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A Bibliometric Perspective: Research Trends in Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS)

Nur Anis Zulaikha Sharif Azam[1]*, Norshahrizan Nordin[1,2,3], Suhaiza Hanim Mohamad Zailani[4], Fadhlur Rahim Azmi[5], Mohd Saiful Izwaan Saadon[6], Wan Zuki Azman Wan Muhamad[7], Suraiya Ibrahim[1], Nur Syuhadah Kamaruddin[1], Wan Norsyafawati W. Muhamad Radzi[1], Mahmoud El-Banna[8], Abdurrahman Faris Indriya Himawan [9]

[1]Faculty of Business & Communication, Universiti Malaysia Perlis
[2]Healthcare Management – Special Interest Group (HEm – SIG)
[3]Management of Technology – Special Interest Group (MoTEm – SIG)
[4]Universiti Malaya (UM), Malaysia
[5]Universiti Teknologi Mara (UiTM) Cawangan Melaka, Malaysia
[6]Universiti Malaysia Terengganu (UMT), Terengganu, Malaysia
[7]Institute of Engineering Mathematics, Universiti Malaysia Perlis
[8]German Jordanian University (GJU), Amman, Jordan
[9]Telkom University (Tel-U), Bandung, Indonesia

ABSTRACT

This study presents a comparative bibliometric analysis of two decision-making methodologies: Multi-Criteria Decision Making (MCDM) and the Mahalanobis Taguchi Gram-Schmidt (MTGS) method. The primary objective is to examine the scholarly landscape, research growth trajectories, and geographic dissemination of these approaches better to understand their academic evolution and potential for future research. MCDM has been extensively utilized across diverse disciplines to address complex decision-making problems involving multiple criteria. In contrast, MTGS represents a relatively nascent technique that mitigates multicollinearity through Gram-Schmidt orthogonalization. Drawing upon the Scopus database as the sole data source, this study systematically analyzes publications from 2020 to 2025. Key bibliometric indicators, including annual publication trends, subject area distributions, and contributing countries, are evaluated using Microsoft Excel, VOSviewer, and Harzing's Publish or Perish. The findings indicate a pronounced dominance of MCDM in the literature, with 228 publications primarily situated within the domains of Computer Science, Engineering, and Mathematics. Conversely, MTGS is represented by only 10 publications, predominantly within technical fields such as Engineering and Computer Science. In terms of geographic contribution, India, China, and Iran emerge as leading contributors to MCDM research, while MTGS-related studies are primarily concentrated in China and Malaysia. It is important to acknowledge that this study is limited to Scopus-indexed publications within the 2020 to 2025 timeframe, which may restrict the comprehensiveness of the analysis by excluding relevant literature from other databases or earlier periods.

Keywords: Multi-Criteria Decision Making (MCDM), Mahalanobis Taguchi Gram-Schmidt (MTGS), Bibliometric Analysis, Decision-Making Methods, Research Trend

1.0 INTRODUCTION

Multi-criteria decision-making (MCDM) encompasses a set of techniques that integrate both quantitative and qualitative factors (Saad et al., 2025). This approach systematically incorporates the perspectives and objectives of multiple decision-makers, allowing them to rank observations, establish criteria priorities, and assess their relative importance. Additionally, MCDM methods help resolve inconsistencies arising from conflicting viewpoints while ensuring a structured decision-making process. Instead of relying on a single criterion for evaluation, these methodologies utilize multiple criteria, providing a more comprehensive and balanced assessment framework (Shams et al., 2025).

*Corresponding Author: aniszulaikha@studentmail.unimap.edu.my

The application of various MCDM methodologies provides distinct advantages in decision-making processes. Firstly, these methods enhance resilience, allowing decision-makers to effectively adapt to evolving conditions. Secondly, they improve precision by integrating multiple performance dimensions, enabling a comprehensive evaluation. Thirdly, MCDM approaches facilitate a deeper understanding of trade-offs among different alternatives, supporting well-informed decisions. Lastly, it offers flexibility, enabling stakeholders to prioritize criteria based on specific project requirements or constraints. Consequently, MCDM methodologies serve as essential tools in navigating the complexities of material selection, ensuring optimal alignment with project objectives and performance standards (Adamu et al., 2025). Multi-Criteria Decision-Making (MCDM) algorithms, which integrate mathematically sound soft computing techniques, offer a structured, efficient, and reliable approach for evaluating bank performance. These methodologies facilitate comprehensive comparisons by incorporating multiple financial indicators, enhancing decision-making precision in banking assessments (Işık et al., 2025).

