Review Article GU J Sci 38(1): x-x (2025) DOI: 10.35378/gujs.1378573

Gazi University
Journal of Science

http://dergipark.gov.tr/gujs

The Use of Multi-Criteria Decision-Making Techniques in The Domain of Ergonomics: A Literature Review

Aylin ADEM[1,*], Ugur ATICI[2], Mehmet Burak SENOL[3], Metin DAGDEVIREN[1]

[1]*Gazi University, Industrial Engineering Dept. 06570, Ankara, Türkiye*
[2]*Alfer Muhendislik, 06930, Ankara, Türkiye*
[3]*CES Advanced Armour, 06909, Ankara, Türkiye*

Highlights

- This paper focuses on classification ergonomic papers by their utilized techniques.
- A systematic approach was used for reviewing the literature.
- The AHP and TOPSIS are frequently employed in ergonomic studies.

Article Info

Received: 19 Oct 2023
Accepted: 26 Jun 2024

Keywords

Ergonomics,
Human factors,
Multi-criteria decision making,
Literature review

Abstract

Ergonomics briefly aims to provide work and human harmony. In providing it, there are different kinds of problems need to be solved by various methods. To generate reasonable solutions for these problems the Multi-Criteria Decision Making (MCDM) techniques are utilized in the literature. A systematic review of literature was carried out at the intersection of ergonomics and MCDM to figure out the answers to the questions about how MCDM techniques are employed in ergonomics problems, on which subjects the application area is concentrated, which MCDM technique is frequently utilized. Electronic databases were investigated in the years between 2010 to 2024. It was determined that MCDM techniques are utilized to solve a wide range of ergonomic problems from design to ergonomic risk score calculation. It was specified that the AHP and TOPSIS techniques are frequently employed and the fuzzy extensions of these two methods are frequently preferred by the authors.

1. INTRODUCTION

Ergonomics; literally, deals with the interaction between work and humans in an office or production environment. It tries to provide work-human harmony based on this interaction [1]. It is foreseen that with this harmony, various benefits such as increasing the work efficiency of the employee, allowing the employee to feel safe at work, increasing the motivation of the employees, and ensuring the sense of belonging to the institution and social peace will emerge [2]. Ergonomics can be expressed under two main headings as cognitive and physical ergonomics, according to the structure of human characteristics it deals with. Physical ergonomic risk factors; hand-arm vibration and whole-body vibration, thermal convenience of workers, industrial noise, illumination, material handling, and bad posture. As an integrated impact of these effects, fatigue is also among the physical ergonomic risk parameters [3-5].

On the other hand, it is possible to express the main field of activity of cognitive ergonomics as measuring mental workload, digitizing the measured values, and interpreting the obtained values, and organizing the production environment according to these values [6]. Considering that employees in a production environment are exposed to both physical and cognitive difficulties, it can be said that it is important to design a working environment that considers the physical and mental ergonomic risk parameters. Multi Criteria Decision Making (MCDM) approaches, which provide an effective solution approach in the presence of multiple alternatives and conflicting criteria, are used in the literature for solving almost any decision problem or as an aid to a decision [7].

*Corresponding author, e-mail: aylinadem@gazi.edu.tr

It is known that these approaches are utilized effectively in the literature as a fast and appropriate solution mechanism in situations such as determining the weights of the selection criteria and evaluating the alternatives based on the criteria in a decision problem [8]. Moreover, MCDM methods can sometimes be used to identify data that will provide input to a mathematical modeling or a different solution approach [9]. When the relevant literature is examined, it is seen that MCDM techniques are frequently utilized in the field of activity of the science of ergonomics, and it is applied in a very wide scientific field. Moreover, MCDM techniques were utilized in obtaining the solutions of different ergonomic problems, in addition to the feature of choosing an ergonomic product/device for them.

Summarizing this interdependent literature is the primary aim of the current paper. To put it more clearly, this study aimed to investigate how MCDM techniques contribute to the solution in the face of physical and cognitive ergonomic problems. In this context, the relevant literature was researched in-depth, and a systematic approach was followed. Using domestic and foreign search databases, all kinds of accessible articles were examined, and the results were shared in this study.

The papers that find solutions to ergonomics problems with MCDM approaches are grouped and inferences are conducted about which areas of ergonomics MCDM techniques focus on. This paper aimed to show how and for what purposes MCDM methods are used in the fields of ergonomics and to determine what possible future study areas in the literature can be. The absence of such a study investigating the intersection of ergonomics and MCDM fields in the literature is the original aspect of this study.

This paper is structured as follows: In the second part of the paper, the research methodology is given. In the third chapter, studies that use MCDM approaches for the solution of the problems which are related to physical ergonomic risk factors and cognitive ergonomics are included, and these are summarized and then there is a summary of how they look for many features in the problems of mental factors and how they use the techniques. In the fourth chapter, the obtained results were discussed, and in the fifth and last part of the study, concluding remarks of the study were given.

2. RESEARCH METHODOLOGY

During the literature review, the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) criteria Moher et al. [10] were adhered to (please see Figure 1). "Web of Science" and "Scopus" were the databases investigated in the current paper. In this literature survey, to determine the papers which are about the intersection of ergonomics and MCDM the combinations of following keywords were utilized: ergonomics, "human factors", noise, "thermal comfort", vibration, "manual material handling, "cognitive ergonomics", posture, "repetitive task", MCDM and Multi Criteria Decision Making.

Books, book chapters, conference proceedings, and review articles unrelated to the study issues were not examined. Moreover, the paper published before 2010, not in English, not a journal article and not related to human health was not included in the paper. The papers published later 2010, in English, indexed in Web of Science and Scopus and related to ergonomics were included to the survey. The article selection procedure is shown as it moves through the exclusion-inclusion criteria in the Prisma flowchart in Figure 1. The search yielded 479 articles from the databases selected. During the first stage of evaluation, duplicate articles were removed from 479 publications, and a total of 166 papers were eliminated. After that, papers were evaluated based on their abstracts and after applying the exclusion criteria in three steps, a total of 127 articles were included in the analysis.

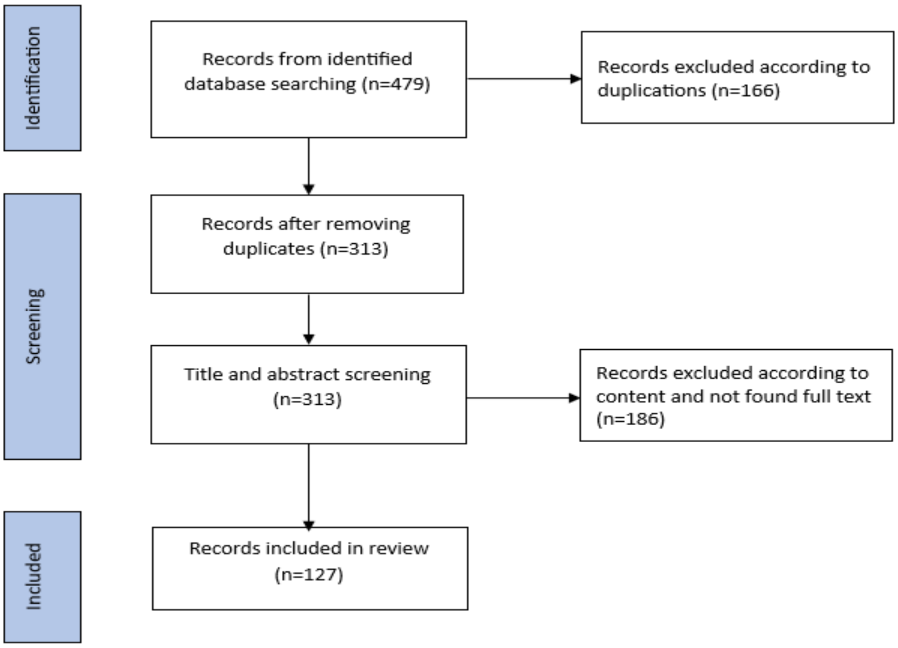

***Figure 1.** Flowchart for PRISMA protocol [10]*

3. RELATED WORKS

First, the physical ergonomics risk parameters and MCDM related studies were examined, grouped, and presented. After that, cognitive ergonomics and MCDM related studies were handled in the same way. The papers were grouped according to the handling way of the ergonomic problems and the utilization style of the MCDM technique in gaining solutions.

3.1. Physical Ergonomics Risk Parameters Related Studies

Noise, vibration, thermal comfort, and illumination parameters, which are among the physical ergonomic risk parameters, appear as risk factors in almost all firms and threaten employee health. It has been seen in the literature research that solutions have been found by applying MCDM approaches to equipment selection, work system design, and ergonomic problems in all kinds of evaluation studies. Here, the studies are grouped and summarized.

Design

Hasmaden et al. [11] aimed to create an integrated design process that incorporates solar energy technologies into environmental noise-dampening structures, by utilizing TOPSIS-based solution algorithm. They wanted to create a method for integrating solar energy technologies with noise reduction buildings. The method is demonstrated in a pre-existing community on the side of a heavily traveled road. Optimal tilt angles for yearly, semi-annual, seasonal, and monthly periods have been found using local climate and sunlight data. Noise barrier alternatives were evaluated with the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method. Adem, Çakıt and Dağdeviren [12] analyzed the green ergonomics design principles with the help of Hesitant fuzzy Analytical Hierarchy Process (AHP) with group decision making approach. Green ergonomics is a brand-new term which is about the bi-directional relationship between human and nature. Adem [13] used the fuzzy Analytical Hierarchy Process with a group decision-making technique to analyze and investigate the steps that need to be made to make JIT work with green ergonomics approach. Moschetti et al. [14] assessed the Responsive Building Envelope Designs by considering different criteria among user needs (thermal comfort, visual comfort, and acoustic comfort) by utilizing robustness based MCDM to normalize the functions to a single multi-target key performance indicator. Jiang et al. [15] utilized the MCDM and GIS based digital twin approaches to plan urban road planning by considering different ergonomics related criteria like noise and air quality. They utilized AHP method in their paper. Marzouk et al. [16] proposed a framework for increasing building system energy performance using building information modeling by assessing various options for installed building systems. Their evaluation criteria were included in operating cost saving, energy consumption, life cycle cost saving, and carbon emission. They utilized Simple Additive Weighting (SAW) and TOPSIS methods. Sarkar and Bardhan [17] studied to improve the indoor environment by considering ventilator optimization and furniture position, by applying different techniques, including AHP-TOPSİS integration. For determining optimized indoor layout design type, they consider the following criteria: indoor air velocity, pollutant concentration, and air heat and external solar radiation. The goal of Kiani Sadr et al. [18]'paper was to use MCDM methodologies and noise pollution modeling to analyze the building of airdrome. The airport zoning factors were determined using the Delphi approach and subsequently prioritized utilizing the Analytic Network Process (ANP). The noise level at airports was mapped using the computer-aided noise reduction program.

