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APPLICATION OF FUZZY LOGIC IN WEAVING PROCESS: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

The process of weaving continues to be one of the most intricate chains of transformation within the textile industry. This complexity arises from the diverse range of structures, the multiple stages involved, the intricate machinery utilized, the utilization of various materials, and the combination of both creativity and precision. Consequently, there exists a necessity for tools that can enhance efficiency, flexibility, and decision-making within this field. This review of existing literature aims to provide pertinent information regarding the utilization of logic in the realm of weaving.

In this research study, a systematic literature review methodology was employed to examine the application of fuzzy logic within the weaving process. Data for this study was collected from reputable databases, including ScienceDirect, IEEE Xplore, Textile Research Journal, and Google Scholar.

To select relevant articles for this study, the Prisma framework was utilized, resulting in the inclusion of solely journal articles for the literature review. A comprehensive framework was developed to elucidate the impact of employing fuzzy logic, the approach presented in this framework provides a comprehensive and highly effective method for tackling the complex challenges associated with ambiguity, modification, and subtlety that are frequently observed in the intricate and intricate process of weaving.

The findings of various studies explored aspects such as the properties of warp and weft fabrics, the performance of weaving machines, the organizational performance of weaving companies, and occupational health and safety concerns. While these studies have provided valuable solutions, they unfortunately remain insufficient in the face of the weaving process, which persists as a complex field characterized by uncertainties, variations, and intricacies that are inherent to the practice. This uniqueness of each woven product fosters an environment conducive to experimentation and further research.

Keywords: *Fuzzy logic, Warp, and weft fabrics, weaving loom, weaving company, working conditions, Weaving productivity.*

1. INTRODUCTION

In the 1960s, Lotfi Zadeh took it upon himself to develop the concept of fuzzy logic as a direct response to the inherent limitations that traditional binary logic had when it came to effectively and accurately representing and inferring concepts that were imprecise or uncertain in nature. The basic idea of this concept is that the value of practical concepts can be determined on a gradual scale, rather than being limited to absolute truth or falsehood. In the field of fuzzy logic, variables are assigned values on a continuous spectrum from 0 to 1, representing the degree of membership in a particular category. To illustrate, rather than delineating whether an item is classified as large or small, the utilization of fuzzy logic permits the articulation that an item may possess a composite nature consisting of both largeness and smallness. This flexibility allows us to capture the nuances and degrees of truth that exist in many phenomena in the real-world Fuzzy logic, an approach rooted in the concept of fuzzy sets defined by elements exhibiting diverse levels of membership ranging from 0 to 1, heavily relies on the deployment of fuzzy operators to execute a wide array of operations encompassing conjunction, disjunction, and negation. Following its inception, fuzzy logic has been continuously investigated and utilized in a plethora of applications across the domain of weaving. The exploration and employment of fuzzy logic in such applications have continued to evolve over time. It also uses fuzzy rules to express and justify inaccurate or heuristic knowledge. The realm of artificial intelligence, with its vast breadth and scope, permeates a diverse array of disciplines and sectors, traversing numerous spheres such as automation, decision-making, process control, planning, resource management, and healthcare, among a multitude of others**.**

To the best of my knowledge, the initial recorded utilization of fuzzy logic in the weaving can be traced back to the year 1994. The publication entitled "Advanced Application of Statistical and Fuzzy Control to Textile Processes" was authored by Gary Daves, Sunshiny Rim, and Amit Kumar. The paper studied the application of fuzzy logic to optimize and coordinate the performance of the slasher weaving process.

Since that time, fuzzy logic has continued to be explored and employed in various applications within the realm of weaving. Then, there were 15 articles focused on 4 distinct aspects of the weaving process: Seven articles examined the application of fuzzy logic to model and assess characteristics of fabric quality. In 2003 [Xiangyi Zeng and Ludovic Koehl] presented a method based on fuzzy logic for representing and analyzing the outcomes of subjective evaluation on the fabric hand provided by experts in the fields of fashion or quality inspection**[1]**. In 2006, [EK CEVEN and Öner Özdemir] established a fuzzy logic model and principles based on experimental data, facilitating the prediction of chenille fabric's abrasion behavior. The utilization of fuzzy logic in this study also enabled the economical optimization of abrasion resistance, offering practical advantages for fabric production**[2]**. In 2017, [Thouraya Hamdi and Adel GHITH] selected fuzzy logic as a methodology due to its ability to consider the ambiguity and uncertainty inherent in drape behavior, which can fluctuate between artistic patterns and types of clothing. The fuzzy logic methodology employed in this study was validated through a testing phase that involved classifying fabric samples into different categories based on the method's findings**[3]**. Also In 2018, [EB Priyanka and Thangavel Subramaniam] employed fuzzy logic to analyze surface roughness and measure the fractal dimension, a commonly utilized parameter in fabric texture analysis. The combination of fuzzy logic with other techniques, such as genetic algorithms, has been investigated in texture recognition for fabric identification**[4]**. In 2019, [Najmeh Dehghan-Manshadi and Mohsen Hadizadeh] utilized a fuzzy logic model that exhibited efficiency in predicting bending rigidity by utilizing input parameters such as yarn count, yarn diameter, yarn spacing, yarn bending rigidity, and yarn length**[5]**. In 2019, [Thouraya Hamdi, Adel Girth and Faten Fayala] developed a predictive model using fuzzy logic that considers various fabric parameters and their impact on drape. Fuzzy logic provides a flexible and intuitive framework for capturing the subjective nature of human perception and decision-making, which is relevant in the context of evaluating fabric drapes**[6]**. Additionally, in 2020, [Maher Alsayed, Halil _Ibrahim C¸ Elik and Hatice Kubra Kaynak] devised a fuzzy logic model for predicting the air permeability of multifilament polyester woven fabrics. The fuzzy logic model yielded satisfactory and accurate prediction results, with a mean absolute error of 2.32%**[7]**.

Four articles pertaining to the application of fuzzy logic in the realm of weaving machine technology were examined. In 2004, [M. Cengiz KAYACAN, Mehmet DAYIK, Oguz COLAK and Murat KODALOGLU] formulated a fuzzy logic model utilizing empirical data and expert knowledge, rendering it a dependable instrument for evaluating the impact of yarn properties on weft yarn velocity. The outcomes derived from the fuzzy logic model were juxtaposed against experimental results, thereby showcasing the efficacy of employing fuzzy logic in governing the weft insertion system**[8]**. In 2008, [Mehmet DAYIK, M. Cengiz KAYACAN, Mustafa ACAR and Hakan ÇALIS] determined that fuzzy logic can be utilized to regulate a weaving loom. The devised fuzzy logic model revealed that the elevation of the shed is the most influential parameter in determining warp tension, whereas weft yarn density exerts a relatively lesser influence**[9]**. In 2009, [Dayik Mehmet, C¸ Alis¸ Hakanb and Kacacan M. Cengizc] employed fuzzy logic to realize adaptive control of the let-off system in weaving. The let-off system in weaving bears the responsibility of stabilizing warp tension by controlling the pace at which the fabric is taken up. The fuzzy logic controller formulated in this study demonstrated enhanced performance in comparison to conventional control techniques**[10]**. In 2019 [Ratna SAFITITRI and Tatang Mulyana] introduced a new approach to fabric defect detection using image processing and fuzzy logic, which improves accuracy and reduces inspection time**[11]**.

Three articles relating to the application of fuzzy logic in weaving production. In the year 2018 an academic study authored by [Lindani K Ncube, Takawira R CHIKOWORE , Nqobizitha R

SIBANDA , Peeps GONDE] introduced a decision support apparatus rooted in fuzzy logic principles. This tool was specifically designed to aid in the strategic planning of weaving orders. Its primary function is to ascertain the ideal quantity of orders that can be efficiently processed within the confines of the weaving establishment, taking into consideration the availability of raw materials and the demands of customers. Rigorous examination of the model demonstrated a potential enhancement of 30% in production output as well as a 1.2% increase in daily profits**[12]**.

