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Towards a Comprehensive Decision Framework With Linguistic Neutrosophic Data:

GRA-Based Combined Approach to Technology-Enabled General High School Education Quality Evaluation

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ABSTRACT

High school education quality assessment holistically evaluates student development, teaching effectiveness, and curriculum implementation. It integrates academic performance with core competencies like critical thinking. This comprehensive process involves multiple stakeholders to inform school improvement and ensure education aligns with broader developmental goals for every learner. The technology-enabled general high school education quality evaluation is multiple attribute group decision making (MAGDM). In this paper, the 2-tuple linguistic neutrosophic number (2TLNN) grey relational analysis (GRA) method (2TLNN-GRA) is constructed based on GRA and 2-tuple linguistic neutrosophic sets (2TLNSs). The 2TLNN-GRA method is constructed for solving the MAGDM problem. Finally, the numerical example for technology-enabled general high school education quality evaluation is constructed with some comparative analysis.

KEYWORDS

Multiple Attribute Group Decision Making (MAGDM), 2TLNSs, GRA Method, Education Quality Evaluation

INTRODUCTION

Multi-attribute group decision making (MAGDM) is a structured process for reaching a collective choice when multiple alternatives must be evaluated against several, often competing, criteria by a group of individuals (Cao et al., 2026; Li et al., 2026; Xiao et al., 2026; Zulqarnain et al., 2025). It is fundamental in complex scenarios where no single option excels in every aspect, requiring a balanced synthesis of diverse perspectives. The process typically involves defining a set of potential alternatives and a common set of evaluative dimensions or attributes (Lei et al., 2023; Ning et al., 2025; Xu et al., 2025). Each decision-maker then provides their assessment, often based on personal expertise or preference, regarding each alternative's performance concerning each attribute (Guo et

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al., 2024; Gupta et al., 2024; Hendiani & Walther, 2024; Huo et al., 2024). The core challenge of MAGDM lies in aggregating these individuals, frequently subjective, judgments into a coherent group consensus or ranking (Ning et al. 2025a, 2025b; Wang et al., 2024; Zhang et al., 2024). This involves mathematical techniques to fuse qualitative and quantitative data, reconcile differing opinions, and weight the importance of both various attributes and different experts. Advanced methods like those integrating fuzzy sets or grey systems are employed to handle the inherent uncertainty and imprecision in human judgment (Ning & Wei, 2023; Wang et al., 2023; Zhang et al., 2023; Zhang et al., 2022). The ultimate goal is to derive a systematic, transparent, and defensible ranking that best reflects the collective wisdom of the group, guiding an optimal final selection (Zhang et al., 2025; Zhang & Liu, 2025; Zhang & Zhu, 2025a, 2025b).

Grey relational analysis (GRA) (Deng, 1989) is a method used to measure the relational degree between various factors within a system by analyzing the geometric similarity of their data sequences. It determines how closely different sequences follow a chosen reference pattern. Unlike traditional statistical methods requiring large datasets, GRA is effective with small, incomplete, or uncertain information. The core process involves normalizing data, calculating relational coefficients based on distance differences, and then deriving a final relational grade for each comparative sequence. This grade quantifies the influence or correlation, aiding in factor identification, system behavior analysis, and multi-criteria decision-making by ranking alternatives based on their proximity to an ideal benchmark (Abdullahu et al., 2024; Sun et al., 2022; Wei, 2011a). GRA has been widely applied as an effective tool for addressing problems in systems with incomplete or uncertain information (Lu & Lin, 2020; Özomay & Akalin, 2022; Pang et al., 2022; Sun et al., 2018). Over the past decade, its methodological framework and applicable environments have continuously expanded and deepened through ongoing research. Early research focused on integrating GRA with novel forms of uncertain information representation. Wei (2011b) pioneered the application of GRA to a 2-tuple linguistic variable environment to handle multiple attribute group decision-making problems with incomplete attribute weight information. This approach determined weights by establishing an optimization model based on the maximizing deviation method and ranked alternatives by calculating their linguistic degrees of grey relation to the positive and negative ideal solutions, effectively preventing information distortion in linguistic processing. In the same year, Wei (2011a) further extended the research to the domain of intuitionistic fuzzy sets. For situations where attribute values were intuitionistic fuzzy numbers and weight information was incomplete or entirely unknown, corresponding GRA optimization models were established, and a simplified formula for determining weights when they were completely unknown was derived. The method was subsequently extended to an interval-valued intuitionistic fuzzy environment. As the forms of linguistic expression in decision-making became more complex, the application of GRA evolved accordingly. Lei et al. (2019) investigated multiple attribute group decision-making under probabilistic linguistic term sets. They utilized the core idea of GRA to construct a model for determining attribute weights and made selections by comprehensively calculating the grey relational coefficients between alternatives and the probabilistic linguistic positive and negative ideal solutions. The method was ultimately applied to the waste incineration plant location problem. Wei et al. (2020) addressed probabilistic uncertain linguistic information. They innovatively combined the CRiteria Importance Through Intercriteria Correlation (CRITIC) method to objectively derive completely unknown attribute weights and made decisions based on an improved GRA method that calculated relative relational degrees, applying this to the site selection planning for electric vehicle charging stations. Recent studies have shown a trend towards methodological integration and deepening cross-domain applications. He et al. (2021) developed a dynamic decision support model integrating a knowledge-based cluster, multiple multi-criteria decision-making techniques, and GRA for evaluating and selecting advanced manufacturing machine tools, specifically addressing scenarios involving mixed objective and grey-imperfect data. Regarding fuzzy environments and social network decision-making, Garg et al. (2023) proposed a fuzzy GRA technique capable of handling both experts' linguistic evaluations and crisp numerical values.