Pandey and Shukla [19] utilized fuzzy graded mean integration method and Additive Ratio Assessment (ARAS) to determine and measure the factors which are related to human performance in air traffic control. Harkouss et al. [20] studied the optimizing passive design for low-energy buildings across various climates. They followed four phases in designing the whole system by considering occupants' adaptive thermal comfort. Elimination and Choice Translating Reality (ELECTRE) was utilized in determining of the handled problem results by addressing different decision-makers' opinions. Hsieh et al. [21] aimed to determine the major human-based error sources of Taiwanese emergency departments (EDs). To establish the error variables, the human factors analysis and classification system (HFACS) was employed to investigate 35 adverse occurrences. To assess the impact of errors, AHP and fuzzy TOPSIS were used. Temperature-aware routing is vital in wireless body area networks for reducing damage to adjacent body tissues caused by node temperature rise. Existing temperature-aware routing systems, on the other hand, tend to determine the next hop based on the temperature parameter alone, neglecting to consider for conveyance delay and data loss induced by human position. Kim et al. [22] presented a MCDM method-based increased mobility and temperature-aware routing protocol to figure out this issue. To give appropriate weight factors and determine the next hop while considering different routing parameters, the proposed protocol uses an analytical hierarchy process and a simple additive weighting method. Ahmadi et al. [23] the ANP and Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) methodologies are used to prioritize and assess the Ergonomic Checkpoints measures. To demonstrate the use of weighted Checkpoints, an empirical study was conducted in the assembly and packaging business. According to the results of the empirical investigation, the weighted Ergonomic Checkpoints handbook can determine the approximate risk of workplaces and flag riskier scenarios. The goals of Chiu and Hsieh [24] were to create a latent human error analysis procedure, investigate the elements that contribute to latent human error in aircraft maintenance activities, and devise an effective improvement plan to address those errors. The error factors were evaluated using Fuzzy TOPSIS with four criteria. This study establishes a new analytic process for examining latent human error and proposes a fuzzy TOPSIS-based strategy for assessing human errors. He et al. [25] proposed fuzzy TOPSIS to investigate a car early period failure body noise vibration harshness complaint of customers. Biomechanical, physiological, and psychophysical techniques are commonly used in the ergonomic design of manual materials handling jobs. Kalibatas et al. [26] proposed an approach by utilizing MCDM assessment to find the optimal solution for the building's indoor environment from the optimal values. Utilized criteria can be listed as follows: thermal comfort related criteria (like air humidity, etc), surface area to volume proportion, noise related criteria et al. They employed the Multi-objective Optimization by Ratio Analysis (MOORA) to evaluate indoor environment parameters. Xu et al. [27] proposed a comprehensive assessment methodology for thermal energy storage design, which comprises prescreening, ranking and performance objective examination based on AHP and TOPSIS. Azammi et al. [28] made a conceptual design of automobile engine rubber mounting composite using ANP. The reliability analysis of facility layout was performed by integrating F-AHP to optimize design with safety and human factors in an operating theatre [29]. An ergonomic school furniture design was performed with respect to F-AHP, F-TOPSIS [30]. Mistarihi et al. [31] proposed chair attachment cushion design with an optimal air blowing technique to eliminate the negative side effects of prolonged sitting by F-AHP and F-TOPSIS. Tsarouchi et al. [32] used a newly developed MCDM framework for the formulation of alternative layouts and task allocations on a human–robot workplace design. Table 1 shows the papers that address the design function of ergonomics by using MCDM techniques.

Table 1. *The methods used and the problems addressed in the studies (Physical Ergonomics in (Design))*

Authors and year	**AHP**	**ANP**	**ARAS**	**DEMATEL**	**ELECTRE**	**F-AHP**	**SAW**	**F-TOPSIS**	**MOORA**	**R-MCDM**	**TOPSIS**	**Other**	**Addressed problem area (Design)**
Chiu and Hsieh [24]								*					aircraft maintenance activities
Pandey and Shukla [19]			*										human performance in air traffic control
Hasmaden et al [11]											*		solar energy technologies
Ahmadi et al [23]		*		*									ergonomic checkpoints measures
Harkouss, et al [20]					*								thermal- comfort related optimization
Hsieh et al. [21]	*										*		human error analysis in emergency departments
Kalibatas, et al [26]									*				solution for the building's indoor environment
Adem, et al [12]						*							green ergonomics
Marzouk, et al [16]							*				*		building system energy performance
Kim et al. [22]	*						*						temperature-aware routing protocol.
Adem [13]						*							green ergonomics-JIT
Moschetti et al [14]										*			responsive building-thermal comfort
Jiang et al [15]	*												urban road planning
He et al [25]								*					Investigating a car in ergonomic conditions
Sarkar and Bardhan [17]	*										*		indoor environment
Kiani Sadr, et al [18]		*											noise pollution modeling
Xu et al. [27]	*										*		thermal energy storage design
Azammi et al. [28]		*											automobile engine
Lin and Wang [29]						*							facility layout
Incekera [30]						*		*					ergonomic school furniture
Mistarihi et al. [31]						*		*					chair attachment cushion
Tsarouchi et al. [32]												x	human–robot workplace

Ergonomic risk assessment

Satapathy [33] handled the occupational health problems in construction site for Indian. They conducted a literature survey and questionnaire to determine risk factors. After determining the risk factors, they applied the Weighted Aggregated Sum Product Assessment (WASPAS) technic to prioritize these ergonomic risk factors. Adem and Dağdeviren [3] proposed a guide concerning Physical Ergonomic Risk Factors (PERFs) calculation details, a decision-making tool for evaluating ergonomic risk factors, and a method for calculating a company's total ergonomic risk score. The Pythagorean fuzzy AHP was used to evaluate PERFs in a company. Utilizing the integrated fuzzy AHP and VIKOR techniques, Ramavandi et al. [34] presented a new risk assessment method for a hot and humid working environment. To assess the significance of risk-influencing features, the AHP approach was used. In addition, the VIKOR approach was used to score the working stations. Environment, temperature, air velocity, mean radiant intensity, humidity, seniority structure, work intensity, personal protective equipment, work nature and work duration were considered as a set of criteria for generating safety assessment indexing system.

Delice and Can [35] introduced a new ergonomic risk assessment approach for manual lifting activities that considers two sets of criteria: lifting-related criteria and human-related factors. For this, they utilized Modified Kemeny Median Indicator Ranks Accordance (KEMIRA-M) and a best-worst method (BWM). Carpitella et al. [36] presented a MCDM-based strategy to improve organizational risk assessment, focusing on the importance of human behavior in the industry. The DEMATEL approach is offered as a mathematical framework for evaluating mutual interactions among a set of human elements engaged in industrial processes, with the goal of emphasizing intervention priorities.

Zeb et al. [37] analyzed the health and environment related factors of cement industry, ie air, noise, soil contamination and human health with the help of DEMATEL method. Noise pollution was determined as the most important critical factor. Factors that contribute to seafarers' occupational accidents on board were discovered and evaluated in the work of Özdemir et al. [38]. To filter through the different remedies with a model employing the fuzzy AHP, the severity of the factors that led to the accidents and their relationships with each other were investigated. One of the specified criteria was the human factors which include the followings lack of teaching, ignorance, negligence, occupational annoyance, tiredness, and potentially hazardous movements). Khandan et al. [39] handled the issue that to prioritize corrective activities, risk factors for MSD were assessed in production companies utilizing a method called Assessment of Repetitive Tasks combined with Fuzzy TOPSIS. Khandan et al. [40] examined the ergonomic risk factors of a manufacturing organization. The entropy approach was then used to rank the ergonomic risk factors. The handled the risk factors which including repetitive motions. Khandan and Koohpaei [41], addressed a manufacturing company with respect to ergonomic risk concerns that could affect health by using TOPSIS method. Fata et al. [42] (2021) ranked ergonomics risks by AHP and VIKOR. Wicaksono et al. [43] evaluated the fatal accident factors in the petroleum industry by a hybrid ANP and DEMETAL approach. The ergonomics intervention practices in Indian glass industry were identified and prioritized by fuzzy Delphi method and MCDM tools [44]. Sharma et al. [45] studied on the assessment of risk factors of musculoskeletal disorders by ordinal priority approach using as an MCDM method. They applied this method to professional vehicle drivers related risk factors. Table 2 shows the summary of ergonomic risk assessment papers.

Table 2. *The methods used and the problems addressed in the studies (Ergonomic Risk Assessment)*

Authors and year	**AHP**	**DEMATEL**	**BWM**	**F-AHP**	**WASPAS**	**F-TOPSIS**	**TOPSIS**	**VIKOR**	**KEMİRA**	**Addressed problem area (Ergonomic Risk Assessment)**
Delice and Can [35]			*						*	ERA
Ramavandi, et al [34]	*							*		ERA
Zeb, Ali, and Khan [37]		*								ERA
Khandan, et al [39]						*				ERA
Satapathy [33]					*					ERA
Carpitella et al [36]		*								ERA
Adem and Dağdeviren [3]				*						ERA
Khandan and Koohpaei [41]							*			ERA
Khandan, et al [40]										ERA (ENTROPY)
Özdemir, et al [38]				*						ERA
Fata et al [42]								*		ERA
Wicaksono et al [43]		*								ERA
Rathore [44]										ERA (Fuzzy Delphi)
Sharma et al. (2022) [45]										ERA (ordinal priority approach

Selection

Balasbaneh et al. [46] aimed to present a multi-criteria evaluation of several retrofitting scenarios with a focus on window replacement. Each solution was evaluated using four separate criteria: operating energy use, global warming potential emission, embedded energy, and cost. The AHP-TOPSIS integration was used to choose the best environmentally friendly window for a building. The results revealed that a double-glazed window is the best solution, followed by a plenum window. Adem et al. [47] developed a novel method based on spherical fuzzy AHP to assess online learning environments according to standards for human-computer interaction (such as cognitive workload,design of interface etc).

Mitra [48] handled interesting issue related about the thermal comfort. The author addressed the fabric selection problem according to the thermal comfort properties, (fabric porosity, fabric cover, fabric thickness, fabric areal density) with the help of AHP- MOORA integration. The author evaluated the 13 fabric alternatives according to the four thermal comfort properties. Bac et al. [49] studied on the selection of Heating, Ventilating and Air-Conditioning (HVAC) systems by utilizing Stepwise Weight Assessment Ratio Analysis (SWARA) and WASPAS methods. They considered ergonomics as a main criterion and, ventilation, relative humidity, visual impact, noise level and thermal comfort as sub-criterion.

To design the device for loud sound annulment, Molla et al. [50] addressed the material selection and multiphysics modeling. They utilized TOPSİS method for selection of the related materials. Ramezanzade et al. [51] tried to select the best renewable energy projects at the subnational level utilizing integrated approach that considers ecological (one of the environmental factors was the noise), economic, technical, and social factors by employed VIKOR and ARAS. Dimin et al. [52] solved the problem of the selection of conceptual design for Spin Grind Dryer Seaweed Powder Machine by utilizing AHP- TOPSİS integration by considering ergonomics as one of the determined criteria. To evaluate Autonomous vehicle driving systems alternatives in terms of considered risk criteria, including human-factors related ones Erdoğan et al. [53] a MCDM methodology integrating DEMATEL, ANP, and VIKOR techniques in a spherical fuzzy environment. Balasbaneh et al. [54] studied the assessment of windows type in schools with respect to the noise pollution, carbon emission, cost, and social life cycle assessment criteria. They utilized TOPSİS and AHP techniques. Narayanamoorthy et al. [55] addressed the issue of bio-medical waste disposal methods and they proposed a solution with the help of Hesitant Fuzzy Multi-Objective Optimization based on Simple Ratio Analysis. The two of their assessment criteria were noise and health risk. Avikal et al. [56] solved the selection of power supply source for telecom towers by utilizing fuzzy AHP and TOPSİS under noise pollution, air pollution and reliability criteria. The purpose of Rahimdel and Mirzaei [57] was to use MCDM methodologies under a fuzzy environment to select feasible options for reducing whole-body vibrational health risks for truck drivers during mining operations. They utilized AHP-TOPSIS integration Sánchez-Lozano and Rodríguez [58] addressed the selection training aircraft for military. One of the selection criteria was the ergonomics. They utilized AHP technic to gain the weights of criteria. Mitra [59] handled the cotton fabric selection problem according to the thermal comfort properties, (fabric porosity, fabric cover, fabric thickness, fabric areal density) with the help of Evaluation Based on Distance from Average Solution (EDAS) method. Adar et al. [60] studied the problem of prioritization of the treatment and disposal methods of wastes containing polychlorinated biphenyl. They solved their problem by fuzzy AHP and one of their selection criteria is ergonomics / social. Adar and Delice [61] handled healthcare waste treatment selection issue by considering ergonomics related criteria. They solved their problem by utilizing MAIRCA under fuzzy environment.