2.0 MAHALANOBIS TAGUCHI GRAM-SCHMIDT (MTGS)

The Mahalanobis Taguchi Gram-Schmidt (MTGS) system represents an advancement of the Mahalanobis Taguchi System (MTS), originally developed by Dr. Genichi Taguchi to enhance decision-making in complex multivariate environments (Taguchi & Jugulum, 2002). While MTS integrates Mahalanobis Distance (MD) with Taguchi's orthogonal arrays (OA) and signal-to-noise ratio (SNR) to facilitate pattern recognition, classification, and predictive modeling, it is often limited by the presence of multicollinearity within datasets, affecting the precision of its analysis.

To address these limitations, MTGS incorporates the Gram-Schmidt Orthogonalization Process (GSOP), which eliminates multicollinearity by orthogonalizing variables, thereby improving the accuracy of Mahalanobis Distance (MD) calculations (Tan et al., 2023). This refinement significantly extends the applicability of MTGS in complex decision-making scenarios where conventional MTS approaches may struggle (Peng et al., 2022). The versatility of MTGS has been demonstrated in diverse fields such as quality control, fault detection, and medical diagnostics, reinforcing its role as a powerful decision-support tool. As data-driven methodologies continue to evolve, MTGS presents itself as an innovative framework capable of enhancing intelligent and adaptive decision-making processes (Tan et al., 2023). MTGS was selected due to its robustness in handling multicollinearity and its effectiveness in feature selection and classification tasks, particularly in high-dimensional datasets.

In today's digital age, decision-making methods like Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS) play an important role in building sustainable societies through the smart use of data. MCDM is widely used in digital sustainability projects because it helps decision-makers compare different options by considering many factors, such as environmental impact and technology readiness. This supports global goals like the United Nations Sustainable Development Goals (SDGs) by providing clear and structured ways to make decisions (Sousa et al., 2021). Recent research also shows that MCDM is being combined with tools like artificial intelligence (AI), big data, and digital management systems to improve sustainability and digital governance in organizations. On the other hand, MTGS is becoming more popular in areas like digital health, smart factories, and AI-based systems because it can handle complex data and avoid problems like overlapping variables. Both MCDM and MTGS help improve the accuracy of decisions and support the creation of smart, connected systems that are essential for a sustainable future. Therefore, this study highlights how these two methods contribute to digital innovation and help make better decisions in a world that is becoming more connected and data-driven.

3.0 METHODOLODY

This study aims to compare the effectiveness of Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS) in decision-making processes. The research sample was systematically compiled using data from Scopus, a leading academic database. The dataset includes comprehensive bibliographic records such as citation details, funding acknowledgements, abstracts, and keywords. The selection focuses on scientific publications from 2020 to 2025, ensuring alignment with the study's scope. Scopus's advantages over other databases have been extensively discussed in prior research (Harzing et al., 2016), particularly regarding its broad indexing coverage over time (Mongeon & Paul-Hus, 2016).

The bibliometric analysis begins with defining the study's scope, which centres on comparing MCDM and MTGS methodologies. This research utilizes two separate datasets, one for MCDM and another for MTGS, to enable a comparative analysis of both approaches. To ensure methodological accuracy, Scopus is used as the primary data source, with Boolean operators applied to refine search queries. The search string for MCDM is formulated as ("Multi-Criteria Decision Making" OR "MCDM") AND ("Multi-Attribute Decision Making" OR "Multi-Objective Decision Making"), specifically targeting titles, abstracts, and keywords. Meanwhile, the search string for MTGS is ("Mahalanobis Taguchi" OR "Mahalanobis Taguchi System") AND ("Gram-Schmidt"), ensuring optimal retrieval of publications relevant to the research objectives.

