-called, Brexit) which are usually available in abundance. Natural language processing, also known as text analytics or text mining [Chiang et al. 2012] are tools usually used to work with this sort of data.

We end this section by concluding that although there is no pattern on the association of PSM and analytics, at least it exists and could be a future trend topic. In addition, issues related to language and its interpretation seem to be of greater interest in these studies. Lastly, we noticed that despite our study had covered publications from 2015 onwards, we only found the survey multimethodology from 2019 onwards.

5. Conclusions

Operational Research (OR) is a multidisciplinary area of knowledge that develops especially with real problems resolution. For this reason, the discipline evolves with the movement of the world and its questions. Currently, it develops in opposite but complementary directions,

beyond the traditional OR. One of them is data science, as more and more institutions and organizations are making large amounts of data and information available, while we also have more and more powerful analytical tools. The other which deals with the complexities of a wicked contemporary world, with many stakeholders, conflicting goals, and diverse interests. Such problematic situations are, in general, addressed through more qualitative methodologies, among which we can list the various problem structuring methods from the Soft OR. Connecting these two research focuses, recently and tentatively named Smart OR, can be a relevant contribution to the discipline. The objective of this research is to verify how an approach focused on data processing can contribute to addressing a so-called complex problem and vice versa within social-technical contexts.

This study focused on multi-methodological cases of the two main PSMs reported in practical cases in the literature: SSM and SODA together to analytical tools. As it is a recent issue, literature brought very few and scattered cases, but still some conclusions can be drawn. We listed them below:

- Studies mixing PSM and an analytic tool are concentrated in recent years (from 2019 and on).
- There is no particular pattern on the association of a PSM and an analytic tool. Each case was a particular one.
- The decision contexts are diverse from outsourcing to blood supply chain.
- The technological context (e.g. cybersecurity, blockchain technology, human-robot interaction) seems to be as important as the cases that needs to address the huge amount of data.
- Language, its interpretation, meanings, and evaluation seem to be an issue of interest among researchers that involve PSMs and analytic tools.

Future avenues: A concern with language

Although it was not the focus of this research, one issue caught our attention. It was the concern with some language analysis tool being associated with PSMs. In the case of SSM, three works deliberately addressed this issue. Mahalepa and Goede [2017] used SSM to analyze interpretive interviews with participants in an academic research project in the context of interpretive research methodology reflecting on the hermeneutic nature of qualitative data. Yet, Bootom [2018] emphasizes the use of Rich Picture, a tool already part of SSM to validate the statements (verbal data) of participants beyond enhancing them by means of this visual device. Lastly, SSM was combined to Critical Discourse Analysis (CDA), this for the problematization of naturalized discourse. These articles were not listed in the related table as they are conference papers. Despite this, we cannot ignore it as a research area of growing interest.

We believe that there is still much to be explored in terms of practice and research involving these two important areas of research. We emphasize future studies exploring language as it is the main input information in PSMs however we shall not be limited to them.

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