Turskis and Juodagalvienė [62] addressed determining the form of staircases for residence structures. by utilizing hybrid MCDM technic (by combining Multiplicative Exponential Weighting (MEW), method of EDAS, an ARAS method, expert judgement, and SWARA. One of the considered criteria was ergonomics in that paper. Agarski et al. [63] handled the equipment selection (forklift selection) problem to enhance performance and occupational safety. Using four alternative criterion weighing procedures to select working equipment. Five weighing scenarios were created using groups of different factors. Some of the safety factors of them were as follows: additional lighting; a complete cabin.

Mohanty et al. [64] utilized a fuzzy MADM framework for evaluating superior ergonomically designed products. The process is demonstrated through the choosing of an office chair as an example. For comparison the alternatives' prioritization, TOPSIS, VIKOR, and The Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE) techniques were investigated. Yılmaz Kaya and Dağdeviren [65] suggested an integrated approach for evaluating workplace safety equipment that considers both universal design (UD) and technical criteria. The evaluation procedure was handled by AHP and fuzzy PROMETHEE. Lisboa et al. [66] proposed a decision-making framework to rank human-machine interaction technologies used in In-Vehicle Information Systems; the final set included 101 technologies. Using a group decision-making approach (AHP based), they evaluated alternatives based on different ergonomics related criteria (such as innovation, safety, pleasure from regular use, and so on) that were specified by domain experts. Temucin and Tozan [67] proposed a decision support system for determining the suitable AC in construction sector. One of the utilized selection criteria noise levels of AC. The appropriate AC selection problem is directly related to the ergonomic conditions of construction workers. Sánchez-Lozano et al. [68] employed the combination of AHP-TOPSS methodologies with Fuzzy Logic to address the process of choosing the top military training aircraft by considering several factors. The selection process combined quantitative or technical criteria with qualitative criteria. Naim and Hagras [69] proposed a newly developed hybrid group fuzzy solution to determine the appropriate reading lighting in a communal area. Liu et al. [70] addressed the robot selection problem under fuzzy environment by utilizing TOPSIS. One of the considered criteria in that paper was the human-machine interface. Advanced manufacturing technology evaluation and selection is a challenging topic to solve since it involves various attributes that are difficult to consider on their whole. Maldonado-Macías et al. [71] proposed a fuzzy TOPSIS decision-making model that is used to evaluate advanced manufacturing technology for ergonomic compatibility qualities in an intuitionistic fuzzy environment. Alam and Ghosh [72] suggested an integrated decision-making method to detect the suitable cotton alternative by considering thermal comfort attributes of fabrics. They determined the weights of criteria by utilizing the AHP technique while they employed the TOPSIS method in finding the rankings of cotton fabric alternatives according to their thermal comfort. Padillo et al. [73] studied on the selection of noise reduction alternative system selection in terms of the environmental impact of road traffic noise by fuzzy extensions of ELECTRE and TOPSIS methods. A newly developed MCDM methodology for choosing ventilation operation in terms of providing thermal comfort strategy in hospital isolation rooms was employed by [74]. Yu et al. [75] handled the issue of evaluation the safety of container cranes based on BWM and the Pythagorean F-VIKOR model. Jalilzadehazhari et al. [76] developed a decision-making framework; and AHP method to resolve conflicts in selecting windows and blinds for energy consumption and enhancing indoor comfort. AHP and TOPSIS were used for prevention of breakdowns by selecting condition monitoring techniques [77]. Table 3 presents the summary of papers that handles the selection process using MCDM methods in the domain of ergonomics/ human factors.

Table 3. *The methods used and the problems addressed in the studies (Selection)*

Authors and year	**AHP**	**ARAS**	**DEMATEL**	**MCGDM(N)**	**F-AHP**	**SRA**	**MAIRCA**	**WASPAS**	**F-TOPSIS**	**MOORA**	**PROMETHE**	**EDAS**	**SWARA**	**TOPSIS**	**VIKOR**	**Other**	**Addressed problem area (Selection)**
Mohanty, Mahapatra, and Mohanty [64]											*			*	*		chair
Turskis and Juodagalvienė [62]		*										*	*				stairs
Balasbaneh, et al [54]	*													*			window
Narayanamoorthy et al. [55]						*											bio-medical waste disposal methods
Ramezanzade et al. [51]															*		renewable energy
Dimin, et al [52]	*													*			machine
Erdoğan, et al [53]			*												*		autonomous vehicle driving systems
Avikal, et al [56]					*									*			power supply source for telecom towers

Adar and Delice [61]							*										healthcare waste treatment technology
Bac et al [49]								*					*				heating, ventilating and air-conditioning systems
Sánchez-Lozano and Rodríguez [58]	*																training aircraft for military
Mitra [48]	*									*							fabric
Alam and Ghosh [72]	*													*			fabric
Mitra [59]												*					fabric
Molla, et al [50]														*			material
Agarski, et al [63]	*																forklift
Yılmaz and Dağdeviren [65]	*										*						equipment
Balasbaneh, et al[46]	*													*			window
Lisboa et al. [66]	*																human-machine interaction technologies
Naim and Hagras [69]				*													reading illumination
Rahimdel and Mirzaei [57]	*													*			whole-body vibrational health risks
Liu, et al [70]									*								robot
Maldonado-Macías, et al [71]									*								advanced manufacturing technology
Adar, et al [60]					*												waste disposal
Temucin and Tozan [67]														*			appropriate AC
Adem, et a [47]					*												distance education platforms
Sánchez-Lozano,et al [68]	*													*			aircraft
Padillo et al. [73]														*			noise reduction system
Kim and Augenbroe [74]																*	ventilation operation
Yu et al. [75]															*		container cranes
Jalilzadehazhari et al. [76]	*																window
Gholap and Jaybhaye [77]	*													*			condition monitoring

Evaluation and Assessment

The objectives of Lamii et al. [78] were to explore potential problems in the three main parts of the seaport dry port system and to suggest an approach for risk factor analysis. The purpose of Martins and Garcez [79] was propose a multidimensional and multi-period analysis of road safety. The criticality of a road is determined by the interaction of several elements, including human factors, accident causes and severity levels, and road characteristics/states. The decisionmaker's strategic goal is to gain a wide understanding of the criticality of these road segments in terms of safety so that he may strategically allocate resources to prevent and minimize traffic accident hazards. They based their ion on eleven criteria. They utilized the ELECTRE technique in the evaluation of road safety decision. Tumsekcali et al. [80] modified the SERVQUAL model to include the additional criteria, resulting in the Pandemic SERVQUAL 4.0 model. During the pandemic, the unique service quality evaluation model is built as a three-level hierarchical structure to evaluate public transportation systems to avoid the spread of SARS-CoV-2. The evaluation model is then transformed into a MCDM problem, and a novel AHP integrated WASPAS methodology is used in an interval-valued intuitionistic fuzzy environment. The main aim of the Talib et al. [81] was to develop a road map to assist decision-makers in facilitating the effective deployment of integrated Just-in-Time (JIT)-lean techniques for improved manufacturing performance in India. Through a comprehensive literature investigation and expert perspectives, this study identified twenty-six practices of the integrated JIT-lean manufacturing system and further classified them into five broad categories, one of which was human factors. The importance of these behaviors is determined using the Best-Worst technique, a recently created unique MCDM method (BWM). The findings of this study show that organizational factors and human factors are the most and least important practices, respectively, out of five categories. Zavadskas and Turskis [82] developed the ARAS method and they applied this method to the evaluation of microclimate in office rooms. Eraslan et al. [83] addressed the assessment of office layout problem by utilizing AHP and ELECTRE techniques. Their selection criteria totally based on ergonomics, like working safety, dust, smell, light, working position, noise, working area, position of tool, position of materials. Under the categories of technical and operational airworthiness factors, Şenol [84] used the AHP and ANP to assess the airworthiness factors in armed forces aircraft. Zagorskas and Turskis [85] aimed to discover the greatest and most effective bridge locations that would help strengthen the pedestrian network, enhance the city's image, and provide other benefits. The utilized criteria were road safety, usage, connectivity, image, health, and cost-effectiveness. A new hybrid MCDM model that incorporates five different multi-criteria decision-making methods: Expert judgment, Multiplicative Exponential Weighting (MEW), an EDAS approach, an ARAS method, and SWARA were utilized. The goal of He et al. [86] was to assess human aspects in the construction project management process, such as worker efficiency, worker safety awareness, technical worker quality, and worker emergency capacity, to assist China's construction project in running smoothly. To evaluate human elements in building projects, a multi-attribute group decision-making (MAGDM) strategy based on Pythagorean interval 2-tuple linguistic numbers and the VIKOR method is proposed in this paper. Harirchian et al. [87] conducted a comparative analysis of the seismic vulnerability of reinforced concrete structures by utilizing different MCDM methods. The goal of Havle and Kılıç [88] was to identify and investigate the elements that lead to navigation mistakes in the North Atlantic Region by incorporating a fuzzy AHP into the Human Factors Analysis and Classifying System (HFACS) framework for navigation errors. The most important causes contributing to oceanic errors, according to the findings, are a lack of training offered by airlines, dispatchers' selection of improper routes for maritime crossings, and a failure to take preventative measures against oceanic errors. The wind farm site appropriateness study was presented in Baseer et al. [89]'s paper utilizing a MCDM technique based on GIS modeling. Numerous climatic, financial, aesthetic, and ecological factors were taken into consideration for this research, including the wind resource, road accessibility, closeness to the electrical grid, and the ideal/safe distance from different communities and airports. AHP was utilized during the process. The developed methodology was subsequently implemented throughout Saudi Arabia.