The dataset extraction was conducted on 22 May 2025, ensuring that the study incorporates the most recent scholarly contributions. A detailed quantification process refines the dataset by 2ing the number of identified, screened, and excluded articles, ultimately selecting high-quality publications for bibliometric analysis. To enhance analytical depth, visualization tools are employed to structure and interpret bibliometric data. Microsoft Excel is used for statistical calculations and graphical representations of publication trends, while VOSviewer facilitates co-occurrence network visualizations that highlighting key research linkages. Additionally, Harzing's Publish or Perish is utilized to compute citation metrics, offering a comprehensive assessment of scholarly impact. Collectively, these tools provide an integrated analytical framework that strengthens the comparative understanding of MCDM and MTGS methodologies in decision-making research.

4.0 ANALYSIS AND FINDING

Table 1 and Figure 1 illustrate the yearly distribution of publications on two methodologies: Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS), from 2020 to 2025. This comparison highlights the trends in research interest and application of these two approaches in academic literature.

The data show a consistently high number of publications on MCDM, with a total of 228 over the six years. The number of MCDM-related publications remained relatively stable from 2020 to 2023, ranging from 33 to 40 per year, followed by a notable peak in 2024 with 54 publications. However, there is a noticeable decline in 2025, with only 26 publications recorded by the time of this analysis. In contrast, the number of publications on the MTGS method is significantly lower, with only 10 over the same six-year span. MTGS publications peaked in 2022 with 4 publications, followed by a gradual decline in subsequent years. This suggests that while MTGS is emerging as a potential analytical method, it has not yet gained widespread attention or adoption in academic research compared to the more established MCDM methods.

Table 1 Years of Publication for Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS)

	MCDM	MTGS
2020	37	1
2021	38	2
2022	33	4
2023	40	2
2024	54	1
2025	26	0
Total	228	10

Figure 1 visually supports this data, clearly depicting the dominant presence of MCDM in scholarly publications, while also highlighting the relatively limited but emerging interest in MTGS. The graphical representation aids in understanding the contrast between the two methods in terms of academic usage and popularity over time. This comparison underscores the maturity and widespread application of MCDM, while also pointing to the growing but still nascent interest in MTGS. It suggests potential for further exploration and development of MTGS in future research, particularly for specialized applications where its unique capabilities could complement or enhance existing decision-making frameworks.

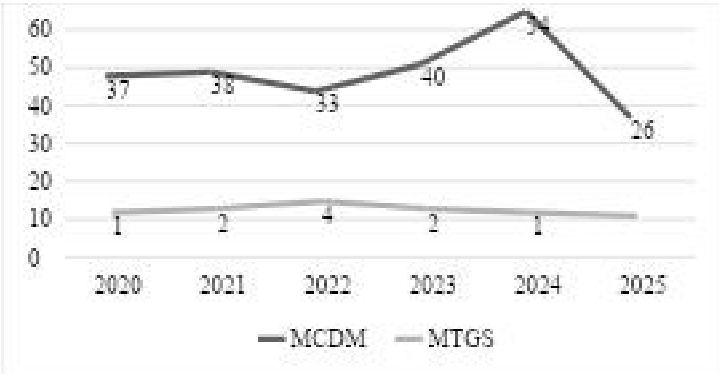

Figure 1. Publication by Years.

Table 2 and Figure 2 present the top 10 subject areas in which Multi-Criteria Decision Making (MCDM) methods have been applied, based on the number of related publications. This analysis helps identify the key academic and practical domains in which MCDM has had a significant impact. From the data, it is evident that Computer Science is the most prominent area, with 121 publications, followed by Engineering with 101. This indicates a strong integration of MCDM approaches in technology-driven and technical disciplines, where complex decision-making is essential.

Mathematics and Decision Sciences also show high relevance, with 74 and 30 publications respectively. This reflects the methodological and analytical nature of MCDM, which relies heavily on mathematical models and decision-theoretic frameworks. In addition, MCDM methods have found applications in Environmental Science (26 publications) and Business, Management, and Accounting (22 publications), suggesting their utility in addressing sustainability issues and strategic business decisions. Other notable areas include Energy (21 publications), Social Sciences (20 publications), Materials Science (10 publications), and

Economics, Econometrics, and Finance (9 publications), indicating the broad, interdisciplinary appeal of MCDM techniques.

