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A Comprehensive Literature Review of Smart Decision Support Systems and its Applications

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Abstract

This paper is presented as a literature review for a comprehensive analysis of smart decision support systems (SDSS) and their different applications within different sectors. The paper traces the improvement of decision support systems (DSS) from their inception in the 1960s until their incorporation with artificial intelligence (AI) and machine learning (ML), resulting in more intelligent and adaptive SDSS. The paper shows the main architectures and base components of DSS and SDSS and highlights the value of data management, the value of model management, and user interface improvements. Special focus is given to multi-criteria decision making (MCDM) methods and their hybridizations with fuzzy, grey system and neutrosophic theories to mention uncertainty and complexity in decision environments. This paper classifies and summarizes recent researches using application domains like material and medical device selection, operations management, logistics, quality evaluation, supply chain management, risk management, and waste management. After this study, the findings indicate that combining MCDM techniques with AI improves decision-making process quality and organizational performance, particularly in complex and uncertain contexts. The paper also identifies current research gaps, like scalability, interoperability, and user interface challenges, and future directions, including deeper cooperation with big data technologies and IoT to further enhance the effectiveness and usability of SDSS.

Keywords: Artificial Intelligence (AI); Supply Chain Management; Healthcare; Operations Management; Quality Evaluation; Risk Management; Waste Management; Fuzzy Set Theory; Grey System Theory; Decision Support Systems (DSS); Smart Decision Support Systems (SDSS); Multi-Criteria Decision Making (MCDM)

1 | Introduction

The use of computers to help decision-makers was presented as an idea in 1963 [1]. In the 1970s, many suggested terms were presented to explain the system that aids decision-makers in the procedure of building structures for the decision-making process. In 1971, Scott Morton was one of the first groups of researchers who put a meaning to the term ‘decision support systems. Since then, a lot of research in the area of decision support systems (DSS) tries to improve and help to modify this concept.

DSS are the information systems (IS) parts that are used to help decision makers to make their managerial decisions. DSS is an information technology-based process that can aid in decision-making processes. DSS has become important since it was initialized in the 1970s. It also becomes one of the most important areas

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of IT practice, and decisions that are made by IT-based decision support can enhance the character and functionality of organizations.

Currently the integration between DSS and AI is one of the most active areas of investment. Whenever there is an IT downturn, like in the early to mid-2000s. The sector of BI software fees grew 12% from 2003 to 2004, and it grew by 7.4% in 2009. The history of DSS presents the evolution of several subsectors of research and practice [3].

DSS has main sub-fields like Personal Decision Support Systems (PDSS): it developed to support one or a small group of managers, so it's a small system to take small decisions. Group Support Systems (GSS): This kind of DSS has communications technologies that help different groups to work together and exchange data among them. Negotiation Support Systems (NSS): This DSS focuses on how the team members in one group or different groups can interact with each other to make their decision. Intelligent Decision Support Systems (IDSS): The result of integration between standard DSS and AI techniques can produce IDSS. Knowledge Management-Based DSS (KMDSS): This type of DSS focuses on how to store the data in an optimal method to be able to store, transform, and retrieve it.

These systems support separate, structural memory and shared knowledge access. Data Warehousing (DW): with the growth of data, the traditional systems can handle this large size of data, so DW systems appear to provide an infrastructure that can manage this large-sized data. Enterprise Reporting and Analysis Systems: This type of DSS contains executive information systems (EIS), business intelligence (BI), and corporate performance management systems (CPM). These modules help the enterprises to deep dive into their data warehouse and extract the knowledge from it to improve the enterprise performance. [4]

Decision-making (DM) is one of the greatest significant processes that is used in our lives because it is a part of daily steps like I want to go, I want to buy, I want to make, and so on. In all these daily steps and others, we must decide. So, DM is one of the vital methods to identify the optimal solution and decision among several feasible alternatives. Decision-making can be deemed a method to solve the problems to achieve optimal/satisfactory solutions. It is also a very sensitive process because the optimal solution now may not be optimal the next time, so the DM process must be precise and timely. Taking the decision at the right time can help us to achieve our goals, save our resources, find new opportunities, and increase our productivity overall. On the other hand, the right decision at the wrong time loses all these benefits, so the right decision is not only the decision itself but also the right time.

DM is a process, so it has steps to achieve its goal. These steps are like (a) studying the problem to get a clear definition of it, (b) collecting information that is used in decision-making, and (c) defining options that can be valuable/applicable and excluding the other ones. (d) choosing the most suitable alternative depends on the predefined criteria, (e) apply one of the most suitable solutions, and (f) examine the final decision to make sure it matched with your vision [5, 6] as appears in Fig. 1.

The predefined criteria that were mentioned before helping us to test each one to see if it matches with our vision or not, and there can be several. Based on it, it is termed MCDM. To achieve this, there are many mathematical techniques that can help us to define the finest alternative based on the predefined criteria, and they are known as MCDM techniques [7]. At present, there is a large grossing of the number of activities that decision-makers and stakeholders have to make every day, and the mindset is to create the decision at the correct time with high quality to achieve the goals.

There are too many fields that gain large value by using MCDM techniques. As an example of these fields, there is healthcare, supply chain, traffic control, agriculture, climate prediction, energy management, disaster management, and so on. These fields use different techniques for using MCDM, like in supply, which can be used in smart packaging, simulation, dynamic pricing, Using smart packaging, data-driven decision support systems can be developed to achieve grocery store supply chains throughout outbreaks and minimize food excess.

The cases in this topic are like practical case studies of a single item in grocery retail. The cases like that have a gap as no real-world application validation and limited scope to single-product simulation and related to uncertainty, sensitivity analysis of stock capacities, freshness discount rate, and inventory turnover under uncertain demand. This topic also has future works like expanding the system to multiple products and real-world case studies and integrating with IoT sensors for actual decision-making. [8]

Also in agriculture, MCDM is used with Big Data, the Internet of Things (IoT), artificial intelligence, cloud computing, and remote sensing to analyze their challenges and suggest improvements in the case of a systematic review of DSS applications in agriculture. But also, it has gaps like limited scalability and interoperability, a lack of user-friendly interfaces, and difficulty in integrating multi-source data. In this case, climate adaptation and yield prediction models with uncertain environmental data represent the uncertainty.

We can also develop AI-based predictive models, improve interoperability, and create user-friendly DSS interfaces for farmers [9].

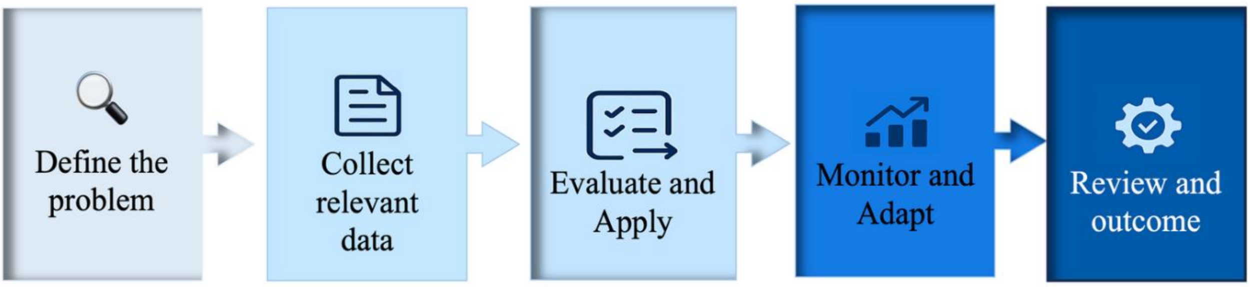

Figure 1. Steps of MCDM Techniques.