Wang and Chou [90] aimed to provide a fuzzy multi criteria decision model for evaluating patient safety in Taiwanese hospitals. Staff and committees from four hospitals in southern Taiwan were invited, and these facilities were assessed based on five human factors indicators. The suggested model investigates Fuzzy TOPSIS techniques. Celik et al. [91] performed a survey in Istanbul to inquire about the attributes of the rail transit network (metros, trams, light rail, and funicular). They provided a novel methodology for evaluating customer satisfaction levels for Istanbul's rail transit network that incorporates statistical analysis, SERVQUAL, interval type-2 fuzzy sets, and VIKOR. The amount of crowdedness and density in the train, the train's internal air-conditioning system, noise level and vibration during the journey, and phone services are all identified as features that need to be improved. Virto et al. [92] found a set of compromise solutions via achievement function based on a MCDM approach for underwater noise reductions from commercial shipping. Farhadi et al. [93] improved and evaluated a flood monitoring system by integration of remote sensing techniques and Electre methods. Silva et al. [94] developed the decision-making process that utilizes the integration of AHP and TOPSIS methods for buildings performance in terms of energy efficiency and thermal comfort. Cui et al. [95] applied hierarchy based MCDM analysis for different control strategies for radiant floor cooling systems in different climate zones in terms of thermal comfort related criteria. Padillo et al. [96] applied fuzzy AHP in noise action plans for prioritizing road stretches in the traffic. Wan et al. [97] investigated the influence of the supply vane angles and supply air temperature on the ventilation performance using TOPSIS for thermal comfort. The factors contributing to human error for airworthiness management strategy was prioritized with ANP [98]. Kose et al. [99] improved an interval valued pythagorean F-AHP and F-TOPSIS approach for ergonomic assessment of setup process under single-minute exchange of dies. Arroyo et al. [100] employed choosing by advantage based MCDM tools for integrating different human factors-based factors like environmental and social to evaluate asphalt mixtures with and without waste tires. Şenol et al. [101] determined the display panel of a general utility helicopter by ranking the indicators with respect to criteria and a linear utility function based MCDM algorithms. ELECTRE III method was employed for evaluating heating, ventilating and air conditioning systems [102]. Turhan et al. [103] proposed an integrated MCDM framework that includes KEMIRA-M to urban planners for mitigating impact of heat islands on energy consumption and thermal comfort of buildings. Yılmaz et al. [104] proposed a modified weighted sum model as an MCDM tool to determine appropriate building envelope considering comfort and performance for a primary school classrooms which have a profound effect on pupils. Wani et al. [105] proposed a newly developed MCDM framework to balance energy consumption and thermal comfort in buildings consumption while accommodating the distinct preferences of the DM. Noise vulnerability of cities, e.g. Jamshedpur, India was assessed by AHP for identifying and predicting vulnerable zones associated with noise pollution [106]. Fu et al [107] employed a cloud based MCDM approach to assess the health risk of rockeries in Chinese classical gardens. Upadhyay et al [108] assessed internet of things related ergonomics-based healthcare issues by AHP. Table 4 shows the papers that uses MCDM techniques in the evaluation/assessment process respectively.

Table 4. *The methods used and the problems addressed in the studies* (*Evaluation*)

Authors and year	**AHP**	**ANP**	**ARAS**	**ELECTRE**	**BWM**	**F-AHP**	**WASPAS**	**EDAS**	**SWARA**	**TOPSIS**	**VIKOR**	**Other**	**Addressed problem area (Evaluation)**
Zavadskas and Turskis [82]			*										microclimate in office rooms.
Eraslan et al,[83]	*			*									office layout
Tumsekcali et al [80]	*						*						generating Pandemic SERVQUAL 4.0 mode
Wang and Chou [90]										*			patient safety in Taiwanese hospitals
Celik et al [91]											*		customer satisfaction levels
Havle and Kılıç [88]						*							human Factors Analysis and Classifying System
He et al. [86]											*		analysing construction project wtr human factors
Harirchian et al [87]	*									*			the seismic vulnerability of reinforced concrete structures
Şenol [84]	*	*											airworthiness factors in civil and military aircraft
Baseer, et al [89]	*												wind farm site appropriateness
Zagorskas and Turskis [85]			*					*	*				most effective bridge locations
Lamii, et al [78]	*												seaport dry port system
Martins and Garcez [79]				*									road safety
Talib et al [81]					*								effective deployment of integrated lean techniques
Virto et al [92]												*	noise reduction
Farhadi et al. [93]				*									flood monitoring
Silva et al. [94]	*									*			building performance
Cui et al.[95]												*	floor cooling systems
Padillo et al. [96]						*							noise action
Wan et al. [97]										*			ventilation performance
Yazgan and Yilmaz [98]		*											airworthiness management
Kose et al.[99]						*				*			setup process
Arroyo et al. [100]												*	asphalt mixtures
Şenol et al. [101]												*	helicopter display panel
Avgelis and Popodopoulos [102]				*									thermal comfort
Turhan et al. [103]												*	urban planning
Yılmaz et al. [104]												*	classroom evaluation
Wani et al. [105]												*	building evaluation
Pahari et al. [106]	*												noise pollution
Fu et al [107]												*	health risk evaluation
Upadhyay et al [108]	*												healthcare system evaluation

3.2. Cognitive Ergonomics Risk Parameters Related Studies

In the literature, cognitive factors were considered criteria in studies in which cognitive ergonomics and MCDM were performed together. The factors that cause the human error and their importance are among the topics researched in the MCDM and Cognitive ergonomics literature. F-DELPHI, F-AHP, and F-TOPSIS were used together to reduce the number of errors in manufacturing enterprises by Parameshwaran [109]. The weight and priority values obtained from the MCDM methods were used to determine the severity and probability level of the error by using FMEA analysis as input [109]. Tavakoli and Nafar [110] used an MCDM, a combination of Shannon entropy and TOPSIS, to prioritize causes of human error in the maintenance of power grids. In qualitative analyses, cognitive factors such as inaccuracy, lack of consideration, and concentration, which cause the human error, were considered. Mazzuto et al. [111] used a hybrid method of human error with DEMATEL and FCMs. Cognitive factors such as Prescription errors and knowledge therapy were evaluated.

Lin et al. [112] used MCDM, a combination of AHP and FIM, for mobile communication package selection. The cognitive structure of the service operator has been identified and prioritized as a value-adding factor for the mobile phone. SWARA and ARAS were used in personnel selection by [113]. Among the evaluation criteria, cognitive criteria such as proactivity, general aptitude, communication, and problem-solving were taken into account. Carnero and Gómez [114] used MACBETH and F-AHP to select alternatives for the medical gas supply. Efe [115] used F-VIKOR and F-CM approaches to select dishwashers according to their quality functions. A hybrid MCDM method, a combination of TOPSIS and AHP, was used for internal auditor selection by [116]. Cognitive criteria such as being able to analyze, risk awareness, dedication, and proactivity were used for weighting. F-AHP and F-DELPHI methods were used by [117] to evaluate experience management practices. Factors such as information protection, transformation, and control, which are cognitive criteria, are included in the critical success factors. MCDM, a hybrid combination of IF-AHP, IF-TOPSIS, and IF-VIKOR techniques, was used by [118] to evaluate neuroergonomics qualitative criteria. Oh et al. [119] used DEMATEL and ANP together to evaluate the usability of biometric devices. Cognitive criteria such as satisfaction and privacy concerns are prioritized. MCDM was used to determine the usability of mobile health devices by [120]. Mobile device features are enumerated using EUM. It has been reported that the importance of cognitive criteria such as satisfaction and user interface aesthetics is less than application effectiveness. In the literature, cognitive ergonomic factors have been considered in accidents occurring in different sectors such as manufacturing and construction. MCDM was used to prioritize the determining factors and criteria. SODA was used by de Morais Correia et al. [121] to evaluate workstations in the shoe manufacturing industry. It is aimed to minimize the factors that disrupt concentration, which is one of the cognitive ergonomics goals. TOPSIS was used by [122] to determine the factors causing accidents. Cognitive factors such as erroneous risk perception, lack of experience, and performance uncertainty. It has been reported by [123] that the prevention of occupational accidents should focus not only on safety but also on vulnerable workers. Unsafe cognitive factors have been reported to be one of the causes of accidents at work. DEMATEL has been used to prioritize risky cognitive factors. Karuppiah et al. [124] used F-ANP and DEMATEL to analyze misconduct risks to improve safety. Cognitive bias, distraction, and safety awareness are considered in the evaluation of misbehavior. A hybrid method of DEMATEL and ANP was used by Rostamzadeh et al. [125] to determine the effects of falls from height on construction workers. Concentration and distraction, which are cognitive factors, were evaluated as criteria affecting the risk of falling.

In the literature, the features preferred by users and customers were prioritized using MCDM, and cognitive ergonomic factors were considered among these features. Design characteristics were determined using quality function deployment in office chair design by Mohanty [126], and the relationship between design characteristics and customer satisfaction was determined using adaptive NFIS. It has been reported that physical ergonomics factors and cognitive ergonomics factors should be considered in design activities to increase customer satisfaction. AHP and F-CEA were used for the usability evaluation of virtual reality devices used in fire training by Bourhim and Cherkaoui [127]. Production system performance was determined by [128] using cognitive mapping and MCDM. AHP and ANP were used to determine cognitive performance factors, prioritize cognitive mapping factors, and determine their weights. AHP was used by Rahman et al. [129] to evaluate alternatives for material handling system selection. Physical activities affecting the choice of material handling procedure were determined. Ergonomic criteria have been determined as one of the strategic criteria of the enterprise. Cognitive ergonomics has been considered a sub-criterion of ergonomic criteria. MCDM techniques have been used to prioritize criteria in different scientific disciplines, and cognitive ergonomic factors are among the criteria taken into consideration. F-AHP and F-TOPSIS methods were used by [130] in deciding to change jobs. Among the factors evaluated, care knowledge and cognitive errors were examined NASA-TLX and SMCAA were used by [131] to measure cognitive workload. The mental workload required by the job has been evaluated. F-DEMATEL was developed by [132]. It has been reported that the proposed method can be used to blur cognitive maps in MCDM techniques. WBR and Electre III methods were used together for multi-expert multicriteria decision-making problems by [133]. With the developed method, hospital grading, a cognitive and complex problem, has been examined in the Chinese case. Flexibility engineering is compatible with socio-technical systems. Incorporating MCDM qualitative and quantitative factors into the assessment makes flexibility engineering more complex. A hybrid model of F-AHP and F-VIKOR was used to evaluate flexibility by [134]. Cognitive factors such as awareness, perception error, evaluation and understanding error were weighted. ANP was used by Alhubaishy and Aljuhani [135] to determine the importance of the criteria for the digital transformation of behaviors in education. Cognitive factors such as lack of ability, lack of experience, and lack of social awareness were evaluated as difficulties in digital transformation. Applications used in diagnosing type 2 diabetes mellitus by Gupta et al. [136] were graded using TOPSIS, VIKOR, and PROMETHEE II. Cognitive criteria such as learnability, efficacy, memorability, aesthetic, cognitive load, and satisfaction were used in the evaluation.

As a result, it can be concluded that AHP and TOPSIS methods are maybe the most applied techniques in studies where MCDM techniques and cognitive ergonomics are used together. The methods used and the problems of the studies are presented in Table 5.

***Table 5**. The methods used and the problems addressed in the studies (Cognitive Ergonomics)*

Authors and year	MCDM technique																										Addressed problem area
	AHP	ANP	ARAS	DEMATEL	Electre III	EUM	F- DEMATEL	F-AHP	F-ANP	F-CEA	FCM	F-DELPHI	FIM	FMEA	F-TOPSIS	F-VIKOR	MACBETH	NASA-TLX	NFIS	PROMETHEE	SMCAA	SODA	SWARA	TOPSIS	VIKOR	WBR	
Mazzuto et al. [111]				*							*																Reducing human error
Parameshwaran [109]								*				*			*												
Tavakoli and Nafar [110]																								*			
Lin et al. [112]	*												*														Selection of alternatives
Karabašević, et al. [113]			*																				*				
Carnero and Gómez [114]								*									*										
Efe [115]											*					*											
Petridis et al. [116]	*																							*			
Mardani et al. [117]								*				*															Evaluation qualitative criteria
Adar et al. [118]	*																							*	*		
Oh et al. [119]		*		*																							Usability of devices
Kasali et al. [120]						*																					
Correia et al. [121]																						*					
Bowo et al. [122]																								*			Determination of root cause accidents
Shakerian et al. [123]				*																							
Karuppiah et al [124]									*																		
Rostamzadeh et al. [125]		*		*																							
Mohanty [126]																			*								Evaluation of devices features
Bourhim and Cherkaoui [127]	*									*																	
Eraslan and Dağdeviren [128]	*	*																									Production system performance
Ragman et al. [129]	*																										Material handling
Yavuz [130]								*																*			The decision making to change job
Delice and Can [131]																		*			*						Measuring cognitive workload
Gül [132]							*																				Blur cognitive maps
Liao et al. [133]					*																					*	Hospital grading
Zarei et al. [134]								*								*											Flexibility engineering
Alhubaishy and Aljuhani [135]		*																									Ranking of the criteria in digital transformation
Gupta et al. [136]																				*				*	*		Diagnosis of type 2 diabetes

4. DISCUSSION

As time passes ergonomics science has moved to a more remarkable position than it was. In fact, when designing any system (regardless of which system it is), if a human is a part of this system, then it needs to be considered human factors related issues. This situation has started to attract more attention both in academia and in real life. This can be verified from the tables showing the frequency of the publications in recent years and the topics they have covered (see Tables 1- 5). When the distribution of the publications over the years is evaluated, it can be said that the use of MCDM techniques in problems in the field of ergonomics has tended to increase over the years (see Figure 2). It can be said that MCDM techniques are utilized effectively in solving problems in the field of ergonomics, especially latest years. Fuzzy extensions of MCDM techniques are frequently used in very specific situations such as ergonomic device selection, design of a production environment, or living space, when employees need to be protected from ergonomic risks (see Tables 1- 5).

