"EXPLORING DECISION-MAKING STRATEGIES IN ENVIRONMENTS OF UNCERTAINTY: THEMATIC EVOLUTION AND EMERGING TRENDS POST-COVID-19"

Rosivaldo Cardoso Santiago[1,2], Aloísio Santos Nascimento Filho[3],

[1]Postgraduate Program in Management and Industrial Technology, Centro Universitário SENAI/CIMATEC, Brazil;

[2]Oswaldo Cruz Foundation, Brazil;

[3]SENAI Institute for Innovation in Advanced Health Systems SENAI/CIMATEC, Brazil.

Abstract: This study addresses the current challenging scenario of decision-making in environments of uncertainty, where the rapid evolution of society and technology creates a complex and volatile environment. Traditional approaches based on objective facts and experience are being challenged by the breadth and speed of change. The research explores pre- and post-COVID-19 thematic evolution, highlighting the interconnection between adaptation and deep uncertainty, as well as the increasing integration of emerging technologies such as artificial intelligence. The methodology combines content analysis and bibliometric tools such as MySae and VOSviewer, providing detailed insights into thematic evolution and interrelationships in the literature. The study identifies areas of research continuity, such as decision-making under uncertainty and emerging technologies, and suggests investigating the impact of disruptive global events. This innovative methodological approach aligns advanced technology with qualitative research, pointing to the future of academic research.

Keywords: deep uncertainty; covid-19; bibliometrics; scratches; semantic networks

"EXPLORANDO ESTRATÉGIAS DE TOMADA DE DECISÃO EM AMBIENTES DE INCERTEZA: EVOLUÇÃO TEMÁTICA E TENDÊNCIAS EMERGENTES PÓS-COVID-19"

Resumo: Este estudo aborda o desafiador cenário atual da tomada de decisão em ambientes de incerteza, onde a rápida evolução da sociedade e da tecnologia cria um ambiente complexo e volátil. Abordagens tradicionais baseadas em fatos objetivos e experiência passada estão sendo desafiados pela amplitude e velocidade das mudanças. A pesquisa explora a evolução temática antes e pós-COVID-19, destacando a interconexão entre adaptação e incerteza profunda, bem como a crescente integração de tecnologias emergentes como inteligência artificial. A metodologia combina análise de conteúdo e ferramentas bibliométricas, como MySae e VOSviewer, proporcionando insights detalhados sobre a evolução temática e inter-relações na literatura. O estudo identifica áreas de continuidade na pesquisa, como tomada de decisão sob incerteza e tecnologias emergentes, e sugere investigar o impacto de eventos globais disruptivos. Esta abordagem metodológica inovadora alinha tecnologia avançada com pesquisa qualitativa, apontando para o futuro da pesquisa acadêmica.

Palavras-chave: incertezas profundas; covid-19; bibliometria; riscos; redes semânticas

1. INTRODUCTION

The management practice shows that during projects and processes, several decisions need to be made and, in this context, several dilemmas arise, with different profiles, whose choices impact the next steps [1,2]. Thus, decision-making under uncertainty is marked by feelings of conflict and doubt that hinder or delay the choice between different options for action [2].

Uncertainty is a broad concept and is associated with several terminologies, such as ambiguity, risk, lack of accurate information, inaccuracy, incompleteness, contradiction, and subjectivity. In the study by Lipshitz and Strauss [3], a framework was developed to understand how decision-makers in military organizations deal with these uncertainties and make decisions in uncertain situations in the real world. Tversky and Kahneman [4,5] pointed out that people tend to want to reduce uncertainty and sometimes use mental shortcuts instead of more complex reasoning. This desire to avoid uncertainty can lead to exaggerated expressions of certainty, which can impact individual decisions and even public policy at the organizational level [2].

