British Journal of Multidisciplinary and Advanced Studies:
Arts, Humanities and Social Sciences 4 (6),20-49, 2023
Print ISSN: 2517-276X
Online ISSN: 2517-2778
Website: https://bjmas.org/index.php/bjmas/index
Published by European Centre for Research Training and Development UK

Empirical Analysis of Decision Recommendation Models for Various Processes from A Pragmatic Perspective

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doi: https://doi.org/10.37745/bjmas.2022.0358 Published November 26 2023

Citation: Priyanka Gonnade and Sonali Ridhorkar (2023) Empirical Analysis of Decision Recommendation Models for Various Processes from A Pragmatic Perspective, *British Journal of Multidisciplinary and Advanced Studies*: Arts, Humanities and Social Sciences 4 (6),20-49

ABSTRACT: *Decision recommendation models allow researchers and process designers to identify & implement high-efficiency processes under ambiguous situations. These models perform multiparametric analysis on the given process sets in order to recommend high quality decisions that assist in improving process-based efficiency levels. A wide variety of models are proposed by researchers for implementation of such recommenders, and each of them varies in terms of their functional nuances, applicative advantages, internal operating characteristics, contextual limitations, and deployment-specific future scopes. Thus, it is difficult for researchers and process designers to identify optimal models for their functionality-specific use cases. Due to which, they tend to validate multiple process models, which increases deployment time, cost & complexity levels.To overcome this ambiguity, a detailed survey of different decision process recommendation models is discussed in this text. It was observed that Fuzzy Logic, Analytical Hierarchical Processing (AHP), Technique for Order Performance by Similarity to Ideal Solution (TOPSIS), and their variants are highly useful for recommendation of efficient decisions. Based on this survey, readers will be able to identify recently proposed decision recommendation models, and identify functionality-specific models for their deployments. To further assist the model selection process, this text compares the reviewed models in terms of their computational complexity, efficiency of recommendation, delay needed for recommendation, scalability and contextual accuracy levels. Based on this comparison, readers will be able to identify performance-specific models for their deployments. This text also proposes evaluation of a novel Decision Recommendation Rank Metric (DRRM), which combines these parameters, in order to identify models that can optimally perform w.r.t. multiple process metrics. Referring to this parameter comparison, readers will be able to identify optimal recommendation models for enhancing performance of their decision recommendations under real-time scenarios.*

KEYWORDS: Decision, Process, Recommendation, AHP, Fuzzy, TOPSIS, Machine, Learning, Bioinspired, Process

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INTRODUCTION

Challenges in industrial selection and business process management often thwart the efforts of several interacting decision-making organizations [1, 2]. preferred implementation from the top down. While each thing strives to achieve its own goals as efficiently as possible, it is affected by the activities of other organisms at the same or higher level. Engineering control [10], logistics [15], manufacturing [9], and road network management [13] are only a few examples of fields where hierarchical decision-making is commonplace. To explore these concerns, researchers create a fictional university setting. University research is being strengthened by new methods of developing research. University-wide efforts impact how professors approach their research. This protocol is followed by all departments and academic establishments. Faculty engagement and departmental initiatives both have the potential to impact expansion plans for scholarly inquiry at universities. Despite some degree of oversight from higher up, every university decision-making institution pursues its own goals to the fullest extent possible using research and development strategies. The professors and departments may act in response, but the university administration may take steps to dampen the effect, such as by redistributing funds or instituting caps. Methods for efficiently coding the objectives and decision criteria of all parties involved to improve the quality of research conducted by the institution. Problems in multi-level optimization, decision-making, or programming [1, 4, 8]. Multiple parts of a choice may be optimized as separate, hierarchical subproblems with the help of multilevel programming [23]. For these uses, just a subset of its parameters need to be optimized for the remaining variables. Programming at two levels, or bilevel, is a subset of multilevel programming (in particular, when researchers talk about trilevel programming). In bilevel programming, the "leader" entity makes the higher-level decisions while the "follower" entity makes the lower-level decisions [5, 6, 11, 12, 14, 20]. Trichotomous options have three distinct levels each. A middle-level entity may also serve as a leader for certain bottom-level entities in a trilevel decision where the top-level entity functions as the leader and the middle and bottom levels are its followers. After the first two stages, the decision-making process becomes increasingly convoluted [7]. Models developed for trilevel choices may be easily transferred to other multilevel decision situations since they have all the necessary components. In this study, researchers examine the decision-making process across three levels of management. Lai [19], Bard and Falk [4], White [28], Shih et al. [25], and Bard and Falk [4] have all looked at trilevel decision-making/programming. The investigation is narrowed down to a single follower. Most practical tri-level applications include a number of decision entities interacting at the middle and lower levels. Since faculty goals and reactions to university initiatives may differ, it's important to view them independently. In addition to providing a variety of decision-making situations, these skills may interact in a number of ways, for as by sharing limits and selection criteria. Faculty answers and connections to related departments will shape the institution's conclusions. Trilevel decision problems were studied by Shih et al. [25], but they did not categorize their relationships or provide alternative models. A third degree of decision-making complexity is introduced by the interdependence of higher- and lower-level entities. The entity in the middle level of a trilevel decision problem has direct influence on the entity at the top, while the entity at the bottom only has indirect impact. The suggested action of the top-level decision entity may be modified based on the replies from the lower levels. University divisions (or research institutes) may have some influence over the final choice. When making decisions, certain academic departments work together while others do not. The many

scenarios presented by the trilevel possibilities are the result of the decisions made by a wide range of entities at the two lower levels. There is a dearth of approaches and results for modeling intricate decision-making contexts in the literature. According to [25], a generic solution to a decision problem cannot be proposed when the constraint set affects all decision components.

Collaborative decision-making is a common theme in the literature on engineering management [1, 2] and IFS [3]. (GDM). Decision makers (DMs) enter intuitive fuzzy [4] preference data on each item in relation to a criterion, and the values of these preferences are combined into a single evaluation decision matrix. DMs make errors because they are scared to put concrete numbers into the decision matrix. Xu [5] detailed a method for completing intuitionistic fuzzy preference relations that lacked complete data (IFPR). A little later, Jiang and Xu [6] came up with two reasonable methods for dealing with partial IFPRs. These explanations deal with the gaps in the IFPR but not the decision matrix based on the IFS. The authors of this research paper suggest a new approach to dealing with missing information in IFS-based decision matrices. Additive and multiplicative methods [7-9] have been investigated by researchers interested in IFPR consistency and repair. There was not enough attention paid to ensuring the decision matrix based on IFS was consistent. In this piece, researchers use Cronbach's alpha coefficient to the IFS setting to assess the reliability of the decision matrix. A new method for developing a decision matrix was also developed. Since several DMs provide ratings for each product, combining the ratings into one is being investigated. Research on IFS aggregation has been conducted by a number of scholars [10-18]. Keeping relationships between criteria is difficult even if these operators use IFS-based data about DM preferences. This problem was addressed by adapting the Bonferroni mean (BM), Frank's symmetric mean (MSM), and Maclaurin's symmetric mean (MSM) to IFS. Despite the fact that generality was provided, some operators nonetheless chose to ignore it. Extending the MSM operator to the IFS setting is the focus of this essay (IFGMSM). The following operators may be constructed more quickly and easily with the help of IFGMSM. Step two involves assigning relative importance to various factors inside the decision framework. Estimating the weights of criteria may be done using tools like the analytical hierarchy process (AHP) [22], [23], a method for ranking preferences in accordance with how close they are to the perfect answer, and entropy measures [24, 25]. When just some of the criteria weights are available, or if decision makers wish to demonstrate inequality across criteria, they turn to mathematical programming methodologies [26, 27]. By choosing preferences close to the positive ideal solution or distant from the negative ideal solution, DMs may more readily arrange the weights (relative importance) of each criterion. Think through the specifics of each criteria before assigning weights. [28]. In this work, researchers provide a novel mathematical model for IFS that determines the best course of action. The appropriate item is chosen from the pool of possibilities using a complicated proportion assessment (COPRAS) strategy that has been recently improved using information from the IFS. Because of its flexibility in handling preference data from several angles and providing a ranking order for different preference values, researchers decided to include IFS into COPRAS. To better understand the challenges, researchers first surveyed works in engineering and technology management that have used MCDM to enhance decision making. As a means of evaluating DMs, Sun et al. [32] proposed a system that prioritizes R&D efforts, reduces complexity in selection sets, and produces rankings.

