

Literature Review: Fuzzy Model - MCDM (Multi-Criteria Decision Making) for Career Adapt-Abilities Scale in Vocational Education

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ABSTRACT

This study analyzes the potential integration of fuzzy logic and Multi-Criteria Decision-Making (MCDM) to measure the Career Adapt-Abilities Scale (CAAS) for Mechanical Engineering vocational high school students. Rapid industrial automation and digitalization require more accurate assessments of career adaptability, while conventional methods remain limited in addressing uncertainty and subjective responses. Using a systematic literature review and bibliometric analysis of 25 Scopus-indexed articles published between 2021 and 2026, this study examines research trends in Fuzzy-AHP, Fuzzy-TOPSIS, and Fuzzy Inference Systems and their relevance to evaluating the psychological dimensions of concern, control, curiosity, and confidence. The findings indicate that fuzzy-MCDM effectively processes linguistic and multi-criteria data, enabling a more comprehensive and contextual assessment of career adaptability. The study offers a conceptual framework for improving career adaptability evaluation and supporting vocational students' career readiness in responding to the demands of modern industry. This is an open access article under the [CC-BY-SA](https://creativecommons.org/licenses/by-sa/4.0/) license.



Introduction

Industrial developments based on automation, digitalization, and digital transformation require vocational education graduates, particularly vocational high school students in Mechanical Engineering, to possess a high degree of adaptability to technological change, job dynamics, and

labor market uncertainty. Several studies on vocational education indicate that modern industry requires a workforce that not only possesses technical competencies and skills but also is capable of continuously adapting to changing industry needs and digital work patterns (digital era skills) Zhang and Wang (2024).

The challenge of industrial development is now evident in the mismatch between learning outcomes in engineering education and industry demands, as outlined in a study on engineering curriculum redesign, which identified a gap in adaptive competencies and the need for more flexible career transitions in the face of the transformation of Industry 4.0 and 5.0 Alogla (2025).

Career adaptability is a key skill for vocational high school students. Career adaptability is measured using the Career Adapt-Abilities Scale (CAAS), which emphasizes four dimensions: concern, control, curiosity, and confidence. Several studies in other countries have shown that the Career Adapt-Abilities Scale (CAAS) significantly influences readiness for career change. Studies also show that career adaptability is closely related to students' resilience in the face of job uncertainty, environmental pressures, and the dynamics of the transition from school to industry Pong and Leung (2023).

In vocational settings such as Mechanical Engineering Vocational High Schools, career adaptability assessments still tend to use conventional Likert scales, which are limited in capturing the ambiguity of student perceptions and variations in subjective assessments of career readiness. Consequently, fuzzy logic and Multi-Criteria Decision-Making (MCDM) approaches have begun to be widely researched as methods capable of handling uncertain, ambiguous, and subjective data. Several studies relevant to this study demonstrate how fuzzy logic improves the accuracy of performance evaluations in the vocational field by converting linguistic data into more stable and adaptive measurable values, for example, in a fuzzy-based vocational performance evaluation system that corrects variations in instructor and student assessments in the context of engineering learning. Fuzzy logic has also proven effective in addressing student behavioral uncertainty, career strategy determination, and psychological analysis related to employability, as demonstrated in the application of fuzzy decision support systems and fuzzy control to college students' job search strategies Li (2025) Xiao and Liu (2024).

Career adaptability assessments in vocational settings still predominantly rely on conventional Likert-scale instruments, which assign fixed numerical values to responses such as "somewhat confident" or "often curious." However, student responses to CAAS items inherently carry linguistic ambiguity that a single integer value cannot fully represent. As demonstrated by Chuang et al

(2022), The psychological factors underlying career adaptability including self-efficacy, motivation, and fear of failure operate with degrees of intensity that vary continuously rather than discretely across students Chuang et al (2022). This subjective and gradient nature of psychological constructs makes Likert-based instruments structurally limited in capturing the full spectrum of a student's career readiness profile. Furthermore, found that in the Indonesian polytechnic context, career adaptability skills are simultaneously shaped by teaching quality, social support, and career self-efficacy, forming a complex interplay of criteria that a single-scale instrument cannot adequately disentangle Mahfud et al (2022). Fuzzy logic addresses this limitation by representing each linguistic response as a membership function, thereby preserving the nuance and uncertainty that a crisp numerical score discards.

