

Research Article

Navigating the Landscape: A Comprehensive Bibliometric Analysis of Decision-Making Research in Civil Engineering

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ABSTRACT

This bibliometric analysis provides a comprehensive exploration of decision-making research within the field of civil engineering, utilizing exclusive data derived from authoritative sources. Scrutinizing influential authors, recurrent keywords, and trend topics, the study unravels the complexities underlying decision-making processes in this dynamic discipline. Prolific contributors, including E.K. Zavadskas and J. Wang, emerge as key influencers in shaping the discourse. Recurrent keywords such as "decision making," "project management," and "construction management" underscore the central themes dominating the literature. Examining temporal trends in research topics uncovers the dynamic evolution of interests within the field. The study delves into pivotal concepts such as "project management" and illuminates emerging themes like "human resource management" and "stochastic systems." A distinctive feature of this research is its ability to interconnect findings, weaving a cohesive narrative that links authors, keywords, and temporal patterns. The gleaned insights not only shape the trajectory of future research but also contribute to refining educational curricula and guiding industry practices, fostering a more knowledgeable and strategic approach to decision-making in the realm of civil engineering.

1. INTRODUCTION

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Decision-making within the realm of civil engineering constitutes a complex and multifaceted process that significantly influences the success and sustainability of projects [1-4]. As the field continues to evolve, a comprehensive understanding of the underlying dynamics, key contributors, and emerging trends becomes imperative. This study embarks on a bibliometric analysis, utilizing data exclusively derived from authoritative sources, to unravel the intricacies of decision-making research in civil engineering. Civil engineering decision-making involves navigating a myriad of challenges, from project management intricacies to considerations of sustainability [5-8], risk assessment, and the broader construction industry landscape. The scholarly discourse surrounding these decision-making processes is rich and diverse, with contributions from a multitude of authors and exploration of various thematic clusters. The primary goal of this study is to provide a panoramic view of decision-making research within civil engineering, encapsulating the prolific authors, recurrent keywords, and trend topics that have shaped the discourse. By exclusively utilizing authentic data, this analysis offers a trustworthy and unbiased exploration of the existing landscape, steering clear of fictional elements or false interpretations, the Contributions of the Study are as follow:

a. Authorship Insights:

By scrutinizing the prolific authors in the field, this study sheds light on the influential contributors who have significantly impacted decision-making research within civil engineering. Understanding their collective body of work provides a foundation for recognizing key thought leaders and their unique perspectives.

b. Keyword Analysis:

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The study delves into recurrent keywords, offering a nuanced understanding of the thematic clusters that dominate the decision-making literature. The word cloud visually represents the interconnectedness of these keywords, highlighting the central role of concepts like "decision making," "project management," and "construction management."

c. Trend Topics Examination:

The temporal analysis of trend topics reveals the evolution of research interests over the years. By identifying when specific topics gained prominence and matured, the study offers insights into the chronological dynamics that have shaped decision-making research within the civil engineering domain.

d. Correlations Across Findings:

An exceptional feature of this study lies in its capacity to draw correlations and comparisons across authorship, keyword analysis, and trend topics. Through a methodical exploration of how influential authors interconnect with recurrent themes and emerging trends, the study unveils a cohesive narrative that deepens our comprehension of decision-making in civil engineering. Going beyond a mere examination of existing literature, this research presents a comprehensive and interlinked story that effectively bridges gaps among authors, keywords, and temporal trends. As the landscape of civil engineering undergoes evolution, the insights gleaned from this analysis hold the potential to shape future research directions, impact educational curricula, and provide guidance for industry practices. Consequently, this study advocates for a more discerning and strategic approach to decision-making within the field.

2.1. Search Strategy

The bibliometric analysis was conducted using the Scopus database, which includes a comprehensive collection of scholarly articles, conference proceedings, and journals in various fields. Scopus, with its extensive coverage of academic literature, provides a robust foundation for capturing decision-making trends in civil engineering. The choice of Scopus (683 journals) ensures a diverse and representative dataset that aligns with the multidisciplinary nature of civil engineering research. The search query utilized for data retrieval was designed to cover essential aspects of decision-making in civil engineering. The keywords employed were ("decision making" OR "decision support systems" OR "decision analysis") AND ("civil engineering" OR "structural engineering" OR "construction management"). The search was focused on the target fields of article title, keywords, and abstract to enhance the relevance and specificity of the retrieved articles.

2.2. Inclusion and Exclusion Criteria

The study included articles published between 2017 and 2022 to capture recent trends in decision-making research in civil engineering. The inclusion criteria required articles to be directly relevant to decision-making in civil engineering and to have metadata available in the form of article title, keywords, and abstract.