In the year 2018, [Tundo and Enny ITJE SELA] embarked on a mission to acquire more precise outcomes in ascertaining the suitable and fitting quantity of production, considering the factors of stock, demand, and production expenses. The utilization of fuzzy logic within the domain of woven fabric industry anticipates facilitating and rendering more unbiased the process of determining the production quantity for entrepreneurs, given the ever-evolving characteristics of stock, demand, and production costs**[13]**.in the year 2019, [Iman SUBHI Mohammed and Israa Mohammed LHAMDANI] made a significant contribution to the field of textiles defect detection and classification by designing and implementing a computerized system. This system effectively employed a wide array of sophisticated methodologies, encompassing the utilization of cutting-edge image processing algorithms, the application of rigorous statistical techniques, the integration of highly intricate neural networks, and the incorporation of intricate fuzzy logic principles. By integrating these methodologies, Mohammed was able to achieve an impressive distinction rate of 91.4286% in accurately identifying textile defects. However**,** the researcher's investigation did not stop there**.** Recognizing the potential for improvement, Mohammed further enhanced the system's performance by applying fuzzy logic to the outputs of the neural network. This additional step resulted in a remarkable increase in the distinction rate, reaching an impressive 97%. These findings highlight the effectiveness and potential of the proposed system in the realm of textile defect detection and classification**[14]**.

One article related to the application of fuzzy logic in occupational safety. In 2022 [Murat KODALOGLUA and Feyza Akarslan KODALOG] were chosen the Fuzzy logic because it allows the evaluation of temperature physiology and occupational health in weaving businesses, which is important for preventing occupational diseases and accidents. And more the fuzzy logic helps in determining the rate of change in the index of predicted percentage of dissatisfied (PPD) in relation to thermal comfort conditions**[15]**.

The following defines the paper's structure: The research technique is described in Section 2 of this article. The literature review is presented in Section 3 and contrasts the articles that were retrieved for this study using fuzzy logic during the weaving process. The discussion in Section 4, the future research in Section 5, and the conclusions in Section 6.

2. REVIEW METHODOLOGY

This study uses the Prisma framework and the systematic literature review technique to carry out an exhaustive literature evaluation. Tanfield provided a series of specific stages to perform systematic literature review in 2003**[16]**; these processes were strictly followed in our research project. These procedures largely involve creating a successful search strategy, specifying the selection criteria, and implanting a comprehensive quality evaluation and data extraction process. Then, in following parts, a thorough explanation of each of these stages is given. The Prisma framework's structure must be understood to succeed this research. Consequently, a search paradigm was developed,

Early results were obtained by consulting reliable resources including ScienceDirect, IEEE Xplore, Textile Research Journal, and Google Scholar. Preliminary data then endured various circumstances. Research field restrictions, language choice, research and review articles, time restrictions, and article filters were all part of the selection criteria. The most relevant and applicable studies that align with the aims and goals of this study were carefully chosen and incorporated into the comprehensive examination of existing literature. Conversely, any research articles that did not meet the criteria of the screening process were not included in this investigation.

The methodology employed for the review, known as the Prisma Framework, is thoroughly elucidated d in Figure 1.

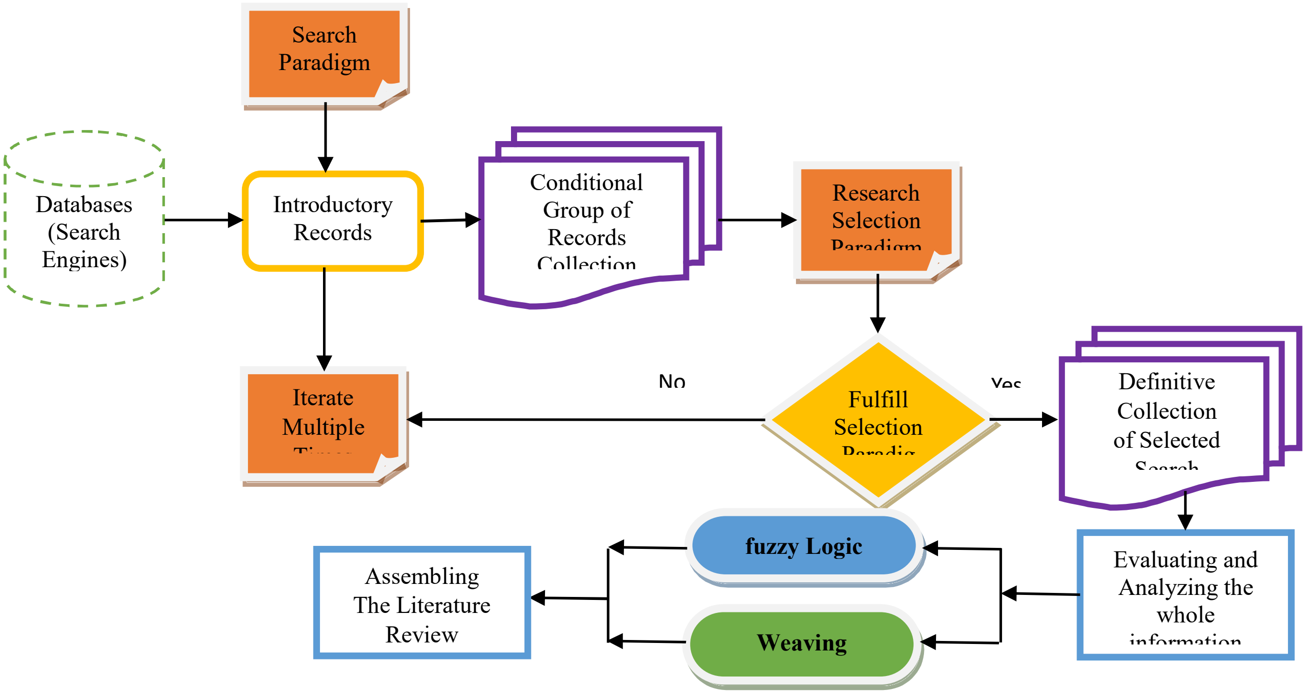

Figure 1: Shows The Structure Of The Scientific Review Process Used.

2.1. Prisma Framework

2.2.1. Step1. Identification

The first step is to develop a search strategy; The search strategy for this study was adapted to four databases (ScienceDirect, IEEE Xplore, Textile Research Journal, and Google Scholar).
Search keywords are determined as follows: Fuzzy logic – Warp and weft fabrics – Looms – Textile business – Workers' health – Weaving productivity. Initially, **854** documents were extracted according to the search strategy of the identification process.
To develop the search strategy, the identification step of the Prisma command is performed and illustrated in **Figure 2**.

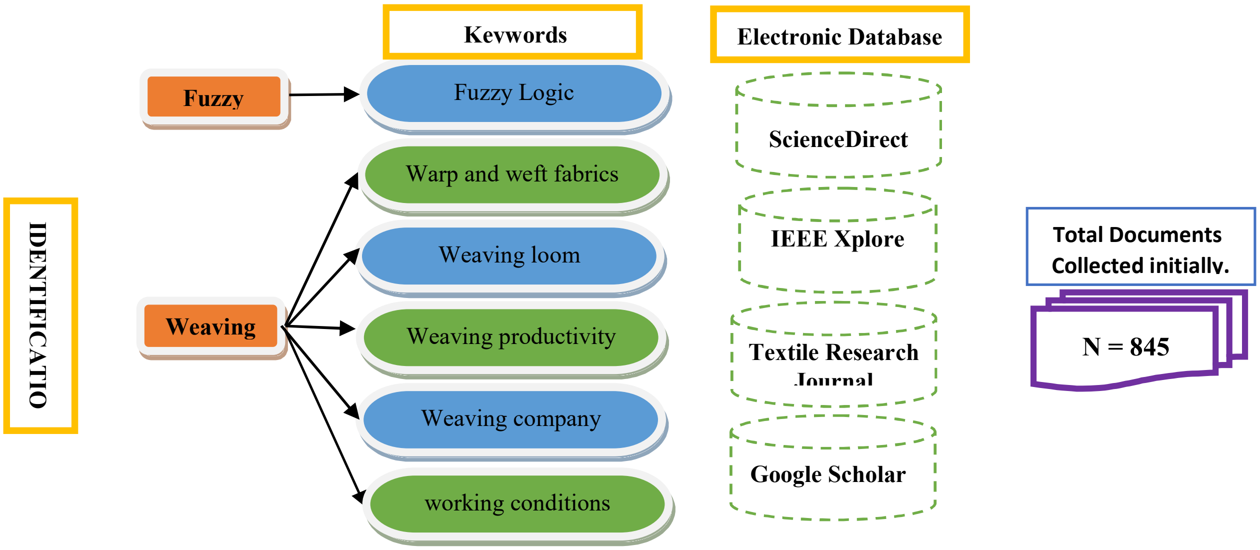

Figure 2: shows the Prisma framework's identification phase.