MCDM methods, especially fuzzy variants such as Fuzzy-AHP, Fuzzy-TOPSIS, and complex models such as complex Pythagorean hesitant fuzzy MCDM, have been used to assess competency and psychological factors of employability more holistically and accurately. One study showed that fuzzy-based MCDM is able to aggregate subjective and fluctuating multi-criteria information in educational and career decision-making more reliably than traditional methods He (2025).

Although these findings are highly relevant to the context of vocational education, to date there has been no research specifically integrating the Career Adaptability Scale (CAAS) with the fuzzy-MCDM approach in the context of Mechanical Engineering vocational high school students. This research gap exists. Measuring career adaptability through the CAAS reflects a subjective psychological construct and cannot always be accurately represented through a numerical scale. Student responses often contain ambiguity and uncertainty, especially in the context of vocational education such as Mechanical Engineering, where career readiness is influenced by a combination of technical and non-technical factors. The Fuzzy-MCDM approach is relevant because it is able to capture the fuzzy nature of student responses and provides a mechanism for determining the weights between CAAS dimensions in a more systematic and expert-based manner.

Unlike vocational programs in service-based sectors where career trajectories tend to be more predictable, Mechanical Engineering students navigate a uniquely volatile landscape shaped by the rapid adoption of CNC technology, industrial robotics, and automation systems characteristic of Industry 4.0 and 5.0 transitions. As documented in a Southeast Asian systematic review, vocational graduates in technology-intensive fields face amplified career uncertainty due to the accelerating pace at which specific competencies become obsolete while demand for new ones simultaneously emerges Kumar et al (2024). This technological volatility intensifies the salience of all four CAAS

dimensions; concern about the future, perceived control over career decisions, curiosity to explore alternatives, and confidence in one's abilities making the precise and contextually sensitive measurement of career adaptability particularly critical for students in Mechanical Engineering vocational programs.

Accordingly the integration of fuzzy logic and MCDM enables a more accurate, comprehensive, and contextual analysis of career adaptability for vocational high school students majoring in Mechanical Engineering, particularly in facing the demands of job readiness in the ever-evolving industrial era. Based on this need, this study formulated three research questions:

RQ1. How are research keywords related to fuzzy logic, MCDM, and career adaptability scales related to vocational education related to literature review and bibliometric analysis?

RQ2. How do previous research findings explain the potential application of the fuzzy-MCDM approach in assessing or developing a career adaptability model for vocational high school students majoring in Mechanical Engineering?

RQ3. How can the fuzzy-MCDM approach be applied to assess the career adaptability of vocational high school students majoring in Mechanical Engineering based on the results of the literature review?

This study contributes to the development of a new analytical framework for measuring career adaptability that is more sensitive to data uncertainty. Methodologically, this study strengthens the integration of SLR and bibliometrics in analyzing the dynamics of fuzzy-MCDM research in the vocational field. Practically, the results of this study provide a basis for schools, guidance counselors, and vocational school administrators to design career interventions that are more accurate, data-based, and in line with the demands of the future engineering industry.

Method

The method applied in this research is a literature review using bibliometric analysis to measure trends, developments, methodological approaches, dominant keywords, and research themes related to career adaptability, fuzzy logic, and Multi-Criteria Decision-Making (MCDM) methods in the context of vocational education, specifically in Mechanical Engineering. The research focuses on scientific publications published between 2016 and 2025 to provide a current overview of how fuzzy logic and MCDM approaches are used in evaluation or decision-making processes in the domains of career education and psychology.

This approach is a systematic and structured research process. During the implementation stage, this research explores various sources of information, such as journal articles, research reports, and other scientific works related to the research issue. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) is a well-known guideline used in the development and reporting of systematic studies, with the aim of ensuring quality and transparency in research. These guidelines provide a systematic framework for identifying, selecting, analyzing, and presenting relevant publications, resulting in accurate and reliable findings Moher et al (2009).