It is important to highlight that the current decision-making scenario in uncertain environments presents new and significant challenges [6]. The rapid development of society and technology has created an increasingly complex and volatile environment in which decision-makers face constant uncertainty. Traditional approaches, based only on objective facts and experiences, are proving insufficient to deal with the breadth and speed of change [6,7,8], Just look at what happened during the unknown period full of risks, ambiguities, and deep uncertainties.

Some research has been dedicated to the study of theory and decision methods related to group, behavioral, and emergency decision-making in contexts of diffuse uncertainty, mainly due to the impact of the COVID-19 pandemic [6]. Although new concepts, approaches, and methodologies have emerged, such as DMDU (Decision Making in Deep Uncertainties) to deal with the constant unexpected surprises, there is a need to understand this universe of approaches and tools, and how they can talk and perhaps complement each other [7], just as they behaved after one of the great practical examples of uncertainty like COVID-19.

In this context, analyzing the latest trends and advances or setbacks in decision-making approaches and methods in uncertain environments can help identify and understand, for example, how data mining techniques, artificial intelligence, and heuristic learning are being applied to support decision-making. do in a context of increasing uncertainty. [6,7,8], as well as the behavior of scientific research before and after COVID-19, perhaps identifying gaps, needs, and opportunities for new knowledge, focusing on concrete actions, regardless of the nomenclatures that are being used.

Given this scenario, this study aimed to identify the state-of-the-art, trends, and relevant and critical aspects of decision-making strategies in uncertain environments.

1.1 THEORETICAL FRAMEWORK:

1.1.1 Decision Making in Uncertain Environments: Concepts

Decision-making in contexts of uncertainty is influenced by the quality and availability of data. Uncertainty, defined by the discrepancy between what is known and what should be known, can range from risks, where the probabilities of outcomes are known or estimable, to deep uncertainties, where there is a substantial lack of knowledge to assess possible outcomes. During this scenario, ambiguity stands out because it results from the lack of clarity about the probabilities of the results, leading to subjective interpretations and influenced by individual biases. Each of these approaches requires distinct decision-making strategies [9, 10].

1.1.2 Optimal Decision-Making under Uncertainties:

Optimizing decision-making uses machine learning techniques for informed choices in uncertain situations, especially in critical industries like healthcare and transportation. Still, human discernment is essential. Mohammadi and Farsijani [11] describe various decision-making approaches, but these techniques have limitations, including the need for an accurate understanding of the probability distribution [11].

1.1.3 Decision Making under Deep Uncertainties (DMDU):

Deep uncertainties, as opposed to common uncertainties such as risks and ambiguities, indicate a substantial deficit in the understanding of a phenomenon or system [12]. The strategy, in these cases, evolves from "predict to act" to "prepare, monitor and adapt" [12]. This approach underscores the need for flexibility and responsiveness as new data emerges. Kwakkel and Haasnoot [13] subdivide DMDU strategies into approaches based on optimization, adaptation, and exploration. However, DMDU methods often ignore individual nuances of decision-makers and institutional contexts, such as attitudes, preferences, biases, practices, and organizational resources [14].

2. METHODOLOGY:

The research was carried out through a Systematic Literature Review (RSL) following the steps of Booth, Sutton, and Papaioannou [15]. The Scopus, Web of Science, and ScienceDirect databases were selected, with the guiding question: "What is the state of the art, what are the trends, and what aspects are relevant and critical in decision-making strategies in environments of uncertainty?". The descriptors used were: (("Decision-Making Strategies" OR "Decision Making") AND ("optimized Uncertainties" OR "Deep Uncertainties" OR "Uncertainties Under optimized" OR "DMDU")). The types of documents analyzed were articles and review articles. The survey was segmented into before (until 2019) and after COVID-19 (2020-2023) with the milestone of 21/08/2023. The data were exported in RIS format and analyzed for patterns and trends, using tools such as Mysae and Vosviewer.

