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Exploring the Landscape of Multicriteria Decision Making in Software Project Management: Trends, Challenges, and Future Directions

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Abstract

INTRODUCTION: This critical review investigates the utilization trends of Multicriteria Decision Making (MCDM) in software project management, emphasizing its applications, implementation challenges, and emerging trends.
OBJECTIVES: The study explores recent literature published between 2019 and 2024, utilizing a systematic methodology to analyze the effectiveness and limitations of MCDM techniques in software project planning, selection, and execution.
METHODS: A Boolean search strategy on Scopus was employed to identify relevant literature. The systematic methodology involved analyzing the identified literature to discern patterns, gaps, and recommendations for integrating MCDM methodologies within software engineering projects.
RESULTS: The review identifies key patterns, challenges, and emerging trends in adopting MCDM techniques in software project management, providing insights and recommendations for future research and practice.
CONCLUSION: This critical review offers valuable insights into the landscape of MCDM utilization in software project management, highlighting areas for improvement and future exploration.

Keywords: Multicriteria Decision Making, MCDM, Software Project Management, Implementation Challenges

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1. Introduction

Multicriteria Decision Making (MCDM) has emerged as a vital tool in addressing the complex decision-making processes inherent in software project management [1]. With the increasing complexity of software projects and stakeholders' diverse and often conflicting requirements, traditional decision-making approaches still need to be revised. MCDM techniques offer a structured framework for evaluating multiple criteria simultaneously, facilitating informed and rational decision-making amid uncertainty and ambiguity [2]. Despite the growing recognition of MCDM's potential benefits, its integration within software project management practices remains a topic of ongoing exploration and debate. Understanding the current landscape of MCDM utilization in software engineering is crucial for identifying trends, challenges, and opportunities for improvement [3].
The primary objective of this review is to critically examine the utilization trends of MCDM techniques within the context of software project management. By synthesizing recent literature and empirical evidence, this review aims to identify patterns and trends in adopting and implementing MCDM methodologies in software

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engineering projects. Furthermore, it seeks to evaluate the effectiveness and limitations of existing MCDM techniques in addressing the unique challenges of software project management. Additionally, the review explores emerging trends and future directions for integrating MCDM within the software development lifecycle. Ultimately, it aims to provide recommendations for practitioners and researchers to enhance the application of MCDM in software project management.

A systematic methodology is employed to achieve these objectives. This methodology comprises several key steps. A Boolean search strategy is formulated based on relevant keywords and criteria, leveraging the Scopus database to retrieve recent literature. Subsequently, search results are screened based on predefined inclusion and exclusion criteria to select relevant articles for further analysis. Following this, data extraction and synthesis are conducted to identify common themes, trends, and challenges associated with using MCDM techniques in software project management. MCDM methodologies and their applicability within the software development context are critically analyzed. Finally, findings are synthesized to provide insights, recommendations, and avenues for future research and practice in MCDM and software project management.

2. Multicriteria Decision Making in Software Project Management

Multicriteria decision-making (MCDM) techniques play a crucial role in software project management by providing a systematic framework for evaluating and selecting alternatives based on multiple criteria [4]. These techniques enable decision-makers to consider various factors simultaneously, such as cost, time, quality, and stakeholder preferences, when making complex decisions throughout the software development lifecycle [5].

In terms of an overview of MCDM techniques, a diverse range of methods can be applied in software project management [6]. Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), ELECTRE, and PROMETHEE are among this context's most commonly used MCDM techniques. Each method offers its unique approach to decision-making, with strengths and limitations that make it suitable for different types of decision problems.

The relevance of MCDM to software project management lies in its ability to address the multifaceted nature of decision-making in this domain. Software projects often involve numerous stakeholders with varying priorities and objectives, making it challenging to make decisions that satisfy all parties involved. MCDM provides a structured approach to prioritize objectives, weigh criteria, and evaluate alternatives, thereby facilitating more transparent and informed decision-making processes [7, 8].