The literature was found using the Scopus database, ensuring that the selected search terms were relevant to the fuzzy approach based on multi-criteria decision-making (MCDM) related to career adaptability in the context of engineering students' vocational studies. In this systematic review, the search sequence per selected electronic database was as follows:

TITLE-ABS-KEY (("fuzzy" OR "fuzziness" OR "fuzzy logic" OR "fuzzy set") AND ("mcdm" OR "multi-criteria decision making" OR "multi-criteria analysis" OR "decision support") AND ("education" OR "learning" OR "teaching" OR "instruction") AND ("approach" OR "method" OR "strategy" OR "framework"))

The literature search was conducted exclusively through the Scopus database, a decision supported by three considerations. First, Scopus provides the broadest and most consistent coverage of engineering and applied sciences journals among multidisciplinary academic databases, ensuring comprehensive retrieval of fuzzy-MCDM studies relevant to the engineering education context of this review Yusop et al (2022). Second, Scopus offers native bibliometric export capabilities including cited-by counts and author keyword data that are directly compatible with VOSviewer for co-occurrence network analysis, which is integral to the bibliometric component of this study. Third, recent systematic reviews in closely related domains, including studies on career adaptability in vocational education conducted within the Southeast Asian context and on fuzzy-MCDM applications in educational evaluation James et al (2023), have similarly relied on Scopus as their primary or sole database, demonstrating its sufficiency for capturing the relevant body of literature. A preliminary keyword cross-check confirmed substantial overlap between Scopus and Web of Science results for the applied search string, further validating this decision.

A keyword search was conducted to identify various studies discussing the application of fuzzy and Multi-Criteria Decision-Making (MCDM) approaches in educational contexts, including methods, strategies, frameworks, and decision support models. This keyword combination aims to capture relevant literature to understand how fuzzy and MCDM techniques are used in evaluation

processes, decision-making, or the development of learning methods, thus providing a basis for analyzing their potential integration in assessing the career adaptability of vocational high school students. This search helps build a strong theoretical foundation for the development or analysis of fuzzy and MCDM approaches in the context of career assessment in Mechanical Engineering Yusop et al (2022) Do et al (2024).

Inclusion and exclusion criteria were applied to ensure the selection of studies relevant to the research question. Inclusion and exclusion criteria must be applied to each study. The initial search yielded 870 articles. Articles were selected based on the inclusion and exclusion criteria outlined in Table 1. These criteria narrowed the selection to 113 articles, which were then further evaluated for quality and relevance to the topic discussed in this study. Inclusion and Exclusion Criteria presented in Table 1.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria
Articles published between 2021 and 2026
Most Relevant Results with Fuzzy Logic
Studies have undergone peer review
Subject area limited to Engineering
Publications are available in full text through the Institute's access
Exclusion Criteria
Articles published before 2020
Articles with less relevant results using Fuzzy Logic
Articles not peer-reviewed
Articles outside the scope (subject area)
Publications not available in full text through institutional access

Furthermore, several articles were excluded from the selection process because they did not meet the established inclusion criteria. The 25 selected articles were analyzed to answer the research questions, using a data extraction procedure visualized using a PRISMA flowchart.

The literature selection process in this study followed the PRISMA flowchart in Figure 1, which consists of identification, screening, eligibility, and inclusion. An initial search of the Scopus database yielded 1,801 articles. After removing 931 duplicate articles, the process continued with filtering based on publication year, leaving 870 articles. Subsequent selection focused on the

Engineering field, yielding 350 disciplinary-relevant articles. Further examination of peer-reviewed status left 219 articles. In the eligibility stage, the focus was determined on articles containing the keyword "Fuzzy Logic," narrowing the number to 38 articles. After ensuring that all articles were open access, 25 articles were deemed to meet the final criteria and were included in the analysis. This overall process ensured that the reviewed literature met the standards of relevance, academic quality, and accessibility for further analysis. PRISMA diagram presented in Figure 1.