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For these recommenders, researchers provide a number of different deployment alternatives, each with its own set of unique features, advantages, limitations, and long-term goals based on the specifics of the recommended use case. It is a challenge for researchers and engineers alike to determine which models are best suited for a certain application. They take their time evaluating various process models, which extends the time to implementation and the cost involved. The following part discusses many types of suggestion processes for decision-making, with the goal of reducing ambiguity. After that, researchers evaluate the models based on their processing speed, scalability, latency, and contextual accuracy. Unexpected findings concerning the evaluated models and suggestions for improving their performance in multiple application contexts are presented in this investigation for different use cases.

Detailed review of existing decision recommendation models

Researchers have presented a broad range of decision suggestion models, and each one differs in terms of its internal functioning properties and application cases. This section explores these models' functional quirks, practical benefits, internal operational traits, situational constraints, and potential future applications. For instance, the research described in [1] provides a comprehensive overview of the major advancements in fuzzy and linguistic decision-making over the last 50 years, including articles, models, strategies, and trends. When people are ambiguous, imprecise, or utilize natural language to assess alternatives, criteria, etc., fuzzy and linguistic decision-making (FLDM) systems may be able to handle challenging real-world choice situations. There are three stated goals for this essay. The fundamental concepts of word-based decision information representation and fuzzy set theory are first discussed. We next examine frameworks for multicriteria, consensus-driven, and multipartite multicriteria decision making. The second section of the paper looks at novel, complex decision-making frameworks that rely on the "wisdom of the crowd" to make judgments. Its accompanying difficulties are discussed, and important recommendations for more study in the field are presented.

According to research in [2], healthcare involves complex decisions. Right now, having a tool that encourages proper decision-making is crucial. The healthcare process is complex, with phases ranging from basic through palliative care that differ and are related based on the illness. Each stage must make a crucial choice based on the activities made before it. The best answer is an IDSS model based on data mining. The existing IDSS and GDSS used a one-step construction approach for preset targets. In contrast, healthcare decision-making at all levels is dynamic. This paper proposes an interconnected decision-making model (IDM) for IDSS in healthcare that considers both early and later treatment phases in order to make the optimal decisions. In this study, verified simulated diabetes data were used. Eight distinct data sets of various sizes were divided into two groups for decision-making. Between 25 and 58 features and 300 to 11,000 occurrences are found in each primary and secondary care data collection. The most accurate algorithms were Ensemble (Ens.) of J48, Logistic, NaiveBayes Updateable, RandomTree, BayesNet, and AdaBoostM1. The accuracy of the prediction model raised the efficacy of decision-making by 56%. In a focus group comprised of IT and medical professionals,

everyone agreed that the IDM-IDSS-healthcare solution was practical. The solution to IDM-IDSS-healthcare needs the use of many agents.

According to a research [3], linguistic multiple attribute decision making (LMADM) is often used in decision-making contexts like evaluating alternatives. LMADM assessment data is presented in straightforward terms. This paper shows that every basic linguistic phrase in LMADM has a continuous representation (a linguistic two-tuple) with a word-corresponding rounding operation. In certain circumstances, the order of possibilities indicated by linguistic two-tuples and the order expressed by basic linguistic words may not coincide. In this work, preference ordering by likeness to an ideal solution is examined together with the weighted, ordered, weighted geometric, preference ranking organization strategy for enrichment evaluation. The research examines the LMADM's inconsistent language scale ranking problem. Researchers demonstrate the consistency of the linguistic scale for LMADM. Then, in order to ensure the consistency of the linguistic scale ranking, analytical consistency requirements are presented for the supplied option rules. Scientists compare simulations and theories to get a result. The simulation-based comparisons demonstrate how well the chosen choice procedures work to avoid inconsistent ranking in LMADM.

According to studies in [4], decision science is becoming more and more interested in making significant judgments via social networks (SN-LSDM). Clustering and consensus building are two of the primary SN-LSDM processes. Similarity of thoughts forms the basis of traditional grouping. Researchers assert that a trustworthy foundation for clustering is the connections that decision makers' (DMs') trust. Trust Cop-KMeans based clustering, a semi-supervised technique leveraging trust connection limitations, is presented in this work. The CRP helps to reduce conflict. Costs and resources are limited for CRP. MCC models are often used when group decision-making is required. Trust is crucial to decision-making since it gives the impression that a DM with a high degree of trust is often taken into account for their point of view. According to studies, a DM with weak consensus but strong trust may be able to lower consensus costs by decreasing trust. As a result, a more precise MCC model includes intentional trust erosion. Numbers are used to demonstrate the applicability of the clustering approach and consensus model. In comparative study, the effects of trust loss and trust restriction on clustering and CRP are examined.

Preference modification may be able to assist decision-makers in achieving more consensus, according to a variety of feedback mechanisms found in models for obtaining consensus [5]. Most feedback systems disregard how receptive decision-makers are to ideas. According to the limited confidence model in opinion dynamics, a decision-maker only considers preferences that are within a certain confidence interval. The decision-makers (TFADM) who lack confidence might benefit from this study's unique consensus-building strategy with targeted feedback. When a learning system assesses uncertain restricted confidences, personalized feedback offers more pleasant direction. Finally, a

numerical example and simulation analysis are used to evaluate how well the suggested model builds consensus.

When there are high degrees of uncertainty and ambiguity in the decision-making process, it is allegedly difficult to maintain consistency in the decision matrix [6]. In earlier research on the intuitionistic fuzzy (IF) theory, preference relation consistency was given greater attention than decision matrix consistency. In order to circumvent the issue, this paper proposes a unique two-stage selection procedure. When decision makers (DMs) decline to input certain values into the decision matrix, they commit a mistake. A new method fixes the problem by first including the missing data. Before examining the consistency of the decision matrix, compute the Cronbach's Alpha Coefficient (CAC) for the IF context. Inconsistencies are eventually fixed in the decision matrix. In the next step, a new aggregation operator is introduced. Furthermore, a ranking system and innovative mathematical approach for determining the weights of criteria are described. Researchers use a numerical example to evaluate the advantages and disadvantages of the suggested framework.

Process specialists recognized in [7] that decision-makers in many different professions are required to do multi-objective evaluations of enormous volumes of data using competing criteria. Although data visualization is a useful tool for examining challenging "solution spaces," little is known about how it could support multi-objective evaluations. This study investigates the influence of data volume and visual complexity on judgment quality in multi-objective scenarios with difficult options. Researchers examine the connections between decision speed and accuracy, competency in using charts, and four popular multidimensional chart styles (scatter plot matrices, parallel coordinates plots, heat maps, and radar charts). Researchers use rank- and score-based (MOA RS) accuracy metrics to evaluate multi-objective evaluations and trade-offs. Even though accuracy is independent on the kind of chart utilized, Heat Maps (HM) speed up analysis. According to study, there is a "limit" to the factors that participants are able to consider. This is supported by contradictory evidence about the impact of chart complexity on performance. This demonstrates that there is a limit to the complexity of data needed to make judgments. Graph-using participants fared better, demonstrating that individuals may be trained to use complex representations while making judgments.