Key applications and use cases of MCDM in software project management encompass various stages of the software development lifecycle [9]. From requirements elicitation and prioritization to software architecture design, project planning, resource allocation, and quality assurance, MCDM techniques find applications in various decision-making scenarios [10]. For example, MCDM can help prioritize features based on stakeholder preferences and project constraints in requirements engineering, ensuring that limited resources are allocated to the most critical requirements. Similarly, in project planning, MCDM techniques can assist in selecting the most suitable development methodologies, estimating project timelines, and allocating resources effectively to meet project objectives [11].

In comparing Multicriteria Decision Making (MCDM) techniques for software project management, it is essential to delve into the intricacies of each method, understanding their underlying principles and practical implications [12]. One prominent technique is the Analytic Hierarchy Process (AHP), renowned for its hierarchical structuring of decision problems. AHP breaks down complex decisions into pairwise comparisons, facilitating the assessment of criteria and alternatives. This structured approach allows decision-makers to systematically weigh the relative importance of different factors, providing a clear framework for decision-making [13]. However, AHP heavily relies on subjective judgments, which can introduce biases and inconsistencies into the decision-making process. Despite this drawback, its ability to capture nuanced preferences and priorities makes it a valuable tool in certain contexts [13, 14].

Another widely used technique is the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), known for its simplicity and intuitive ranking mechanism. TOPSIS evaluates alternatives based on their similarity to ideal and anti-ideal solutions, providing a straightforward ranking based on overall performance [15]. This method is particularly suitable for decision-makers seeking a clear and concise ranking of alternatives. However, TOPSIS assumes linear relationships between criteria, which may not always hold in real-world scenarios. Additionally, its sensitivity to normalization methods and criteria weights underscores the importance of careful parameter selection [16].

ELECTRE (Elimination and Choice Expressing Reality) offers a different approach, comparing alternatives against predefined thresholds for each criterion [17]. This method allows for flexibility in threshold setting and consideration of qualitative or imprecise data, making it suitable for decision problems with uncertain or qualitative information. However, ELECTRE's sensitivity to threshold and parameter settings can lead to variations in results, requiring careful calibration to ensure robust outcomes. Despite this, its ability to accommodate diverse preferences and flexible threshold setting makes it a valuable tool in certain decision-making contexts [18].

PROMETHEE (Preference et al. Method for Enrichment Evaluations) aggregates preferences from pairwise comparisons to generate a partial ranking of alternatives. PROMETHEE considers positive and negative outranking flows, allowing for a comprehensive assessment of alternatives based on multiple criteria [19]. This method facilitates consensus-building among decision-makers and sensitivity analysis to explore different scenarios. However, PROMETHEE requires careful specification of preference functions and parameter settings, which can affect the reliability of results. Its sensitivity to criteria scales and weight changes highlights the importance of thorough sensitivity analysis and validation [20].

Each MCDM technique offers distinct advantages and limitations, making them suitable for different decision-making contexts within software project management. The choice of technique should be guided by factors such as the nature of the decision problem, data availability, stakeholder preferences, and computational resources. By understanding the characteristics and trade-offs of each technique, decision-makers can make informed choices to address the multifaceted challenges of software project management effectively.

3. Methodology

Three key stages were meticulously followed in executing the methodology.

3.1. Boolean Search Strategy on Scopus

The search strategy was meticulously crafted, focusing on optimizing the retrieval of relevant literature while minimizing noise. Keywords were strategically selected and combined using Boolean operators to target articles pertinent to Multicriteria Decision Making (MCDM) within the domain of software project management. The search was further refined by limiting the keywords to specific terms, including "Multi-criteria Decision Making," "Multicriteria Decision-making," "Software," and "MCDM," ensuring precision in the retrieval process.

3.2. Selection Criteria and Inclusion Process

Rigorous selection criteria were established to identify articles meeting the predefined eligibility criteria for inclusion in the review. These criteria encompassed various parameters such as relevance to MCDM and software project management, publication year, document type, and language. Articles retrieved through the search strategy underwent meticulous screening to determine their suitability for inclusion, with duplicates removed to ensure the integrity of the selection process.