3. RESULTS AND DISCUSSION:

It identified 1,305 pre-Covid and 625 post-Covid articles, for a total of 1,930. From 1978-2010, the topic was little researched, but from 2011-2023, there was a consolidated upward trend in the survey, regardless of COVID-19. Details of the research are presented in Figures 1 to 5, as summarized by the methodology.

Figure 1: Journals and Authors that published the most on the subject.

CLASS	PERIÓDICOS ANTES E DEPOIS COVID-19				AUTORES ANTES E DEPOIS COVID-19			
	Periodical	PRE	POS	TOTAL	Autores	PRE	POS	TOTAL
1	Environmental Modelling & Software	29	15	44	kwakkel, j.h.	14	7	21
2	Journal of Cleaner Production	11	29	40	keller, k.	9	8	17
3	Environmental Science & Policy	22	13	35	lempert, r.j.	8	5	13
4	Futures	12	22	34	reed, p.m.	6	5	11
5	Global Environmental Change	20	10	30	haasnoot, m.	9		9
6	European Journal of Operational Research	18	6	24	trutnevyte, evelina	8		8
7	Applied Energy	13	10	23	elsawah, sondoss	2	6	8
8	Energy Policy	10	10	20	walker, w.e.	7		7
9	Journal of Hydrology	10	10	20	pishvaee, mir saman	3	4	7
10	Science of The Total Environment	7	11	18	moallemi, enayat a.	2	5	7
11	Ecological Economics	9	6	15	tatari, omer	6		6
12	Journal of Environmental Management	5	9	14	tavakkoli-moghaddam, reza	2	4	6

Source: Own Authorship

Figure 2: Evolution of keywords in the abstracts of article abstracts

TOMADA DE DECISÃO EM INCERTEZAS PROFUNDAS, ANTES, DURANTE E APÓS COVID-19								
PALAVRAS NO ABSTRACT MÍNIMO 13 REPETIÇÕES	PRE-COVID 13 GERAL	PERCENTUAL TOTAL	POS COVID ABSTRACT 13	PERCENTUAL DO TOTAL	IMPACTO DURANTE COVID	TOTAL ABSTRACT 13	PERCENTUAL DO TOTAL	IMPACTO ANTES E DEPOIS DA COVID
uncertainty	319	29,08%	287	29,53%	1,54%	606	29,43%	1,21%
climate change	92	8,39%	85	8,74%	4,27%	177	8,60%	2,50%
planning	137	12,49%		0,00%	-100,00%	137	6,65%	-46,72%
optimization	59	5,38%	66	6,79%	26,25%	125	6,07%	12,88%
deep uncertainty	59	5,38%	56	5,76%	7,12%	115	5,59%	3,85%
scenario	105	9,57%	169	17,39%	81,65%	274	13,31%	39,03%
resilience	41	3,74%	67	6,89%	84,43%	108	5,25%	40,34%
decision making	53	4,83%	48	4,94%	2,21%	101	4,91%	1,53%
sustainability	36	3,28%	54	5,56%	69,29%	90	4,37%	33,20%
adaptation	43	3,92%	37	3,81%	-2,89%	80	3,89%	-0,88%
robustness	54	4,92%	54	5,56%	12,86%	108	5,25%	6,56%
covid-19		0,00%	25	2,57%		25	1,21%	
risk assessment	12	1,09%	7	0,72%	-34,16%	19	0,92%	-15,64%
sensitivy analysis	15	1,37%		0,00%	-100,00%	15	0,73%	-46,72%
article	59	5,38%		0,00%	-100,00%	59	2,87%	-46,72%
system dynamics	10	0,91%		0,00%	-100,00%	10	0,49%	-46,72%
deep learning			7	0,72%		7	0,34%	