2.2.2. *Step2. Evaluation*

In the second step of the Prisma model, we move on to assessing and filtering relevant information. This crucial stage involves establishing specific criteria for our research and implementing them effectively. Our primary aim is to compile a comprehensive collection of literature that delves into fuzzy logic and its application in the weaving process. To ensure accuracy, we have restricted our investigation timeline from 2003 to 2022. Furthermore, this study focuses exclusively on exploring how fuzzy logic can be applied within the realm of weaving, narrowing down our research areas accordingly.

Only full articles and review papers were chosen, and the language of research papers was restricted to English. Notably, a total of **803** documents were eliminated during the screening stage, while 42 research papers were extracted and forwarded to the next stage. The screening process of the Prisma framework is elucidated in **Figure 3**.

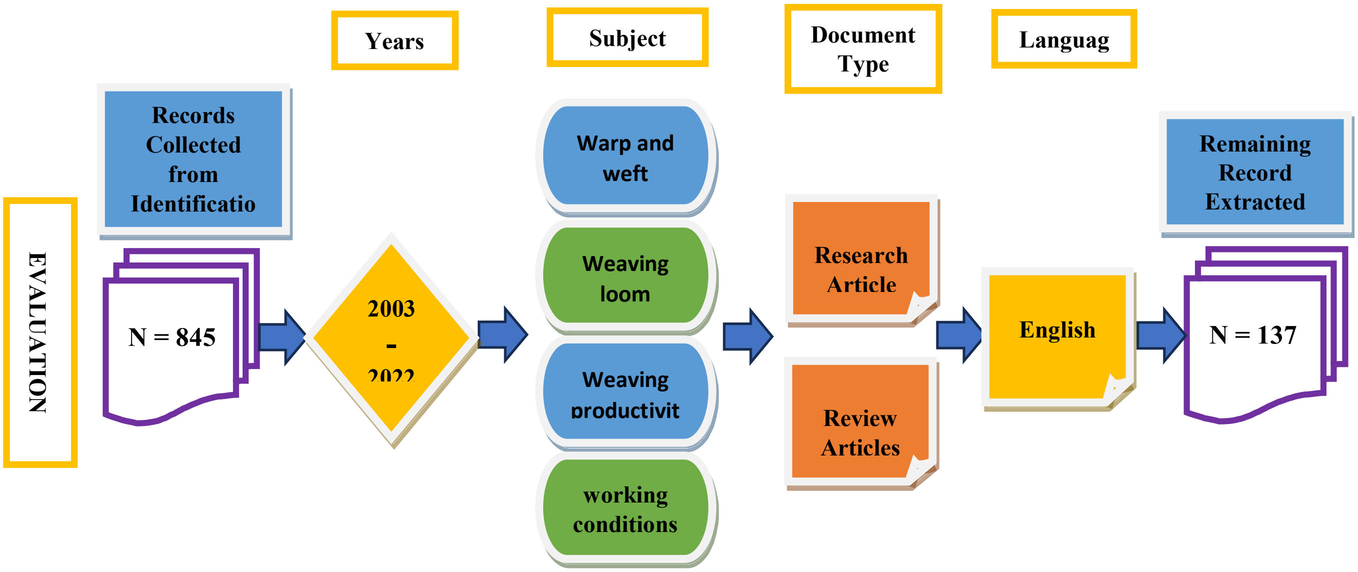

Figure 3: shows the Prisma framework's screening phase.

2.2.3. *Step3. Meeting the Requirement*

The focus of this research revolves around comprehensive research articles and review articles. To ensure accuracy, we meticulously sifted through all the gathered material to eliminate any duplicates. Each article's abstract underwent a meticulous examination to guarantee its relevance to our study objectives. Furthermore, each of the chosen articles underwent a thorough review.

In addition, **95** papers were found not to fulfill our standards during the quality evaluation process and were therefore disqualified from consideration. The remaining **42** articles successfully passed this stage and became eligible for further inclusion or exclusion analysis. A visual representation of the quality assessment process can be found in **Figure 4.**

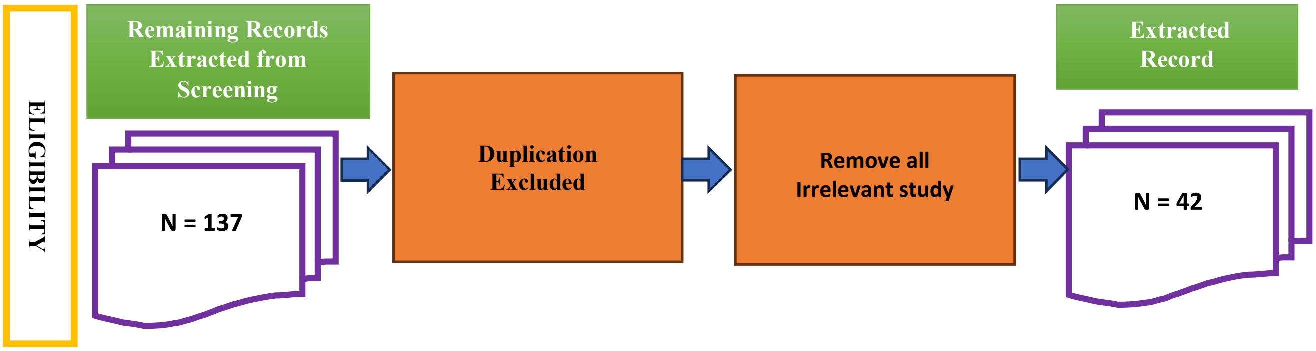

Figure 4: shows the Prisma framework's eligibility stag

2.2.4. Step3. Inclusion and Exclusion

Inclusion and exclusion criteria were clearly defined, and after thorough inspection and evaluation of all extracted documents, eight documents were excluded from the study. Finally, a total of 55 articles were selected for the literature search. The embedding phase of the Prisma instruction is illustrated in **Figure 5**.