3.3. Data Extraction and Analysis Framework

A structured framework was devised to extract and analyze data from the selected articles systematically. Key information about MCDM techniques, their application within software project management, challenges encountered, and reported outcomes were extracted. This framework facilitated the organization and synthesis of data across the selected studies, enabling the identification of common themes, trends, and insights pertinent to the review objectives.

By adhering to this methodological approach, the review ensured a comprehensive examination of the utilization trends of MCDM techniques in software project management, drawing insights from a carefully curated selection of relevant literature.

28 articles met the established selection criteria were included in the review. These articles underwent rigorous screening to ensure their relevance to Multicriteria Decision Making (MCDM) within software project management.

The search strategy was refined by limiting the keywords to enhance precision and relevance. Specifically, the keywords were restricted as follows:

- Limited to Multi-criteria Decision Making
- Limited to Multicriteria Decision-making
- Limited to Software
- Limited to Software Engineering
- Limited to MCDM

By applying these keyword limitations, the search aimed to optimize the retrieval of articles directly related to MCDM and its application within software project management. This targeted approach facilitated the identification of pertinent literature while minimizing the inclusion of irrelevant material.

4. Prominent Publication Venues

The distribution of publications across various source titles provides insights into the prominent venues for research at the intersection of Multiple Criteria Decision Making (MCDM) and software engineering (Table 1).

IEEE Access emerges as the most prolific publication venue, with six publications. IEEE Access is known for its multidisciplinary approach, providing a platform for research across various fields, including software engineering and decision-making methodologies. Sustainability (Switzerland) follows closely behind with three publications. As a journal focused on sustainability-related research, its inclusion in the list highlights the growing interest in incorporating MCDM techniques to address sustainability challenges within software engineering practices. Lecture Notes in Computer Science is another notable venue, with two publications. This series is well-regarded for its coverage of cutting-edge research in computer science, making it a fitting platform for disseminating research findings related to MCDM and its applications in software engineering. Other source titles, such as Neutrosophic Sets and Systems, Lecture Notes in Networks and Systems, and various conference proceedings, contribute to the diverse landscape of publication venues within the field. These venues offer specialized platforms for disseminating research findings and fostering interdisciplinary dialogue. The presence of conference proceedings, such as the 2022 3rd International Conference on Issues and Challenges in Intelligent Computing Techniques and the 2019 IEEE Conference on Application, Information, and Network Security, underscores the importance of academic conferences as forums for presenting and discussing research findings, facilitating collaboration, and driving innovation within the field.

Table 1. Prominent Publication Venues and Number of Publications

NO.	Source Title	Number of Publications
1	IEEE Access	6
2	Sustainability (Switzerland)	3
3	Lecture Notes in Computer Science	2
4	Neutrosophic Sets and Systems	1
5	Lecture Notes in Networks and Systems	1
6	2022 3rd International Conference on Issues and Challenges in Intelligent Computing Techniques	1
7	Agriculture (Switzerland)	1
8	Engineering Applications of Artificial Intelligence	1
9	2019 IEEE Conference on Application, Information, and Network Security	1
10	Proceedings of the American Society for Engineering Management 2023 International Annual Conference	1

5. Discussion

5.1. Publication Trends over time

The distribution of publication years in the dataset provides valuable insights into the evolution of research at the intersection of Multiple Criteria Decision Making (MCDM) and software engineering (Figure 1). In 2019, two publications marked the early emergence of research interest in this domain, suggesting a nascent exploration stage or potentially a niche area of study within the broader context of software engineering [21, 22].

The number of publications doubled to six in 2020 [23-28], signifying a notable uptick in scholarly output. This increase might reflect a growing recognition of the significance of MCDM techniques in addressing the complexities inherent in software engineering decision-making processes. Despite a slight decrease to four publications in 2021 [29-32], the field maintained a steady presence in the academic landscape, indicating sustained interest and ongoing exploration of MCDM applications within software engineering contexts.

In 2022 [33-36], the trend mirrored the previous year with four publications, suggesting stability in research output. This consistent activity could indicate a maturing research area with established methodologies and ongoing investigations into new applications. A notable surge occurred in 2023 [37-45], with nine publications marking the peak of scholarly activity within the timeframe under consideration. This substantial increase may reflect heightened interest, expanded collaborations, or breakthroughs in MCDM methodologies tailored specifically for software engineering challenges.