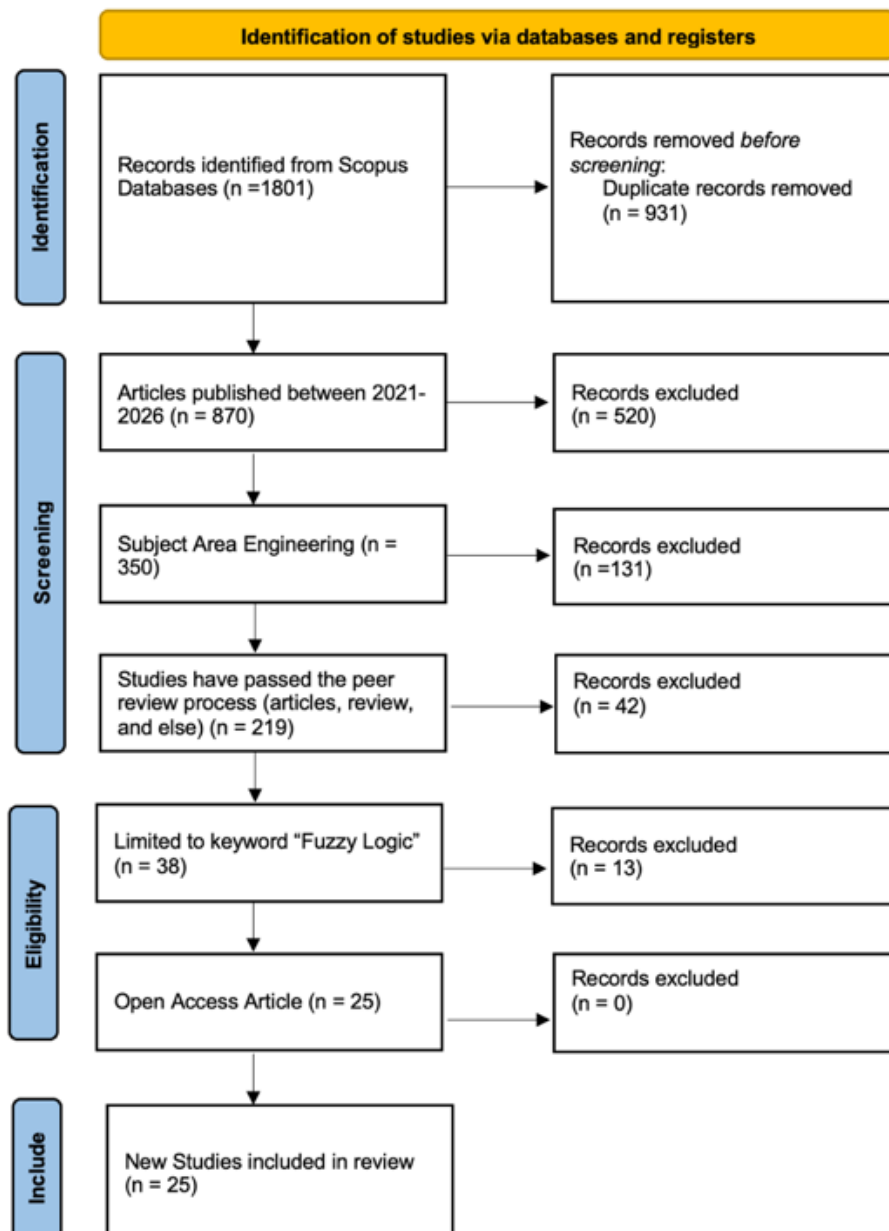


Fig 1: PRISMA Diagram

Result and Discussion

Global Visualization of Research Based on Bibliometric Analysis (VOSviewer)