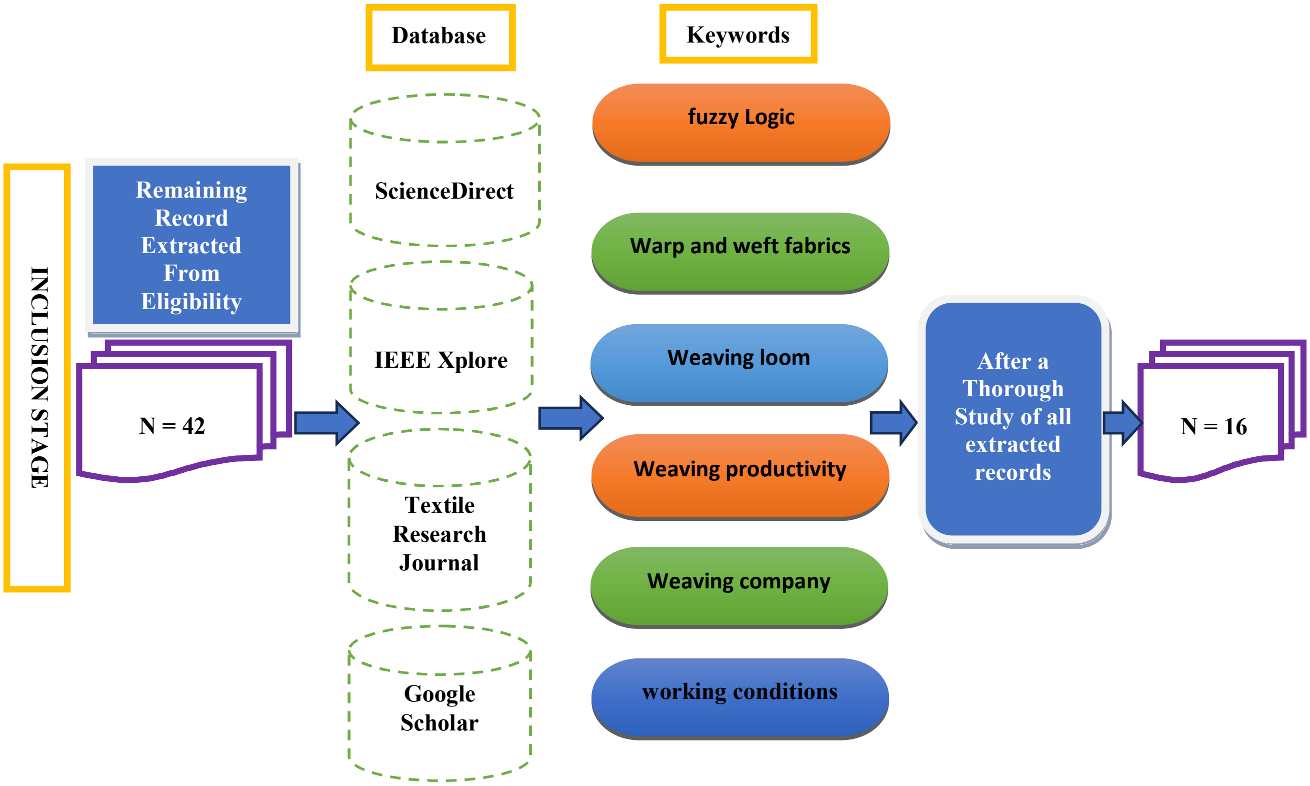

Figure 5: The Prisma framework's inclusion stage.

3. REVIEW METHODOLOGY

3.1. Demographics

3.1.1 Contribution by Publishers

At this stage, the contributions of the different editors were identified. It can be seen in **Figure 6**. “International Textile Center” is at the top, with a maximum number of publications of 3 articles. “John Wiley and Sons Ltd” ranked second with 2 articles and other articles published by different publishers.

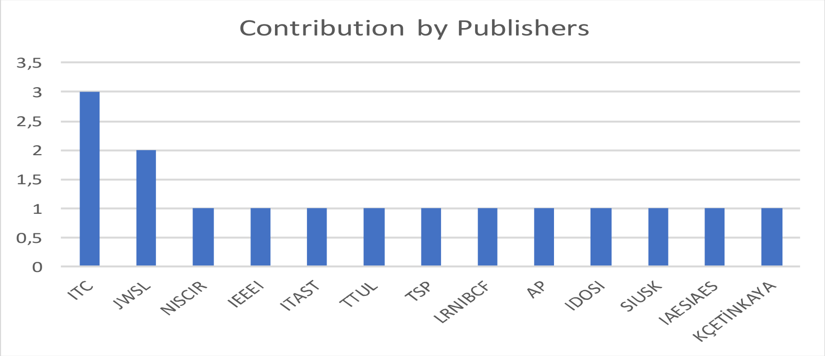

Figure 6: Contributions by publishers.

3.1.2. Contribution by Journal

Data is gathered from a variety of sources. The sources utilized to find and choose articles about weaving technology and the use of fuzzy logic are listed in **Table 1**.

Year	Journal	Abbreviation	Impact Score
1994	National Textile Center	NTC	0,25
2003	International Journal of Intelligent Systems	Int. J. Intell. Syst.	8.52
2004	Fibres et Textiles in Eastern Europe	Fibres Text. East. Eur.	0.9
2006	Indian Journal of Fibre & Textile Research	I J. FIBRE TEXT. RES.	0,6
2008	The Journal of The Textile Institute	JTEXT I	1.7
2009	The Journal of The Textile Institute	JTEXT I	1.7
2017	International Journal of Electronics and Electrical Engineering	Int. j. electron. electr. eng.	0.94
2018	International Journal of Intelligent Systems	Int. J. Intell. Syst.	8.52
2018	Journal of Textiles and Polymers	J. text. polym	0
2018	International organization of Scientific Research	IOSR	0
2018	International Journal on Informatics for Development	IJID	0
2019	International Conference on Industrial Enterprise and System Engineering	IcoIESE	0.21
2019	International Journal of Electrical and Computer Engineering	IJECE	2.72
2020	Autex Research Journal	Autex Res. J.	1.40
2020	Textile Research Journal	Text. Res. J.	2.455
2022	International Journal of 3D Printing technologies and Digital Industry	IJ3DPTDI	0

Table 1 lists the articles' sources.

3.1.3 Contribution by top Authors

The table below lists the top **7** writers who made the most contributions to the fields of fuzzy logic and weaving process.

Authors	Number of Citations (2023)	Author's Affiliation
Amit Kumar	**63550**	Researcher In Machine Learning & Data Science
Halil Ibrahim	**4421**	Nisantasi University Medical School
Xiangyi Zeng	**4031**	The ENSAIT Textile Institute
Öner Özdemir	**3797**	Sakarya Üniversitesi (SAÜ)
Mustafa ACAR	**3395**	Necmettin Erbakan Üniversitesi,
Manshadi	**2280**	University of Queensland
M. Cengiz KAYACAN	**1028**	Süleyman Demirel Üniversitesi

Table 2 Top eight authors' contributions.

3.1.4 Contribution by Country

According to **Figure 7**, the United States, Poland, Pakistan, and the United Kingdom are the three countries that provide the most articles to this field.

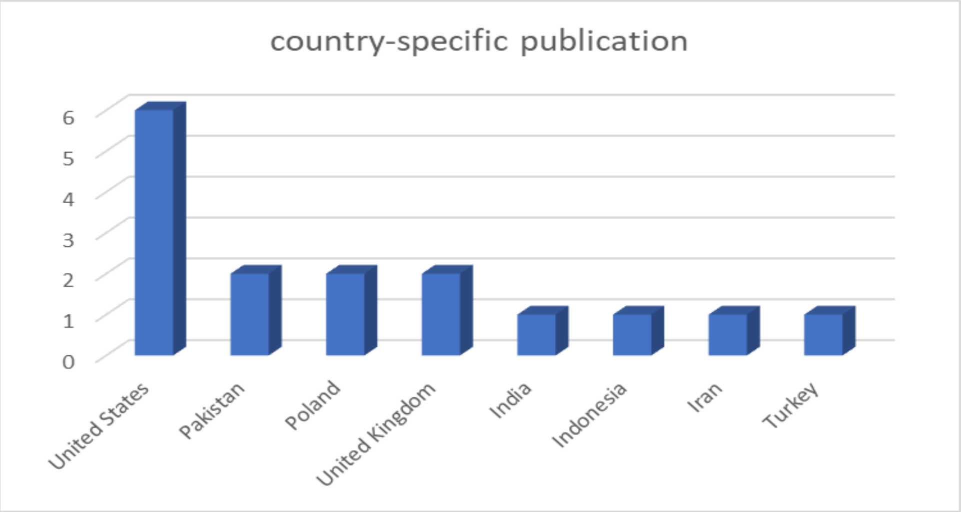

Figure 7: Details of a country-specific publication.