Now we can conclude that MCDM techniques are very important in many fields, and to use them, we have to define the criteria that are suitable for this field and the most probable technique and then apply the steps of the MCDM technique to achieve the required goals in the right time.

This paper will be continuous with the following structure: Section 2 describes the review framework and methodology that were used to collect and analyze the previous studies. Section 3 describes the architecture and main parts of DSS and SDSS, followed by the detailed exploration of MCDM techniques in Section 4. Section 5 classifies and reviews recent applications of SDSS across multiple domains such as supply chain management, material selection, healthcare, logistics, quality evaluation, risk management, and waste management. Section 6 lists the outcomes and offers a conversation about the key findings. Section 7 views the value of integrating AI with MCDM techniques, identifies current challenges and highlights research gaps, and offers possible avenues for the future. Section 8 brings the investigation to a close and outlines its key findings.

2 | Review Framework

The objective of this study is to provide an in-depth presentation of SDSS approaches, their applicable sector, and the significance of these applications to enhance the decision-making process in recent years. Articles that were found using search parameters in the Scopus database. 173 papers (102 articles, 38 conference papers, 15 reviews, 10 book chapters, 5 conference reviews, and 3 books) were found when searching for the title "smart decision support system and its applications," which may appear in the title, keywords, or abstract of papers published between 2018 and the present. Fig. 2 displays the participation percentages of the literature.

Papers published in conference proceedings, book chapters, conference reviews, and books have been omitted first in order to lower the number of reviewed papers to an acceptable quantity. The selection criteria are shown in Fig. 3: English, the state of the final publication, and the emphasis on SDSS methods, classification into application areas such as logistics, operations management in healthcare, risk management, waste management, medical device and material selection, disease identification and treatment, healthcare information systems, and supply chain management. 94 research publications are included in the final list for review, which has a publication status of "Final" and takes into account applications of just MCDM approaches.

3 | Overview of SDSS Techniques

3.1 | Decision Support System Architecture

DSS are the base that SDSS can build on. So, diving into DSS will help with understanding and good planning for SDSS. According to the previous studies, DSS consists of three main components, like: management of data, management of models, and management of user interfaces. Fig. 4 and Fig. 5 contain an applied case with more details. The data management component is the component that can integrate, ingest, store, and retrieve the data; model management consists of quantitative models that make the DSS able to analyze and solve the problems; and the user interface component is the component that helps improve the communication between users and systems.

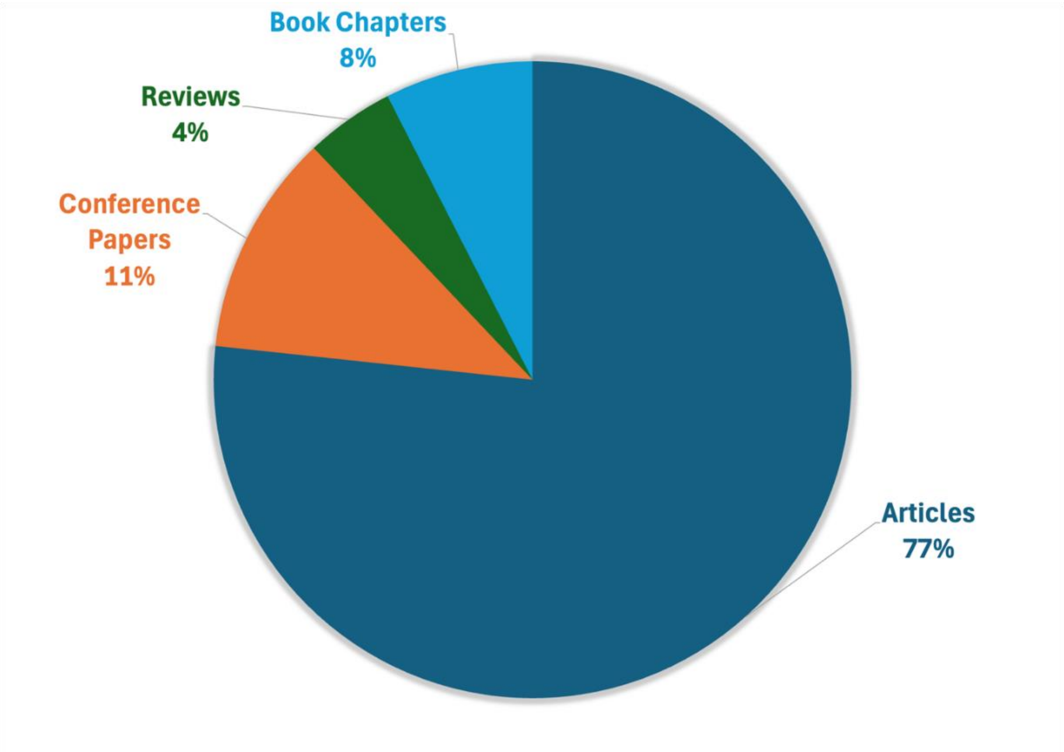

Figure 2. Participation Percentages of Literatures.

DSS also has three principal architectures: network architecture, centered architecture, and hierarchy architecture. Each one has its advantages and limitations that keep it suitable for specific applications. The network architecture is built on isolation of models, so each DSS contains its management of data, management of models, and management of user interfaces, and the change in one DSS doesn't affect the others, but it does face some difficulties in data exchange and integration. Centered DSS, this architecture is designed to keep databases in one place, and all models access it. It is very good in data exchange, but it is difficult to modify something because it affects all other models. In hierarchy architecture, the users have strong control over the models because the supervisor can manage the exchange of data between models, but it adds more complexity to the structure [10].

3.2 | Smart Decision Support Systems

The traditional DSS, as mentioned before, was created by developing its steps, and it works in a systematic manner, but to improve its performance, we can integrate it with up-to-date technologies like AI and ML to upgrade the traditional DSS to SDSS. The SDSS can work with high capabilities like working with huge amounts of data, analyzing vast amounts of data, and delivering the insights in a smart manner to simulate human decisions. SDSS also can understand the problem and define the most suitable method to take the decision based on the nature of the case and criteria and then decide the potential solution with its advantages and disadvantages. So, it is presenting like humans.

SDSS can work in different sectors like smart manufacturing, intelligent marketing systems, and medical diagnostics. The objective of SDSS is to increase productivity, with research indicating that approaches combining data-driven and knowledge-based systems can boost productivity by 7.21% [5].

Traditional DSS contain management of data, management of models, and management of user interfaces. Also, SDSS contains components like these but with an intelligent side. Data management—this component has improved to work with big data frameworks and real-time data processing, and it can work with external data sources. Model management, this component enhanced by adding advanced algorithmic approaches, AI, and ML models. Also, with user interface management, interfaces have evolved significantly to contain interactive Visualizations, dashboards, and mobile accessibility [9].