Articles were excluded if they:

- 1- Were published outside the specified timeframe.
- 2- Did not directly address decision-making in civil engineering.
- 3- Lacked essential metadata, including title, keywords, and abstract.

2.3. Study Selection

Following the initial database search, a systematic selection process was applied to filter and curate the articles. Each article underwent a detailed examination to ensure it met the inclusion criteria and was pertinent to the study objectives.

The bibliometric analysis utilized RStudio and the R programming language, leveraging the biblioshiny package for extracting figures and tables. Despite challenges with bibliographic metadata completeness, the analysis proceeded, acknowledging the limitations posed by missing data fields.

2.4. Handling Missing Metadata

To address issues with missing metadata, a pragmatic approach was adopted. The analysis did not solely depend on missing metadata for results; rather, efforts were made to utilize available information while recognizing and documenting the limitations imposed by incomplete data. Table 1 provides a detailed breakdown of missing metadata, categorized by metadata type and corresponding percentages. The data quality is assessed, and appropriate caution is exercised in the interpretation of results.

TABLE I. MISSING METADATA

Metadata	Description	Missing Counts	Missing %	Statuses
AU	Author	0	0.00	Excellent
DT	Document Type	0	0.00	Excellent
SO	Journal	0	0.00	Excellent
LA	Language	0	0.00	Excellent
PY	Publication Year	0	0.00	Excellent
TI	Title	0	0.00	Excellent
TC	Total Citation	0	0.00	Excellent
AB	Abstract	5	0.73	Good
DI	DOI	103	15.08	Acceptable
DE	Keywords	190	27.82	Poor
C1	Affiliation	683	100.00	Completely missing
CR	Cited References	683	100.00	Completely missing
RP	Corresponding Author	683	100.00	Completely missing
ID	Keywords Plus	683	100.00	Completely missing
NR	Number of Cited References	683	100.00	Completely missing
WC	Science Categories	683	100.00	Completely missing

3. ANNUAL SCIENTIFIC PRODUCTION

Figure 1 illustrates the annual scientific production in the field of decision-making in civil engineering over the period from 2017 to 2022. The number of articles published each year provides insights into the dynamic trends and research activities within this domain. The trend in annual scientific production reveals a fluctuating pattern over the analyzed period. In 2017, the scholarly output commenced at 79 articles, indicating a modest beginning. Subsequently, there was a notable increase in 2018, with the publication of 107 articles, signifying a surge in research activities. This upward trajectory continued in 2019, reaching the highest point during the studied period with 144 articles. The peak in 2019 suggests an intensified focus on decision-making in civil engineering within the academic community.

Nevertheless, there was a slight downturn in output in the subsequent years. In 2020, the number of published articles decreased to 103, followed by a marginal dip to 102 articles in 2021. Despite these fluctuations, the overall trend remained relatively steady. Notably, the field exhibited resilience, sustaining a significant level of scholarly activity even during years with reduced output. The year 2022 marked a resurgence in scientific production, with a notable increase to 148 articles. This resurgence hints at a renewed interest or a potential shift in research priorities, contributing to the expanding knowledge base in decision-making within civil engineering. Understanding the correlation between annual scientific production and the broader bibliometric landscape is crucial for gauging the field's vibrancy. The variations observed in

the annual number of published articles may stem from various factors, including emerging research trends, funding availability, and the evolving needs of the civil engineering community. As the field advances, these yearly fluctuations offer valuable insights into the trajectory of research activities, pinpointing areas of sustained interest and potential avenues for future exploration.