3.1.5 Year-Wise Publications

In this segment, we will provide an overview of various articles categorized by their respective publication years. Figure 8 showcases a noticeable surge in the quantity of articles published in recent times.

This can be attributed to the growing recognition of fuzzy logic as an incredibly potent tool for streamlining weaving process and aiding decision-making endeavors.

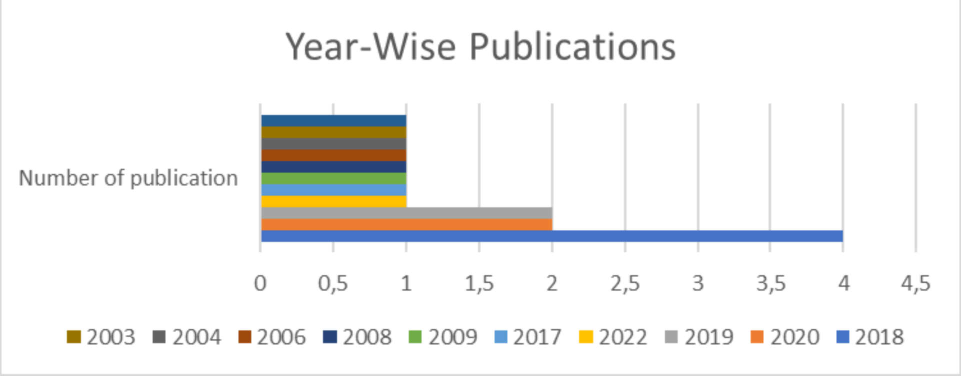

Figure 8: Data on publications by year.

3.2. Classify

This work studies two terms: fuzzy logic and weaving process. For the weaving process, we have divided the fuzzy logic into four main axes:
1. Fuzzy logic and properties of warp and weft fabrics (**PF**).
2. Fuzzy logic and performance of weaving machines (**WM**).
3. Fuzzy logic and organizational effectiveness of a textile company (**TC**).
4. Fuzzy logic and occupational safety and health (**SH**).

In Table 3, a detailed comparison of each research article is made based on the research objectives, methods, and results.

Reference 1	**Fuzzy logic**		x	**objectives**	The present paper aims to introduce the novel application of statistical and fuzzy logic control techniques within the realm of the textile industry, with a specific focus on their implementation in the slashing process. The slashing process can greatly benefit from the integration of statistical and fuzzy logic control techniques, as they can effectively optimize the process parameters and minimize production errors.
	Waiving process	**SH**		**Methods**	The utilization of process modeling is employed in this paper in order to thoroughly analyze the slashing process, thereby facilitating a comprehensive comparison between the conventional control techniques and the novel control techniques that have been recently developed.
		TC			
		WM	x	**Results**	The current research paper effectively emphasizes the urgent necessity for the development and enhancement of control techniques in the process of slashing, a crucial procedure that is currently heavily reliant on heuristics and the accumulated wisdom gained through experience.
		PF			
Reference 2	**Fuzzy logic**		x	**objectives**	The article introduces a fuzzy logic-based method for representing and analyzing subjective evaluations of fabric hand, providing a quantitative criterion for assessing the quality of textile products. It also models the relationship between subjective fabric hand evaluation and objective numerical data measured on the KES.
	Waiving process	**SH**		**Methods**	The article utilizes fuzzy logic-based techniques to represent and analyze subjective evaluations of fabric hand. It employs the Mamdani method for modeling the relationship between subjective and objective evaluations using a fuzzy logic controller (FLC).
		TC			
		WM		**Res ults**	The proposed method for representing and analyzing subjective evaluations of fabric hand achieved a rate of success of up to 60% in a silk evaluation. The results

		PF	x		demonstrate the effectiveness of the method in objectively assessing the fabric hand of textile products.
Reference 3	**Fuzzy logic**		x	**objectives**	The article contributes to the understanding of the factors influencing the abrasion behavior of chenille fabric, specifically focusing on yarn count, pile length, and twist level. It introduces the use of a fuzzy logic system for predicting abrasion resistance, providing a more economical approach to optimization.
	Waiving process	**SH**		**Methods**	The article utilizes a fuzzy logic system to study the effects of chenille yarn count, pile length, and twist level on the abrasion resistance of chenille fabric. Experimental data from chenille yarns with varying characteristics are used to establish the fuzzy logic model and construct basic principles. Correlation analysis is performed to assess the relationship between measured and predicted mass loss values.
		TC			
		WM		**Results**	The study finds that high twist levels and pile lengths improve the abrasion resistance of chenille fabric, while yarn count has a significant effect on mass loss. Correlation analysis confirms a strong linear relationship between measured and predicted mass loss values. The use of a fuzzy logic system allows for more economical optimization of abrasion resistance.
		PF	x		
Reference 4	**Fuzzy logic**		x	**objectives**	This article presents an introduction to the application of fuzzy logic, as well as the use of the two-dimensional Fast Fourier Transform (2D-FFT) technique for fabric texture analysis. This analysis is specifically focused on the measurement of surface roughness, a property that plays a crucial role in various industries. This research offers significant potential for improving the understanding and optimization of fabric properties, thereby enhancing product quality and performance.
	Waiving process	**SH**		**Methods**	The study makes use the fuzzy logic, which is a type of logic that deals with uncertainty and imprecision, and the two-dimensional fast Fourier transform (2D-FFT), a mathematical algorithm that transforms a two-dimensional signal into its frequency domain representation, for the purpose of analyzing fabric texture. More specifically, it focuses on using these techniques to measure the surface roughness of fabrics.
		TC			
		WM		**Results**	The research paper presents evidence that the application of FD-FFT, an algorithm that employs fuzzy logic in combination with three-dimensional visualization and interpretation techniques, yields a rapid and dependable metric for quantifying the roughness of fabric surfaces.
		PF	x		
Reference 5	**Fuzzy logic**		x	**objectives**	The main contributions elucidated in this article focus on the pioneering application of fuzzy logic in the prognosis of the subtleties of drape behavior, thus unveiling a new dimension in the field of the weaving process. In addition, the identification and subsequent elucidation of fabric parameters that exert a prodigious influence on the draping phenomenon. The implications of these advances save time and boost productivity.
	Waiving process	**SH**		**Methods**	The techniques employed in this scientific paper include the use of fuzzy logic, an analytical tool that enables the processing of imprecise and uncertain information, and the fuzzy method. A computer framework that facilitates decision-making based on uncertain or vague data.
		TC			

		WM		Results	The results of this article show that changing fabric parameters significantly affects fabric drape, and there is a representative correlation between experimental and calculated values using the fuzzy system.
		PF	x		
Reference 6	Fuzzy logic		x	objectives	The paper presents a novel approach to predicting the behavior of drape by employing a fuzzy logic method, a technique that has not been explored in previous studies conducted on this subject matter.
	Waiving process	SH		Methods	The paper effectively employs a sophisticated fuzzy logic approach, which is a powerful computational tool that enables the classification of various fabric samples into distinct categories, solely relying on their drape values.
		TC			
		WM		Results	The paper introduces a set of membership functions that are employed in the fuzzy logic approach to anticipate the drape behavior by defining the input and output variables. By assigning membership degrees to different linguistic terms associated with the input and output variables, the fuzzy logic method facilitates the modeling of complex and non-linear relationships between these variables, thereby enhancing the accuracy and robustness of the drape behavior prediction model.
		PF	x		
Reference 7	Fuzzy logic		x	objectives	The paper introduces a fuzzy logic model for predicting fabric bending rigidity, which is a crucial property for determining the end-use quality of products. The model demonstrates higher prediction accuracy compared to other modeling methodologies.
	Waiving process	SH		Methods	The paper utilizes a fuzzy logic model to predict fabric bending rigidity. The input variables are converted into fuzzy numbers and triangular membership functions are defined. The model partitions the output variable into fuzzy intervals to make predictions.
		TC			
		WM		Results	The fuzzy logic model shows lower prediction errors for fabric bending rigidity compared to mathematical, empirical, and artificial neural network models. The mean prediction error percentages for fabric bending rigidity in the warp and weft directions are 8.76 and 8.14, respectively.
		PF	x		
Reference 8	Fuzzy logic		x	objectives	The present study focuses on the development of a highly sophisticated and comprehensive fuzzy logic model for accurately and precisely predicting the air permeability of multifilament polyester woven fabrics. This research endeavor aims to overcome the limitations of existing models and provide a cutting-edge solution to the industry by harnessing the power of fuzzy logic. By utilizing this innovative approach, the proposed model not only considers the inherent uncertainties and vagueness associated with fabric properties.
	ing proc	SH		Methods	Regression analysis, a statistical technique used to examine the relationship between a dependent variable and one or more independent variables, was employed in this study as one of the methodologies to construct models that can accurately forecast air