Table 2 Top 10 Subject Areas in Multi-Criteria Decision Making (MCDM)

Rank	MCDM	
1	Computer Science	121
2	Engineering	101
3	Mathematics	74
4	Decision Sciences	30
5	Environmental Science	26
6	Business, Management, and Accounting	25
7	Energy	21
8	Social Sciences	20
9	Materials Science	14
10	Economics, Econometrics, and Finance	9

Figure 2 complements the table by showing the distribution of publications across these subject areas in a pie chart. The figure highlights the dominance of Computer Science and Engineering, while also emphasizing the diverse applicability of MCDM across both technical and non-technical fields. This widespread application across various disciplines demonstrates the versatility and importance of MCDM as a decision-support tool. It also suggests that future research can benefit from exploring untapped areas or integrating MCDM with emerging fields to address increasingly complex decision-making challenges.

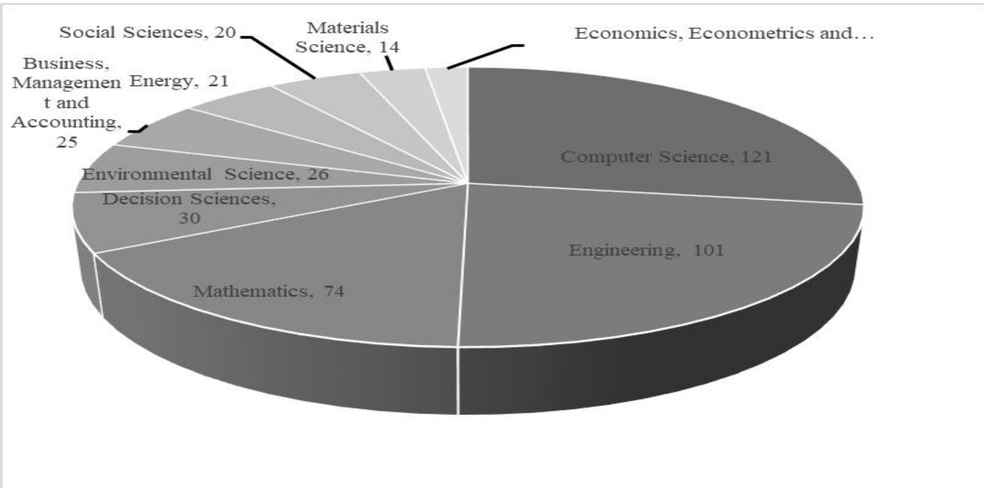

Figure 2. Top 10 Subject Areas in Multi-Criteria Decision Making (MCDM).

Table 3 and Figure 3 highlight the top 10 subject areas in which the Mahalanobis Taguchi Gram-Schmidt (MTGS) method has been applied. Although the overall number of publications is relatively low compared to other methodologies, the data provides useful insights into the domains where MTGS has gained traction. Engineering emerges as the most frequent subject area, with 7 publications, accounting for 31% of the total, indicating that MTGS is particularly favored in technical and applied sciences. This is followed by Computer Science (4 publications, 17%), suggesting the method's growing relevance in data-driven and computational fields. Other key areas include Chemical Engineering, Materials Science, and Mathematics, each with 2 publications (representing 9% of the total), reflecting the method's use in quantitative and industrial contexts. Additionally, Physics and Astronomy, Business, Management and Accounting, Decision Sciences, Energy, and Environmental Science each account for 1 publication (4% each), indicating that MTGS has begun to expand into diverse interdisciplinary fields, albeit on a smaller scale. Figure 3 visually depicts this distribution through a pie chart, emphasizing the concentration of MTGS applications in engineering and computational domains, while also revealing its exploratory use in areas such as business and environmental studies.