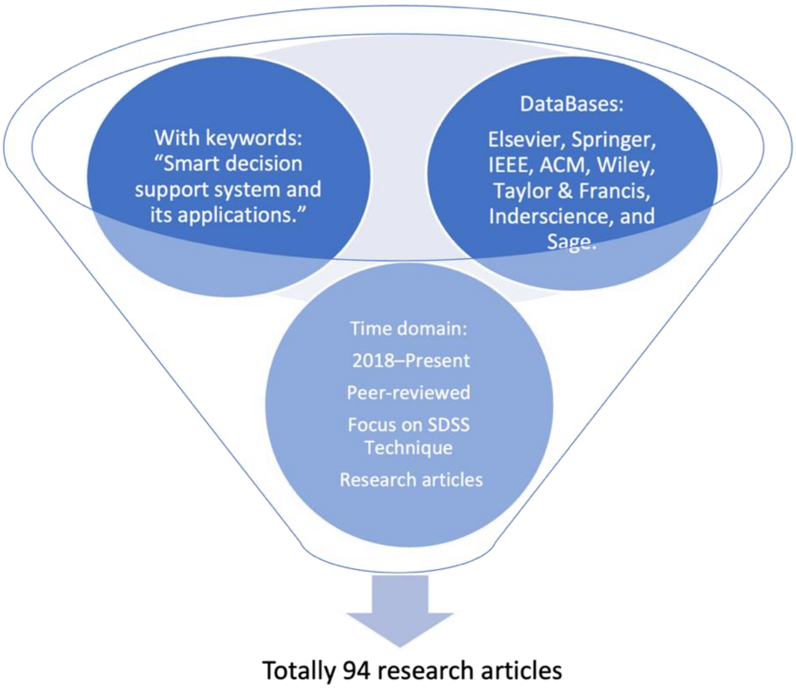

Figure 3. Selection and Refinement Strategy.

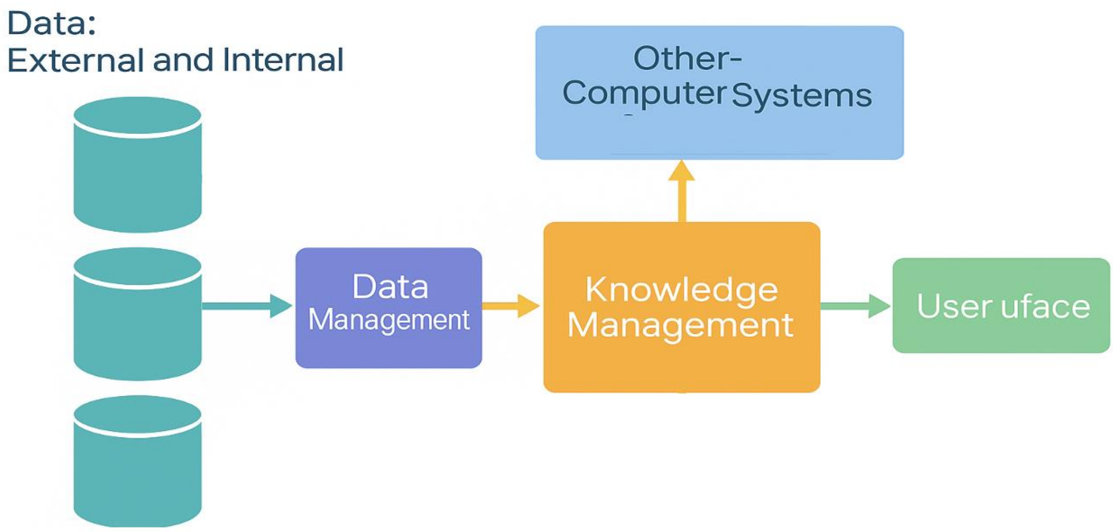

Figure 4. Decision Support System Components.

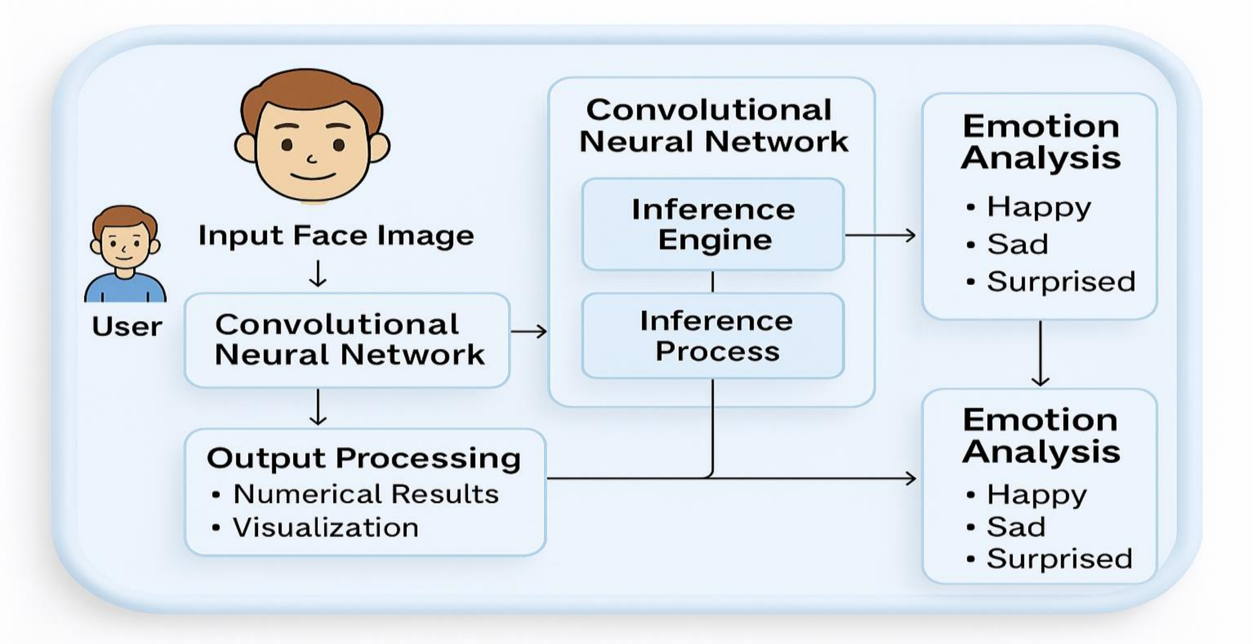

Figure 5. Applied Case on Decision Support System Components.

3.3 | Multi-Criteria Decision Support System Architecture

MCDM methods have systematic steps that the users must follow, so at first the decision matrix must be built, and it contains the possible alternatives and the criteria that we can select based on; this exists in most of MCDM methods. So, we will briefly discuss some of them, which earlier researchers used in MCDM in several fields. Benjamin Franklin is credited with developing another idea known as decision analysis (1706–1790). ELECTRE I, which debuted in 1965, was the first successful use of MCDM. [11].

MCDM methods have four basic steps: (1) structuring the decision process, and it contains selection of alternatives and criteria detection (2) define the criteria weights. (3) utilizing value judgment in evaluation and tradeoffs (4) calculating final rank and making decisions [12]. These steps help in selecting the most suitable solution from multiple attribute options. There are some MCDM techniques that have been frequently used in recent years.