		TC			permeability, an important property in various fields such as civil engineering, material science, and geotechnical engineering.
		WM		Results	The fuzzy logic model that was developed in this study demonstrated highly satisfactory and remarkably accurate prediction outcomes for the measurement of air permeability. The results obtained from this study not only validate the viability and efficacy of the developed fuzzy logic model, but also highlight its potential for application in the field of air permeability prediction, thus contributing to the advancement of knowledge and understanding in this domain.
		PF	x		
Reference 9	Fuzzy logic		x	objectives	The article contributes to the understanding of how yarn properties, such as linear density and twist coefficient, affect weft yarn velocity in air jet weaving looms. It also introduces the use of fuzzy logic control system in controlling the weft insertion system.
	Waiving process	SH		Methods	The article uses a fuzzy logic system to control the weft insertion system in air jet weaving looms. Experimental data and expert knowledge are used to establish the fuzzy logic model and construct basic principles.
		TC			
		WM	x	Results	The fuzzy logic model used to control the weft insertion system in air jet weaving looms shows promising results when compared with experimental results. The effects of yarn properties, such as linear density and twist coefficient, on weft yarn velocity are determined by the fuzzy logic system.
		PF			
Reference 10	Fuzzy logic		x	objectives	The article introduces a fuzzy logic model to determine warp tension in the shedding operation, considering shedding height and weft yarn density and elasticity as parameters. The study demonstrates the feasibility of using fuzzy logic to control a weaving loom.
	Waiving process	SH		Methods	The article utilizes expert knowledge and the results of recent experiments to determine the membership functions and relationship rules for the fuzzy logic model and gives specific details about the data used in the experiments that are not provided in the available sources.
		TC			
		WM	x	Results	The parameter with the greatest impact on warp tension during weaving is known as the shedding height, and has been identified as the most influential factor. This parameter can have a maximum effect of 55 cN, which is considerable in terms of its impact on warp thread tension. In addition, it should be noted that a decrease in yarn elasticity can be attributed to a 15% increase in warp yarn tension.
		PF			
Reference 11	Fuzzy logic		x	objectives	The article makes a notable contribution to the field of weaving as it delves into the intricate realm of control systems for the let-off system. Through a comprehensive analysis, it diligently compares various control systems to evaluate their efficacy in regulating the tension of the warp. In doing so, it highlights the advantages inherent in using fuzzy logic-based control to achieve extreme accuracy in warp thread tension.
	ing proc	SH		Methods	The article employs a blend of traditional control systems, namely conventional, PID, and fuzzy logic-based control systems, to effectively regulate the let-off system in a weaving loom. These control systems are put into action by means of a servomotor,

		ETC			encoder, proximity sensor, and PID controller, which work in unison to ensure smooth and accurate operation. To achieve this, the system takes samples from the proximity and encoder sensors, extracting vital signals that are subsequently analyzed using the PID controller.
		WM	x	Results	The article posits that additional investigation is necessary to delve into the enduring steadiness and dependability of the control system based on fuzzy logic in real-world industrial environments. It further suggests that future studies should consider exploring the enhancement of control parameters and configurations for various categories of weaving looms, with the ultimate objective of attaining more effective regulation of warp tension.
		PF			
Reference 12	Fuzzy logic		x	objectives	The paper presents an innovative and groundbreaking methodology for the detection of fabric defects by means of image processing techniques combined with the utilization of fuzzy logic principles, a novel approach that not only enhances the precision and correctness of the detection process, but also remarkably diminishes the amount of time required for inspection.
	Waiving process	SH		Methods Used	The investigation employs a total of 120 training data, which is a significant amount of data used to train the automated fabric inspection system. Additionally, to comprehensively assess and validate the system's efficacy, the research incorporates 80 offline test data, which are carefully selected to represent real-world scenarios that the system might encounter.
		ETC			
		WM	x	Results	The automated fabric inspection system can achieve an impressive accuracy rate of 97.5% in its ability to accurately identify fabric defects. This high level of accuracy is essential in ensuring that any flaws or imperfections in the fabric are detected and addressed promptly. Furthermore, the system can achieve this remarkable level of accuracy while maintaining an average processing time of only 1.15 seconds. This efficient and swift processing time is crucial in a fast-paced manufacturing environment, where time is of the essence and delays can have significant consequences.
		PF			
Reference 13	Fuzzy logic		x	objectives	The present research article brings forth a pioneering contribution to the field of textile weaving order planning, through the introduction of an innovative decision support tool that operates based on fuzzy logic. This state-of-the-art tool serves to enhance the efficiency of production processes by means of two key strategies: firstly, by optimizing the number of orders processed; and secondly, by maximizing the utilization of raw materials.
	Waiving process	SH		Methods	The tool was meticulously designed using fuzzy logic, a powerful computational paradigm that enables uncertainty and imprecision to be dealt with systematically. This innovative tool was skillfully implemented in Matlab 7.8.347. This cutting-edge approach not only integrates human expertise, but also enhances the interpretability and transparency of the system, making it an invaluable tool in fields ranging from engineering to finance.
		TC	x		
		WM		Results	L'examen et la validation du modèle ont abouti à un résultat impressionnant : 80% des commandes entrantes ont été traitées avec succès, ce qui dépasse le taux existant de 50%. Une telle révélation montre une amélioration remarquable de 30 % de l'efficacité globale du traitement des commandes, qui se traduit à son tour par une augmentation louable de 1,2 % de la marge bénéficiaire journalière.
		PF			