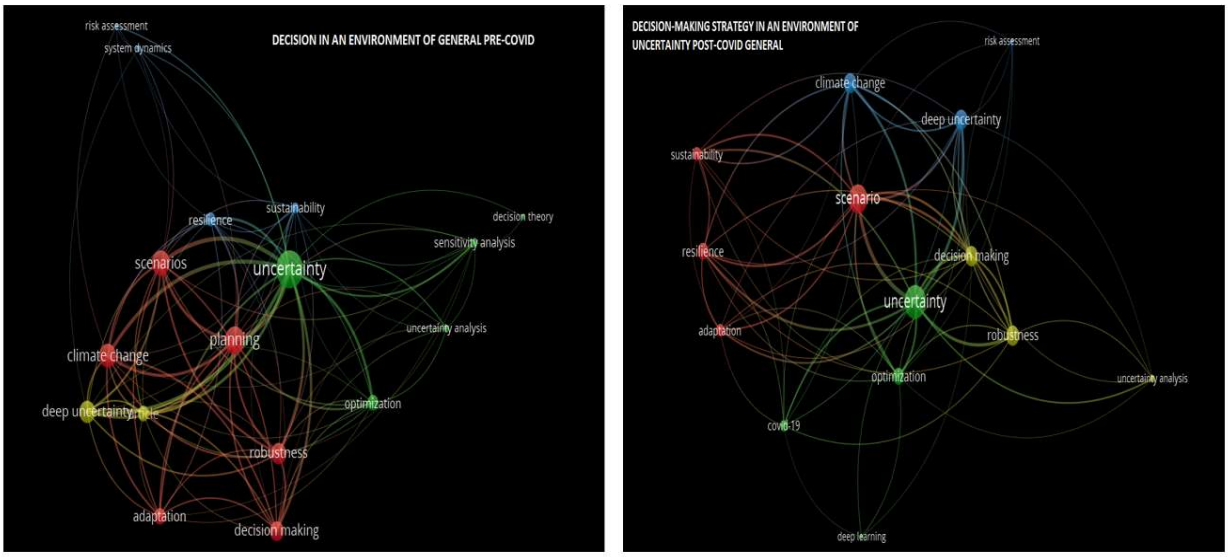
Source: Own Authorship

Figure 3: Word clusters before and after COVID-19

CLUSTERS PRÉ-COVID 19				CLUSTERS PÓS COVID			
CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4	CLUSTER 1	CLUSTER 2	CLUSTER 3	CLUSTER 4
CLIMATE CHANGE	UNCERTAINTY	RISK ASSESMENT	DEEP UNCERTAINTY	ADAPTATION	UNCERTAINTY	CLIMATE CHANGE	DECISION MAKING
DECISION MAKING	OPTIMIZATION	RESILIENCE	ARTICLE	RESILIENCE	OPTIMIZATION	DEEP UNCERTAINTY	ROBUSTNESS
ROBUSTNESS	DECISION THEORY	SUSTAINABILITY		SCENARIO	COVID-19	RISK ASSESMENT	
ADAPTATION	SENSITIVITY ANALYSIS	SYSTEM DYNAMICS		SUSTAINABILITY	DEEP LEARNING		
SCENARIOS	UNCERTAINTY ANALYSIS						
PLANNING							