3.3.1 | Analytic Network Process (ANP) and Analytic Hierarchy Process (AHP)

The AHP is a framework that works to manage complex decision-making by applying hierarchical structures and pairwise comparisons to determine each criterion's weight, and AHP was pioneered by Thomas L. Saaty [13]. When this approach is extended by addressing interdependencies among decision elements will be related Analytic Network Process. These methods have an advantage as their output is more reliable but also have disadvantages as they can't work with modern decision-making contexts that contain complex data [13].

3.3.2 | TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)

This technique is used to order the options according to how far away they are geometrically from the ideal and negative-ideal solutions. It has become popular due to its natural approach and reasonably direct implementation. Research compared Fuzzy AHP and Fuzzy TOPSIS, and they found that based on the application context, each one has advantages. Fuzzy AHP consumes less computational time for smaller datasets, while Fuzzy TOPSIS often performs better with larger, more complex datasets [14].

3.3.3 | VIKOR (VIšekriterijumsko KOmpromisno Rangiranje)

VIKOR is used with incompatible criteria to identify the rank of alternatives and find compromise solutions for problems. The researcher compared VIKOR with TOPSIS in various ways, such as evaluating energy generation technologies, and they indicate that the methods may generate different rankings depending on the problem characteristics [12].

3.3.4 | PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation)

PROMETHEE presents a ranking technique that is used to compare alternatives in pairs through each criterion. It has been useful in energy planning, particularly for assessing renewable energy options for electricity and heat supply [12].

3.3.5 | Fuzzy Set Theory in MCDM

When fuzzy set theory is integrated with MCDMs, it can generate a significant evolution in addressing uncertainty and fuzziness in decision-making processes. Fuzzy MCDM approaches enable the handling of imprecise information through linguistic variables and fuzzy functions, enhancing the ability to model real-world decision situations [14]. By applying fuzzy to traditional approaches, such as fuzzy TOPSIS, fuzzy AHP, and fuzzy VIKOR, it enables it to handle uncertain data environments. By applying these approaches, we can find applications across different domains, like selecting the supplier in manufacturing, making decisions in healthcare, and energy planning [14].

3.3.6 | Grey System Theory for Decision Analysis

Another approach to handling uncertainty in decision-making is Grey System Theory (GST), which provides another way to handle uncertainty in decision-making when data is incomplete or limited. The use of techniques like Grey AHP and Grey DEMATEL helps with decision-making even with limited information by improving resilience in rapidly changing environments such as pandemic response planning [13].

3.3.7 | Hybrid MCDM Approaches

When multiple MCDM methods integrate with each other, they emerge as a new approach to increase the strengths of different techniques while reducing their limitations. Hybrid models consist of various methodologies to improve precision, scalability, and adaptability in decision-making processes [13]. Much research on integration between artificial intelligence and MCDM has clarified significant potential for improving decision support features. For example, a hybrid approach using explainable ML algorithms combined with MCDM established improved performance in supplier selection cases. One model used a decision tree to minimize the complexity, followed by AHP to rank alternatives, while another used FUCOM for criteria weighting and TOPSIS for supplier ranking, and followed by a decision tree classifier [15].

4 | Application Sectors of SDSS

The previously published papers are briefly presented in this area according to the application that is covered in them. Brief tabular forms are used to present the information gathered from several sources, including the author(s), year of publication, DSS technique (s), criteria weighting technique, uncertainty model, sensitivity analysis tool, purposes, and study outcomes.

4.1 | Supply Chain Sector

Well-organized supply chain management has become critical to certify that the correct products arrive on time in the right place with minimum cost. These products include medical devices, raw materials, final products, and anything related to the supply chain process without affecting any part of the supply chain process. As listed in Table 1, applied cases of DDS methods in solving several supply chain management areas, like suppliers' selection, distribution networks management, defining the analytical features for effective control of vendor-managed catalogs, appropriate management policies, etc.

4.2 | Material Selection Sector

As listed in Table 2, MCDM methods have been accepted to choose the most proper materials in industry. Various materials that are used in different fields of industry, like steel that can be used in main fields, must be selected carefully due to their value and price, and each industry field uses some specific material, so the type of material and its quantity must be selected carefully to match the business plan of the organization. Additionally, a lot of criteria are employed in the selection process that need to be taken into account. Therefore, choosing the right materials would contribute to raising industry standards and quality.

4.3 | Logistics Sector

In the process of DM, the concept of logistics can act as a function of the main management functions, which can help in logically defining the purposes when the organization wants to develop many actions at the same time to achieve the predefined goals. Table 3 shows some MCDM methods that can measure the comparative performance of real-time location systems successfully, select and rate the most suitable alternative, solve location selection problems for different types of facilities, select reversal logistics facility providers, define the short list of the alternatives, etc.

4.4 | Operations Management Sector

Operations management, as enumerated in Table 4, is a very important application area in DSS, taking into consideration the applications of DSS techniques for efficient resource management, using management and full quality management applications, arranging of seven sigma projects, etc.

4.5 | Quality Evaluation Sector

Quality evaluation is a very important factor in many sectors, like healthcare and sensitive industry sectors that must be secure, efficient, customer-based, on time, and reasonable. Any unconventionality in the set purposes may lead to bad value of industry tactics service. To do this in today's extremely reasonable ecosystem, healthcare must pay due attention to meeting the expectation of each patient while providing quality and effective healthcare services. Table 5 displays how different MCDM techniques, like AHP, TOPSIS, VIKOR, ELECTRE, PROMETHEE, etc., have been employed to appraise the quality of services in numerous of the universally spread healthcare units.

Table 1. DSS Techniques in the Sector of Supply Chain Management.

ID	Author(s)	MCDM technique	Research goals	Research output
1	El Mokrini et al. [16]	AHP	Examine how well the six distribution networks that make up the public sector supply chain are operating. Morocco	A set of assessment criteria was used to determine the optimal distribution network for the products.
2	Ganguly et al. [17]	Fuzzy AHP	The supplier selection issue in India was resolved by applying fuzzy AHP.	The most crucial element is the performance of the supplier.
3	Khumpang and Arunyanart [18]	fuzzy TOPSIS, rank order centroid	Using rank order centroid and fuzzy TOPSIS to address supplier selection challenges in Thailand	In a fuzzy environment, there are five options from which to choose the best provider. And the most crucial factor is quality.
4	Abdullah et al. [19]	SMART	Several performance metrics that aid in supply chain process improvement were ranked using a DSS framework that was created with MCDM.	In a fuzzy environment, there are five options from which to choose the best provider.
5	Stević et al. [20]	MARCOS	Choosing the most environmentally friendly suppliers for a particular unit.	Savings compared to other solutions was shown to be the most significant signal that may influence the choice in the end.
6	Yazdani et al. [21]	DEMATEL, BWM, EDAS	For the purpose of rating suppliers in various Spanish industries, applications of the DEMATEL, BWM, and modified EDAS methodologies were suggested.	A sensitivity analysis study is used to assess MARCOS's ability to choose the best provider among the eight available alternatives.
7	Biswas [22]	PIPRECIA, CoCoSo, MABAC, MARCOS	Twenty suppliers were ranked using the MABAC, CoCoSo, and MARCOS methodologies, and criteria weights were determined using PIPRECIA.	Results from the DSS approaches would be reliable. Additionally, it was observed that the well-known businesses did not fare well.
8	Sumrita [23]	Fuzzy Delphi, fuzzy SWARA, COPRAS	One of the fuzzy Delphi methods is creating the shortlist of requirements for choosing a vendor-managed inventory supplier.	Based on how well they performed in terms of vendor-managed inventory, three suppliers were ranked. A sensitivity analysis study demonstrated the effectiveness of the suggested strategy.
9	Abdel-Basset et al. [24]	Rough numbers: MABAC, PFS, BWM	To address supplier selection challenges, the industry can use an integrated application of MABAC, BWM, PFS, and rough figures.	Product quality was determined to be the most significant factor using BWM. Five rival suppliers were rated using the MABAC approach, which used PFS and approximate data.
10	Sumrit [25]	Grey-DEMATEL, Fuzzy Delphi	Using the fuzzy Delphi and grey-DEMATEL approaches, the key success factors that resulted in an efficient vendor-managed inventory were put into practice.	The key success criteria for implementing vendor-managed inventory were goal similarity, trust, management commitment, and information exchange.
11	Moosivand et al. [26]	TOPSIS, AHP	AHP was used to determine the weights of the criteria, and TOPSIS was then used to rank five managerial methods in order to prevent medicine shortages in Iran.	The most successful strategies seemed to be those pertaining to information systems and supply chains.