However, the trend witnessed a slight decline in 2024 [46-48], with three publications. While this decrease could suggest a potential plateau or saturation in research output, it may also signify a transitional phase characterized by consolidation of findings, refinement of methodologies, or redirecting research efforts toward emerging trends or unresolved issues.

The observed trends suggest a dynamic and evolving landscape at the intersection of MCDM and software engineering. The steady rise in publications from 2019 to 2023 indicates a progressive maturation of the field, marked by increasing interest, contributions, and academic discourse. This growth trajectory underscores the relevance and significance of employing MCDM techniques to address the multifaceted challenges inherent in software engineering decision-making processes.

The peak in publications in 2023 reflects a period of heightened scholarly activity, possibly driven by advancements in MCDM methodologies, growing awareness of their applicability, or the recognition of pressing industry needs. However, the subsequent decline in 2024 warrants careful consideration and further investigation. It may indicate a natural ebb in research output following a period of rapid expansion, or it could signal shifts in research priorities, emerging paradigms, or external factors influencing scholarly pursuits.

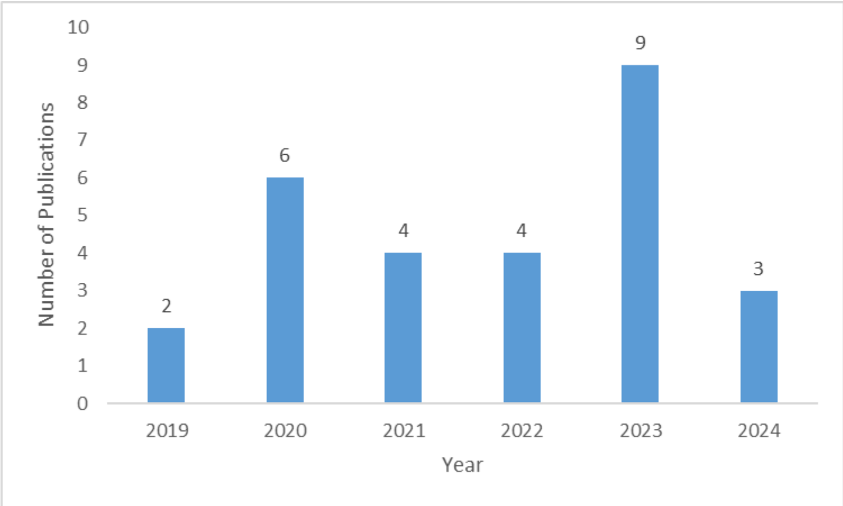

Figure 1. Publication Trends over Time

5.2. Influential Authors and Collaborations

Examining authorship within the dataset sheds light on individuals who have made significant contributions to the body of literature at the intersection of Multiple Criteria Decision Making (MCDM) and software engineering (Figure 2). Notably, certain authors emerge as particularly prolific in their research output. Leading the list with three publications, Silva L. demonstrates a sustained commitment to advancing knowledge and understanding within this specialized domain. Their prolificacy suggests a deep engagement with research topics and methodologies, potentially indicating expertise in specific MCDM and software engineering aspects. Following closely behind, Rezk H., Abdelkareem M.A., Britto A., and Olabi A.G. each contribute significantly to the scholarly discourse with two publications each. Their consistent presence underscores their active involvement in shaping the research landscape and suggests a breadth of expertise across various facets of MCDM and its applications in software engineering. Beyond individual contributions, the dataset hints at potential collaborative networks and partnerships among authors. While not explicitly stated, multiple publications by the same authors may signify collaborative efforts, shared research interests, or even mentorship relationships. Collaboration within the research community fosters interdisciplinary perspectives, accelerates knowledge exchange, and catalyzes innovation. The clustering of prolific authors within the dataset presents an opportunity for further exploration and analysis of collaborative dynamics. Investigating co-authorship patterns, identifying common themes or research agendas, and examining the impact of collaborative endeavors on research outcomes can provide valuable insights into scientific inquiry's collaborative nature within the MCDM and software engineering domain.