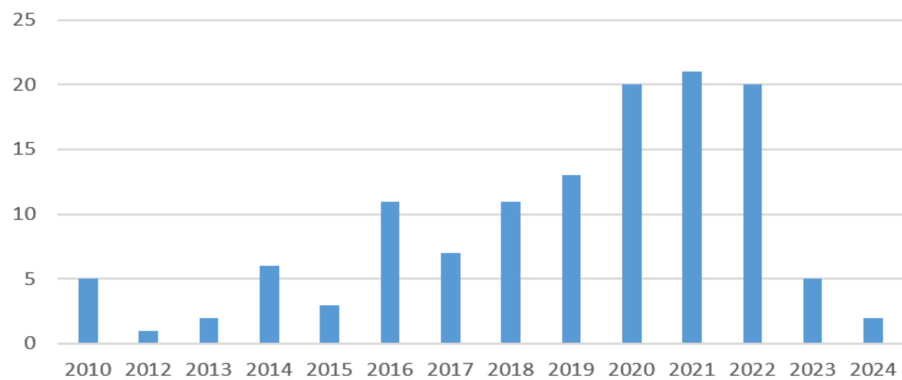

Figure 2. *The number of published papers over the years*

When both cognitive and physical ergonomics and MCDM studies are evaluated together, it is possible to express the application areas under 4 basic headings (see Figure 3) Under the heading of the design, the following issues were addressed in general in the related literature: product design; workplace, machine, working area, office; living area.

Similarly, in developing the new ergonomic risk assessment methods, or extending the traditional ergonomic risk assessment techniques with fuzzy scales, risk or precaution ranking issues were the issues of ergonomic risk assessment heading.

Figure 3. *Classification of the application areas*

Moreover, equipment, machine, material, manufacturing process or tool selection were the addressed issue under the heading of selection. Finally, evaluation of service quality, environmental concerns, or the relationship between alternative process of science disciplines were listed under the evaluation headings. On the other hand, it has been observed that MCDM techniques are utilized alone or in a solution-aiding position in systems containing direct physical ergonomic risk factors such as ventilation systems, noise reduction systems, and vibration barrier systems. Therefore, this situation shows that MCDM techniques are not only employed for the selection of a product/process based on ergonomic criteria but are also used in very different areas such as ergonomic risk score calculation, product, or process design, comparing different alternative systems with each other. In classical OHS risk scoring studies, it is known that in addition to the known matrix methodologies in the evaluation of OHS risks, new methods are also developed based on MCDM [137]. However, in terms of OHS, studies focusing only on the ergonomic conditions of the production environment and trying to obtain an ergonomic risk score have also started to take place in the literature. These studies differ from the classical OHS studies in the literature as studies that try to calculate the risk score with integrated loading by calculating the exposure of the workers as well as the ambient noise or thermal values of the environment. Of course, classical MCDM or MCDM techniques extended with fuzzy numbers are often preferred for problems in cognitive ergonomics as well as in gaining solutions to physical ergonomic risks related problems. Especially based on human-machine interaction, it is seen that MCDM techniques are used to make calculations related to mental loading, and MCDM techniques are used in a decision-aiding position even in a specific cognitive ergonomics field such as neuro-ergonomics. It has been observed that MCDM techniques are used effectively within the scope of cognitive ergonomics, such as finding the root causes of human errors caused by fatigue or inattention in any kind of process.

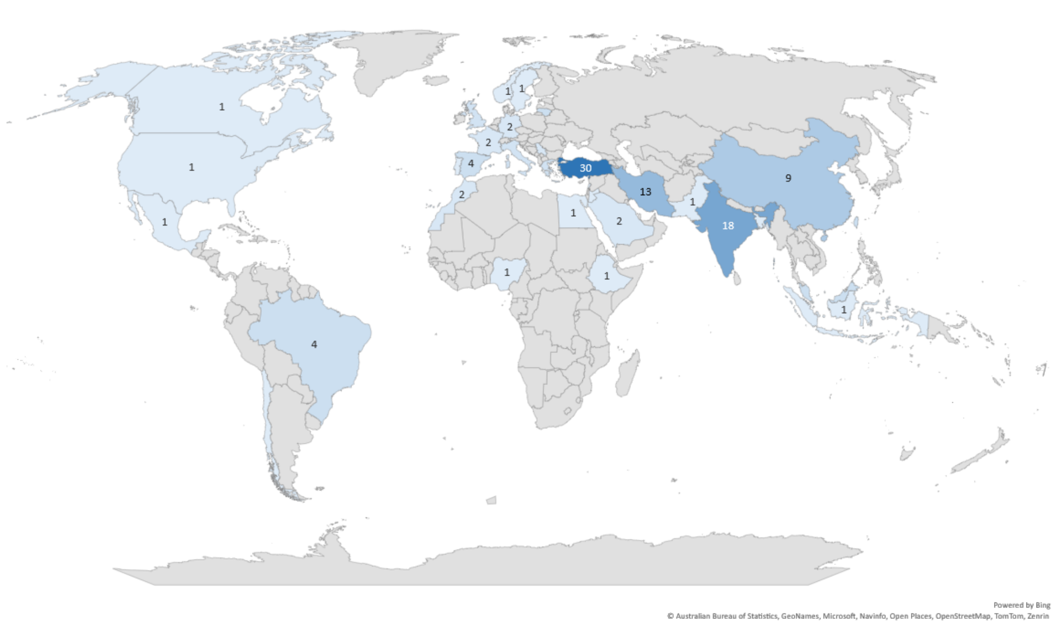

Figure 4. *Distribution of published articles by country (2010-2024)*

Figure 4 shows the distribution of published articles by country from 2010 to 2024 about. The country information of the corresponding author was taken into consideration as a basis while determining which country the relevant article belongs.

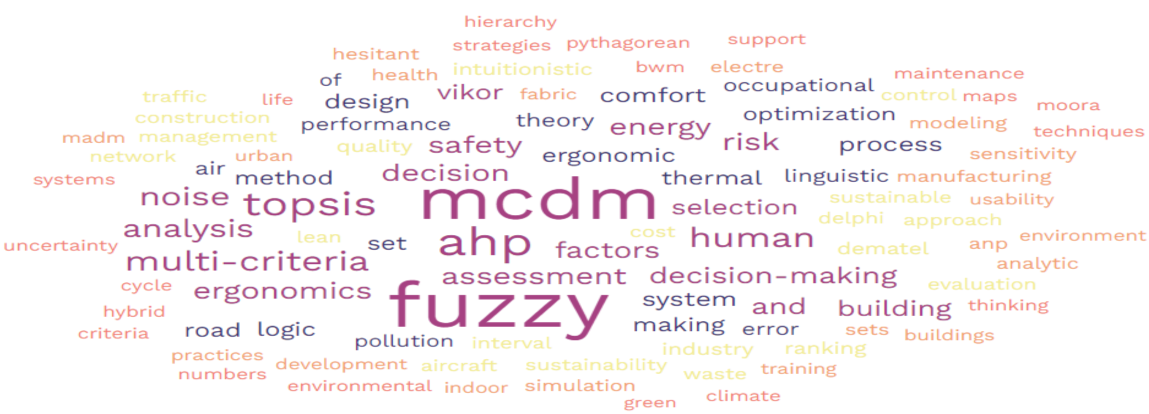

Figure 5*. The word cloud for keywords of articles*

According to the keywords of the published articles, the word cloud was presented in Figure 5. According to the cloud, the names of the MCDM techniques were preferred frequently as keywords. For illustrating this TOPSIS, and AHP words can be given. Figure 6 shows the density of MCDM techniques in the articles. According to Figure 6, the most frequently employed MCDM techniques can be listed in the decreasing order as AHP, TOPSIS, F-AHP, VIKOR, ANP, F-TOPSIS and so on.

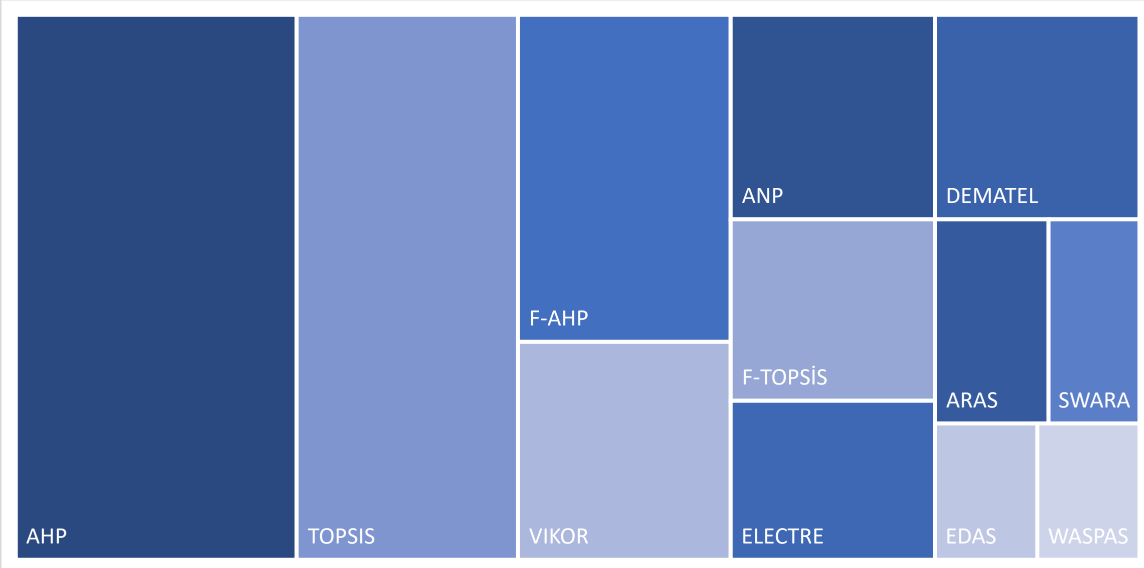

***Figure 6**. The density of MCDM techniques utilized in the articles*

5. CONCLUSIONS AND FUTURE REMARKS

Human factors and ergonomics are the very remarkable issue as it is expected to make a positive contribution in terms of productivity and are in our lives in both production-related business activities and non-business activities. Especially when designing a new work system; there are questions that need to be answered and critical factors to be considered, whether human-related, including determining machine layouts, determining the route to be followed by raw materials and personnel, determining the breaks that employees will take during the day, determining the areas where raw materials and work in process products will be stored. Even in its simplest form, there are many critical questions that must be answered in designing a work system. In short, there are problems in all systems in which humans a part of it that need to be solved.