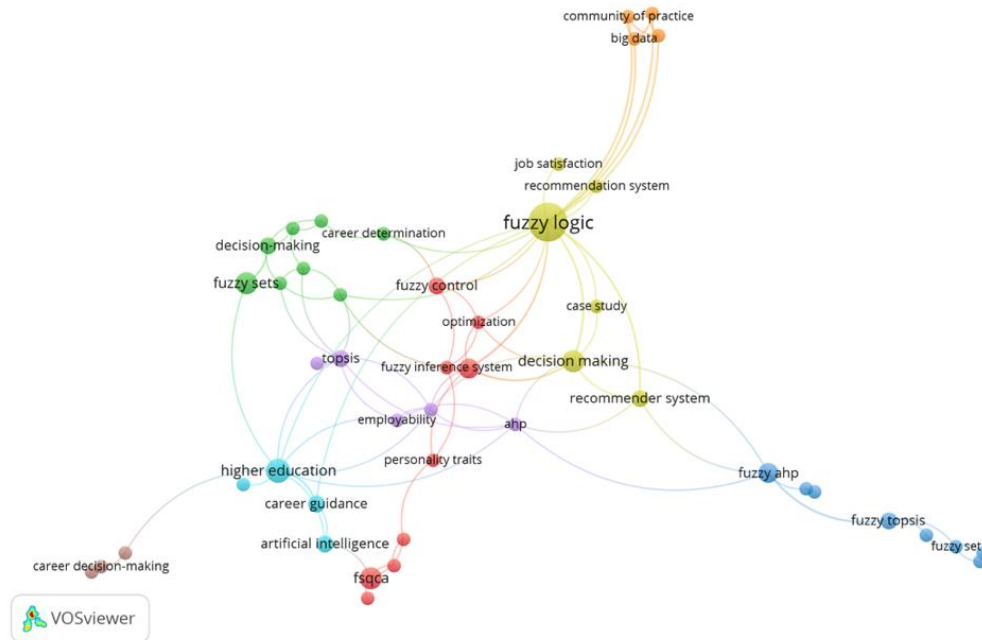


Fig 2: Network Visualization

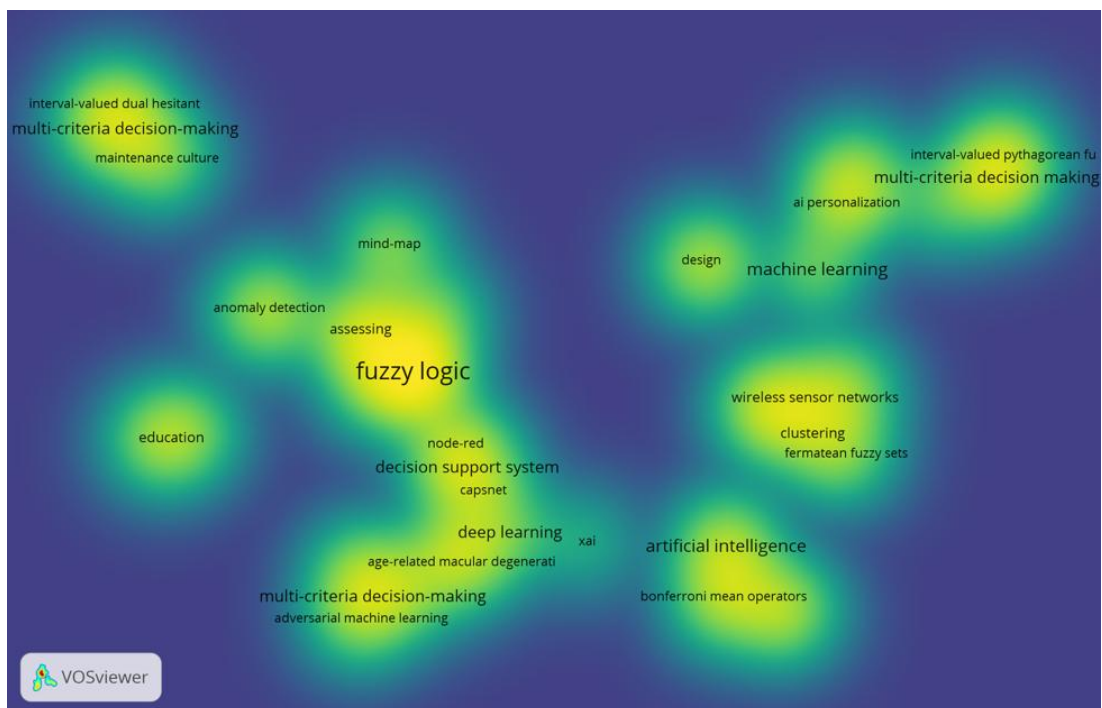


Fig 3: Density Visualization

The results of the keyword network visualization are described in the following Table 2:

Cluster Color	Dominant Keywords	Thematic Focus	Cluster Conclusion
Yellow Cluster	<i>fuzzy logic, decision making, recommender system, job satisfaction, optimization, case study</i>	Fuzzy logic as a core method in decision making and recommendation systems	This cluster shows that fuzzy logic plays a central role in research, particularly in building recommendation systems, supporting decision-making, and solving optimization problems. This reflects the dominance of fuzzy logic as a basic framework in multi-criteria evaluation.
Green Cluster	<i>fuzzy sets, decision-making, career determination, decision-making</i>	Decision making with a fuzzy approach and its implications for career determination	This cluster emphasizes the strong relationship between fuzzy sets and decision-making processes, including in the context of career choice and employability, demonstrating the relevance of fuzzy-MCDM in the context of career guidance and vocational education.
Red Cluster	<i>fuzzy inference system, personality traits, employability, fuzzy control</i>	Evaluation of personality, competence, and employability using fuzzy	This cluster shows that fuzzy is used to assess non-technical characteristics such as personality and employability. This indicates the potential use of fuzzy in assessing career adaptability due to the subjective and uncertain nature of the construct.
Blue (Dark/Light) Cluster	<i>fuzzy AHP, fuzzy TOPSIS, fuzzy set</i>	fuzzy-MCDM Methods (AHP, TOPSIS, dsb.)	This cluster shows that research has focused heavily on the development and application of fuzzy-MCDM methods for decision analysis. This provides an important methodological basis for developing fuzzy-MCDM-based career adaptability assessment models.
Tosca Cluster	<i>higher education, career guidance, artificial intelligence, career decision-making</i>	Fuzzy and AI in higher education and career guidance	This cluster demonstrates that fuzzy and artificial intelligence technologies are used in the context of career guidance and education, thus strengthening the relevance of the fuzzy approach in evaluating vocational students' career readiness and adaptability.
Orange Cluster	<i>big data, community of practice, recommendation system</i>	Application of big data and communities of practice in recommendation systems	This cluster demonstrates the direction of fuzzy research developments related to big data and community-based learning. While not directly related to career adaptability, this cluster demonstrates the integration of fuzzy with big data-based recommendation systems in an educational context.