Digital twins (DTW) update digital representations of the world in a feedback loop [8] to aid in decision-making by employing simulation, virtual environments, data from plant equipment, and details from physical systems. Modern hardware and software are integrated, interactive, and heterogeneous, therefore software architectures need to be able to govern information flow. Researchers in this study present a software architecture that combines a manufacturing process simulator with the ROS-Robot Operating System, using Tecnomatix and ROS Melodic for testing, in order to streamline information exchange with an autonomous decision-making system. Researchers demonstrate how readily an autonomous decision-making system based on reinforcement learning

(RL) process may interface with it by using a software architecture example for a challenging manufacturing plant case study.

According to the [9] research, it is challenging for autonomous driving on highways to plot routes and make safe and effective judgments since there are several dynamic automobiles around. While route design places greater emphasis on the kind of vehicle and lane curvature, behavioral evaluations for ego-car driving on specified routes often center on the distribution of neighboring automobiles. The two modules in this article are distinct from one another and operate in different coordinate systems. Researchers create a decision architecture for lane shifting or following based on spatiotemporal lane-change gaps in relative movement coordinates, with nodes representing gaps and edges connecting gaps. Closing the choice gaps requires combining the decision topology with the dynamic vehicle behavior of the surrounding environment. Following a choice, a secure and efficient path from the ego-vehicle to the necessary decision gap is made via polynomial trajectory generation (PTC). It was shown that in dynamic, high-speed contact situations, this technique worked successfully and in real time.

When computing with words in linguistic group decision making, decision makers (DMs) employ customized individual semantics (CISs) coupled to linguistic expressions [10]. (GDM). PIS training must be ongoing since DMs' PISs are dynamic and change when agreement is reached. A consensus approach for linguistic GDM is put out by researchers and is based on PIS learning. It is suggested to use a continuous PIS learning model and consistency-driven technique to update PISs while the consensus process is underway. In order to pinpoint the consensus procedure, a consensus assessment and feedback suggestions (CAFS) based on the PIS are produced. This article examines and supports the usage of consensus techniques based on PIS learning process using numerical examples and simulated testing sets.

Although research on signal processing and information fusion in this area is still in its infancy, there is a substantial body of work in cognitive psychology that models human decision-making [11]. Researchers look at an issue including local decisions made by humans, a fusion center, and distributed detection (FC). The idea of signal detection holds that promoting variety may enhance people's ability to make decisions as a group. We examine two cases. 1) Human ability variation stands in for heterogeneity, and local decision-makers have autonomy. Due to perceptual and behavioral similarities, people form linked local judgments, and correlation measures heterogeneity. In both situations, heterogeneity improves the efficiency of FC detection. In order to improve decision-making performance, participants in the second scenario are chosen from correlated human agents using portfolio theory (PT). Performance of simulated data is shown and compared.

Intelligent decision-making and effective trajectory planning are strongly connected in autonomous driving technology, particularly on routes with dynamic, interactive traffic. This study integrates long-term behavior planning (LTBP) with short-term dynamic planning (STDP) to develop a closed-loop

maneuverer and trajectory planning system that can swiftly and effectively adapt to a changing environment [12]. It is recommended to use a specific voxel structure and the "voxel expansion" approach to build 3D driving corridors in LTBP, which involves analyzing the conditions of neighboring cars. The optimal route is then selected by building a QP problem out of the voxel sequences of the moves that the Dijkstra search found to be the least costly. STDP employs a small-scaled QP problem to monitor or modify the LTBP reference trajectory in response to dynamic impediments. An RSS Checker (Responsibility-Sensitive Safety) Checker affects real-time security. Using data from actual highways, the approach's utility and efficacy have been evaluated.

Consistency is a significant issue in linguistic decision-making [13], and there are several measures and strategies in the literature to address it. Studies on linguistic consistency do not account for the reality that different individuals may have different meanings for the same terms, nor do they prioritize decision makers' personal individual semantics (PISs) above their ostensible linguistic preferences. This study proposes a PIS-based approach to enhance linguistic group judgment. By fusing decision customized representation (DTR) with PIS-based modeling, the proposed technique assesses and improves language preference consistency. An detailed numerical and comparative analysis backs up the suggested approach.

A game-theoretic decision-making paradigm for connected autonomous vehicles (CAVs) at unsignalized roundabouts is provided in order to increase the security and efficiency of the intelligent transportation system, especially in complicated metropolitan areas [14]. To enhance decision-making efficiency and accuracy, a motion prediction module is developed utilizing model predictive control (MPC). The decision-making process also considers the vehicle's comfort, safety, and productivity. determining the boundaries of the decision-making process. The CAV decision-making process at an unsignalized roundabout is simulated using the Stackelberg and Grand Coalition Games (SGCG). Three distinct driving situations are used to test the decision-making algorithms. The testing results validate the practicality and efficacy of the proposed paradigm for game-theoretic decision-making by CAVs working in complicated urban situations. While the grand coalition game strategy improves the efficiency of the transportation system, the Stackelberg game strategy makes sure that each driver's driving goals are accomplished.

Turning left at unsignalized crossings is a challenging operation for autonomous urban automobiles due to the junction's design and the variable traffic conditions [15]. In this article, a hierarchical planning and decision-making system based on significant turning points is proposed (CTPs). The senior planner uses a parameterized extraction method to generate CTPs from road map data. CTPs create junction pathways that are behavior-focused. These adjustments boost search planning's efficiency. The low-level planner uses a partly observable Markov Decision Process (MDP) solution

to generate less cautious but still safe 2-D real-time plans. At a variety of unsignalized crossings, our method enables commute-efficient 2-D planning choices to be made in real-time.

According to the [16] study, InPLTSs may improve the flexibility of qualitative decision-making information expression, particularly in high-pressure, low-knowledge scenarios. In this paper, researchers propose a system for group decision-making (GDM) based on imperfectly probabilistic language preference linkages (InPLPRs). Classification is completed before assessing an InPLTS's capacity to transfer complicated information. Then, to more precisely estimate missing data, an InPLPR multiplicative consistency is applied. To evaluate the level of agreement among a large number of people while taking GDM concerns into account, a consensus index is developed. Individual InPLPRs could not be consistent upon agreement; as a consequence, a mathematical programming paradigm that takes information distortion into account is suggested. To merge individual preference relations into a collective one, a reliability-induced ordered weighted geometric operator is provided. The induced variable reliability of this operator is defined by the degree of confidence and consistency index of the individual preference relations. An integrated multiphase strategy using InPLPRs is used to overcome GDM challenges. A detailed validity test and comparative analysis illustrate the benefits of the presented technique, which is used in a numerical depiction of fire emergency judgments.

The degree to which researchers rely on autonomy depends on how often humans and robots interact and make choices together [17]. Standard black-box models for data-driven decision making and machine learning leave little room for interpretation. It is essential to design decision-making procedures that take interpretability into account. The Trustworthy Decision-Making (TDM) paradigm, which blends sequential decision-making with symbolic planning, has been proposed by researchers. The algorithm learns interpretable subtasks to build a complex, higher-level composite work that can be assessed using a measure of trust. TDM converges on the optimum symbolic plan and enables interpretability at the subtask level by design. By combining them with conventional sequential decision-making algorithms, a TDM-based strategy combines the benefits of symbolic planning with TDM. Experiments improve the intelligibility of subtasks and enable trust score-based planning.

In this work, a constructive induction approach is used to build a cost function for performance evaluation of an average multiple level of cues with multiple level of choices (MLC2) cognitive decision-making model throughout a switching time period. It illustrates how to assess a constructive cost function under beginning circumstances using the Lyapunov function. Finding a Lyapunov function for the conventional MLC2 model turns into a performance indicator problem, leading to iterative techniques like adaptive dynamic programming for software development. This is achieved by presenting both the mathematical properties of a Lyapunov function and a set of scientific findings supporting its construction. The Lyapunov function has a ton of evidence in its favor.