Reference 14	Fuzzy logic		x	objectives	The contribution of this paper lies in the use of fuzzy logic techniques, in particular the Tsukamoto and Sugeno methods, to address the various production challenges facing the weaving industry. By employing these methods, the paper seeks to address the problems and complexities inherent in the production process, thereby facilitating the identification of optimal solutions. Through this examination, the paper strives to highlight the most effective method for accurately modeling the complex environment of fabric production.
	Waiving process	SH		Methods	- The paper uses the Tsukamoto method and the Sugeno method, both of which are fuzzy logic methods, to solve the production problems in the weaving fabric industry. The Tsukamoto method involves determining input and output variables as fuzzy sets, fuzzification of input variables, processing fuzzy set data using the maximum method, and defuzzification of the output using a weighted average method. The Sugeno method uses constants or mathematical functions of the input variables.
		TC	X		
		WM		Results	The results of the paper show that the Tsukamoto method using Weka rules provides production predictions that are closest to the actual production data in the weaving fabric industry. The comparison of the results obtained from both the Tsukamoto and Sugeno methods indicates that the Tsukamoto method with Weka rules yields more accurate predictions.
		PF			
Reference 15	Fuzzy logic		x	objectives	The paper presents an innovative and advanced system that effectively merges the powerful capabilities of image processing techniques, statistical methods, neural networks, and fuzzy logic algorithms, thereby offering a comprehensive and robust solution for the detection and classification of textile defects with an exceptionally high discrimination rate, which is of utmost importance in the textile industry.
	Waiving process	SH		Methods	The utilization of Gabor filters within the system serves the purpose of detecting edges and accentuating any areas of fabric images that may be deemed defective. To train the neural network for defect detection and classification, both statistical and geometry features that are extracted from the fabric images are employed. Subsequently, fuzzy logic is implemented to enhance the discrimination rate of the neural network outputs.
		TC	X		
		WM		Results	Further research in the field can delve into the exploration of the seamless integration of various other cutting-edge and state-of-the-art methodologies, including but not limited to the utilization of deep learning algorithms, with the overarching goal of augmenting and enhancing the precision, correctness, and efficiency of the textile defect detection and classification processes.
		PF			
Reference 16	Fuzzy logic		x	objectives	The article makes a significant contribution to the field by employing fuzzy logic as a methodology to construct models that can effectively predict the thermal comfort conditions experienced within weaving facilities. By utilizing this innovative approach, the study aims to shed light on the importance of acknowledging and understanding the potential risks that may arise within the work environment, ultimately seeking to prevent the occurrence of occupational diseases and accidents.
	Waiving process	SH	X	Methods	The article uses fuzzy logic-based models to evaluate thermal comfort in weaving facilities. It employs the PMV (Predicted Mean Vote) and PPD (Predicted Percentage of Dissatisfied) indices to assess the impact of personal and environmental factors on thermal comfort. Measurements are conducted using thermal comfort devices and the TS EN ISO 7730 standard.
		TC			
		WM		Results	The article presents the PMV-PPD measurements conducted in a weaving mill, providing values for variables such as clothing coefficient, metabolic rate, relative humidity, air flow velocity, and temperature. The results demonstrate the relationship between these variables and the perceived thermal environment.
		PF			

Table3: Detailed comparison of research article.

4. DISCUSSION

This scholarly and rigorous Systematic Literature Review has meticulously examined and critically analyzed a diverse range of primary studies, encompassing a wide breadth and depth of research in its comprehensive evaluation. The first application of fuzzy logic in the textile field was made by [Gary Daves, Sunshiny Rim, and Amit Kumar,1993], the paper studied the application of fuzzy logic to optimize and coordinate the performance of the slasher weaving process. Since that time, fuzzy logic has continued to be explored and employed in various applications within the realm of weaving.

This article was followed by others dealing with 4 different aspects of the weaving process. **8 articles** on the application of fuzzy logic to model and evaluate fabric quality characteristics:

Evaluating the fabric hand in **2003**: this article presents a fuzzy logic-based method for representing and analyzing subjective evaluations of the fabric hand. It generates a quantitative criterion for characterizing the quality of textile products and models the relationship between the subjective evaluation of the fabric hand and the objective numerical data measured by the Kawabata Evaluation System (KES).

Optimizing abrasion resistance in **2006**: The paper investigates the effects of chenille thread count, pile length and thread twist level on the abrasion resistance of chenille fabric using a fuzzy logic system. The study shows that higher twist levels and pile lengths improve abrasion resistance, while the number of yarns has a significant effect on mass loss. Correlation analysis confirms a strong linear relationship between measured and predicted mass loss values. The fuzzy logic system offers a more economical way of optimizing abrasion resistance.

Surface roughness measurement in **2018** by: The article discusses the use of fuzzy logic and 2D-FFT for tissue texture analysis, for surface roughness measurement. It highlights the advantages of using FD-FFT with fuzzy logic for fast and reliable measurement of tissue roughness. The study uses computer-simulated tissue images and scanned real tissue images to demonstrate the effectiveness of the proposed method.

Predicting fabric behavior in **2017** and **2020** by: Both articles use fuzzy logic to predict the drape behavior of textile fabrics, showing that fabric parameters exert a significant influence on drape. In addition, they highlight the importance of drape in garment selection and development and discuss the influence of bending and shear properties on drape behavior.

Measuring bending stiffness in **2019** by: The paper presents a fuzzy logic model for predicting the bending stiffness of fabrics as a function of input variables such as thread count, diameter, spacing, bending stiffness and length. The fuzzy model outperforms mathematical, empirical, and artificial neural network models in terms of prediction accuracy.

Air permeability assessment in **2020** by: The article develops a fuzzy logic model to predict the air permeability of polyester multi-filament fabrics. The model considers factors such as the number of filaments in the yarn cross-section, weave density and weave type. The fuzzy logic model outperforms regression analysis in predicting air permeability.

4 articles on the application of fuzzy logic in weaving machines technology.

The design of a weft insertion process optimization system in **2004**: The paper investigates the effects of yarn properties on weft yarn speed in air-jet looms using a fuzzy logic control system. The study compares results obtained from the fuzzy logic model with experimental results.

Controlling warp tension variation during the shedding operation in weaving in **2008**: The article presents a fuzzy logic model for determining warp tension during the shedding operation of a loom. The shedding height is found to be the most effective parameter for warp tension, while weft yarn density does not have the same influence. The study concludes that it is possible to control a loom using fuzzy logic.

Development of a system capable of autonomously adjusting warp feeder tension in **2009**: The article deals with the adaptive control of the weaving shedding system, using conventional, PID and fuzzy logic-based control systems. Experiments compare the warp tension values obtained with each control method, with the fuzzy logic control system exhibiting the lowest warp tension interval and average warp tension value. The main findings suggest that fuzzy logic-based control provides better control of chain tension in the let-off system.

Optimizing tissue defect detection in **2019**: The paper proposes an automated tissue inspection system using image processing and fuzzy logic to detect tissue defects. The system achieves a high accuracy rate of 97.5% and reduces inspection time from 19.87 seconds to 1.15 seconds.

3 articles on the application of fuzzy logic in weaving production.

Optimizing production processes in 2018 by: This paper presents a support tool based on fuzzy logic decision for planning weaving orders. The tool is used to determine the optimum number of orders that can be processed in the weaving shop, based on available raw materials and customer orders. Model verification showed a potential 30% improvement in production and 1.2% in daily profit. Making more accurate and efficient decisions in 2018 by: This paper presents a decision support tool based on fuzzy logic for textile weaving order planning. The tool helps in determining the optimum number of orders that can be processed in the weaving shed based on available raw material and customer orders. The verification of the model showed a possible improvement of 30% in production and 1.2% in daily profit. Ensuring the production of high-quality fabrics in 2019: This research paper focuses on developing a computerized system for detecting and classifying textile defects using image processing, statistical methods, neural networks, and fuzzy logic. The proposed system achieved a distinction rate of 91.4286%, which increased to 97% after applying fuzzy logic to the neural network outputs.

1 article related to the application of fuzzy logic in occupational safety.

The present study aims to enhance the working conditions in the year 2022 by thoroughly examining the thermal comfort levels in weaving facilities. Through the utilization of fuzzy logic, this research specifically focuses on the evaluation of temperature, humidity, and air flow rate within these facilities. The primary objective is to highlight the significance of upholding optimal thermal comfort levels as it directly impacts the health and productivity of the workers. It is imperative to acknowledge that maintaining a suitable thermal environment is of utmost importance in order to ensure the overall well-being and efficiency of the workforce.

5. FUTURE RESEARCH

Reviews of the literature and research articles provide a comprehensive examination of the corpus of knowledge pertaining to a particular subject matter. The primary objective of the authors is to augment understanding and pinpoint areas that necessitate further exploration to facilitate subsequent investigation. The ensuing table delineates the prospective research endeavours derived from the scrutinized articles require investigation so that they can be further investigated. The following table shows the future research of the articles studied.