The VOSviewer density map visualization shows that fuzzy logic is at the center of research concentration, indicated by the densest yellow area. This is in line with the findings of He et al (2025), who explained that fuzzy logic has advantages in handling uncertainty and ambiguity in the assessment and decision-making process, thus naturally appearing as a cluster center in the literature. Furthermore, terms such as decision support system, anomaly detection, and assessing surrounding fuzzy logic indicate that fuzzy methods are widely used in multi-criteria-based evaluation. He et al (2025) asserted that fuzzy-based MCDM is a very effective tool for selecting the best alternative in complex situations, thus supporting the interpretation that the cluster is dominated by decision-making and evaluation research that requires a flexible mathematical approach.

The right side of the map shows the concentration of clusters in machine learning, artificial intelligence, clustering, and Fermatean fuzzy sets. This pattern aligns with the paper Li (2024), which emphasizes that machine learning and artificial intelligence approaches are increasingly being integrated with fuzzy logic to create more adaptive learning and recommendation systems. Li (2024) explains that fuzzy-based systems can enhance learning personalization by managing ambiguous data and generating more accurate automated decisions, thus explaining why machine learning and AI personalization emerged as a strong cluster in the visualization. This density map confirms that current research is moving toward integrating fuzzy logic, MCDM, and artificial intelligence to support smarter and more adaptive decision-making in education and technology contexts.

Paper Sustainability Research Theme Clusters (Based on Article Review)

Discovery from several journals that will be reviewed generally show that the fuzzy-MCDM approach has great potential to be used as a framework for assessing and developing career adaptability models for Mechanical Engineering Vocational School students, mainly because of three things: (1) CAAS has been proven to be a complex multi-dimensional construct; (2) fuzzy-MCDM is very strong in processing subjective, linguistic, and multi-criteria data; and (3) there are already several direct applications in educational, career, and vocational contexts that can be adapted to Vocational Schools.

The CAAS article demonstrates that career adaptability is indeed worthy of being treated as an object of multi-criteria decision-making. The “CAAS-5-SF” study on Turkish high school students validated the five-dimensional model (concern, control, curiosity, confidence, cooperation) and showed that CAAS scores were positively related to problem-solving self-efficacy and negatively to

perceived stress Korkmaz and Kirdök (2025). This means that each dimension represents a psychosocial criterion that contributes differently to career adaptability readiness. A study on Italian high school students found that social, emotional, and behavioral skills (self-management, innovation, social engagement) predicted career adaptability factors and their four sources Pellegrino et al (2025). For vocational high school students in Mechanical Engineering, this suggests that career adaptability profiles are a combination of several criteria: CAAS dimensions, soft skills, academic achievement, and school/industry context exactly the type of problem suitable for fuzzy MCDM modeling.

Several studies have shown that fuzzy MCDM is highly effective for career decision-making and human resource selection. This article uses fuzzy and clustering models to map individual characteristics to career clusters in a flexible manner (each individual has a degree of membership in several career clusters), thereby capturing ambiguity and uncertainty in career preferences and potential He (2025). Another study on MCDM for PhD candidate selection uses AROMAN Fuzzy Z-numbers to weight and score candidates based on criteria such as length of study, problem-solving ability, communication and presentation skills, with expert judgment based on linguistic terms and uncertainty of information sources Gottwald et al (2024) Paraskevas and Madas (2024). Both approaches can be relatively straightforwardly adapted to rank or group Mechanical Engineering vocational high school students based on CAAS scores, workshop practice scores, soft skills, and work field preferences (production, maintenance, CNC, QC), resulting in more personalized career path recommendations and mentoring interventions.