The prominence of certain authors within the dataset reflects not only individual scholarly achievements but broader trends and dynamics within the research community. The presence of prolific authors suggests a concentration of expertise and intellectual leadership, which may influence research agendas, shape scholarly discourse, and guide the direction of future investigations. Furthermore, the prevalence of collaborative authorship underscores the interconnectedness of researchers and the collaborative nature of knowledge production within interdisciplinary fields. Collaborations facilitate the exchange of ideas, methodologies, and perspectives, enriching the research landscape and fostering a culture of innovation and discovery. Overall, analyzing influential authors and collaborations offers valuable insights into the structure, dynamics, and evolving trends within the MCDM and software engineering research ecosystem. Understanding individual scholars' contributions and their networks can inform strategic collaborations, identify emerging research directions, and ultimately advance the collective understanding of this complex and multifaceted domain.

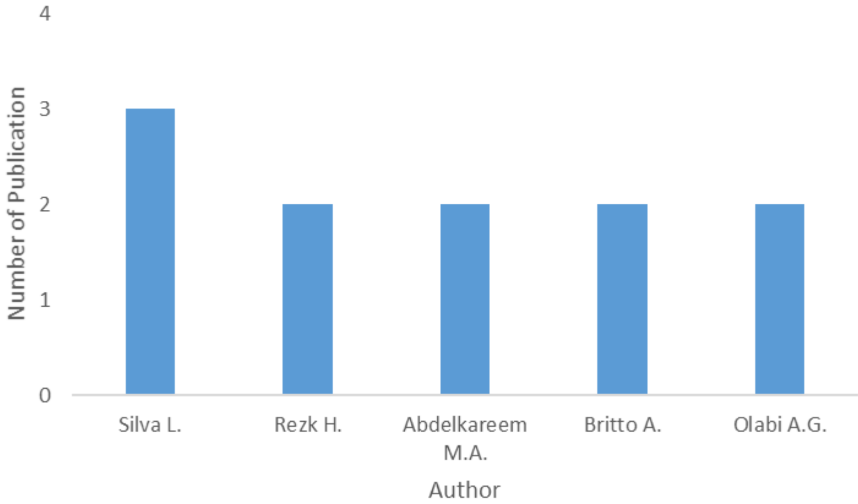

Figure 2. Influential Authors and Collaborations

5.3. Thematic Patterns and Keywords

The analysis of author keywords across research publications illuminates recurring themes and topics within the intersection of Multiple Criteria Decision Making (MCDM) and software engineering (Figure 3).

MCDM and Project management are prominent themes, reflecting a focus on decision-making processes in software engineering contexts. These methodologies are crucial in optimizing resource allocation, project planning, and risk management within software development projects. TOPSIS and Analytical Hierarchical Process (AHP) represent specific MCDM techniques mentioned multiple times. These methodologies provide structured frameworks for evaluating alternatives and making informed decisions based on multiple criteria or objectives. The presence of keywords such as SLR (Systematic et al.) underscores the methodological rigor and evidence-based approach researchers adopt in synthesizing existing knowledge and identifying research gaps within the domain. Emerging areas like search-based software engineering highlight integrating computational intelligence approaches with MCDM techniques to address complex software engineering challenges. This indicates a growing emphasis on leveraging optimization algorithms for decision support in software development. As a broad thematic category, software engineering encompasses various aspects of software development, maintenance, and management where MCDM techniques find application. This reflects the interdisciplinary nature of research in this domain, bridging theoretical concepts from decision science with practical applications in software engineering practice. Finally, the interval-valued neutrosophic Z-number is a niche area within MCDM research, which focuses on decision-making under uncertainty using neutrosophic set theory. These highlights exploring novel methodologies to address real-world decision-making's inherent uncertainties and complexities.

Overall, the analysis of thematic patterns and keywords provides valuable insights into the multifaceted nature of research at the intersection of MCDM and software engineering. Researchers can inform future investigations, foster interdisciplinary collaborations, and advance knowledge within this dynamic and evolving field by identifying common themes and emerging areas of interest.