Authors	Year	future research
XIANGYI ZENG and LUDOVIC KOEHL	**2003**	The article posits the necessity for additional enhancement of the proposed approach to acquire a standardized measure of subjective assessment or an objective measure that fully supplants subjective assessment. Furthermore, it underscores the requirement for a meticulously arranged knowledge repository that encompasses a larger assortment of representative textile samples and considers the subjective evaluations of numerous specialists.
EK CEVEN and ÖNER ÖZDEMIR	**2006**	The article postulates the necessity for further in-depth examination and analysis of additional factors that may potentially exert an influence of abrasion behavior specifically pertaining to chenille fabric. . Furthermore, it is highly recommendable that subsequent studies and inquiries endeavor to explore and investigate the potential application of fuzzy logic systems in to optimize and enhance other fundamental and intrinsic properties of textile materials.

THOURAYA HAMDI and ADEL GHITH	**2017**	the paper examines and validates the effectiveness of the fuzzy logic method in predicting drape behavior for different fabric types and weave structures. Undertake further research to understand the correlations between drape coefficient and bending stiffness, shear stiffness and fabric mass. Explore the impact of other mechanical properties, such as tensile strength or surface roughness, on draping behavior.
EB PRIYANKA and THANGAVEL SUBRAMANIAM	**2018**	The article highlights the need for further research into the integration of GLCM-based texture recognition with other methodologies to improve the identification of diverse tissue patterns. Prospective research projects can look at the inherent capabilities of various image processing techniques and algorithms with the aim of comprehensively analyzing tissue textures across a range of tissue classifications.
NAJMEH DEHGHAN, MANSHADI and MOHSEN HADIZADEH	**2019**	The paper posits that forthcoming investigations should prioritize the broadening of the fuzzy logic model's utilization across various fabric classifications and the examination of its effectiveness in real-world production environments. Furthermore, an additional scrutiny is required to optimize the parameters of the model and enhance its prognostication precision.
THOURAYA HAMDI, ADEL GIRTH and FATEN FAYALA	**2019**	Future research that is recommended in this article encompasses delving into the impact of additional fabric properties on the behavior of drape, alongside the continuous advancement and enhancement of the fuzzy logic method to predict and regulate drape in textile fabrics.
MAHER ALSAYED, HALIL IBRAHIM C¸ ELIK and HATICE KUBRA KAYNAK	**2020**	Further investigation is required in order to construct an all-encompassing artificial intelligence (AI) framework that can accurately forecast the performance characteristics of microfilament woven fabrics by leveraging their inherent physical and structural attributes.
M. CENGIZ KAYACAN, MEHMET DAYIK, OGUZ COLAK and MURAT	**2004**	The article refrains from explicitly indicating potential avenues of research. It is imperative to delve deeper into the subject and explore the various aspects that may still be unexplored. Future research efforts could involve studying the optimization of additional parameters on air-jet looms. By shedding light on these unexplored dimensions, researchers can make a significant contribution to advancing the field.
MEHMET DAYIK, M. CENGIZ KAYACAN, MUSTAFA ACAR and HAKAN ÇALIS	**2008**	The proposed research seeks to unravel the underlying patterns and relationships between the various parameters involved in the weaving process. Additionally, the article emphasizes the need for extensive experimentation and data collection to validate and refine the proposed fuzzy logic-based approach. In conclusion, the article underscores the significance of further research in this area, as it holds great potential for revolutionizing the field of weaving and contributing to the advancement of textile manufacturing techniques.
MEHMET DAYIK, M. CENGIZ KAYACAN, MUSTAFA ACAR and HAKAN ÇALIS	**2009**	The article posits the need for additional investigation into the enduring stability and dependability of the control system based on fuzzy logic in real-world industrial environments. Subsequent inquiries could also delve into the enhancement of control parameters and configurations for various categories of weaving looms, with the aim of attaining superior regulation over warp tension.
RATNA SAFITITRI and TATANG MULYANA	**2019**	The paper, which lacks any specific suggestions for future research in the field of fabric defect detection using image processing and fuzzy logic, fails to offer any concrete recommendations or proposals for further exploration and investigation in this area of study.

LINDANI K NCUBE, TAKAWIRA R CHIKOWORE, NQOBIZITHA R SIBANDA , and PEEPS GONDE	**2018**	Future investigations could focus on the optimization and augmentation of the decision support mechanism predicated on the principles of fuzzy logic. This instrument could be subjected to additional scrutiny and examination within authentic textile weaving production landscapes. Furthermore, scholarly inquiry could delve into the amalgamation of various factors and variables to enhance the precision and efficacy of this tool.
TUNDO and ENNY ITJE SELA	**2018**	The paper suggests further research to explore the application of fuzzy logic methods in other industries and contexts. Additionally, future studies can focus on refining and improving the accuracy of the prediction models by incorporating more variables and considering different rule-based systems.
IMAN SUBHI MOHAMMED and ISRAA MOHAMMED LHAMDANI	**2019**	Further research can investigate the possibility of incorporating additional cutting-edge methodologies, such as the utilization of deep learning algorithms, to enhance both the precision and effectiveness of detecting and categorizing defects within the textile industry.
MURAT KODALOGLUA and FEYZA AKARSLAN KODALOG	**2022**	The article does not explicitly propose avenues for future investigation. Nevertheless, additional research endeavors could potentially delve into the implementation of fuzzy logic models to assess thermal comfort in various sectors and settings. This exploration would encompass consideration of supplementary variables that might exert an impact on occupational safety and well-being.

Table 4: Details of research article.

6. CONCLUSION

The research already carried out shows the importance of applying fuzzy logic in weaving and describes the four different segments addressed by the authors: the properties of a warp and weft fabric, the performance of weaving machines, the performance of the organization of a weaving company, and health and safety in the workplace. For the first segment, the studies cover various areas such as subjective assessment of fabric feel, optimization of abrasion resistance, measurement of surface roughness, prediction of fabric behavior, measurement of bending stiffness and assessment of air permeability. For the second segment, the studies focus on the application of fuzzy logic to weaving machine technology, covering topics such as the optimization of the weft insertion process, the control of warp tension during shedding, the autonomous adjustment of warp feeder tension and the detection of fabric defects. For the third segment, the studies deal with optimizing production processes, making accurate decisions when planning orders and ensuring the production of high-quality fabrics by detecting and classifying defects. For the fourth segment, this study aims to improve working conditions by taking an in-depth look at comfort levels in weaving facilities, focusing on the assessment of temperature, humidity, and air flow.

The use of fuzzy logic offers advantages in terms of modelling, prediction, and optimization, providing effective solutions for improving weaving processes.

The results obtained from the application of fuzzy logic show that it can still be transposed to other segments that have not yet been studied and that need to be experimented with to achieve further results:

1. In the context of stock management, fuzzy logic can be used to make decisions about the quantity of products to order, the optimum time to place an order, or to determine safety stock levels.
2. In the context of warp beam preparation management in the preparation department, fuzzy logic can be used to model and manage the uncertainty and variability of several parameters to be considered, such as the length of warp yarn, the type of yarn, the number of warp beams required, the delivery times, etc.
3. In the context of improving machine performance, fuzzy logic can be used to improve the performance of weaving machines by considering the uncertainty and variability inherent in this process. This can lead to more efficient production, better fabric quality, fewer defects, and

better value for money.

4. In the context of predicting fabric characteristics, this involves the ability to predict or estimate certain properties or performance of fabrics prior to their manufacture or use. For example, predicting breathability, elasticity, or other desired characteristics.

5. In the context of machine maintenance, fuzzy logic can be used to make decisions about maintenance planning, fault detection, prediction of component life, etc. Fuzzy logic can be used to consider parameters that are difficult to quantify precisely, such as variations in performance, environmental conditions, historical data and so on.

And other aspects not yet covered in existing studies.

In summary, the outcomes derived from the implementation of fuzzy logic exemplify its adaptability and efficacy across various sectors. Ranging from inventory control to the enhancement of machinery performance, the anticipation of fabric attributes, and the upkeep of machinery, fuzzy logic presents significant resolutions for dealing with both uncertainty and variability. Moreover, the possibility of applying fuzzy logic to unexplored segments paves the way for novel prospects in terms of research endeavors and practical applications in a multitude of fields.

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