The researcher recommender designer technique offered in [19] presents a planning and decision-making strategy based on reward and risk assessment in order to enhance the computational and real-time efficacy of autonomous vehicle decision-making. It investigates and evaluates the elements that influence planning and judgment in relation to driving. The lateral trajectory forecasts of adjacent cars and the longitudinal trajectory propensity estimates of individual drivers are combined to produce a future risk assessment model (FRAM). A cost function is developed to decouple route from speed in order to allow changes to route design and speed in response to environmental threats. The idea of risk assessment includes the process of making decisions based on motivation. According to simulation results, the recommended approach may make in-the-moment judgments regarding driving habits and trajectory planning that are in harmony with the surroundings, increasing computational effectiveness and safety.

According to [20], three-way decisions (3WD) with a delayed decision option may lower choice risks. This article combines 3WD and MADM based on outranking. The researchers use a MADM matrix and a loss function table to generate an outranked set for each option. Researchers offer three distinct 3WD MADM design approaches. The choice of project investment goals demonstrates the rationality and efficacy of the 3WD strategy. Finally, researchers contrast the results of two distinct experiments. Results indicate that 3WD is effective in a variety of usage situations.

Decision experts in [21] claim that discrete events, continuous processes, unpredictability, and time delay are used to construct hybrid system decision models. State consistency and unexpected behavior are only two of the issues presented by the heterogeneity and concurrency of hybrid systems for making decisions. It is difficult to explain the nonlinear relationship between hybrid conditions and decision results. This article presents a three-tier decision-making method based on M-HSTPN and deep learning (DL). M-HSTPN explains hybrid situations, while DL models depict the nonlinear link between decision results and hybrid scenarios. The selection of decision models and their instruction follow. The hybrid bearing failure detection system is used as an example by the researchers as they examine several decision models and assess the M-HSTPN-benefit. M-HSTPN-DL is capable of accurately modeling hybrid systems and managing the difficult decision-making circumstances they provide.

According to research cited in [22], as theories and applications have been studied, so has the significance of the multi-UAV system's cooperative mission capabilities. When AI is integrated with collective decision-making across several UAVs, mission capabilities are boosted. To make judgments jointly, several UAVs must use multi-agent reinforcement learning. Every UAV is seen as an employee collecting sporadic environmental data. Each acting training level is evaluated by a separate reviewer. Researchers integrate a gate recurrent unit into the actor to provide the UAV access to previous decision data. The centralized critic employs an attention technique to improve learning in difficult

situations. Finally, the system is trained and evaluated using a multi-UAV air combat scenario with cooperative decision-making (CDM). According to experimental findings, this approach converges faster than prior algorithms and could be able to efficiently learn cooperative decision-making procedures.

Soft computing model designers [23] developed a unique fuzzy best-worst multi-criteria group decision-making method employing a multigranular linguistic approach to handle the group decision-making (GDM) problem. In line with the recommended method, experts send information about the assessment using predetermined multi-granularity linguistic word sets (LTS). The fuzzy weights for the criteria are calculated with the help of the enhanced fuzzy BWM (FBWM). Current research using the BWM for group decision-making only provides two unified best and worst criteria, which is inadequate to effectively represent the perspectives of numerous professionals and omits vital information. Due to the divergent viewpoints of the experts and the disparity between the best and worst starting criteria, they will compare each criterion wrongly. Each expert will provide their choice for the best and worst criteria for this article, keeping in mind the need to avoid omitting too much information. Using the study's transformation technique, the opinions of each expert are incorporated in two comparison vectors. A more accurate input-based consistency assessment is also proposed in order to help DMs change decisions that are inconsistent (s). Two scenarios illustrate the approach's usefulness and applicability.

It was suggested in [24] to formulate a Bayesian binary decision-making issue for star networks, in which local agents separately evaluate their own self-interest and a fusion agent makes a choice based on the results of the analysis and its own private signal. Researchers assume that each actor has a unique perspective on the real prior probability when making Bayesian decisions. Research on the issue suggests that when agents are aware of the proper prior, erroneous beliefs may reduce the Bayes risk of the fusion agent. It is intriguing that for the design of sociotechnical systems, local agents' optimum beliefs correspond to probability reweighting models from cumulative prospect theory. Additionally, the asymptotic formulation of optimum beliefs and the local agent fusion agent risk are taken into consideration. As local agents multiply, the optimal risk of the fusion agent falls down exponentially. In the risk exponent theory, a belief that never changes is referred to as being asymptotically perfect. The risk exponent for additive Gaussian noise and mistake costs determine what is considered to be the optimal belief.

It will be difficult to find out how to incorporate autonomous vehicles (AVs) into the traffic ecology of human drivers and decrease their mismatch with them given that human drivers and AVs will coexist on the road for a very long length of time. Since various passengers have varied expectations from AVs, personalization is a challenge. An artificial intelligence (AV) decision-making framework is offered in this research [25]. A range of driving behaviors and social interaction qualities are modeled

for autonomous automobiles in order to optimize safety, comfort, and fuel economy. In non-cooperative decision-making, Nash Equilibrium and Stackelberg Game Theory (NESGT) are applied. Model predictive control (MPC) incorporates predicting and planning of AV motions and gives data to the decision module. Two common lane-change scenarios—merging and overtaking—are examined in order to gauge the practicality and usefulness of the proposed decision-making framework. Both game-theoretic models allow autonomous automobiles to come to conclusions that are comparable to those of humans, according to testing. The Nash equilibrium method costs around 20% more to choose between in real-world driving scenarios than the Stackelberg game-theoretic method.

According to the [26] study, the COVID-19 virus has expanded globally and has an effect on both everyday life and business. To safeguard local economies and communities, many crucial choices must be made. Information is crucial for making informed judgments. Data-driven decision-making employs data-related knowledge and insights to reach conclusions and validate action plans. Governments and policy groups have reviewed the COVID-19 data in an effort to better control the pandemic. Topics including media, knowledge, and medicine are included. This discovery affects a number of preventive and control strategies. In this survey study, researchers discuss data-driven decision-making in the COVID-19 response, which includes prevention and control, counseling, financial aid, employment recovery, and school reopening. Data-driven decision-making has challenges and unresolved problems in the areas of data collection and quality, sophisticated data processing, and decision fairness. This survey article describes data-driven policymaking and provides suggestions for more research.

Process experts assert that information overlap could impede the use of business information in decision-making [27]. Using big data analysis, this research develops a paradigm for making sensible decisions based on corporate information. Density Weight Canopy is used to mine corporate data and enhance K-Medoids (DWC KM). The big data model employs interactive genetic algorithms to determine the optimum decision-making strategy for corporate information via experimental testing, which influences management of decision-making and company competitiveness, after sorting, filtering, and converting the data for this study. The capacity of the company to overcome hurdles rises when there is a 95% match between the best business operation plan and the difficulties that must be handled in the organization's real operation. The most productive business decision-making process only needs six iterations, which increases labor productivity.

According to [28], given the status of the environment and the development in environmental consciousness, green suppliers are necessary. The majority of the approaches for selecting a green supplier now in use are based on a predetermined weighting scheme, rendering them ineffective in circumstances when decision-making is dynamic and challenging. In a neuromorphic environment with a single value, researchers combine entropy, TOPSIS, and GRA to develop a flexible choice

model for selecting green providers. When addressing uncertainty, conventional approaches for selecting environmentally friendly suppliers perform worse than single-valued neuromorphic sets. In this study, the weights of the assessment criteria for green suppliers are determined using a combination of the neuromorphic set with a single value and entropy, and TOPSIS and GRA are used to choose the best green provider. Different TOPSIS and GRA weights are applicable depending on the circumstance in which a decision is taken. A case study and comparative analysis are used to demonstrate the efficacy of this decision model. The results demonstrate the viability of this flexible decision-making strategy.