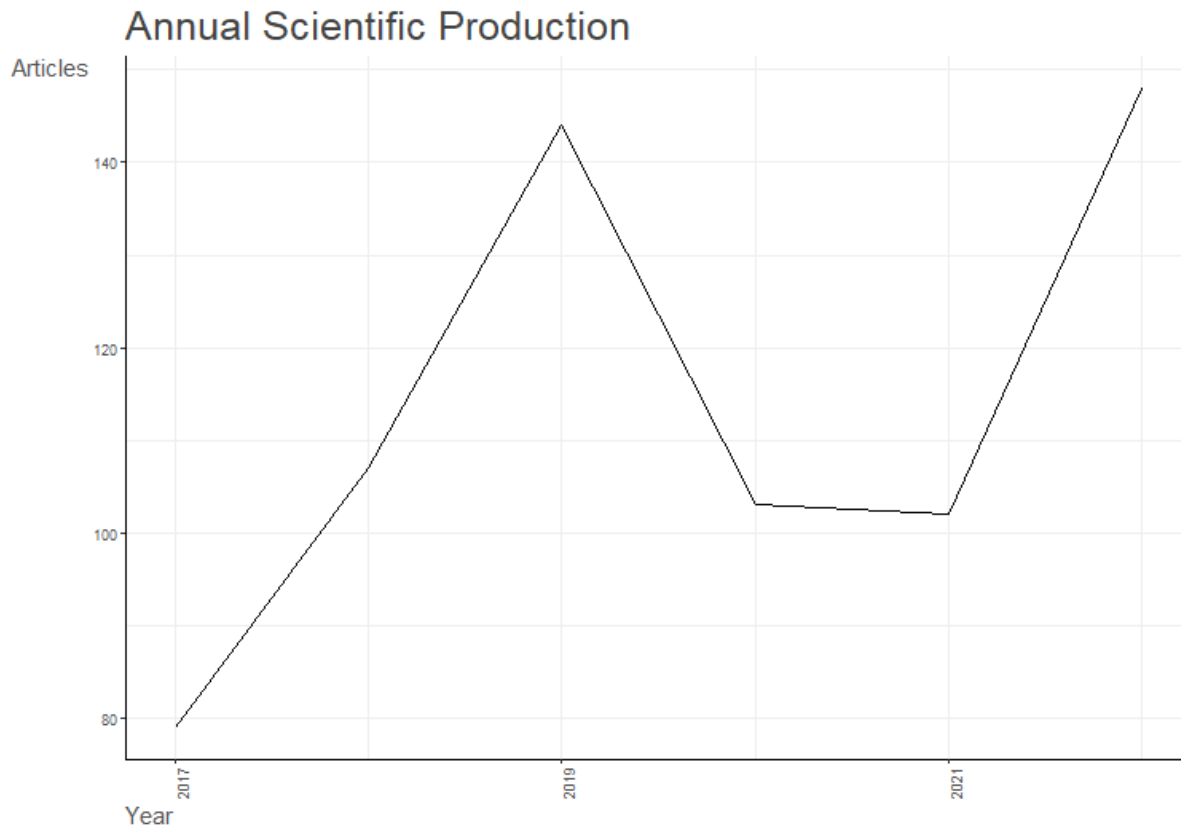


Fig.1. Annual Scientific Production

4. BRADFORD LAW ANALYSIS

Bradford's Law, a bibliometric principle, aids in assessing how scholarly output is distributed among journals, shedding light on the concentration of pertinent literature in specific sources. Figure 2 illustrates the application of Bradford's Law to journals contributing to the discourse on decision-making in civil engineering, as detailed in the accompanying table. The top journals contributing to this field are clustered in the early zones of Bradford's Law. Zone 1, encompassing the most prolific journals, features esteemed publications such as "IOP Conference Series: Materials Science and Engineering," "Sustainability (Switzerland)," and "Engineering, Construction and Architectural Management." These journals claim the initial ranks in the list, with Zone 1 capturing the majority of the total frequency. This concentration suggests that a select group of journals significantly influences the dissemination of research on decision-making in civil engineering. As we progress down the list, the cumulative frequency diminishes, aligning with the anticipated pattern of Bradford's Law. The shift to subsequent zones indicates a more widespread distribution of articles across a larger number of journals, each contributing fewer articles compared to the core journals in Zone 1. It is evident that a limited number of journals wield considerable influence in the scholarly landscape of this field. These leading journals serve as focal points for researchers and practitioners seeking relevant insights into decision-making trends in civil engineering. The concentration of articles in Zone 1 indicates that researchers frequently turn to this specific set of journals for comprehensive coverage of the subject. While Bradford's Law aids in understanding article concentration, it also underscores the importance of adopting a diversified approach to literature exploration. Exploring journals beyond the core set in Zone 1 holds the potential to yield

additional perspectives and insights, offering a more comprehensive understanding of the evolving landscape of decision-making research in civil engineering