Table 3 Top 10 Subject Areas in Mahalanobis Taguchi Grams-Schmidt (MTGS)

Rank	MTGS	
1	Engineering	7
2	Computer Science	4
3	Chemical Engineering	2
4	Materials Science	2
5	Mathematics	2
6	Physics and Astronomy	2
7	Business, Management and Accounting	1
8	Decision Sciences	1
9	Energy	1
10	Environmental Science	1

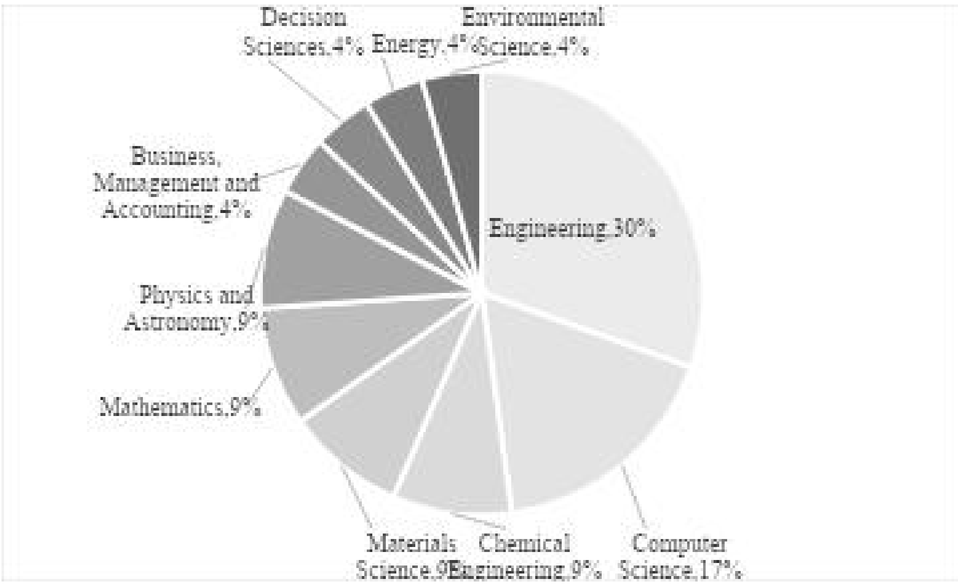

Figure 3. Top 10 Subject Areas in Mahalanobis Taguchi Gram-Schmidt (MTGS).

When comparing the subject-area focus of Mahalanobis Taguchi Gram-Schmidt (MTGS) and Multi-Criteria Decision Making (MCDM), clear distinctions emerge in their breadth and depth of application. MCDM demonstrates a broad and well-established presence across various disciplines, with the highest number of publications found in Computer Science, Engineering, and Mathematics. It is also widely applied in non-technical fields such as Business, Management, and Accounting; Environmental Science; Social Sciences; and Finance. This widespread application reflects MCDM's maturity and versatility as a decision-making tool, widely recognized for its ability to address complex, multi-dimensional problems in both academic and practical contexts.

In contrast, MTGS is still emerging and is more concentrated in technical domains. The majority of MTGS-related studies are found in Engineering, Computer Science, and other mathematically intensive fields such as Chemical Engineering and Materials Science. Its presence in business or social science-related subjects is minimal, indicating that MTGS is currently favored for specialized analytical tasks, particularly those involving variable selection and data classification.

Overall, MCDM appears as a more universally adopted framework across diverse subject areas, while MTGS remains more focused and specialized in its application. This suggests that while MTGS holds strong potential in technical and data-intensive research, it has yet to achieve the widespread interdisciplinary adoption that characterizes MCDM. As MTGS continues to develop and researchers explore its capabilities, its application may expand to a broader range of disciplines over time.

Table 4 presents the ranking of countries that have made significant contributions to publications on Multi-Criteria Decision Making (MCDM). India leads with 50 publications, closely followed by China with 49, indicating strong research engagement in this area. Iran (27), Pakistan (22), and Turkey (16) also show active involvement, marking Asia as a major hub for MCDM research. Other notable contributors include Saudi Arabia (14), the United States (12), Australia (8), Canada (8), and Egypt (8), showing that MCDM is of global research interest. Countries like the United Kingdom, Germany, Taiwan, and Italy also appear in the list with between 6 to 8 publications each, suggesting a modest but relevant involvement.