Articles demonstrate direct applications of fuzzy and soft computing to educational and vocational data. The Fuzzy-based Decision Support Model for Deciding Students' Academic Performance combines various linguistically assessed indicators (grades, attendance, behavior) into decisions about students' academic performance levels using fuzzy rules, allowing subjective teacher assessments to be translated into more consistent and transparent scores Utama and Kurniawan (2021). Another article in Mathematics uses ANFIS to analyze student motivation in vocational subjects and shows that a combination of prior knowledge, innovative learning technologies, and classroom atmosphere are the most significant factors in predicting vocational student motivation Mojsilović et al (2025).

These examples demonstrate that vague psychological/educational data (motivation, attitudes, readiness) can be effectively modeled using fuzzy logic and neurofuzzy systems. This opens up the possibility of modeling vocational high school students' CAAS as a fuzzy inference system that

combines CAAS Likert scale scores, learning environment variables, and workshop behavior indicators to generate a career adaptability index or risk category (e.g., low, medium, high).

Fuzzy-MCDM studies in the engineering and policy domains reinforce the argument that this approach is well-suited to complex and uncertain contexts—similar to the school-to-work transition in vocational high schools. The hybrid MCDM framework developed by Faisal et al. uses Fuzzy Delphi and SWARA to weight criteria, MABAC for ranking, and PSOM–Random Forest for clustering city strategies for carbon trading Faisal et al (2025). Methodologically, this pattern can be paralleled to Mechanical Engineering Vocational Schools: technical aspects (machining process competency, K3, work precision), psychosocial aspects (four dimensions of CAAS, SEB skills), and contextual aspects (access to industrial internships) are used as criteria that are weighted with Fuzzy Delphi/SWARA, then combined through TOPSIS/WASPAS or similar techniques to produce a career adaptability index and intervention priorities.

Recent CAAS literature confirms that career adaptability is a key resource related to various important outcomes (life satisfaction, academic achievement, career decision efficacy, and stress), and that this framework can be extended with a culturally sensitive cooperation dimension. If these dimensions are treated as criteria in a fuzzy-MCDM model, teachers in vocational high school mechanical engineering departments can: (1) profile students based on a combination of CAAS dimensions, soft skills, and vocational performance; (2) group students into career service need clusters; and (3) provide data-informed career recommendations that still accommodate the uncertainty and diversity of individual contexts. Thus, previous research findings consistently indicate that fuzzy-MCDM is not only technically appropriate but also substantively relevant as an approach to assessing and developing career adaptability models for vocational high school mechanical engineering students.

The fuzzy-MCDM approach can be applied to assess the career adaptability of Mechanical Engineering vocational high school students because this method is able to handle the uncertainty and subjectivity inherent in the psychological dimensions in the Career Adapt-Abilities Scale (CAAS). In several previous articles, it was explained that fuzzy set theory is very suitable for use in problems that do not have clear definition boundaries, because "fuzzy set theory is advantageous for problems and notions that lack precise explanations, such as vagueness and doubt" He et al (2024). Thus, CAAS indicators such as concern, control, curiosity, and confidence can be represented in the form of linguistic values and defuzzification to produce a more objective assessment. In addition, He et al (2025) emphasized that the MCDM method is an effective tool in selecting the best alternative in

multi-criteria situations, so it can be used to combine various aspects of Mechanical Engineering students' career adaptability into a measurable composite score.

Practical Application of Fuzzy-MCDM for Career Adaptability Assessment: A Brief Simulation

To illustrate how the fuzzy-MCDM framework can be applied practically by educators, the following simulation demonstrates a step-by-step assessment of a student's career adaptability profile in a Mechanical Engineering vocational high school setting. The procedure adapts the Fuzzy Delphi Method (FDM) and AHP approach used by Xing et al (2024), who successfully constructed a weighted student development assessment instrument for vocational universities in China, and the AHP-fuzzy comprehensive evaluation model proposed by Wu et al (2022), which proved more objective and practical than conventional single-scale methods in multilevel educational evaluation contexts.

Consider Student A, a Grade XII student in the Machining Engineering program. Student A completes the CAAS instrument using a 5-point Likert scale. Each response is converted into a Triangular Fuzzy Number (TFN) to capture the linguistic ambiguity of self-reported psychological constructs James et al (2023). Dimension weights are then determined via Fuzzy AHP pairwise comparison by a panel of three school-based experts a guidance counselor, the head of the Mechanical Engineering program, and an industry partner Zhou and Yang (2025). This weighting procedure is consistent with James et al (2023), who demonstrated that the Fuzzy AHP-TOPSIS hybrid is effective and bias-free for educational evaluation involving multiple decision-makers. The weighted fuzzy scores are subsequently defuzzified using the centroid method [$\text{crisp} = (l + m + u) / 3$], yielding a single Career Adaptability Index (CAI) that maps to an interpretive category for practical use. The complete calculation and its recommendations are presented in Table X below. The Example Fuzzy-MCDM Assessment of Career Adaptability and Recommended Interventions for Student "A" presented in Table 3.