12	Farghaly et al. [27]	AHP	To encourage value-based generic medication purchases in the United Arab Emirates	Real-world clinical results were given the highest importance out of the nine criteria that were taken into consideration.
13	Leong et al. [28]	BWM, TOPSIS, GRA	Ten vendors were ranked using an integrated methodology (GRA-BWM-TOPSIS) based on seven criteria.	A rigorous supplier selection framework was put forward. Grey theory use might improve supplier selection process consistency while successfully handling unpredictable
14	Salimian et al. [29]	IVIFS, MARCOS, VIKOR	Using expanded VIKOR and MARCOS with IVIFS, sustainable providers for medical equipment in organ transplantation networks were chosen.	Four organ transplantation networks' suppliers' performance was evaluated in a group decision-making setting.

Table 2. Application of MCDM Techniques in the Sector of Material Selection.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Nurcan Deniz & Ekim Onur Orhan (2021) [30]	Delphi Method, Smart Pairwise Comparison,	To propose specific selection criteria for engine-driven NiTi instruments and assess them systematically	A validated MCDM-based assessment model with 15 criteria under 4 dimensions (economic, environmental, social, experience-based) was developed for NiTi instruments.
2	Boran et al. [31]	Intuitionistic fuzzy TOPSIS	To evaluate alternative waste treatment technologies using intuitionistic fuzzy TOPSIS.	The suggested method provided more precise ranking results compared to conventional techniques.
3	Arroyave et al. [32]	ANP	To prioritize the criteria to support the choice of material.	The method helped in understanding the significance of each criterion in the decision-making process.
4	Karasan and Kahraman [33]	Intuitionistic fuzzy sets	To contract with the equipment selection problem services fuzzy environment.	The intuitionistic fuzzy approach enabled better handling of uncertainty in expert judgments.
5	Sengul and Sahin [34]	Fuzzy AHP	To evaluate alternative transportation techniques used in organizations.	The approach effectively handled the imprecise information associated with evaluations.
6	Jahan and Edwards [35]	Weighted property index method	To develop a structured method for selecting materials in different applications.	The method facilitated systematic material selection based on multiple performance indicators.
7	Ayvaz et al. [36]	Fuzzy TOPSIS, Fuzzy AHP	To prioritize standards and rank alternatives in waste management systems.	Integration of fuzzy AHP and fuzzy TOPSIS enhanced the robustness of the selection process.
8	Mardani et al. [37]	DEMATEL	To recognize critical factors in the selection of equipment suppliers.	DEMATEL revealed interdependencies among criteria and ranked them accordingly.

Table 3. Application of MCDM Techniques in the Sector of Logistics.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Budak and U stundag [38]	Fuzzy AHP	The comparative effectiveness of three distinct real-time locating systems in Turkey was evaluated using fuzzy AHP.	The best real-time locating system was found to be an IR-RF hybrid.
2	Hu et al. [39]	fuzzy sets, Interval neutrosophic VIKOR	VIKOR was paired with interval neutrosophic fuzzy sets to select the best option from a variety of options.	Compared to previous ranking techniques, the suggested approach was shown to be more appealing and accurate.

3	Dell'Ovo et al. [40]	WSM	In order to help find the finest facilities in Milan, MCDM approaches were combined with GIS.	To verify the sufficiency of a particular area extending the alternatives' realm, suitability maps were created.
4	Sun et al. [41]	Hesitant fuzzy linguistic term sets and MABAC	In order to prioritize patients in a Chinese hospital, a projection-based MABAC algorithm was developed in conjunction with hesitant fuzzy linguistic word sets.	A comparison analysis and a sensitivity analysis demonstrated the usefulness of the suggested method for patient prioritizing.
5	Adalı and Tuş [42]	TOPSIS, EDAS, CRITIC, CODAS	The TOPSIS, EDAS, and CODAS methodologies were used to determine the overall ranking of the hospital site possibilities, while CRITIC was used to assess the relative relevance of the factors taken into consideration when choosing a hospital site.	The several locations under consideration were ranked in the same order by all three distance-based MCDM techniques, with "market conditions" being the most important criteria.
6	Zhu et al. [43]	2-tuple DEMATEL and fuzzy VIKOR	By merging fuzzy VIKOR and 2-tuple DEMATEL, a hybrid MCDM model was proposed to handle the elective admission control problem in a hospital in West China.	Sensitivity analysis and a comparison with alternative methods demonstrated the efficacy of the suggested strategy, offering hospital administrators valuable insights.
7	Yazdi et al. [44]	BMW, ARAS, Z numbers	In order to assess the reverse logistics skills of Iranian healthcare providers, critical success variables were determined.	In a fuzzy environment, reverse logistics providers might be chosen more precisely with the help of the suggested method.

Table 4. MCDM Applications in the Sector of Operations Management.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Amaral and Costa [45]	PROMETHEE-II	In emergency department, support decision making and resource management can used	The mean waiting time was reduced by 70% as a result of bottlenecks being effectively resolved.
2	Hussain et al. [46]	AHP	in Abu Dhabi public healthcare delivery systems' lean philosophical bean be Deployed	Shown a workable approach to implementing lean in healthcare institutions.
3	Hussain and Malik [47]	AHP	Prioritize lean management applications in UAE organizations.	Offered a framework for enhancing productivity and quality in both public and private hospitals.
4	Talib et al. [48]	BWM	Rank quality management providers in different sectors.	"Continuous improvement-based" was ranked lowest, while "leadership-based enablers" was scored top.
5	Pakdil et al. [49]	KEMIRA-M	Prioritize Six Sigma projects in organizations.	The top three rankings were sigma level, revenue enhancement, and patient happiness.
6	Aminjarahi et al. [50]	WSM, VIKOR	Rank lean techniques for emergency departments from physicians' and nurses' perspectives.	Physicians ranked the theory of constraints first, whereas nurses ranked Jiduka and 5S.
7	Bharsakade et al. [51]	Fuzzy AHP	Prioritize causal to seven straightforward wastes in a delivery system factor.	Defects, motion, waiting, and transportation were the main determinants of lean adoption.