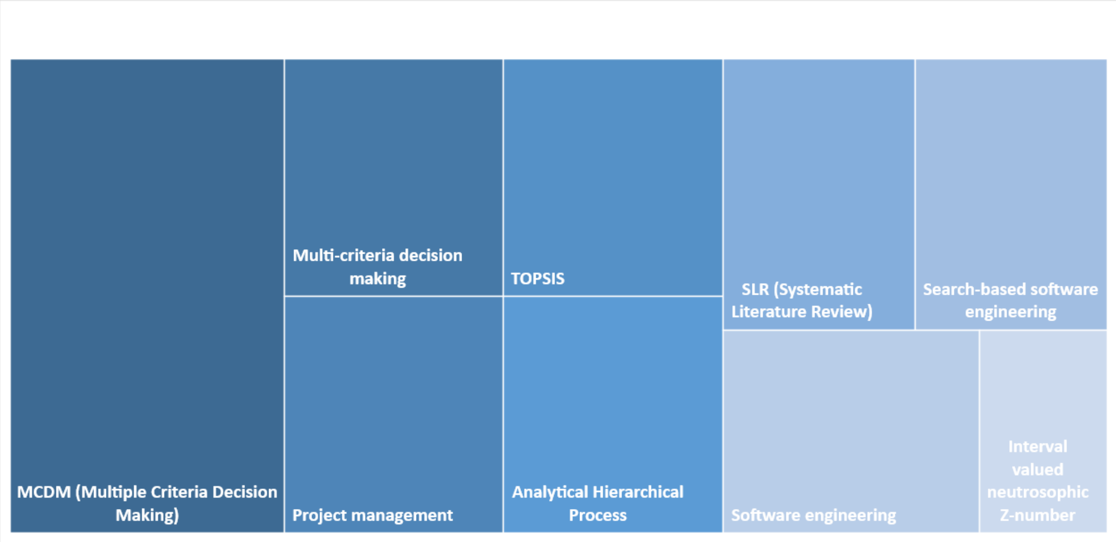

Figure 3. Thematic Patterns and Keywords

5.4. Citation Dynamics

Analyzing citation counts within the dataset provides insights into the visibility and impact of research in the domain of Multiple Criteria Decision Making (MCDM) and software engineering. The mean citation count for publications in the dataset is 10.89, indicating each publication's average number of citations.

This mean value is a central measure of the overall citation impact within the dataset. However, with a standard deviation of 16.37, citation counts exhibit considerable variability around the mean, reflecting the diverse impact levels of individual publications. This variability suggests that while some publications enjoy widespread recognition and influence, others may have limited visibility within the research community.

The distribution of citation counts further reveals interesting patterns. The minimum citation counts of 0 indicates that some publications have not received citations, suggesting a lack of visibility or recognition. Similarly, the 25th percentile also stands at 0, highlighting a significant proportion of publications with minimal citation impact. On the other hand, the median citation count, at 1, represents the midpoint of the distribution and underscores the prevalence of publications with relatively low citation counts.

At the 75th percentile, the citation count rises to 14.75, indicating that many publications have garnered moderate to high recognition and influence within the scholarly community. This suggests a subset of research outputs that have notably impacted the field. Finally, the maximum citation count recorded is 61, demonstrating the potential for certain publications to achieve significant visibility and influence within the MCDM and software engineering domain.

Overall, the citation dynamics within the dataset reflect a heterogeneous landscape of research impact, encompassing publications with varying levels of recognition and influence. This variability underscores the complex interplay of factors influencing citation counts, including publication visibility, relevance, and scholarly impact.

5.5. Emerging Trends and Future Directions

Recent research has focused on refining decision-making methods for project selection, particularly within industry-specific contexts. For example, a study introduces a customized version of the interval type-2 fuzzy ORESTE (IT2F-ORESTE) method for project prioritization in the automotive industry. This novel approach outperforms conventional methods like fuzzy TOPSIS, demonstrating its potential to enhance decision-making processes in project selection. Future research in this area may explore applying customized decision-making methods across diverse industry sectors, addressing specific challenges and requirements unique to each domain.