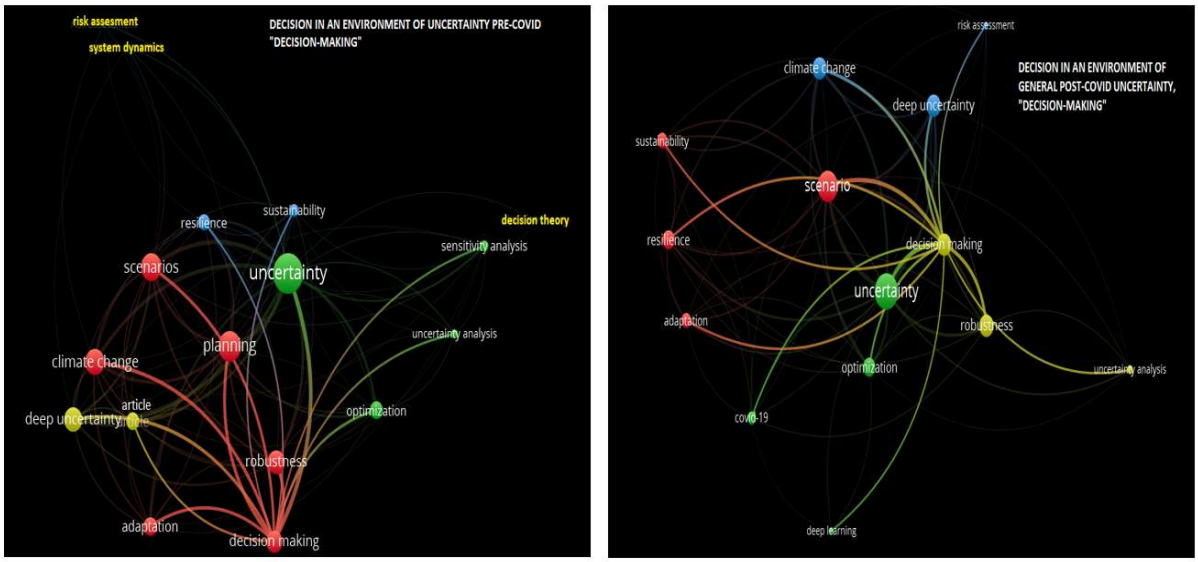
Source: Own Authors

Figure 4: Semantic Network Decision-Making Strategies in Uncertain Environments, Before and After COVID-19



Source: Own Authorship

Figure 5: Semantic Network "decision making" before and after COVID-19



Source: Own Authorship

3.1. Evolution of Key Words in Article Abstract, Before and After COVID-19

In the post-COVID-19 context, there is an increase in the search for more sustainable and robust decisions. Uncertainty remains a central theme, but after the pandemic, terms such as "resilience," "sustainability" and "robustness" have gained prominence, pointing to the need for adaptable systems and long-term solutions. Mentions of "planning" and "scenario" have declined, possibly because of their questionable effectiveness in the face of unforeseen events. There is a growing interest in machine

learning to deal with uncertain environments. Further analysis of the articles can offer additional insights into trends in decision-making in uncertain environments.

3.2- Analysis of Word Cluster Profiles Before and After COVID-19:

Before the pandemic, the emphasis was on long-term sustainable systems. With COVID-19, the need has arisen for systems that face unexpected disruptions and adapt quickly. This has led to a more adaptable and flexible approach, focusing on resilient decisions in the face of uncertainty and disruptive events. The analysis points to an evolution in the way of dealing with uncertainties, adopting more advanced approaches and focusing more on practice than theory, especially in relation to climate change.

3.3- Trajectory of Newspapers Before and After COVID-19:

There has been an increase in interest in sustainability and decision-making in journals such as the Journal of Cleaner Production. On the other hand, some journals, such as Environmental Modeling & Software, have seen a reduction in publications, indicating a possible decrease in the focus on environmental modeling. However, environmental modeling remains relevant, with the focus shifting to more adaptive and practical approaches in the face of uncertainty.

3.4- Analysis of the Semantic Network of Words, Before and After the Pandemic:

After the pandemic, Semantic Network analysis shows deep learning as an emerging area. "Decision making" was positioned much closer to the center of the network and tightened the link with "uncertainty" which remains the network's parent word. However, terms such as "climate change," "sustainability," and "risk analysis" have remained peripheral or distanced themselves from the word "uncertainty." "Planning" and "Article" even though they were consolidated, before COVID-19, and "dynamic systems" and "decision theory" which showed themselves as emerging areas lost strength and were excluded from the network. After the pandemic, "decision making" formed a fragile connection with "risk analysis" and moved closer to "scenarios" that is also much more at the center of the network and continue with its strength, and "risk analysis" remains very distant and without force, all this from the perspective of the visualization of the semantic network.