The resulting CAI of 0.703 (Moderate-High) provides the guidance teacher with a criterion-disaggregated profile that is not available through conventional Likert-scale scoring. Rather than a single average, the teacher can immediately identify that Confidence (0.080) and Control (0.150) require priority intervention, while Curiosity (0.233) represents an existing strength to be leveraged. This output directly supports the type of personalized, data-informed career guidance that Mahfud et al. (2022) found to be consequential in the Indonesian vocational context, where career self-efficacy closely linked to the Confidence and Control dimensions serves as the key mediator of students' career adaptability.

Table 3. The Example Fuzzy-MCDM Assessment of Career Adaptability and Recommended Interventions for Student “A”

CAAS Dimension	Likert	TFN (l, m, u)	Score (w _i)	Crisp Value*	Weighted Score	Intervention Recommendations
Concern	4	(0.6, 0.8, 1.0)	0.30	0.800	0.240	Facilitate industrial visits & career exploration
Control	3	(0.4, 0.6, 0.8)	0.25	0.600	0.150	Decision making & career reflection exercises
Curiosity	5	(0.8, 1.0, 1.0)	0.25	0.933	0.233	Point to relevant internship programs
Confidence	2	(0.2, 0.4, 0.6)	0.20	0.400	0.080	Priority: interview simulation & self-efficacy strengthening
Career Adaptability Index (CAI) — defuzzifikasi centroid					0.703	Moderate-High → Intervention priorities: Confidence & Control

He (2025) affirmed that MCDM methods enable educators to select the most appropriate intervention strategy in multi-criteria situations by systematically comparing alternatives against a weighted ideal, reinforcing the practical utility of the CAI profile for targeted guidance planning.

Conclusion

This literature study shows that the integration of fuzzy logic and Multi-Criteria Decision-Making (MCDM) offers a clearer, more adaptive, and more sensitive approach to psychological characteristics in measuring career adaptability in Mechanical Engineering vocational high school students. Previous research findings have shown that CAAS is a multidimensional construct that contains uncertainty and subjectivity, so conventional assessment methods have not been able to accurately describe the complexity of students' career readiness Amin et al (2025). Through fuzzy's ability to handle ambiguous linguistic data and the strength of MCDM in systematically integrating various criteria, the fuzzy-MCDM approach can accommodate the dynamics of technical, psychosocial, and contextual factors that influence the career readiness of vocational students in the current industrial era. Thus, this approach is not only theoretically relevant but also has a strong empirical basis for application in the context of Indonesian vocational education.

The results of the bibliometric analysis and systematic review show that research related to fuzzy-MCDM in the education and career domain continues to grow, but has not yet touched on

direct integration with CAAS in the context of Vocational High Schools in Mechanical Engineering. This research gap emphasizes the urgency of developing a new evaluation framework capable of producing more accurate, personalized, and data-driven career adaptability profiles. This study contributes by providing a conceptual and methodological foundation for the development of an assessment model that not only supports the career guidance process but can also be utilized by schools and industry stakeholders to design more targeted interventions. In conclusion, this study confirms that fuzzy-MCDM is a strategic approach to improve the accuracy of career adaptability assessments and support the readiness of vocational high school graduates in facing the dynamics of future industrial transformation. Nonetheless, this study acknowledges several limitations inherent to its design. The reliance on a single database (Scopus) and the restriction of the search scope to the Engineering subject area, while methodologically deliberate, may have excluded relevant interdisciplinary studies indexed in other databases such as Web of Science or ERIC.

Furthermore, as this study is conceptual in nature proposing a fuzzy-MCDM framework based on synthesized evidence rather than empirically validating it with real student data the generalizability of the proposed model to the specific cultural, curricular, and institutional contexts of Indonesian Mechanical Engineering vocational schools remains to be established. Future research should therefore prioritize the empirical validation of the proposed framework through direct application with actual CAAS response data from SMK students regarding career adaptability in the Indonesian vocational context and the methodological precedents in cross-cultural CAAS validation.

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