To maximize PET profit over the length of a finite operational cycle is the optimal course of action for a plug-in electric taxi (PET) in a complex environment with time-varying variables (passenger environment, charging station environment, traffic environment, and taxi business management system). To begin with, this is a lengthy sequential decision-making issue. For the purpose of convenience, the model is separated into an outdoor scene and an electric taxi model [29]. The management methods used by taxi companies, charging stations, traffic, and passengers are among the four environmental aspects that have been analyzed and modelled. In order to model transitions between related processes and environmental feedback, the serving and charging processes of the PET are divided into numerous subprocesses, such as cruising, carrying passengers, driving to the charging station, queuing for charging, and connecting to the power grid for charging. There are some unanticipated characteristics of the PET sequential decision-making process that make issue solving more difficult. SARSA addresses this problem. Simulated scenarios demonstrate the effectiveness of the strategy.

[30] asserts that organizations may gather and store vast volumes of student data using cutting-edge technologies. This quantity of knowledge might aid in making a decision. The strategies, programs, and actions used to increase quality are impacted by decisions about higher education. Machine learning algorithms may discover models and anticipate outcomes based on data. Results from machine learning were skewed and mislabeled. Decision rules need to be altered in order to decrease the effect of such mistakes. This article suggests a method for teaching decision rules using supervised machine learning. Following that, colored Petri Nets (HCPN) are utilized to show how the technique is appropriate using hierarchical clustering. The formal approach of the suggested solution ensures defensible and open decision-making procedures. Decision-making accuracy was increased by researchers to 98.68 percent. This research enhances decision-making processes in circumstances involving academic administrations.

According to research [31], three-way decision (TWD) models cannot presently tackle incomplete multiple attribute decision-making (MADM) issues; a three-way MADM model that works in incomplete fuzzy decision systems is necessary (IFDSs). When developing an IFDS, researchers take

decision-makers' preferences into consideration. Similarity is used to produce conditional probabilities with weights. Researchers develop a method for estimating the values of relative utility functions. Then, researchers develop a TWD model in IFDSs and an incomplete MADM (IMADM) problem. This research offers a novel IMADM viewpoint while advancing TWD and MADM ideas. Experimental and comparative studies have shown the superiority, applicability, and consistency of the model.

The effectiveness of product development depends on the enterprise system's (ES) capacity to handle product lifecycle data and support decision-making. New ES paradigms are needed to enable distributed intelligence as the industrial Internet of Things generates more data. Edge computing enables the development of decentralized decision support systems. The design phase of the development of new products has not yet been the subject of any original ES research. This article proposes an edge-based ES [32] design scheme assessment technique. It addresses the information isolation that many decision-makers experience across a variety of industries. It is suggested to use a multigroup decision-making method while analyzing design ideas in a group environment. This article examines the assessment strategies used by customers, specialists, and designers. The fuzzy trapezium cloud (FTC) method is used to translate qualitative designer and expert views into qualitative values. There is less cognitive dissonance and inaccurate information interpretation. EEG data is used to analyze the implicit psychological states of users of a product. To find the best design scheme sets, the evaluation results of several groups are integrated using fuzzy measure and Choquet integral.

The authors of the Soft Computing Model in [33] found Uncertainty in data is a serious problem for decision-making. Linear Diophantine fuzzy numbers help to lessen the uncertainty in decision-making experts' specific expertise. In this article, similarity and distance metrics are constructed for Linear Diophantine Fuzzy Numbers (LDFN). When there are many catastrophes occurring at once, emergency decision-making (EDM) is crucial. In an emergency, decision-makers must move swiftly and reach sound, authorized judgments to avoid financial losses and cultural upheaval. This research proposes a unique EDM approach for Linear Diophantine Fuzzy (LDF) data based on several distance and similarity metrics. Similarity measures may be used to determine how similar two objects are to one another. This technique is used in decision-making, pattern recognition, data mining, and medical diagnosis. This paper presents new similarity and distance measures for linear Diophantine fuzzy collections. Then Jaccard, exponential, cosine, and cotangent were used to construct LDFS similarity metrics. evaluating the data and using brand-new similarity criteria to make a medical COVID-19 virus diagnosis. The benefits of the proposed work are analyzed, and the differences between the new similarity measures are also discussed.

Since economic development has increased coal consumption, the prior coal energy system cannot offer the industrial output needed for sustainable growth. Long-term development depends on a good

coal production decision-making process. In order to anticipate coal output, this study creates a multi-objective fuzzy decision-making model [34] utilizing human input. Profits for the economy, energy, ecology, coal gangue, and safety are among the objectives of the model. A unique multistage many-objective optimization method is used to modify model parameters and improve the accuracy of model solutions. The three steps of algorithm optimization are as follows. In step 1, the ideal convergence model is selected. In stage 2, a diversity maintenance technique is used to maintain the variety of the model solution. A thorough measuring method permits population convergence and variety in the third stage. Five more sophisticated many-objective algorithms are used to compare the model and optimization technique. In simulations using a benchmark function, the recommended optimization method surpasses other methods. The convergence and diversity of Coal Fuzzy Decision-Making (CFDM) models are influenced by a number of different aspects.

Designers proposed dynamic programming in [35] as a technique for dealing with complicated group decision-making issues including linguistic elements like preferences. Since linguistic variables cannot be calculated directly, they are represented using type-2 interval fuzzy sets. Then, interval type-2 fuzzy (IT2F) set analysis is performed using novel distance and similarity models. The decision-makers are then grouped using a dynamic programming (DP)-based clustering algorithm. A unique model determines the weights of clusters and decision-makers by accounting for the cluster center and group size. Two studies have shown the usefulness of the supplied centroid-based ranking system. Its splendor is also evaluated and compared.

Researchers in [36] developed a Recurrent Neural Network (RNN) with a Bidirectional Long Short-Term Memory (Bi-LSTM) cell to forecast lane changes for autonomous vehicles. The suggested decision-making system was trained and validated using data from the vision system, laser scanner, and chassis sensors of autonomous vehicles. The bi-LSTM-based RNN input characteristics include lane measurements, autonomous vehicle velocity, and the relative clearance and velocity with close-by target vehicles. Forecast lane-keeping, lane-changing to the left, and lane-changing to the right are all included in the output. The Bi-LSTM RNN makes a determination after two seconds of observation or two seconds before lane changes. 20.108 datasets were mapped globally. For the Bi-LSTM-based RNN's training, validation, and assessment, respectively, 1,120, 320, and 160 datasets were created. To assess the recommended strategy using a case study, the predictive value of driving data was examined. The projected lane shift option made by the suggested algorithm is more accurate and useful than prior techniques.

Experts developed a computer model in [37] to allow robots to make risky judgments on par with humans. Psychological elements such as range, remorse, and probability weighting all have an impact on human risk-taking. Based on the regret theory, researchers construct a mathematical DM model with psychological implications. Researchers created a state-space representation to quantify the

model, and a fuzzy logic controller to collect decision-makers' preferences. The model was tailored using information from each individual. model, mathematical It describes how dangers seem to human DMs. The model's accuracy was assessed by statisticians. This model's 74.7% average accuracy is close to the participants' 73.3% average accuracy. This model has an average accuracy of 86.6% when only repeated evaluations are considered. Task distribution among HRC systems is difficult because to the contrasts between the benefits and limitations of people and robots. Robots still lack the same degree of dependability as humans, despite recent advances. More is spent on human labor. When HRC systems must operate for long periods of time and have high robot-to-human ratios, several decision-making (DM) issues appear. Computerized DM is required. Team members perform better as a collective when they share mental models. Robots should take after human DM in human-centered automation. The article's recommended DM model resembles a person. Scientists start by examining how DM affects people mentally. These impacts are sent to the DM model's constituent parts. No information is provided on the parts. Researchers create techniques to measure these components. The automated DM model, according to researchers, yields forecasts that are more accurate than those made using the traditional approach. With the suggested methods, it is possible to build DM models that mimic people for cooperative search, assembly, etc.