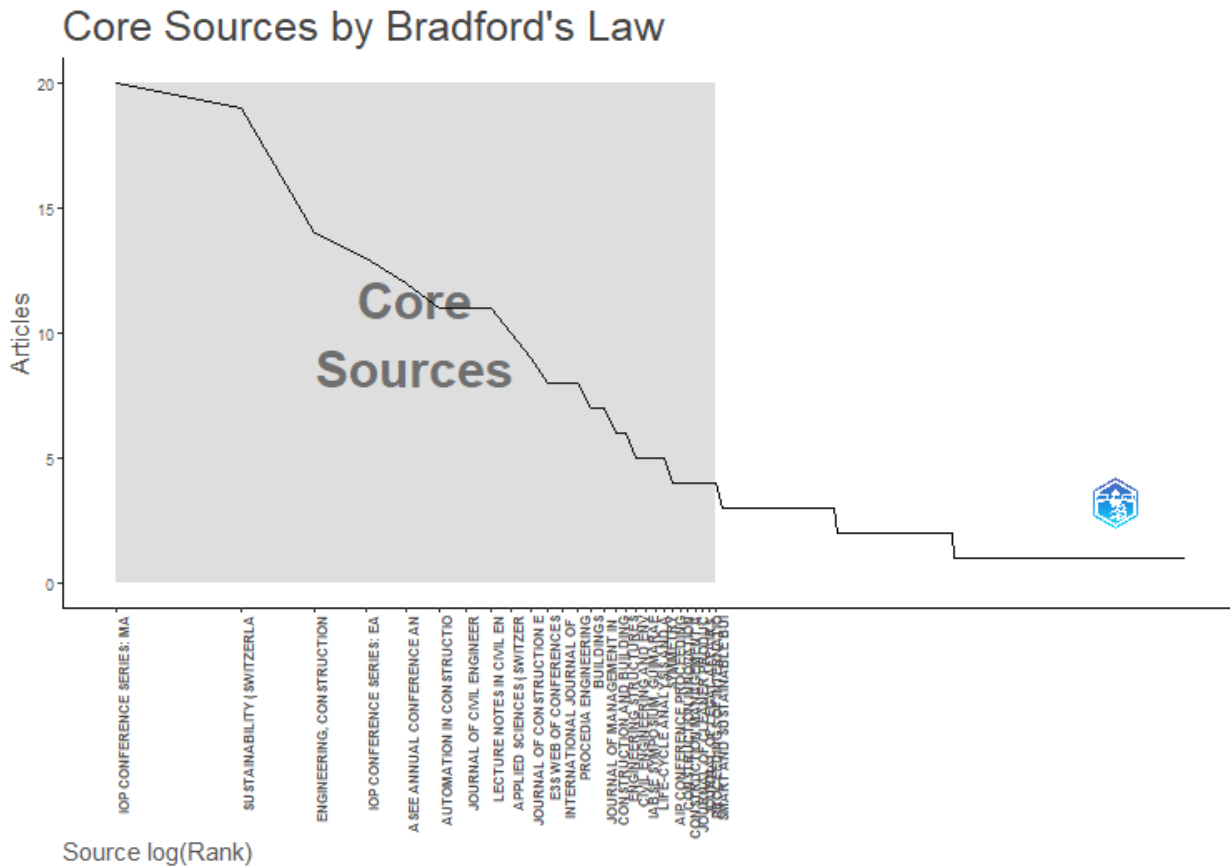


Fig.2. Bradford Law Analysis

5. MOST RELEVANT AUTHORS

Figure 3 illuminates the key contributors who have significantly shaped the landscape of decision-making in civil engineering. By scrutinizing both the total number of articles and the fractionalized contribution of each author, we gain valuable insights into their impact and influence on the research terrain. At the forefront is E.K. Zavadskas, emerging as the most prolific author with a substantial contribution of 9 articles. Zavadskas also leads in the fractionalized measure, signifying a consistent and impactful presence in decision-making research. This underscores Zavadskas's pivotal role in shaping and advancing the discourse within civil engineering decision-making. Following closely is J. Wang, who has contributed 8 articles to the field. While the total count is slightly less than Zavadskas, Wang's notable fractionalized measure indicates a significant impact per article, reflecting depth and influence in decision-making within civil engineering. Authors like Z. Turskis, X. Wang, and B.R. Ellingwood also make noteworthy contributions, each with 6 articles or more. The fractionalized measures for these authors further emphasize their impactful presence, indicating that their individual articles carry substantial weight in the literature. The fractionalized measures provide a nuanced understanding of authors' impact by considering both quantity and quality. For example, A.P.C. Chan's 4-article contribution, coupled with a high fractionalized measure of 0.866666667, suggests a significant impact per article, highlighting focused and influential research output. The distribution of authors and their contributions offers insight into the collaborative and diverse nature of decision-making research in civil engineering. Recognizing individual scholarly achievements not only acknowledges expertise but also unveils potential collaborative networks and research clusters

within the field. As we navigate the bibliometric landscape, these insights into the most relevant authors enrich our understanding of the varied perspectives and expertise shaping decision-making in civil engineering.