Efficient project management in global software development (GSD) settings remains a critical area of focus for researchers. Recent studies have sought to identify and prioritize critical success factors (CSFs) in software project management within the context of GSD. Developing comprehensive frameworks for effective project management can help address the challenges associated with distributed teams, cultural differences, and communication barriers in global software development projects. Future research may delve deeper into refining these frameworks and exploring innovative approaches to optimize project management practices in diverse cultural and geographical contexts.

The increasing reliance on cloud-based E-healthcare services necessitate robust security measures to safeguard sensitive patient data. Recent research introduces a neutrosophic model integrated with the multi-criterion decision-making (MCDM) method for evaluating healthcare security criteria in cloud-based E-healthcare services. This approach offers a systematic framework for assessing security risks and selecting appropriate solutions tailored to specific healthcare environments. Future research may focus on further enhancing the effectiveness and scalability of these security evaluation models, addressing evolving threats and regulatory requirements in the healthcare industry.

5.6. Keyword Co-occurrence

The network graph of the keyword co-occurrence network with identified clusters shows distinct groups of keywords that co-occur together more frequently (Figure 4).

The central positioning of "uncertainty" within the network graph, surrounded by six other keywords forming a complete hexagonal structure, indicates a significant thematic cluster within the dataset. In network analysis, the centrality of a node often reflects its importance or prominence within the network. In this context, "uncertainty" likely is pivotal in connecting various related concepts or themes discussed in the dataset. Its central placement suggests that discussions or research within the dataset frequently revolve around uncertainty and its implications across different domains or contexts.

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The hexagonal arrangement around "uncertainty" further highlights the cohesive nature of the cluster represented by these keywords. Each keyword positioned at the corners of the hexagon shares strong relationships with "uncertainty" and each other. This structural symmetry indicates a balanced distribution of relationships and suggests that the topics or themes represented by these keywords are interconnected and interdependent.

Examining the keywords positioned around "uncertainty" provides insights into this thematic cluster's specific themes or concepts. While "uncertainty" is the central anchor, the surrounding keywords likely represent various aspects, subtopics, or applications related to uncertainty. Analyzing these keywords with their relationships to "uncertainty" can elucidate the multifaceted nature of uncertainty and its implications across different domains, such as decision-making, risk assessment, or predictive modeling.

Overall, the arrangement of "uncertainty" at the center of the network graph with surrounding keywords forming a hexagonal structure signifies a cohesive cluster of closely related terms. This structural organization suggests a focused thematic area within the dataset, with "uncertainty" playing a pivotal role in shaping and connecting the discussions or research topics represented by these keywords. Further exploration of the relationships and themes within this cluster can provide valuable insights into the underlying patterns and dynamics of uncertainty within the dataset