According to [38], driver choices affect the sanity and safety of autonomous commercial vehicles. Deep reinforcement learning is used by a system known as RAD-DRL to make judgments regarding safe driving. An actor-critic framework for analyzing sensor data was originally presented to ensure safe driving. This design allows the dynamic integration of vehicle rear anti-collision components. Then, multi-objective optimization is used to construct a better reward function. It evaluates the vehicle's roll stability, kinds of rearward targets, and safety clearance. The RAD-DRL was examined, verified, and trained in the SUMO simulation environment using a range of random seeds (Simulation of Urban Mobility). After 30,000 training cycles, this RAD-dependability DRL's and effectiveness were shown. Simulations show that RAD-DRL is more prevalent and effective while driving on expressways. It made excellent decisions when the car in reverse abruptly rushed around a bend.

According to a survey [39], one of the most important hospital departments is the emergency room. (ED). The ED promotes hospital service efficiency objectives. The unexpected patient care, variable patient arrivals, and complexity of the ED make it a challenging system. Simulators aid in operational analysis and ED analysis. Even while previous ED simulation models have contributed to improving ED performance in terms of patient satisfaction and efficient treatment services, patient throughput times remain a significant issue. Waiting, the length of a patient's stay, and decision-making all affect how quickly patients move through the system. In order to address patient throughput time, this project intends to develop a cutting-edge simulation model of emergency department (ED) patient flow (SIM-PFED). By combining discrete event simulation with agent-based simulation and using order preference by similarity to the ideal solution, SIM-PFED offers a novel approach for patient flow in

emergency rooms. Three actual ED datasets were used to assess SIM-PFED. SIM-PFED increases patient throughput in the emergency department while concurrently decreasing wait times and durations of stay. The results also demonstrated how SIM-efficient PFEDs may assist ED decision-makers in selecting the ideal circumstances for the highest level of cost efficiency and quickest throughput time.

Despite the fact that data may be promptly evaluated and utilized to make crucial choices, Despite the confluence of AI and IoT, there are still issues that need to be overcome. When making judgments using AI, insufficient data may cause poorer efficacy or the deactivation of intelligent IoT networks (so-called "sparse decision making" or "SDM"). Recommendation systems that use IoT as the backbone of their network are susceptible to SDM [40] issues. To trust everything you read is irrational. Insufficient evidence may also be used to support reliable information (also known as sparse trust problem). In this study, the TT-SVD SDM model is proposed for AI-enabled IoT systems. This approach more extensively combines rating and trust information to handle the issues of cold start, sparse data, and sparse trust. The trust tendency is a representation of the impact of both trustees and trustors. To do this, researchers provide a dual model called TrusterSVD and TrusteeSVD, which builds on the prior rating-only recommendation model known as SVD++ (TrusteeSVD). The TT-SVD is produced by averaging these two models. In the "all users" and "cold start users" scenarios, this model beats SVD and TrustSVD, and accuracy may increase by 29% as a consequence of the experimental findings. Complexity research claims that this paradigm is suitable for huge sparse data sets. This approach may be able to overcome the issue of constrained choices by adding two-way trust recommendations and boosting intelligent recommendation systems.

A paradigm for preventing manipulation in social network group decision-making based on an optimum feedback model was presented by decision-making experts in [41]. First, "individual manipulation," where each expert modifies their own behavior to increase relevance (weight; and second, "group manipulation," when a group of experts persuades disparate professionals to adopt particular proposal advice obtained via a specified feedback parameter To provide experts adequate weights, a fair policy for group minimum adjustment cost (FP GMAC) is created, and to lessen "individual manipulation," a behavioral weights assignment approach that mimics "dictatorship" to "democracy" is created. To avoid "collective manipulation," researchers are developing an optimal feedback system with individual adjustment costs and consensus threshold limits. Consistent experts are better able to balance adjustment costs and group agreement when this strategy is used, and they are also more receptive to proposal ideas and the group's consensus on a particular decision-making issue. The optimal feedback model is shown and validated using an example.

Work in [42] develops a coalitional game strategy-based cooperative decision-making framework for connected autonomous vehicles (CAVs) to improve productivity and safety in multi-lane merging

zones. To improve the decision-making process' accuracy, a motion prediction module is created using a condensed model of a single-track vehicle. The cost function and decision-making restrictions are developed while keeping in mind safety, comfort, and effectiveness. A multitude of driving factors are being researched in order to create personalized and human-like smart mobility. There are four main CAVS coalition types in a multilane merging zone. The coalitional game strategy with model predictive control is then used to make the CAV decisions in the circumstance (CGT MPC). The suggested course of action is then evaluated in two distinct driving scenarios. The results of the tests indicate that the proposed coalitional game-based strategy may correctly assess the circumstances and adapt to different CAV driving behaviors in multi-lane merging zones. It ensures CAV safety and efficacy in difficult, dynamic traffic scenarios while taking into account the goals of individual vehicles, proving the practicality and efficiency of the suggested method.

Large, complicated, and expensive mechanical equipment makes the maintenance-output conflict worse, and it also hinders coal mines from expanding and becoming more productive, according to developers of soft computing models in [43]. This research suggests a collaborative decision-making strategy for production planning and maintenance of fully automated mining equipment in order to overcome production-maintenance conflicts. The Hybrid Genetic Whale Optimization Algorithm is being used by researchers to improve the production planning and maintenance of fully automated mining equipment (HGWOA). Using integrated and independent models, the decision-making procedures for production planning and maintenance were investigated. Joint decision-making reduces costs and downtime by 36.06 and 40.76%, respectively. It helps coal mines and associated sectors strike a balance between maintenance and output.

According to studies from [44], group decision-making (GDM) gets more challenging as the number of members increases. The process of obtaining agreement in GDM is influenced by the quantity, diversity, and caliber of participants and information. Typical ways lower the size of the GDM by splitting big groups into smaller ones, while heterogeneity is controlled by organizing heterogeneous data. 1) How is the group's size decided? 2) How can data loss during transformation be minimized? This paper uses fuzzy cluster analysis to merge heterogeneous data for challenging GDM problems. The optimal number of groups is determined using the F-statistic and fuzzy cluster analysis (FCA), which is used to divide up a huge group. Based on similarities, different pieces of information will be retained. Small groups reach an agreement to develop a common worldview. When the groups cannot agree, the small GDM matrix is updated via a feedback mechanism, and TOPSIS is then used to choose the optimal choice. Experimentation is used to evaluate the proposed strategy and determine the optimum emergency rescue strategy. The findings indicate that the suggested strategy expedites the selection of a rescue technique.

An attitudinal consensus threshold (ACT) was used to provide the theoretical foundation for a dynamic feedback system in group decision making by [45] in order to give guidance for disagreeing experts and encourage agreement (GDM). It is unusual for the approach to be able to employ the ACT consistently, which covers all possible group consensus states from lowest to maximum. It is applicable to GDM situations with a range of consistency criteria. A sensitivity analysis approach using visual simulation is offered to identify the number of feedback experts and the lowest adjustment cost for different ACT intervals. Experiments show that when the ACT score is higher, there are more adjustment expenses and feedback specialists. Numerous decision-making situations are quantitatively duplicated with various ACT intervals to represent the feedback process.