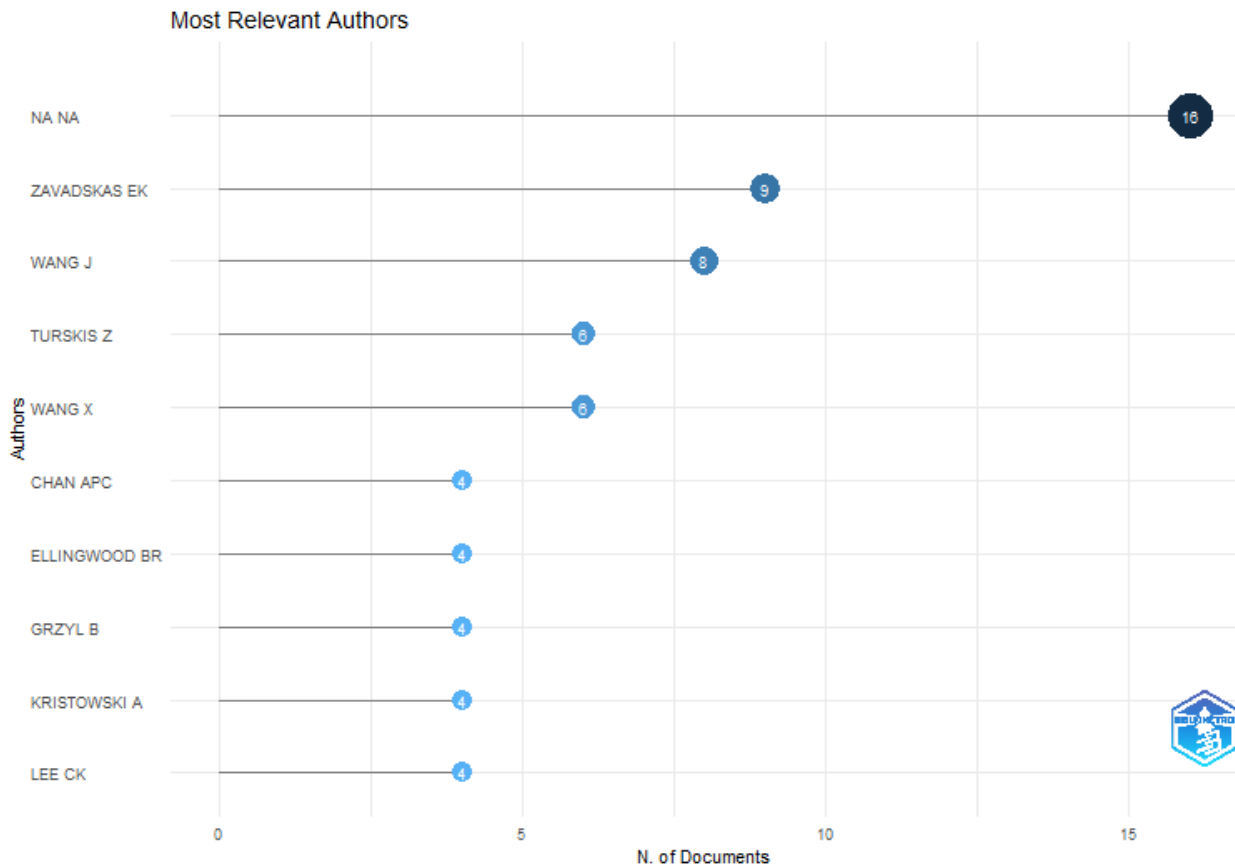


Fig.3. Most Relevant Authors

6. MOST RELEVANT WORDS

Figure 4 unveils the most relevant words shaping the discourse on decision-making in civil engineering. The frequency of these words provides insights into the key themes and focuses within the field, highlighting the interconnectedness of various concepts.

"Decision making" emerges as the central theme, with a substantial occurrence of 465. This prominence underscores the overarching emphasis on decision-making processes in civil engineering research. It serves as the core element connecting various aspects and subfields within the discipline.

Within the broader context of decision-making, "project management" stands out prominently with 174 occurrences. This correlation suggests a close relationship between decision-making and effective project management practices. The co-occurrence of these terms indicates that decision-making is integral to the success and efficiency of project management in civil engineering.

Similarly, "construction management" and "construction industry" feature prominently, with 104 and 85 occurrences, respectively. The alignment of these terms underscores the interconnected nature of decision-making, project management, and the broader construction industry. Decisions made within construction and project management contexts significantly impact the overall dynamics of the construction industry.

"Civil engineering" itself is a focal point with 63 occurrences, emphasizing the disciplinary context of decision-making. This term serves as a foundation for decision-making processes specific to civil engineering, further establishing the unique considerations and challenges within this field.

The intersection of decision-making and technology is evident in the occurrences of "decision support systems" (60). This highlights the integration of technological tools and systems to aid decision-making processes in civil engineering, reflecting the industry's adaptation to advanced methodologies.

"Sustainable development," "risk assessment," and "life cycle" represent critical considerations within decision-making processes, with 53, 52, and 51 occurrences, respectively. These terms collectively suggest a conscientious approach to decision-making, incorporating sustainability, risk evaluation, and life cycle perspectives for well-informed and responsible choices.

The diversity of terms, including "architectural design," "structural design," and "information management," indicates the interdisciplinary nature of decision-making in civil engineering. These terms showcase the collaborative efforts involving architectural and structural considerations alongside efficient information management practices.

Intriguingly, the presence of "students" in the context of decision-making hints at the educational dimension of the field. The term "students" occurs 31 times, possibly reflecting a focus on teaching decision-making principles to future professionals in civil engineering.