4. CONCLUSION:

The analysis of clusters, strength and semantic network of words, trajectory of the authors, and trajectory of the journals proved to be effective in scientific research on decision-making strategies in environments of uncertainties facilitating identification of relevant topics and concepts, visualization of trends, evolution and changes, detection of emerging trends, identification of central concepts, visualization of conceptual relationships, as a validation tool, corroboration of partial results, providing insights for future research, holistic understanding of the field of study, assistance in formulating more informed questions, identifying research gaps and developing innovative approaches, identifying potential collaborations, analyzing credibility and impact, formulating hypotheses and research questions.

As a limitation of this research, I highlight data limitations, lack of qualitative context, changes in research terms, changes in terminology, and dependence on the tools used, such as data from the journal Capes, Mysae, Vosviewer, the number of keywords analyzed among others.

5. REFERENCES:

[1]MARCH, James G; SIMON, Herbert A. Organizations John Willy & Sons. New York, 1958.

[2]KALE, Alex; KAY, Matthew; HULLMAN, Jessica. Decision-making under uncertainty in research synthesis: Designing for the garden of forking paths. In: Proceedings of the 2019 CHI conference on human factors in computing systems. 2019. p. 1-14.

[3]LIPSHITZ, Raanan; STRAUSS, Orna. Coping with uncertainty: A naturalistic decision-making analysis. Organizational behavior and human decision processes, v. 69, n. 2, p. 149-163, 1997.

[4]KAHNEMAN, Daniel. Thinking, fast and slow. Macmillan, 2011.

[5]KAHNEMAN, Daniel; TVERSKY, Amos. Judgment under uncertainty: heuristics and biases. Fast and Slow: Two Ways. São Paulo: Objective, p. 524-539, 2012.

[6]CAO, Shufen et al. A Review of Decision Theory and Methods. The Frontiers of Society, Science and Technology, v. 5, n. 3, 2023.

[7]STANTON, Muriel C. Bonjean; ROELICH, Katy. Decision making under deep uncertainties: A review of the applicability of methods in practice. Technological Forecasting and Social Change, v. 171, p. 120939, 2021.

[8]KWAKKEL, Jan H.; HAASNOOT, Marjolijn. Supporting DMDU: A taxonomy of approaches and tools. Decision making under deep uncertainty: From theory to practice, p. 355-374, 2019.

[9]LAU, Chi Ieong et al. Decision-making impairment under ambiguity but not under risk may underlie medication overuse in patients with chronic migraines. Headache: The Journal of Head and Face Pain, 2023.

[10]BOTELHO, Catarina et al. Uncertainty deconstructed: Conceptual analysis and state-of-the-art review of the ERP correlates of risk and ambiguity in decision-making. Cognitive, Affective, & Behavioral Neuroscience, p. 1-21, 2023.

[11]MOHAMMADI, Reza; FARSIJANI, Hasan. Optimization under Uncertainty: Machine Learning Approach. International Journal of Innovation in Management, Economics and Social Sciences, v. 3, n. 2, p. 23-32, 2023.

[12]HADJISOTIRIOU, Sophie et al. Decision-making under deep uncertainty for pandemic policy planning. Health policy, v. 133, p. 104831, 2023.

[13]KWAKKEL, Jan H.; HAASNOOT, Marjolijn. Supporting DMDU: A taxonomy of approaches and tools. Decision making under deep uncertainty: From theory to practice, p. 355-374, 2019.

[14]STANTON, Muriel C. Bonjean; ROELICH, Katy. Decision making under deep uncertainties: A review of the applicability of methods in practice. Technological Forecasting and Social Change, v. 171, p. 120939, 2021.

[15]BOOTH, A; SUTTON, A.; PAPAIOANNOU, D. Systematic Approaches to a Successful Literature Review; Sage Publications: Thousand Oaks, CA, USA, 2016.