For individualized, safe driving, researchers developed a revolutionary method to autonomous vehicle decision-making and motion control in [46]. New models and algorithms for lane-change intentions are provided. Using the dynamic potential field (DPF), the recommended decision-making module depicts interactions between the ego vehicle and neighboring cars, ensuring safety and personalization while driving. The trajectory is planned and controlled using the artificial potential field and constrained Delaunay triangulation (CDT). The brand-new integrated controller efficiently executes motions. The suggested approach and a conventional tactic are contrasted. The findings demonstrate that the recommended strategy can make suitable autonomous driving judgments efficiently and practically in dynamic environments.

To expand investments in renewable energy, experts created a strategy in [47]. This paradigm describes a three-stage process. Finding preferences for incomplete matrices is the initial stage. The requirements are assessed by four decision-makers using a balanced scorecard. At this level, partial preferences are used to anticipate missing values in relation matrices. Second, consensus-based group decision-making is used to identify hazy preferences (CGDM). In the last step, the fuzzy Pythagorean DEMATEL technique is used to determine the weights of the criteria. In order to distinguish between various renewable energy investment strategies, this research develops a unique multi-criteria decision-making (MCDM) model based on incomplete preferences, CGDM, and Pythagorean fuzzy sets. Learning and development are the most significant balanced scorecard-based method for increasing investments in renewable energy. Internal processes are still another important factor. Initiatives using renewable energy need a high initial investment. Technology developments have reduced the cost of creating renewable energy. The generation of renewable energy may be increased via innovative technology. To save costs, renewable energy investors should keep an eye on technological developments.

There are many consensus-reaching procedures (CRTs) for group decision-making [48]. (GDM). Building trust should be essential in group interactions that lead to the creation of preferences. In this article, researchers explore a CRP for developing trust-based connections. As approaches for achieving

agreement, this CRP combines strengthening interpersonal ties with leader-based preference change. Researchers emphasize the need of strengthening leader and trust links in order to address GDM concerns in the CRP for trust relationships. In order to manipulate trust relationships in GDM tasks, researchers provide the specific strategic manipulation issue known as trust relationship manipulation and discuss clique-based techniques to do so. The theory is supported by simulations.

Knowledge-based approaches have been used for both the dynamic modification of an industrial process' operational index and plant-wide operational optimization [49]. The bulk of methods in use today have problems acquiring data. Researchers offer the decision-making GAN (DMGAN), a revolutionary framework based on generative adversarial networks (GANs). It produces human-level decisions for plant-wide operation right away after learning from operational data. The suggested DMGAN's two adversarial and three cycle consistency criteria enhance posterior inference. As industrial processes become more complicated, reinforced U-Nets (RU-Nets), which improve the standard U-Net and increase a generator's generalization power, are added. These improvements include a design based on building blocks, a more general combinator, and drop-level regularization. Three quantitative benchmarks for evaluating plant-wide performance are suggested in this article. The biggest mineral processing mill in Western China is used as a case study to illustrate the possible performance of the recommended DMGAN in contrast to domain-expert decision-making.

An innovative generalization that may be used to homogeneous functions is presented in work in [50]. The researchers provide the traits and circumstances. Academics have developed a new paradigm for decision-making theory (DMT) based on this generalization. The consistent influenced/disturbed decision-making process is the name of this new paradigm. The researchers developed a variety of fictitious scenarios to demonstrate this new mental paradigm. For a wide variety of scenarios, fuzzy logic, TOPSIS, and other soft computing models perform better than other models. As a consequence, it is clear that many different models are explored in order to provide decision-making recommendations. The computational complexity, suggestion effectiveness, delay needed for recommendations, scalability, and contextual accuracy levels of various models are compared in the next section of this book. This will let the readers choose the best models for performance-specific use cases, which will be to their advantage under different scenarios.

RESULT ANALYSIS & COMPARISON

Following the in-depth examination of newly presented models for decision-making and recommendation, it has become clear that these models exhibit a great deal of diversity with regard to the internal working and recommended features they exhibit. This section provides a comparison of the models that have been reviewed in terms of their levels of computational complexity (CC), efficiency of recommendation (ER), delay needed for recommendation (D), scalability (S), and contextual accuracy (CA). The goal of this section is to make the process of selecting a model easier.

British Journal of Multidisciplinary and Advanced Studies:
Arts, Humanities and Social Sciences 4 (6),20-49, 2023
Print ISSN: 2517-276X
Online ISSN: 2517-2778
Website: https://bjmas.org/index.php/bjmas/index
Published by European Centre for Research Training and Development UK

Each of these parameters was quantized into fuzzy ranges of Low (FL), Medium (FM), High (FH), and Very High (FVH) with quantization levels of 1, 2, 3, and 4, respectively. This will make it easier for readers to compare these models on uniform scales. Based on this strategy, comparison of these models is tabulated in table 1 as follows,

Model	**CA**	**CC**	**D**	**ER**	**S**
FLDM [1]	H	FM	FVH	H	FM
Ens. [2]	FVH	H	H	H	H
LMA DM [3]	H	FM	H	FM	FL
SN LSDM [4]	H	H	FM	H	FM
TF ADM [5]	H	FL	FL	H	FM
IF CAC [6]	FL	H	H	FL	H
MOA RS [7]	FM	H	H	FL	H
RL DTW [8]	FVH	FVH	FL	H	FM
PTC [9]	FM	H	H	H	FM
CAFS [10]	FL	FM	H	FM	H
PT [11]	H	FM	FM	H	H
LTBP STDP [12]	H	H	H	FVH	H
DTR [13]	H	FM	H	FM	FL
SGCG [14]	H	H	H	H	FM
MDP [15]	H	H	FM	FM	H

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InPL PR [16]	FM	H	H	FL	H
TDM [17]	FVH	FM	H	H	H
MLC2 [18]	FM	H	FM	H	H
FRAM [19]	H	H	H	FM	H
3WD MA DM [20]	FVH	FVH	H	H	FVH
MHS TPN [21]	H	FM	H	H	H
CDM [22]	FM	H	FM	FL	FL
FB WM [23]	H	H	H	FM	H
Bayes [24]	FM	H	H	FM	H
NE SGT [25]	H	FM	H	H	FM
DWC KM [27]	H	H	FM	H	FM
TOP SIS GRA [28]	FVH	FM	FL	FVH	FVH
SAR SA [29]	FL	FM	H	H	H
HCPN [30]	H	H	FM	FM	H
TWD IFDS [31]	H	FVH	H	H	FM
TCF [32]	FM	H	FM	FL	H

LDFN [33]	H	H	FM	FL	H
CFDM [34]	H	H	FVH	H	FVH
IT2F DP [35]	FVH	FM	FL	FVH	H
RNN Bi LSTM [36]	FVH	H	FM	FVH	FVH
HRC [37]	FM	H	H	H	H
RAD DRL [38]	FVH	H	FM	FVH	FVH
SIM PFED [39]	FM	FM	H	H	H
Trust SDM [40]	H	FVH	FM	H	H
FP GMAC [41]	H	H	H	FM	FM
CGT MPC [42]	H	H	H	H	FM
HG WOA [43]	FVH	FL	FL	H	H
FCA [44]	H	FM	H	H	FM
ACT GDM [45]	H	FM	H	FM	H
DPF CDT [46]	FVH	FL	FM	H	H

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DEMA TEL [47]	H	H	H	FVH	H
CRP [48]	FM	H	FL	H	H
DM GAN [49]	FVH	H	FL	FVH	FVH
DMT [50]	H	FM	FVH	FM	H