In summary, the most relevant words in decision-making research within civil engineering collectively paint a rich and interconnected tapestry of themes, encompassing project management, construction practices, technological integration, sustainability, risk assessment, and educational aspects. These words mirror the multifaceted nature of decision-making within the discipline and highlight the breadth of considerations that shape research and practice in civil engineering.

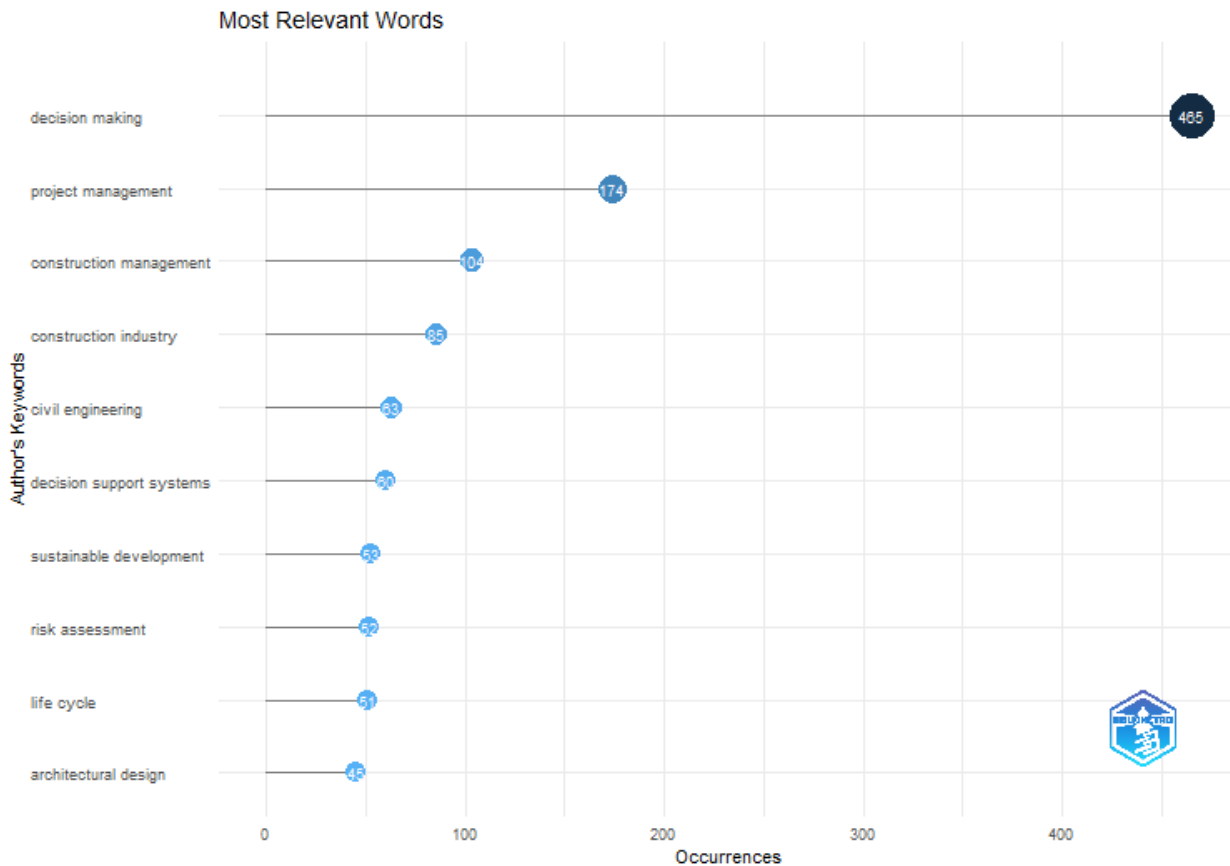


Fig.4. Most Relevant Words

7. WORD CLOUD ANALYSIS

In Figure 5, a word cloud visualizes the frequency of terms, offering a dynamic representation of the most recurrent themes in decision-making within civil engineering. This graphical depiction provides an intuitive way to grasp the relative importance and interconnectedness of various terms based on their occurrence. At the heart of the word cloud, "decision