Table 5. MCDM Applications in the Sector of Quality Evaluation.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Krishankumar et al. [52]	VIKOR, linguistic hesitant fuzzy set.	Hospital performance Evaluated and took into consideration hesitation and dissimilar stakeholders.	Ranking four hospitals from finest to worst.
2	Tuzkaya et al. [53]	IVIFS and PROMETHEE	Evaluate the quality of a public field in Istanbul.	Solutions enhanced service quality based on patient views.
3	Torkzad and Beheshtinia [54]	AHP, TOPSIS, ELECTRE	Appraise the quality of four Iranian subsectors using hybrid MCDM methods.	Hybrid methods improved overall healthcare system quality.
4	Rouyendegh et al. [55]	Fuzzy AHP and DEA	Measure the effectiveness of many hospitals in Turkey.	Approach flexibility to assess the competence of any organization.
5	Fei et al. [56]	BWM	Assess hospital service quality in uncertain environments using belief function theory.	Provided proper guidance for quality evaluation.
6	Li and Wei [57]	Hesitant fuzzy linguistic term sets and TOPSIS	Propose large-scale group decision-making for evaluating healthcare services.	Serves as a decision sustenance tool for evaluating new medical technologies.
7	Amiri et al. [58]	BWM and fuzzy preference programming	Assess hospital performance in Tehran using integrated MCDM methods.	Ranking Five hospitals in Tehran
8	Erjaee et al. [59]	Fuzzy set theory and AHP	Evaluate healthcare sustainability.	Helped assess and improve healthcare system sustainability.
9	Al Awadh [60]	AHP	Prepare the short list of criteria and model seven SERVQUAL dimensions for hospital service quality.	Improved monitoring and service level in Saudi hospitals.
10	Hasania and Mokhtari [61]	Fuzzy BWM, DEMATEL, DEA	Period evaluation of Iranian hospital performance in different periods using integrated MCDM techniques.	Supported sustainable healthcare system management.

4.6 | Risk Management Sector

DSS systems contain various related organizational, technical, communal, and environmental risks, which may have harmful results on operational management in organizations. Applied cases of DSS methods in the risk management sector are shown in table 6, taking into consideration flood-induced supply chain failure prediction as public risk and complex risk in the growth steps of used devices like fire risk and risk involved in logistics subcontracting, ranking of safety executive risks, and defining of risk factors that disrupt emergency lifesaving medicine supply chains.

Table 6. Applications of MCDM Methods in the Sector of Risk Management.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Omidvari et al. [62]	IVIFS, CODAS, BWM	Rank the various hospital wards and estimate the weights of the fire risk criteria and sub-criteria.	Powerhouses were at the highest risk of fire; hence, alarm systems were of utmost importance.
2	El Mokrini and Aouam [63]	Fuzzy PROMETHEE, Fuzzy TOPSIS	Risk assessment for Moroccan healthcare logistics outsourcing.	Aided legislators in establishing priorities for healthcare supply chain prevention and mitigation.
3	Khalilzadeh et al. [64]	PROMETHEE, Fuzzy SWARA	Using FMEA and PROMETHEE, classify the main health and care executive risks associated with oil and gas projects.	Aided legislators in establishing priorities for healthcare supply chain prevention and mitigation.
4	Akter et al. [65]	DEMATEL, Grey theory	Determine and examine significant risk factors that are interfering with the supply chain for life-saving medications.	Identified risk factors to guarantee the ongoing supply of life-saving emergency medications.

4.7 | Waste Management Sector

There is a lot of pressure on the relevant urban facilities units to dispose of their garbage in a sustainable, economical, and hygienic manner due to the growing worldwide population and the public's increasing need for quality facilities. In addition to causing serious environmental pollution, improper and dangerous waste management can lead to health issues such as infectious disease transmission and groundwater contamination. Table 7 makes clear that prior studies have mostly examined MCDM applications to assess the suitability of waste treatment methods and recycling locations.

Table 7. MCDM Techniques in the Sector of Waste Management.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Baidya et al. [66]	Fuzzy AHP	Examine the biomedical waste management procedures used in an Indian tertiary hospital.	Key areas for biomedical waste practices improvement were identified with the use of fuzzy AHP.
2	Ren et al. [67]	fuzzy AHP, VIKOR	Examine medical waste disposal options while taking social, technical, financial, and environmental factors into account.	Fuzzy AHP and VIKOR together produced a strong alternative ranking.
3	Asadi et al. [68]	fuzzy TOPSIS, Fuzzy AHP	Offer a sustainable approach to the disposal of medical waste by utilizing integrated MCDM methodologies.	Higher ranking accuracy under uncertainty was provided by fuzzy approaches.
4	Jayalakshmi and Jayanthi [69]	AHP, DEMATEL	Determine and rank the obstacles to hospitals' adoption of green supply chain management.	The main obstacles were a lack of managerial support, training, and awareness.
5	Pourjavad and Shirouyehzad [70]	ANP, DEMATEL	Analyze the causal connections between the sustainability obstacles in the management of medical excess.	Strategic planning for sustainable waste management was made easier by the integration of DEMATEL and ANP.

4.8 | Smart Cities Planning and Management Sector

Recently, SDSS have been practical in urban development in smart cities planning and its facilities management, as they assist in coordinating complex, multi-task operations. Tools such as the Program Evaluation and Review Technique (PERT) and project management software like MS Project are commonly used with MCDM techniques to improve scheduling, resource allocation, and cost estimation. These systems help decision-makers to identify critical paths, optimize time plans, and create reports for task management, budgeting, workload distribution, and resource utilization. Their application is particularly beneficial in engineering, construction, and IT projects, enhancing both strategic planning and operational execution [71, 72].

4.9 | Smart City Disaster Management Sector

In the domain of disaster management in smart cities, intelligent decision support systems (IDSS) play a very important function in improving preparedness, response, and also recovery in natural disasters. integration between technologies like AI, big data, and DSS components to use to enhance the real-time, complex, and uncertain decision-making in different cases such as heatwaves, cold waves, and forest fires. Key techniques include fuzzy logic, expert systems, evolutionary algorithms, and convolutional neural networks (CNN), which are used for early warning, fire detection, and dynamic resource allocation.

The study emphasizes the value of machine learning models like reinforcement learning (RL) and generative adversarial networks (GAN) in predicting wildfire spread and analyzing disaster data. The study output presents that integration of DSS with AI significantly reduces response time and improves decision accuracy, particularly through real-time data streams from APIs, UAVs, and CCTV systems. Table 8 lists examples of used techniques in this field.

Table 8. MCDM Techniques in the Sector of Smart City Disaster Management.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Jung et al. [73]	Fuzzy Logic, RL, Expert Systems, CNN, GAN	To design an intelligent DSS integrating AI and big data for heatwaves, cold waves, and wildfires in smart cities.	The framework improves disaster response speed and accuracy through real-time data from APIs, UAVs, and CCTVs.
2	Ishak et al. [74]	Conceptual DSS Model for Reservoir Operations	To build a DSS for real-time decision-making in managing water reservoirs during heavy rainfall emergencies.	The DSS model helps prevent flooding by optimizing reservoir water discharge during emergencies.
3	Akay et al. [75]	Dijkstra Algorithm, GIS-based Route Optimization	To enhance route planning and firefighting response through GIS and algorithmic modeling in forest fire scenarios.	GIS-enhanced DSS enables identification of the fastest and safest routes, improving firefighter effectiveness.
4	Alarifi et al. [76]	Artificial Neural Networks (ANN)	To develop AI models for predicting the magnitude of earthquakes based on seismic data.	ANN-based models enhance earthquake prediction reliability using large volumes of seismic data.
5	Goymann et al. [77]	Neural Networks for Flood Prediction	To predict flood levels using trained neural networks based on historical and real-time environmental data.	Neural network models proved effective in early flood detection and can outperform traditional systems.