Table 4 Ranking Countries Contributing to the Publication in Multi-Criteria Decision Making (MCDM)

Ranking	Country	Publications
1	India	50
2	China	49
3	Iran	27
4	Pakistan	22
5	Turkey	16
6	Saudi Arabia	14
7	United States	14
8	Australia	8
9	Canada	8
10	Egypt	8
11	Taiwan	8
12	United Kingdom	8
13	Germany	7
14	Malaysia	7
15	Italy	6

Table 5 illustrates the countries that contributed to the development and publication of research on the Mahalanobis Taguchi Gram-Schmidt (MTGS) method. China ranks first with six publications, indicating a leading role in this specific technique. Malaysia follows with three publications, highlighting its emerging interest in this niche methodology. India indicareappears with a single contribution, suggesting limited yet foundational engagement in MTGS-related research.

Table 5 Countries Contribute to the Publication in Mahalanobis Taguchi Gram-Schmidt (MTGS)

Ranking	Country	Publications
1	China	6
2	Malaysia	3
3	India	1

Comparing both tables reveals distinct differences in the breadth and geographical distribution of research contributions between the two decision-making methods. MCDM enjoys a much broader global engagement, with 15 countries actively contributing

and significantly higher publication volumes. This indicates that MCDM is a more widely adopted and explored methodology across various academic and industrial applications. In contrast, MTGS appears to be a more specialized or emerging technique, with only three countries contributing and a much smaller number of publications. Notably, while China and India are active in both areas, Malaysia's presence in MTGS highlights its specific interest in advancing newer or less conventional decision-making approaches. This contrast underscores the established status of MCDM in global research versus the more nascent development of MTGS, suggesting potential growth areas for countries like Malaysia in specialized decision-making methods.

5.0 FUTURE OF STUDY

Future research can broaden the bibliometric scope by integrating databases such as Web of Science, Dimensions, and CrossRef, thereby enabling a more comprehensive analysis of MCDM and MTGS's academic impact. Additionally, citation network and collaboration analyses can help identify key researchers and emerging research clusters that shape these methodologies. To improve MTGS's capabilities, future studies could explore integrating machine learning models, enabling it to handle complex, high-dimensional data more effectively. Investigating real-world applications such as healthcare diagnostics, risk assessment, and AI-driven decision support systems could further validate its practical relevance. Moreover, comparative analysis with other methodologies, such as Deep Reinforcement Learning (DRL) and Quantum Decision Theory (QDT), can highlight MTGS's unique strengths in decision-making processes. Lastly, longitudinal studies tracking MCDM and MTGS's evolution could provide insights into historical trends, adaptation patterns, and future research opportunities.

6.0 CONCLUSION

This study presents a comprehensive bibliometric comparison of Multi-Criteria Decision Making (MCDM) and Mahalanobis Taguchi Gram-Schmidt (MTGS) methodologies, shedding light on their respective academic development, application domains, and geographic research trends. MCDM emerges as a well-established and extensively utilized decision-making framework, with broad interdisciplinary appeal and significant global research activity, particularly in Asia. In contrast, MTGS is identified as a promising but still emerging methodology, currently limited in adoption but showing potential, especially within technical and data-intensive fields.

While MCDM enjoys robust integration across domains such as Computer Science, Engineering, and Business, MTGS's applications are more concentrated in Engineering and computational sciences. The disparity in publication volume and contributing countries further underscores the maturity of MCDM compared to the nascent growth trajectory of MTGS. However, the unique advantages of MTGS, particularly in handling multicollinearity, position it as a valuable tool for future specialized analytical applications.

This comparative insight serves as a foundation for future research directions, emphasizing the importance of integrating advanced bibliometric techniques and expanding interdisciplinary collaborations to enhance the visibility and applicability of MTGS. Continued exploration of MTGS's capabilities, especially in combination with emerging technologies like machine learning and quantum computing, could significantly elevate its impact in the broader decision-making landscape.

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