Table 1. Empirical analysis of different decision recommendation models

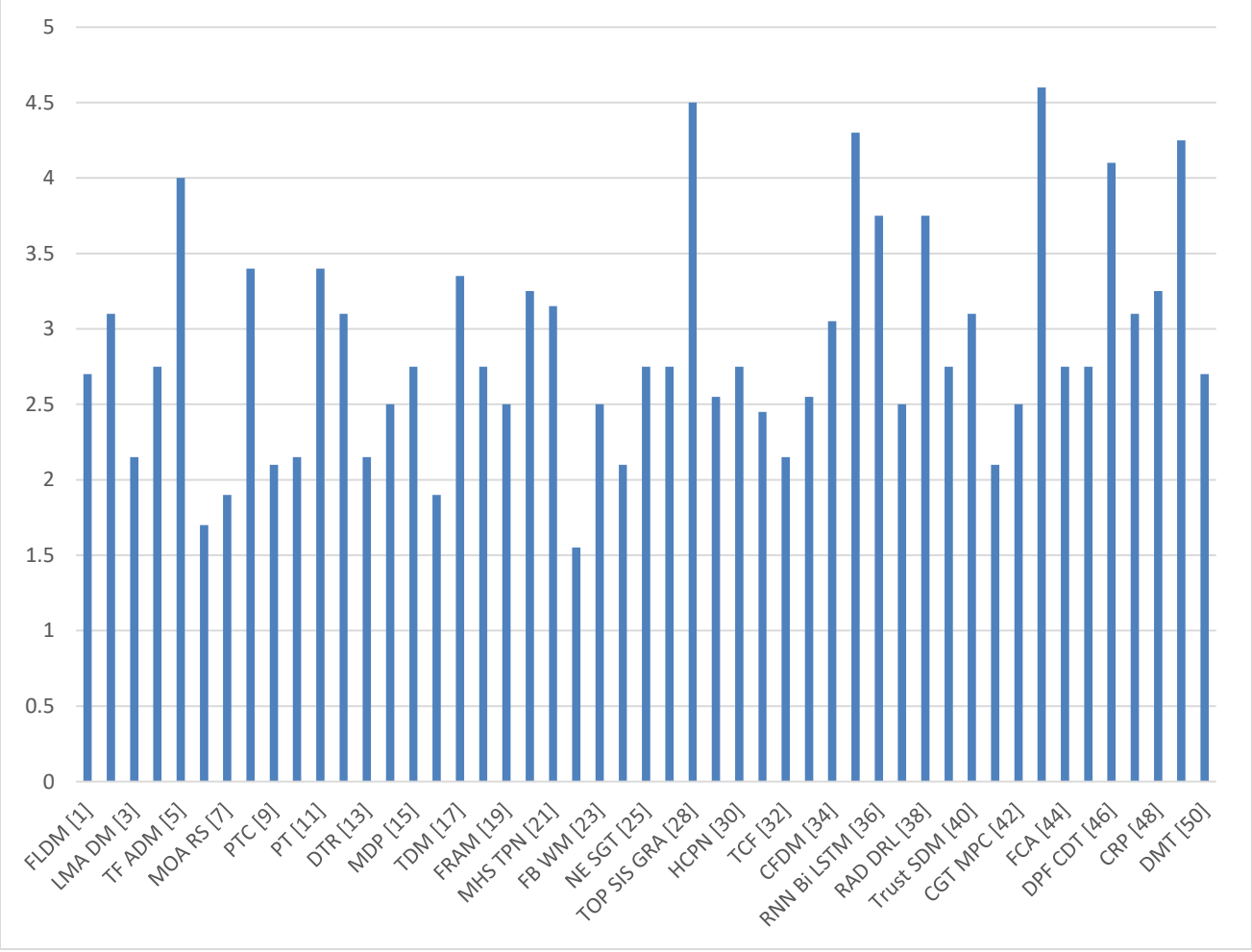

Figure 1. DRRM performance for different decision recommendation models

British Journal of Multidisciplinary and Advanced Studies:
Arts, Humanities and Social Sciences 4 (6),20-49, 2023
Print ISSN: 2517-276X
Online ISSN: 2517-2778
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Published by European Centre for Research Training and Development UK

Based on this evaluation, it can be observed that Ens. [2], RL DTW [8], TDM [17], 3WD MA DM [20], TOP SIS GRA [28], IT2F DP [35], RNN Bi LSTM [36], RAD DRL [38], HG WOA [43], DPF CDT [46], and DM GAN [49] showcase higher contextual accuracy, which makes them highly useful for accurate decision recommendation use cases. It can also be observed that TF ADM [5], HG WOA [43], and DPF CDT [46] showcase lower computational complexity, thereby making them useful for low complexity decision recommendation scenarios.

In terms of computational delay or response time, TF ADM [5], RL DTW [8], TOP SIS GRA [28], IT2F DP [35], HG WOA [43], CRP [48], and DM GAN [49] are observed to have faster response, thus can be deployed for real-time use cases. While, LTBP STDP [12], TOP SIS GRA [28], IT2F DP [35], RNN Bi LSTM [36], RAD DRL [38], DEMA TEL [47], and DM GAN [49] showcase high recommendation efficiency, which makes them suitable for critical decision recommendation scenarios.

In terms of scalability, 3WD MA DM [20], TOP SIS GRA [28], CFDM [34], RNN Bi LSTM [36], RAD DRL [38], and DM GAN [49] showcase better performance, thus can be used for a wide variety of application scenarios.

These metrics are combined via equation 1, to evaluate Decision Recommendation Rank Metric (DRRM), which will assist in identification of models that have higher accuracy, lower complexity, faster response, better scalability and high recommendation efficiency levels.

$$DRRM = \frac{CA + ER + S}{5} + \frac{1}{CC} + \frac{1}{D} \dots (1)$$

Based on this evaluation and figure 1, it can be observed that HG WOA [43], TOP SIS GRA [28], IT2F DP [35], DM GAN [49], DPF CDT [46], TF ADM [5], RNN Bi LSTM [36], and RAD DRL [38] showcase better overall performance, thus must be selected for high-performance decision recommendation use cases.

CONCLUSION AND FUTURE SCOPE

Following the in-depth examination of newly presented models for decision-making and recommendation, it has become clear that these models exhibit a great deal of diversity with regard to the internal working and recommended features they exhibit. Based on the evaluation of these models, it can be observed that Ens. [2], RL DTW [8], TDM [17], 3WD MA DM [20], TOP SIS GRA [28], IT2F DP [35], RNN Bi LSTM [36], RAD DRL [38], HG WOA [43], DPF CDT [46], and DM GAN [49] showcase higher contextual accuracy, which makes them highly useful for accurate decision recommendation use cases. It can also be observed that TF ADM [5], HG WOA [43], and DPF CDT [46] showcase lower computational complexity, thereby making them useful for low complexity decision recommendation scenarios. In terms of computational delay or response time, TF ADM [5], RL DTW [8], TOP SIS GRA [28], IT2F DP [35], HG WOA [43], CRP [48], and DM GAN [49] are observed to have faster response, thus can be deployed for real-time use cases. While, LTBP STDP [12], TOP SIS GRA [28], IT2F DP [35], RNN Bi LSTM [36], RAD DRL [38], DEMA TEL [47], and

DM GAN [49] showcase high recommendation efficiency, which makes them suitable for critical decision recommendation scenarios. In terms of scalability, 3WD MA DM [20], TOP SIS GRA [28], CFDM [34], RNN Bi LSTM [36], RAD DRL [38], and DM GAN [49] showcase better performance, thus can be used for a wide variety of application scenarios. When these metrics were combined, then it was observed that HG WOA [43], TOP SIS GRA [28], IT2F DP [35], DM GAN [49], DPF CDT [46], TF ADM [5], RNN Bi LSTM [36], and RAD DRL [38] showcase better overall performance, thus must be selected for high-performance decision recommendation use cases. In future, researchers must use a hybrid combination of these models, and develop Fuzzy, AHP or TOPSIS based deep learning techniques for efficient decision recommendation operations. Researchers can also integrate bioinspired models in order to improve recommendation efficiency for different use case scenarios.

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