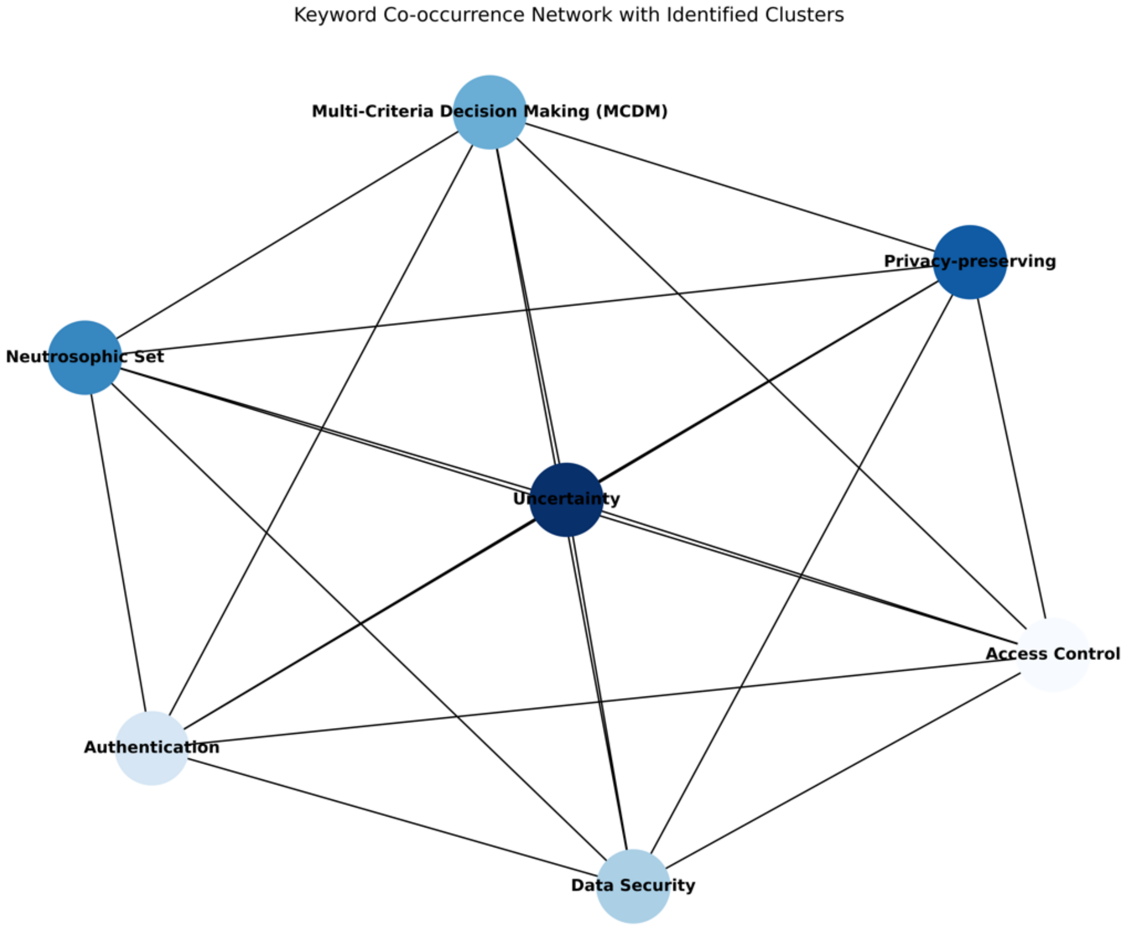

Figure 4. Keyword Co-occurrence

6. Conclusion

The landscape of Multicriteria Decision Making (MCDM) in software project management is dynamic and evolving, marked by increasing scholarly interest, methodological advancements, and practical applications. This critical review has comprehensively explored the utilization trends, challenges, and future directions within this domain, drawing insights from recent literature and empirical evidence.

Through a systematic analysis of recent publications, key patterns and trends in adopting and implementing MCDM methodologies have been identified. MCDM techniques such as the Analytic Hierarchy Process (AHP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), ELECTRE, and PROMETHEE have been highlighted for their relevance and applicability in software project management contexts. These methods offer structured frameworks for evaluating alternatives, prioritizing objectives, and making informed decisions based on multiple criteria.

However, the review also underscores several challenges and limitations associated with integrating MCDM techniques within software project management practices. Subjectivity and bias, data availability and quality, complexity and computational resources, stakeholder consensus and communication, model sensitivity and validation, and integration with organizational processes emerge as critical considerations that must be addressed to realize the full potential of MCDM.

Future research and practice in this field are expected to focus on refining decision-making methods, addressing industry-specific challenges, optimizing project management practices, enhancing security measures, and leveraging emerging technologies such as cloud computing and artificial intelligence. Collaborative efforts, interdisciplinary approaches, and methodological innovations will advance knowledge and drive innovation within the dynamic intersection of MCDM and software project management.

In conclusion, this review provides valuable insights and recommendations for practitioners and researchers seeking to harness the power of MCDM to navigate the complexities of software project management effectively. By embracing a holistic understanding of MCDM methodologies, addressing inherent challenges, and embracing emerging trends, organizations can make informed decisions and achieve project success in an increasingly competitive and dynamic software development landscape.

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