4.10 | Agriculture and Smart Farming Sector

SDSS has recently been applied in agriculture; this sector uses AI, cloud computing, IoT, Big Data, and remote sensing to improve the productivity of agricultural processes and can optimize resource allocation. Recent literature highlights applications of SDSS in areas like planning missions, managing water incomes, acclimatizing to climate change, and controlling food waste. Methods that can be used in this sector, like fuzzy logic, decision trees, multi-objective linear programming (MOLP), and crop simulation models (DSSAT), are integrated with each other to support precision irrigation, supply chain optimization, and adaptive farming practices.

These systems assist farmers in using real-time data to make well-informed decisions and predictive modeling, ultimately contributing to reduced waste, increased yields of crops, and more sustainable farming practices and operations. Table 9 lists examples of used techniques in this field.

Table 9. MCDM Techniques in the Sector of Agriculture and Smart Farming.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Zhai et al. [78]	simulation models, Fuzzy logic, optimization algorithms,	To survey and evaluate 13 ADSSs applied in Agriculture 4.0 across mission planning, irrigation, climate adaptation, and food waste.	ADSSs increase efficiency and adaptability but need improved GUIs, re-planning capabilities, and better historical data use.
2	Navarro-Hellin et al. [79]	Partial Least Squares Regression (PLSR), ANFIS	To optimize irrigation scheduling for water-limited lemon orchards using data-driven models.	SIDSS outperformed human agronomists, offering more precise irrigation planning.
3	Giusti & Marsili-Libelli [80]	Fuzzy C-Means Algorithm	To improve irrigation decision-making by integrating fuzzy inference and predictive soil moisture models.	FDSS significantly reduced water usage for multiple crop types while improving irrigation accuracy.

4	Schutze & Schmitz [81]	CWPF, GET-OPTIS (climate-based modeling)	To develop optimal irrigation strategies under variable climate conditions for sustainable agriculture.	OCCASION provided robust, climate-aware irrigation strategies through stochastic modeling.
5	Soysal et al. [82]	Multi-Objective Linear Programming (MOLP)	To optimize beef supply chain logistics, minimize cost and CO_2 emissions during food transport.	MOLP-based logistics improved sustainability by reducing emissions and cost while enhancing delivery precision.

4.11| Various Sectors

Papers that do not drop into any of the 10 earlier mentioned categories belong in this section. Policy evaluation, sentiment and gratification analysis, determining the length of time spent in a line, framing real policies, bottleneck examination in a department, referral system performance analysis, assessment of station indicators, ranking of supportable tourism destinations, and other issues have all been successfully resolved through the use of appropriate MCDM techniques, as shown in Table 10.

Table 10. MCDM Techniques in Various Sectors.

ID	Author(s)	MCDM technique	Research goals	Research output
1	Tavana et al. [83]	Fuzzy AHP, fuzzy inference system	Design a strategic framework for tourism service quality assessment.	An integrated approach enhanced the assessment of quality criteria in health tourism.
2	Sardari et al. [84]	Fuzzy AHP, fuzzy TOPSIS	Evaluate the performance of emergency services (ES) in Tehran.	Enabled better planning and improvement of EMS in urban areas.
3	Vafadarnikjoo et al. [85]	Fuzzy DEMATEL, BWM, fuzzy VIKOR	Evaluate barriers to implementing telemedicine during COVID-19 in Iran.	Revealed organizational resistance and lack of infrastructure as major barriers.
4	Osaba et al. [86]	Fuzzy MCDM	Prioritize ethical challenges in decision-making using fuzzy MCDM.	Provided a robust structure for analyzing ethical concerns in healthcare.
5	Boukherroub et al. [87]	ELECTRE III	Rank sustainable strategies for the health sector in Canada.	ELECTRE III effectively ranked feasible and sustainable strategies for healthcare policymaking.
6	Karahan et al. [88]	SVN-CIMAS-CRITIC-RBNAR	To advance a decision support model for evaluating the financial performance of technology companies using neutrosophic logic and MCDM techniques.	A hybrid model (SVN-CIMAS-CRITIC-RBNAR) applied to Borsa Istanbul technology firms; validated through case studies and sensitivity analysis.
7	Alptekinp [89]	Fuzzy AHP and Fuzzy TOPSIS	To evaluate and define the optimal renewable energy alternatives for Turkey considering multiple environmental, economic, and technical criteria.	The ranking of renewable energy sources for Turkey, demonstrating the effectiveness of integrating fuzzy AHP and TOPSIS in energy planning.
8	Galankashi, et al. [90]	Fuzzy Delphi, AHP, and PROMETHEE II	To identify and prioritize sustainability indicators in green supply chain management using expert input and MCDM tools.	A structured ranking of sustainability indicators supporting strategic decision-making in green supply chains.

5 | Result and Discussion

The literature review views that SDSS, specifically those merging MCDM techniques and AI, have significantly advanced decision-making efficiency and effectiveness in different sectors. A detailed discussion on some of these sectors is as follows:

5.1 | Supply Chain Management:

MCDM methods such as AHP, Fuzzy AHP, TOPSIS, and hybrid models have been widely used to improve the supplier selection process, distribution network optimization, and value-based purchasing. Papers also show these methods can assist in determining the most crucial requirements and its criticality (e.g., quality, price, supplier performance), improve consistency and transparency in decision-making processes. Merge fuzzy logic and grey systems to improve handling the uncertainty and incomplete information, leading to more robust supplier selection and risk analysis.

5.2 | Material Selection:

MCDM techniques like Intuitionistic Fuzzy TOPSIS, ANP, and DEMATEL enable the evaluation and ranking of the alternative materials and devices by taking into consideration multiple performance indicators and help in uncertainty handling in expert judgments. The merging between fuzzy sets and hybrid models improves the accuracy and reliability of the selection process.

5.3 | Logistics

Using MCDM tools, if it is combined with fuzzy and grey theories, it can be used to facilitate the location selection process and logistics provider selection. These approaches enhance the accuracy and adaptability of logistics decision-making, especially in uncertain environments [91].

5.4 | Operations Management

Methods such as PROMETHEE-II, AHP, BWM, and VIKOR are used to find the optimal resource allocation and quality improvement projects. For example, applying PROMETHEE-II in queue departments led to a 70% reduction in mean waiting times, presenting the real-world impact of SDSS operations.

5.5 | Quality Control

A range of MCDM methods (AHP, TOPSIS, VIKOR, PROMETHEE, ELECTRE) are used to assess and improve service quality in many sectors. Hybrid and fuzzy approaches provide better handling of vagueness and stakeholder hesitation, leading to more comprehensive quality assessments. [92]

5.6 | Risk Management

SDSS employing MCDM, fuzzy, and grey system methods have been applied to risk evaluation in supply chains, healthcare logistics, fire safety, and emergency drug supply. These systems help organizations identify, prioritize, and mitigate risks more effectively.