On the other hand, MCDM techniques are frequently employed in the literature both as a direct solution finder and as an aid to the solution. In this study, a literature review was conducted by focusing on the question of how and in which areas MCDM techniques are applied to the problems in ergonomics, excluding the OHS risk assessment. To catch the articles published in the index of SCI, SSCI, and E-SCI studies to be examined using Scopus and Web of Science search databases were determined by utilizing various search terms. The articles determined because of the survey were selected because of the examination and screening, up to 127 articles directly related to the subject. These articles were examined in detail and the results of the research were summarized with graphics and tables. According to the results of the survey, it was detected that MCDM techniques are employed in points such as product design, production environment or office design, ergonomic product, device, process, equipment selection, comparison of alternative systems, or providing data to optimization models, and AHP-TOPSIS integration is among the frequently used solution techniques.

It is thought that this study revealed that MCDM techniques are not only used for selection, sorting, and classification-related purposes. Especially with the decision support systems developed, it was observed that adaptation to the digitalized world was achieved in these studies. Moreover, it was observed that MCDM techniques have found application in almost every field of activity of ergonomics. It was determined that possible future work areas are generally concentrated in the field of cognitive ergonomics. Especially the applications made in the field of Neuroergonomics are very limited and the development of this field has been seen to be open for improvement.

It is foreseen that the use of MCDM techniques will increase in the field of human-machine interaction and the solution of ergonomic problems arising from this interaction. Moreover, it is foreseen that especially with decision support systems, it is possible to help solve problems arising from human-machine interaction. It was determined that MCDM techniques are used limitedly in the solution of problems in office environments, where they are generally used to solve ergonomic problems in the production environment.

Another critical area comes from the studies carried out on the lighting factor. Studies in this area are still limited and promising. The limited number of studies evaluating the integrated effect of physical risk factors may lead to considering this field as a suitable field to study. The next step may be the application of MCDM techniques in the integrated assessment of physical and mental risk factors. MCDM techniques and their fuzzy extensions may be utilized in analyzing the problems that may be caused by the integrated effect of physical and mental risks on employees.

CONFLICT OF INTEREST

No conflict of interest was declared by the authors.

REFERENCES

[1] Babalık, F.C. Mühendisler için ergonomi işbilim, Dora Yayınları, (2011).

[2] Sabancı, A.Sümer, S.K. Ergonomi, Nobel, (2015).

[3] Adem, A., Dağdeviren, M., "A Decision-Making Framework for Total Ergonomic Risk Score Computation in Companies", International Journal of Information Technology & Decision Making, 1-28, (2022).

[4] Adem, A., Dağdeviren, M., "A personnel scheduling model containing thermal comfort and equivalent metabolic rate factors", Journal of the Faculty of Engineering and Architecture of Gazi University, 36(1): 303-317, (2021).

[5] Adem, A., Dağdeviren, M., "A job rotation-scheduling model for blue-collar employees' hand–arm vibration levels in manufacturing firms", Human Factors and Ergonomics in Manufacturing & Service Industries, 31(2): 174-190, (2021).

[6] Hollnagel, E., "Cognitive ergonomics: it's all in the mind", Ergonomics, 40(10): 1170-1182, (1997).

[7] Dağdeviren, M., Yavuz, S., and Kılınç, N., "Weapon selection using the AHP and TOPSIS methods under fuzzy environment", Expert Systems with Applications, 36(4): 8143-8151, (2009).

[8] Yüksel, İ., Dagdeviren, M., "Using the analytic network process (ANP) in a SWOT analysis–A case study for a textile firm", Information Sciences, 177(16): 3364-3382, (2007).

[9] Yüksel, İ., Dağdeviren, M., "Using the fuzzy analytic network process (ANP) for Balanced Scorecard (BSC): A case study for a manufacturing firm", Expert Systems With Applications, 37(2): 1270-1278, (2010).

[10] Moher, D., Liberati, A., Tetzlaff, J., and Altman, D.G., "Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement (PRISMA Group)", Annals Of Internal Medicine, 151(4): 264-269, (2009).

[11] Hasmaden, F., Zorer Gedik, G., and Yüğrük Akdağ, N., "An approach to the design of photovoltaic noise barriers and a case study from Istanbul, Turkey", Environmental Science and Pollution Research, 1-18, (2022).

[12] Adem, A., Çakıt, E., and Dağdeviren, M., "A fuzzy decision-making approach to analyze the design principles for green ergonomics", Neural Computing and Applications, 34(2): 1373-1384, (2022).

[13] Adem, A., "A fuzzy decision-making analysis to make just in time compatible with the green ergonomics concept", International Journal of Environmental Science and Technology, 94749-4762, (2022).

[14] Moschetti, R., Homaei, S., Taveres-Cachat, E., and Grynning, S., "Assessing Responsive Building Envelope Designs through Robustness-Based Multi-Criteria Decision Making in Zero-Emission Buildings", Energies, 15(4): 1314, (2022).

[15] Jiang, F., Ma, L., Broyd, T., Chen, W., and Luo, H., "Digital twin enabled sustainable urban road planning", Sustainable Cities and Society, 78103645, (2022).

[16] Marzouk, M., Abdelbasset, I., and Al-Gahtani, K., "Evaluating Building Systems Energy Performance Superiority and Inferiority Ranking", Journal of Environmental Informatics, 38(1): 56-67, (2021).

[17] Sarkar, A., Bardhan, R., "Improved indoor environment through optimised ventilator and furniture positioning: A case of slum rehabilitation housing, Mumbai, India", Frontiers of Architectural Research, 9(2): 350-369, (2020).

[18] Kiani Sadr, M., Melhosseini Darani, K., Golkarian, H., and Arefian, A., "Implement of zoning in order to evaluate the establishment of the airports using integrating MCDM methods and noise pollution modeling softwares", Environmental Health Engineering and Management Journal, 7(2): 97-105, (2020).

[19] Pandey, M.M., Shukla, D., "Evaluating the human performance factors of air traffic control in Thailand using Fuzzy Multi Criteria Decision Making method", Journal of Air Transport Management, 81101708, (2019).

[20] Harkouss, F., Fardoun, F., and Biwole, P.H., "Passive design optimization of low energy buildings in different climates", Energy, 165591-613, (2018).

[21] Hsieh, M., Wang, E.M., Lee, W., Li, L., Hsieh, C., Tsai, W., Wang, C., Huang, J., and Liu, T., "Application of HFACS, fuzzy TOPSIS, and AHP for identifying important human error factors in emergency departments in Taiwan", International Journal of Industrial Ergonomics, 67171-179, (2018).

[22] Kim, B., Shah, B., Al-Obediat, F., Ullah, S., Kim, K.H. and,Kim, K.-I., "An enhanced mobility and temperature aware routing protocol through multi-criteria decision making method in wireless body area networks", Applied Sciences, 8(11): 2245, (2018).

[23] Ahmadi, M., Zakerian, S.A., and Salmanzadeh, H., “Prioritizing the ILO/IEA Ergonomic Checkpoints' measures; a study in an assembly and packaging industry”, International Journal of Industrial Ergonomics, 5954-63, (2017).

[24] Chiu, M., Hsieh, M., “Latent human error analysis and efficient improvement strategies by fuzzy TOPSIS in aviation maintenance tasks”, Applied Ergonomics, 54136-147, (2016).

[25] He, Y.H., Wang, L.B., He, Z.Z., and Xie, M., “A fuzzy TOPSIS and rough set based approach for mechanism analysis of product infant failure”, Engineering Applications of Artificial Intelligence, 4725-37, (2016).

[26] Kalibatas, D., Zavadskas, E.K., and Kalibatienė, D., “A method of multi-attribute assessment using ideal alternative: choosing an apartment with optimal indoor environment”, International Journal of Strategic Property Management,16(3): 338-353, (2012).

[27] Xu, H., Romagnoli, A., Sze, J. Y., and Py, X., “Application of material assessment methodology in latent heat thermal energy storage for waste heat recovery”, Applied Energy, 187: 281-290, (2017).

[28] Azammi, A. N., Sapuan, S. M., Ishak, M. R., and Sultan, M. T., “Conceptual design of automobile engine rubber mounting composite using TRIZ-Morphological chart-analytic network process technique”, Defence Technology, 14(4): 268-277, (2018).

[29] Lin, Q., Wang, D., “Facility layout planning with SHELL and fuzzy AHP method based on human reliability for operating theatre”, Journal of Healthcare Engineering, (2019).

[30] Incekara, C. O., “Post-COVID-19 ergonomic school furniture design under fuzzy logic”, Work, 69(4): 1197-1208, (2021).

[31] Mistarihi, M. Z., Al-Omari, A. A., and Al-Dwairi, A. F., “Designing and Simulation Assessment of a Chair Attachment Air Blowing Methods to Enhance the Safety of Prolonged Sitting”, Biomimetics, 8(2): 194, (2023).

[32] Tsarouchi, P., Michalos, G., Makris, S., Athanasatos, T., Dimoulas, K., and Chryssolouris, G., “On a human–robot workplace design and task allocation system”, International Journal of Computer Integrated Manufacturing, 30(12): 1272-1279, (2017).

[33] Satapathy, S., “Work place discomfort and risk factors for construction site workers”, International Journal of System Assurance Engineering and Management,13(2): 668-680, (2022).

[34] Ramavandi, B., Darabi, A.H., Omidvar, M., “Risk assessment of hot and humid environments through an integrated fuzzy AHP-VIKOR method”, Stochastic Environmental Research and Risk Assessment, 35(12): 2425-2438, (2021).

[35] Delice, E.K., Can, G.F., “A new approach for ergonomic risk assessment integrating KEMIRA, best–worst and MCDM methods”, Soft Computing, 24(19): 15093-15110, (2020).

[36] Carpitella, S., Carpitella, F., Certa, A., Benítez, J., and Izquierdo, J., “Managing human factors to reduce organisational risk in industry”, Mathematical and Computational Applications, 23(4): 67, (2018).

[37] Zeb, K., Ali, Y., and Khan, M.W., “Factors influencing environment and human health by cement industry: Pakistan a case in point”, Management of Environmental Quality: An International Journal, (2018).

[38] Özdemir, Ü., Altinpinar, İ., and Demirel, F., “A MCDM approach with fuzzy AHP method for occupational accidents on board”, TransNav: International Journal on Marine Navigation and Safety of Sea Transportation, 12(1), (2018).

[39] Khandan, M., Koohpaei, A., Nili, M., and Farjami, Y.,"Occupational musculoskeletal disorders management using Fuzzy TOPSIS Assessment of Repetitive Tasks (ART)", Work, 56(2): 267-276, (2017).

[40] Khandan, M., Nili, M., Koohpaei, A., and Mosaferchi, S., “Integrating the ergonomics techniques with multi criteria decision making as a new approach for risk management: An assessment of repetitive tasks-entropy case study”, Journal of Research in Health Sciences, 16(2): 85, (2016).

[41] Khandan, M., Koohpaei, A., “Assessment and analysis of ergonomics conditions based on TOPSIS in a manufacturing company”, Iran Occupational Health, 13(5), (2016).

[42] La Fata, C. M., Giallanza, A., Micale, R., and La Scalia, G., “Ranking of occupational health and safety risks by a multi-criteria perspective: inclusion of human factors and application of VIKOR”, Safety Science, 138, 105234, (2021).