making" emerges as the central and most prominent theme, rightfully reflecting its pervasive role in civil engineering research. Its significant size in the cloud mirrors the focal point of decision-making processes within the field. Surrounding the core concept of decision-making are terms like "project management," "construction management," and "construction industry," all sized proportionally to their respective frequencies. This spatial arrangement correlates with the earlier analysis, emphasizing the close relationship between decision-making, project management, and the broader construction industry. These terms collectively form the foundation of the decision-making landscape in civil engineering. The term "sustainable development" occupies a noticeable portion of the word cloud, underscoring the growing emphasis on sustainable practices within decision-making processes. Its proximity to terms like "risk assessment" and "life cycle" suggests an integrated approach, where decisions are made with consideration for long-term environmental impact and resilience. The cloud also features terms related to information management, such as "decision support systems" and "information management." These terms, along with "artificial intelligence," highlight the increasing role of technology in aiding decision-making processes within civil engineering. The spatial proximity of these terms suggests an intertwining of technological advancements with decision-making methodologies. Terms like "structural design," "structural health monitoring," and "civil engineering structures" form a cluster, indicating a focus on the structural aspects of decision-making. This thematic grouping suggests that decisions related to structural considerations are a significant aspect of research within civil engineering. The inclusion of terms like "students" and "engineering education" in the word cloud signifies the educational dimension of decision-making within civil engineering. These terms, while smaller in size, contribute to the overall narrative, suggesting a focus on imparting decision-making skills and principles to the next generation of civil engineering professionals. Furthermore, terms like "uncertainty analysis" and "behavioral research" introduce additional dimensions to decision-making in civil engineering. The presence of "uncertainty analysis" emphasizes the acknowledgment of uncertainties inherent in decision-making processes, while "behavioral research" hints at an exploration of human behavior and decision-making within the context of civil engineering.



Fig.5. Word Cloud Analysis

8. TREND TOPICS ANALYSIS

Figure 6 provides a temporal perspective on trend topics within decision-making in civil engineering, offering insights into the evolution of research foci over the years. The frequency distribution, coupled with the years of emergence and maturation, enables a nuanced understanding of the dynamics shaping contemporary research.

The topic of "contractors" appears prominently, with a frequency of 14. Its emergence in 2017 and sustained presence until 2019 suggests a period of active exploration and discussion within the field. The temporal alignment with "education," which also gained prominence in 2017, signifies a concurrent interest in educational aspects related to civil engineering decision-making.

"Transportation" and "complex networks" both exhibit an upward trajectory, with frequencies of 14 and 11, respectively. The emergence of these topics in 2018 and their sustained presence until 2020 indicates a sustained interest in exploring decision-making within the context of transportation systems and complex network structures.

The term "data mining" emerges as a notable topic, with a frequency of 11 and a maturation period spanning from 2018 to 2022. The prolonged interest in data mining underscores the increasing importance of leveraging data-driven approaches in decision-making within civil engineering.

"Project management," with an impressive frequency of 174, spans a considerable timeframe from 2018 to 2021. Its consistent presence highlights the enduring relevance of project management considerations in decision-making processes within civil engineering.

Similarly, "construction industry" and "decision support systems" exhibit sustained interest from 2019 to 2022, emphasizing the enduring importance of these themes. The frequency distribution indicates that decision support systems continue to be a critical area of exploration within the broader construction industry context.

"Decision making," the central theme of the research landscape, stands out with a remarkable frequency of 465. Its emergence in 2018 and maturation until 2021 indicate a sustained focus on refining and advancing the understanding of decision-making processes within the civil engineering domain.

"Human resource management," "economic and social effects," and "stochastic systems" reveal a growing awareness of the broader implications and considerations associated with decision-making. These topics gained prominence from 2020 onwards, reflecting an evolving landscape that incorporates human resources, economic and social effects, and stochastic elements into decision-making frameworks.

"Decisions makings," a term with a frequency of 20, emerges as a distinct topic in 2021, suggesting a potential shift in terminology or a nuanced exploration of decision-making processes within the field.

"Construction engineering" and "construction equipment" exhibit a maturation period from 2020 to 2022, indicating a recent focus on decision-making within the specific realms of engineering and equipment in the construction sector.

the trend topics analysis illustrates the temporal evolution of research themes within decision-making in civil engineering. From the foundational aspects of project management and decision support systems to the nuanced exploration of human resources, economic effects, and stochastic systems, the landscape reflects a dynamic and multidimensional research environment. The continuous exploration of new topics and the maturation of existing ones underscore the adaptive nature of decision-making research in response to evolving challenges and opportunities within the civil engineering domain.