5.7 | Waste Management

Fuzzy AHP, VIKOR, DEMATEL, and other hybrid MCDM methods have been used to evaluate waste treatment alternatives and identify barriers to sustainable waste management. These approaches improve the robustness and accuracy of decisions under uncertainty. [93] Fig. 6 presents the percentage of participation of DSS in different sectors. Fig. 7 presents the percentage of participation of used techniques in DSS.

Finally, how other pertinent keywords have been connected to the term MCDM. It becomes clear that the keyword under consideration has a close relationship with the following terms: human, healthcare, policies, mathematical model, hierarchical system, waste management, waste treatment, and developing world.

Examining the uses of MCDM approaches in the designated study areas could be beneficial for practitioners. To process large volumes of data, adapt to changing environments, and deliver more accurate and timely recommendations. Hybrid models, combining multiple MCDM techniques or integrating fuzzy/grey theories, address the limitations of individual methods and improve precision, scalability, and adaptability.

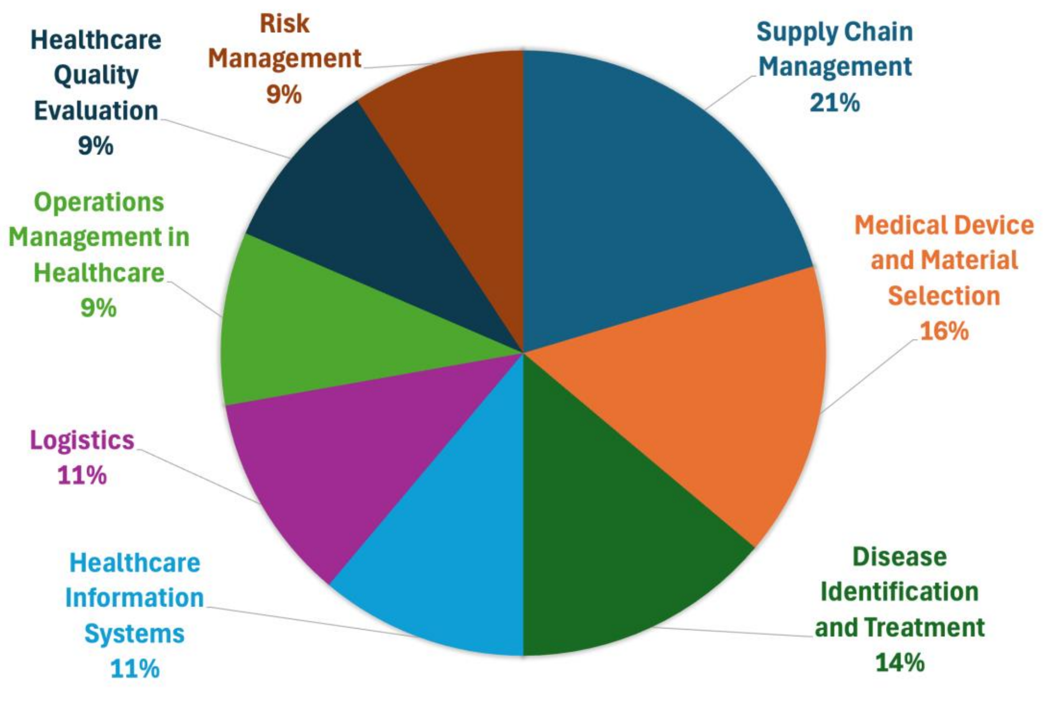

Figure 6. Percentages of DSS application area.

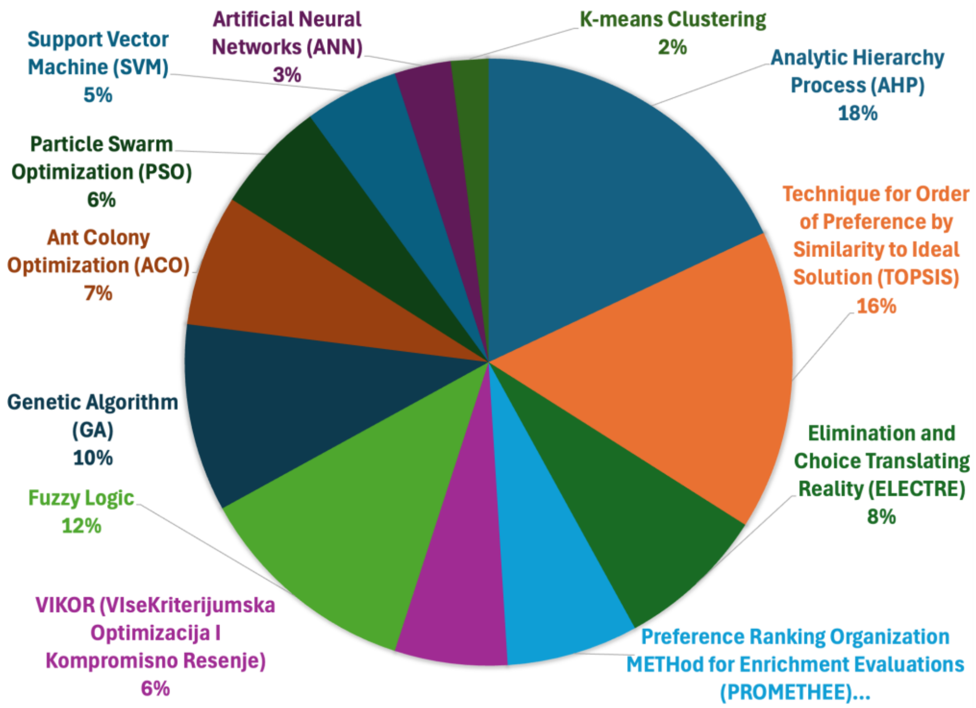

Figure 7. Percentages of DSS-used techniques.

6 | Challenges and Research Gaps

6.1 | Scalability and Interoperability

Many SDSS models face challenges in scaling to large, multi-source datasets and integrating with existing enterprise systems. Limited interoperability can hinder widespread adoption.

6.2 | User Interface and Usability

There is a need for more user-friendly, interactive dashboards and interfaces to facilitate broader adoption among decision-makers, especially in sectors like agriculture and healthcare.

6.3 | Validation in Real-World Settings

A significant portion of the literature is based on theoretical models or single-case simulations, with limited validation in real-world, multi-product, or dynamic environments. This highlights the need for more practical, field-tested SDSS implementations. [94]

7 | Conclusion and Future Directions

This paper confirms that SDSS, especially those that use advanced MCDM and AI techniques, inform timely and strong decisions in complex and uncertain environments. More research is needed to improve scalability, interoperability, and usability challenges and to validate these systems in real-world, dynamic contexts. In the future the integration of SDSS with IoT and Big Data should present since IoT sensor data in real time and big data analytics can further enhance the accuracy and responsiveness of SDSS, especially in supply chain and agriculture applications. Also, deeper integration of explainable AI, predictive analytics, and adaptive learning can improve the decision-making capabilities and transparency of SDSS. In the future researchers should also develop more intuitive and interactive user interfaces which will be crucial for increasing adoption and effectiveness across diverse user groups.

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The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors

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