[43] Wicaksono, F. D., Ciptomulyono, U., Artana, K. B., and Irawan, M. I., “Evaluation of the fatal accident factors in the petroleum industry using hybrid Gaussian multi-criteria decision-making (MCDM) approach”, Cogent Engineering, 9(1): 2154003, (2022).

[44] Rathore, B. “Analysis of enablers to implement ergonomic interventions in Indian manufacturing industry: a multi-criteria decision-making approach”, Global Business Review, (2021).

[45] Sharma, G., Ahmad, S., Mallick, Z., Khan, Z. A., James, A. T., Asjad, M., I.A., Badruddin, S., Kamangar, S., Javed.A., Mohammed and Ahammad, N. A., “Risk Factors Assessment of Musculoskeletal Disorders among Professional Vehicle Drivers in India Using an Ordinal Priority Approach”, Mathematics, 10(23): 4492, (2022).

[46] Balasbaneh, A.T., Yeoh, D., Ramli, M.Z., and Valdi, M.H.T., “Different alternative retrofit to improving the sustainability of building in tropical climate: multi-criteria decision-making”, Environmental Science and Pollution Research, 1-15, (2022).

[47] Adem, A., Çakıt, E., and Dağdeviren, M., “Selection of suitable distance education platforms based on human–computer interaction criteria under fuzzy environment”, Neural Computing and Applications, 347919-7931, (2022).

[48] Mitra, A., “Application of multi-objective optimization on the basis of ratio analysis (MOORA) for selection of cotton fabrics for optimal thermal comfort”, Research Journal of Textile and Apparel, 26(2): 187-203, (2021).

[49] Bac, U., Alaloosi, K., and Turhan, C., “A comprehensive evaluation of the most suitable HVAC system for an industrial building by using a hybrid building energy simulation and multi criteria decision making framework”, Journal of Building Engineering, 37102153, (2021).

[50] Molla, D., Płaczek, M., and Wróbel, A., “Multiphysics Modeling and Material Selection Methods to Develop Optimal Piezoelectric Plate Actuators for Active Noise Cancellation”, Applied Sciences, 11(24): 11746, (2021).

[51] Ramezanzade, M., Karimi, H., Almutairi, K., Xuan, H.A., Saebi, J., Mostafaeipour, A., and Techato, K., “Implementing MCDM Techniques for Ranking Renewable Energy Projects under Fuzzy Environment: A Case Study”, Sustainability, 13(22): 12858, (2021).

[52] Dimin, M.F., Amin, M., and Nasir, A.K.M,. “Selection of Conceptual Design for Spin Grind Dryer Seaweed Powder Machine”, International Journal of Computer Information Systems and Industrial Management Applications, 13266-274, (2021).

[53] Erdoğan, M., Kaya, İ., Karaşan, A., and Çolak, M., "Evaluation of autonomous vehicle driving systems for risk assessment based on three-dimensional uncertain linguistic variables", Applied Soft Computing, 113107934, (2021).

[54] Balasbaneh, A.T., Yeoh, D., and Abidin, A.R.Z., “Life cycle sustainability assessment of window renovations in schools against noise pollution in tropical climates”, Journal of Building Engineering, 32101784, (2020).

[55] Narayanamoorthy, S., Annapoorani, V., Kang, D., Baleanu, D., Jeon, J., Kureethara, J.V., and Ramya, L., “A novel assessment of bio-medical waste disposal methods using integrating weighting approach and hesitant fuzzy MOOSRA”, Journal of Cleaner Production, 275122587, (2020).

[56] Avikal, S., Singhal, R., Sajwan, R., Tiwari, R.K., and Singh, R., “Selection of Best Power Supply Source for Telecom Towers in Remote Areas”, International Journal of Mathematical, Engineering and Management Sciences, 5(5): 913-925, (2020).

[57] Rahimdel, M.J., Mirzaei, M., “Prioritization of practical solutions for the vibrational health risk reduction of mining trucks using fuzzy decision making”, Archives Of Environmental & Occupational Health, 75(2): 112-126, (2020).

[58] Sánchez-Lozano, J., Rodríguez, O.N., “Application of Fuzzy Reference Ideal Method (FRIM) to the military advanced training aircraft selection”, Applied Soft Computing, 88106061, (2020).

[59] Mitra, A., “Selection of cotton fabrics using EDAS method”, Journal of Natural Fibers, 1-13, (2020).

[60] Adar, E., Karatop, B., Bilgili, M.S., and İnce, M., “Prioritization of the treatment and disposal methods of wastes containing polychlorinated biphenyl by fuzzy multi-criteria decision-making and risk assessment”, Environmental Monitoring and Assessment, 192(7): 1-15, (2020).

[61] Adar, T., Delice, E.K., “New integrated approaches based on MC-HFLTS for healthcare waste treatment technology selection”, Journal of Enterprise Information Management, (2019).

[62] Turskis, Z., Juodagalvienė, B., "A novel hybrid multi-criteria decision-making model to assess a stairs shape for dwelling houses", Journal of Civil Engineering and Management, 22(8): 1078-1087, (2016).

[63] Agarski, B., Hadzistevic, M., Budak, I., Moraca, S., and Vukelic, D., "Comparison of approaches to weighting of multiple criteria for selecting equipment to optimize performance and safety", International Journal of Occupational Safety and Ergonomics, 25(2): 228-240, (2019).

[64] Mohanty, P.P., Mahapatra, S.S., and Mohanty, A., "A novel multi-attribute decision making approach for selection of appropriate product conforming ergonomic considerations", Operations Research Perspectives, 582-93, (2018).

[65] Yılmaz Kaya, B., Dağdeviren, M., "Selecting occupational safety equipment by MCDM approach considering universal design principles", Human Factors and Ergonomics in Manufacturing & Service Industries, 26(2): 224-242, (2016).

[66] Lisboa, I.C., Vieira, J., Mouta, S., Machado, S., Ribeiro, N., Silva, E., Ribeiro, R.A., and Pereira, A.F., "An MCDM approach to the selection of novel technologies for innovative in-vehicle information systems", International Journal of Decision Support System Technology, 8(1): 43-55, (2016).

[67] Temucin, T., Tozan, H., "A fuzzy based decision support system for air conditioner selection and an application to Turkish construction sector", Tehnicki Vjesnik-Technical Gazette, 23(4): 1117-1122, (2016).

[68] Sánchez-Lozano, J., Serna, J., and Dolón-Payán, A., "Evaluating military training aircrafts through the combination of multi-criteria decision making processes with fuzzy logic. A case study in the Spanish Air Force Academy", Aerospace Science and Technology, 4258-65, (2015).

[69] Naim, S., Hagras, H., "A type 2-hesitation fuzzy logic based multi-criteria group decision making system for intelligent shared environments", Soft Computing, 18(7): 1305-1319, (2014).

[70] Liu, H.-C., Ren, M.-L., Wu, J., and Lin, Q.-L., "An interval 2-tuple linguistic MCDM method for robot evaluation and selection", International Journal of Production Research, 52(10): 2867-2880, (2014).

[71] Maldonado-Macías, A., Alvarado, A., García, J.L., and Balderrama, C.O., "Intuitionistic fuzzy TOPSIS for ergonomic compatibility evaluation of advanced manufacturing technology", The International Journal of Advanced Manufacturing Technology, 70(9): 2283-2292, (2014).

[72] Alam, M.S., Ghosh, A., "Selection of cotton fabrics for optimal comfort properties using multi-criteria decision making", Journal of Textile and Apparel, Technology and Management, 8(3), (2013).

[73] Ruiz-Padillo, A., Ruiz, D. P., Torija, A. J., and Ramos-Ridao, Á., "Selection of suitable alternatives to reduce the environmental impact of road traffic noise using a fuzzy multi-criteria decision model", Environmental Impact Assessment Review, 61: 8-18, (2016).

[74] Kim, S. H., Augenbroe, G., "Decision support for choosing ventilation operation strategy in hospital isolation rooms: A multi-criterion assessment under uncertainty", Building and Environment, 60, 305-318, (2013).

[75] Yu, J., Xiao, H., Sun, F., Yan, L., and Liu, M., "Research on the Safety Evaluation Method for Quayside Container Cranes Based on the Best–Worst Method–Pythagorean Fuzzy VIKOR Approach", Applied Sciences, 14(3): 1312, (2024).

[76] Jalilzadehazhari, E., Johansson, P., Johansson, J., and Mahapatra, K., "Developing a decision-making framework for resolving conflicts when selecting windows and blinds", Architectural Engineering and Design Management, 15(5): 357-381, (2019).

[77] Gholap, A. B., Jaybhaye, M. D., "Decision Making of Condition Monitoring using AHP and TOPSIS Method". International Journal of Engineering and Advanced Technology 8: 495-499, (2019).

[78] Lamii, N., Bentaleb, F., Fri, M., and Mabrouki, C., "Use of DELPHI-AHP Method to Identify annd Analyze Risks in Seaport Dry Port System", Transactions on Maritime Science, 11(1): 185-206, (2022).

[79] Martins, M.A., Garcez, T.V., "A multidimensional and multi-period analysis of safety on roads", Accident Analysis & Prevention, 162106401, (2021).

[80] Tumsekcali, E., Ayyildiz, E., and Taskin, A., "Interval valued intuitionistic fuzzy AHP-WASPAS based public transportation service quality evaluation by a new extension of SERVQUAL Model: P-SERVQUAL 4.0", Expert Systems with Applications, 186115757, (2021).

[81] Talib, F., Asjad, M., Attri, R., Siddiquee, A.N., and Khan, Z.A., "A road map for the implementation of integrated JIT-lean practices in Indian manufacturing industries using the best-worst method approach", Journal of Industrial and Production Engineering, 37(6): 275-291,(2020).

[82] Zavadskas, E.K., Turskis, Z., "A new additive ratio assessment (ARAS) method in multicriteria decision-making", Technological and Economic Development of Economy, 16(2): 159-172, (2010).

[83] Eraslan, E., Güneşli, İ., and Khatib, W., "The evaluation of appropriate office layout design with MCDM techniques", SN Applied Sciences, 2(3): 1-10, (2020).

[84] Şenol, M.B., "Evaluation and prioritization of technical and operational airworthiness factors for flight safety", Aircraft Engineering and Aerospace Technology, 92(7): 1049-1061, (2020).

[85] Zagorskas, J., Turskis, Z., "Location preferences of new pedestrian bridges based on multi-criteria decision-making and GIS-based estimation", The Baltic Journal of Road and Bridge Engineering, 15(2): 158-181, (2020).

[86] He, T., Wei, G., Lin, R., Lu, J., Wei, C., and Wu, J., "Pythagorean interval 2-tuple linguistic VIKOR method for evaluating human factors in construction project management", Iranian Journal of Fuzzy Systems, 17(6): 93-105, (2020).

[87] Harirchian, E., Jadhav, K., Mohammad, K., Aghakouchaki Hosseini, S.E., and Lahmer, T., "A comparative study of MCDM methods integrated with rapid visual seismic vulnerability assessment of existing RC structures", Applied Sciences, 10(18): 6411, (2020).

[88] Havle, C.A., Kılıç, B., “A hybrid approach based on the fuzzy AHP and HFACS framework for identifying and analyzing gross navigation errors during transatlantic flights”, Journal of Air Transport Management, 7621-30, (2019).

[89] Baseer, M., Rehman, S., Meyer, J.P., and Alam, M.M., “GIS-based site suitability analysis for wind farm development in Saudi Arabia”, Energy, 141: 1166-1176, (2017).