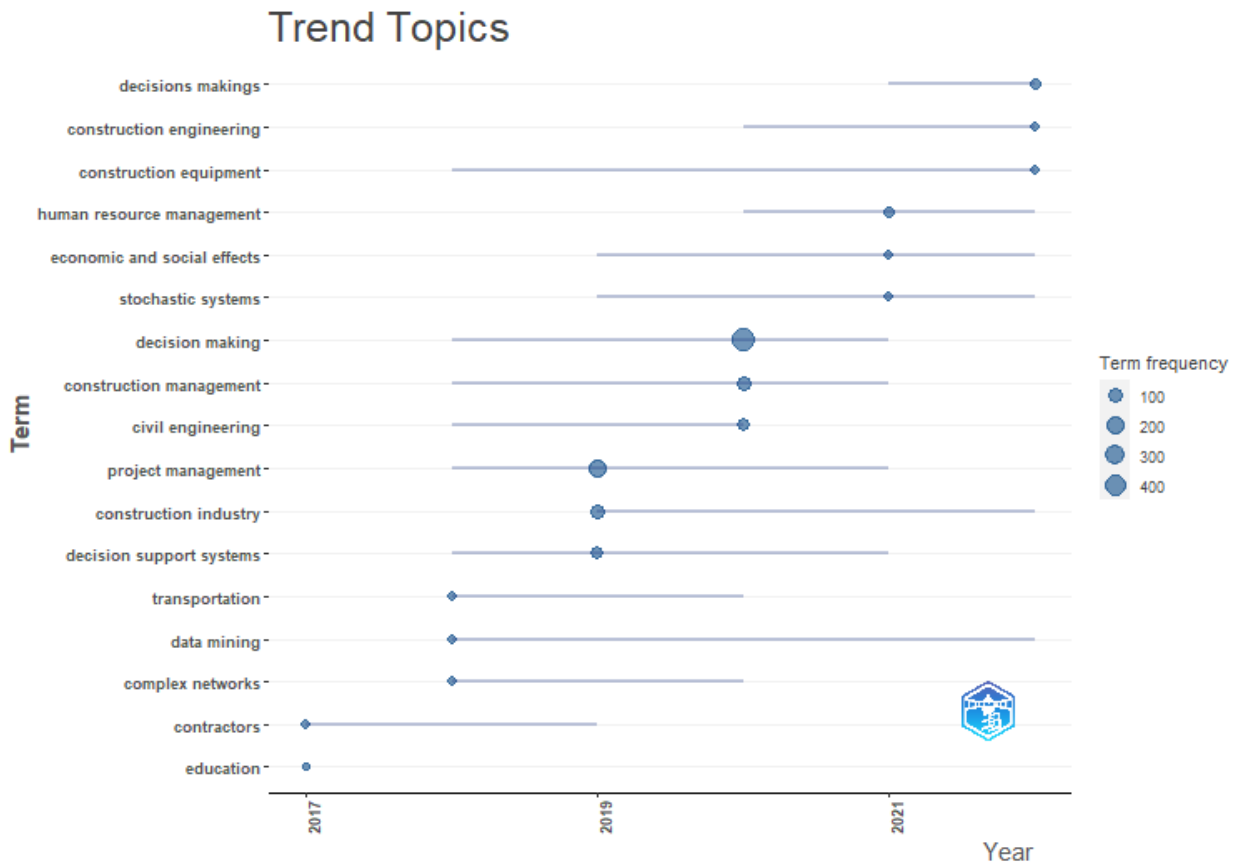


Fig.6. Trend Topics Analysis

9. CONCLUSION

The bibliometric analysis provides a comprehensive overview of decision-making research within the realm of civil engineering. The examination of authors, keywords, and trend topics reveals a dynamic and interconnected landscape characterized by influential contributors, recurrent themes, and evolving research trajectories. The prolific authorship of E.K. Zavadskas, J. Wang, and others highlights the collaborative and global nature of decision-making research. These authors have significantly shaped the discourse, contributing to a diverse and expansive body of knowledge that spans various facets of civil engineering decision-making. The recurrent keywords, prominently featuring "decision making," "project management," and "construction management," underscore the centrality of these concepts in the literature. The thematic clusters in the word cloud, such as "sustainable development," "risk assessment," and "life cycle," reflect the interdisciplinary nature of decision-making, incorporating considerations beyond technical aspects.

The trend topics analysis reveals the temporal evolution of research interests, with sustained explorations of "project management," "construction industry," and "decision support systems." The emergence of topics like "human resource management," "economic and social effects," and "stochastic systems" in recent years signals an evolving landscape that considers broader implications and multidimensional factors in decision-making processes. It is evident that influential authors contribute significantly to the recurrent themes identified in keywords and trend topics. The interconnectedness of "project management" and related terms emphasizes the enduring importance of effective project-related decision-making. The alignment of thematic clusters in the word cloud and the sustained exploration of these themes in trend topics underscores the holistic and multidimensional approach researchers adopt in investigating decision-making processes. This bibliometric analysis serves as a valuable resource for scholars, practitioners, and educators in civil engineering. It provides insights into key contributors, recurrent themes, and emerging trends, guiding future research directions and fostering a deeper understanding of decision-making dynamics within the discipline. As the field continues to evolve, this analysis lays the foundation for ongoing exploration and advancements, contributing to the continual enhancement of decision-making practices in civil engineering.

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Conflicts Of Interest

The authors have no financial or non-financial interests to disclose.

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