[90] Wang, C.H., Chou, H.L., "Assessment of patient safety management from human factors perspective: a fuzzy TOPSIS approach", Human Factors and Ergonomics in Manufacturing & Service Industries, 25(5): 614-626, (2015).

[91] Celik, E., Aydin, N., and Gumus, A.T., “A multiattribute customer satisfaction evaluation approach for rail transit network: A real case study for Istanbul, Turkey”, Transport Policy, 36283-293, (2014).

[92] Virto, L. R., Dumez, H., Romero, C., and Bailly, D., “How can ports act to reduce underwater noise from shipping? Identifying effective management frameworks”, Marine Pollution Bulletin, 174: 113136, (2022).

[93] Farhadi, H., Esmaeily, A., and Najafzadeh, M., “Flood monitoring by integration of Remote Sensing technique and Multi-Criteria Decision Making method”, Computers & Geosciences, 160: 105045, (2022).

[94] Silva, A. S., Almeida, L. S. S., and Ghisi, E., “Decision-making process for improving thermal and energy performance of residential buildings: A case study of constructive systems in Brazil”, Energy and Buildings, 128: 270-286, (2016).

[95] Cui, M., Liu, J., Kim, M. K., and Wu, X., “Application potential analysis of different control strategies for radiant floor cooling systems in office buildings in different climate zones of China”, Energy and Buildings, 282: 112772, (2023).

[96] Ruiz-Padillo, A., Torija, A. J., Ramos-Ridao, A. F., and Ruiz, D. P., “Application of the fuzzy analytic hierarchy process in multi-criteria decision in noise action plans: Prioritizing road stretches”, Environmental Modelling & Software, 81: 45-55, (2016).

[97] Wan, T., Bai, Y., Wu, L., and He, Y., “Multi-criteria decision making of integrating thermal comfort with energy utilization coefficient under different air supply conditions based on human factors and 13-value thermal comfort scale”, Journal of Building Engineering, 39: 102249, (2021).

[98] Yazgan, E., Yilmaz, A. K. “Prioritisation of factors contributing to human error for airworthiness management strategy with ANP”, Aircraft Engineering And Aerospace Technology, 91(1): 78-93, (2018).

[99] Kose, Y., Civan, H. N., Ayyildiz, E., and Cevikcan, E., “An Interval Valued Pythagorean Fuzzy AHP–TOPSIS Integrated Model for Ergonomic Assessment of Setup Process under SMED”, Sustainability, 14(21): 13804, (2022).

[100] Arroyo, P., Herrera, R., Salazar, L., Giménez, Z., Martínez, J., and Calahorra, M., "A new approach for integrating environmental, social and economic factors to evaluate asphalt mixtures with and without waste tires", Revista Ingeniería de Construcción, 33: 301-314, (2018).

[101] Şenol, M. B., Dağdeviren, M., Çilingir, C., and Kurt, M., "Display panel design of a general utility helicopter by applying quantitative and qualitative approaches", Human Factors and Ergonomics in Manufacturing & Service Industries, 20(1): 73-86, (2010).

[102] Avgelis, A., Papadopoulos, A. M. "On the evaluation of heating, ventilating and air conditioning systems", In Advances in Building Energy Research, Routledge, 33-54, (2010).

[103] Turhan, C., Atalay, A. S., and Gokcen Akkurt, G., "An integrated decision-making framework for mitigating the impact of urban heat islands on energy consumption and thermal comfort of residential buildings", Sustainability, 15(12): 9674, (2023).

[104] Yılmaz, Y., Şansal, K. E., Aşcıgil-Dincer, M., Kültür, S., and Tanrıöver, S. H., "A methodology to determine appropriate façade aperture sizes considering comfort and performance criteria: A primary school classroom case", Indoor and Built Environment, 31(7): 1874-1891, (2022).

[105] Wani, M., Hafiz, F., Swain, A., and Broekaert, J., "Balancing energy consumption and thermal comfort in buildings: a multi-criteria framework", Annals of Operations Research, 1-27, (2023).

[106] Pahari, S., Das Chatterjee, N., Barman, N. K., "Noise vulnerability assessment using an integrated approach of multi-criteria decision-making model and geospatial techniques", International Journal of Environmental Science and Technology, 21(6): 5421-5436, (2024).

[107] Fu, L., Pan, J., Tang, Y., and Zhang, Q., "A multi-criteria decision-making approach to assessing the health risk of rockeries in Chinese classical gardens", Heritage Science, 11(1): 92, (2023).

[108] Upadhyay, H. K., Juneja, S., Muhammad, G., Nauman, A., and Awad, N. A., "Analysis of IoT-Related Ergonomics-Based Healthcare Issues Using Analytic Hierarchy Process Methodology", Sensors, 22(21): 8232, (2022).

[109] Parameshwaran, N.S.R., "Performance analysis and quality improvement using fuzzy MCDM and lean tools in a paper industry", International Journal of Integrated Supply Management, 12(3): 205-229, (2019).

[110] Tavakoli, M., Nafar, M., "Estimating and ranking the impact of human error roots on power grid maintenance group based on a combination of mathematical expectation, Shannon entropy, and TOPSIS", Quality and Reliability Engineering International, 37(8): 3673-3692, (2021).

[111] Mazzuto, G., Stylios, C., and Bevilacqua, M., "Hybrid Decision Support System based on DEMATEL and Fuzzy Cognitive Maps", IFAC-PapersOnLine, 51(11): 1636-1642, (2018).

[112] Lin, C.-L., Chen, C.-W., and Tzeng, G.-H., "Planning the development strategy for the mobile communication package based on consumers' choice preferences", Expert Systems with Applications, 37(7): 4749-4760, (2010).

[113] Karabašević, D., Stanujkić, D., and Urošević, S., "The MCDM Model for Personnel Selection Based on SWARA and ARAS Methods", Management (1820-0222), 20(77), (2015).

[114] Carnero, M.C., Gómez, A., "Optimization of Decision Making in the Supply of Medicinal Gases Used in Health Care", Sustainability, 11(10): 2952, (2019).

[115] Efe, B., "Fuzzy cognitive map based quality function deployment approach for dishwasher machine selection", Applied Soft Computing, 83105660, (2019).

[116] Petridis, K., Drogalas, G., and Zografidou, E., "Internal auditor selection using a TOPSIS/non-linear programming model", Annals of Operations Research, 296(1): 513-539, (2021).

[117] Mardani, N., Mardani, A., and Nilashi, M., "Evaluating the Knowledge Management Practices in State Welfare Organization (Behzisti): Application of Fuzzy MCDM Approach", Journal of Soft Computing and Decision Support Systems, 4(3):1-20, (2017).

[118] Adar, T., Emeç, Ş., Delice, E.K., and Akkaya, G., "An Integrated IF-AHP and IF-TOPSIS method for Neuroimaging Techniques Selection", Turkish Journal of Fuzzy Systems (TJFS), 10(1), (2019).

[119] Oh, J., Lee, U., and Lee, K., "Usability Evaluation Model for Biometric System considering Privacy Concern Based on MCDM Model", Security and Communication Networks, 20198715264, (2019).

[120] Kasali, F., Adekola, O., Akinyemi, I., Ebo, I., and Balogun, J., "A Model for Ranking the Usability Attributes of Mobile Health Applications in Nigeria (MCDM Approach)", Covenant Journal of Informatics and Communication Technology, 8(2): (2021).

[121] de Morais Correia, L.M.A., da Silva, J.M.N., dos Santos Leite, W.K., Lucas, R.E.C., and Colaço, G.A., "A multicriteria decision model to rank workstations in a footwear industry based on a FITradeoff-ranking method for ergonomics interventions", Operational Research, (2021).

[122] Bowo, L.P., Prilana, R.E., and Furusho, M., "A modified HEART – 4M method with TOPSIS for analyzing indonesia collision accidents", TransNav : International Journal on Marine Navigation and Safety of Sea Transportation, 14(3): 751-759, (2020).

[123] Shakerian, M., Choobineh, A., Jahangiri, M., Alimohammadlou, M., Nami, M., and Hasanzadeh, J., "Interactions among Cognitive Factors Affecting Unsafe Behavior: Integrative Fuzzy DEMATEL ISM Approach", Mathematical Problems in Engineering, 20208952624, (2020).

[124] Karuppiah, K., Sankaranarayanan, B., and Ali, S.M., "A fuzzy ANP–DEMATEL model on faulty behavior risks: implications for improving safety in the workplace", International Journal of Occupational Safety and Ergonomics, 28(2): 923-940, (2022).

[125] Rostamzadeh, S., Abouhossein, A., and Chalak, M.H., Vosoughi, and S.Norouzi, R., "An integrated DEMATEL-ANP approach for identification and prioritization of factors affecting falls from height accidents in construction industry", International Journal of Occupational Safety and Ergonomics, 1-31, (2022).

[126] Mohanty, P.P., Studies on Product Design Using Ergonomic Considerations Department of Industrial Design. India: National Institute of Technology Rourkela, (2014).

[127] Bourhim, E.M., Cherkaoui, A., editors. Usability Evaluation of Virtual Reality-Based Fire Training Simulator Using a Combined AHP and Fuzzy Comprehensive Evaluation Approach. Data Intelligence and Cognitive Informatics, Singapore: Springer Singapore, (2021).

[128] Eraslan, E., Dağdeviren, M., “A Cognitive Approach for Performance Measurement in Flexible Manufacturing Systems using Cognitive Maps”. Cognitive Maps: IntechOpen, (2010).

[129] Rahman, M.F., Amin, M.B., and Parvez, M., "Application of AHP in Development of Multi-Criteria Ergonomic Approach for Choosing the Optimal Alternative for Material Handling-A Case Study and Software Development to Facilitate AHP Calculation", International Journal of Engineering Research, 3(6), (2014).

[130] Yavuz, A., "An analysis of job change decision using a hybrid MCDM method: a comparative analysis", International Journal of Business and Social Research, 6(3): 60-75, (2016).

[131] Delice, E.K., Can, G.F., "An Integrated mental workload assessment approach based on Nasa-TLX and SMAA-2: A case study", Eskişehir Osmangazi Üniversitesi Mühendislik ve Mimarlık Fakültesi Dergisi, 26(2): 88-99, (2018).

[132] Gül, S., "Spherical fuzzy extension of DEMATEL (SF-DEMATEL)", International Journal of Intelligent Systems, 35(9): 1329-1353, (2020).

[133] Liao, H., Wu, X., Mi, X., and Herrera, F., "An integrated method for cognitive complex multiple experts multiple criteria decision making based on ELECTRE III with weighted Borda rule", Omega, 93102052, (2020).

[134] Zarei, E., Ramavandi, B., Darabi, A.H., and Omidvar, M., "A framework for resilience assessment in process systems using a fuzzy hybrid MCDM model", Journal of Loss Prevention in the Process Industries, 69104375, (2021).

[135] Alhubaishy, A., Aljuhani, A., "The challenges of instructors’ and students’ attitudes in digital transformation: A case study of Saudi Universities", Education and Information Technologies, 26(4): 4647-4662, (2021).

[136] Gupta, K., Roy, S., Poonia, R.C., Nayak, S.R., Kumar, R., Alzahrani, K.J., Alnfiai, M.M.Al-and Wesabi, F.N., "Evaluating the Usability of mHealth Applications on Type 2 Diabetes Mellitus Using Various MCDM Methods", Healthcare, 10(1): 4, (2022).

[137] Gul, M., "A review of occupational health and safety risk assessment approaches based on multi-criteria decision-making methods and their fuzzy versions", Human And Ecological Risk Assessment: An International Journal, 24(7): 1723-1760, (2018).