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Article

Fuzzy Logic: An Application into Marketing Strategy

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Abstract: The term fuzzy refers to things that are unclear or vague. In the real world, we often encounter a situation where we cannot determine whether the state is true or false, and fuzzy logic allows for more flexible reasoning. This is a form of multivalued logic where the truth values of variables can be any real number between 0 and 1, as opposed to Boolean logic where the logical values can only be 0 or 1. Fuzzy logic is therefore a problem-solving technique used to evaluate all available information and thus make the best decisions. When applied to marketing, fuzzy logic allows treating customers in an individual and personalized way, instead of being fully identified within a particular market segment. Fuzzy marketing considers the degree to which a customer belongs to certain segments and subsequently allows them to be targeted with messages that engage them emotionally. To better understand the application and importance of fuzzy logic in marketing strategy, we developed a systematic review of the bibliometric literature (LRSB). It was possible to create a connection between these concepts, marketing and fuzzy logic, to increase the efforts of marketing professionals to achieve competitiveness in the unpredictable business environment.

Keywords: fuzzy; marketing; fuzzy marketing; marketing strategy; consumer behaviour

1. Introduction

The current business environment is characterized by high competition due to increased diversification and globalization. As a result, companies have acknowledged the significance of developing and implementing consumer-centered marketing strategies to enhance customer retention and maximize lifelong profits. Consequently, the fuzzy logic has been integrated into marketing models to create solutions for customer-specific marketing and business issues. Hernández and Hidalgo [1] explain that fuzzy logic is based on observing human behaviors. For instance, fuzzy logic mimics how people analyze problems and make decisions using ambiguous or imprecise values instead of relying on absolute facts or falsehoods. Scott [2] describes fuzzy logic as a computing approach that stems from the mathematical study of multivalued logic that processes possible truth values through the same variable. Unlike classical logic, which requires statements to be absolutely true or absolutely false [3], fuzzy logic involves the use of true values ranging from 0 to 1, indicating that the algorithm can provide solutions based on data ranges rather than on one discrete data point [4]. In this case, fuzzy logic can be used in data interpretation for informative with relative or subjective definitions. In real-life situations, statements of absolute falsehood or truth are rare, given that people perceive and interpret information differently [5]. For example, different customers can have varying interpretations of marketing information leading to other decisions and intentions. Thus, employing fuzzy logic in marketing allows marketers to make decisions based on multiple data ranges from different customers and partners.

Applying fuzzy logic principles to marketing decisions has led to the establishment of the "fuzzy marketing" concept. It is used to reflect how people think and behave by estimating the outcomes of their previous knowledge and experiences [6]. In this case, the fuzzy logic in marketing finds that the truth coefficients lie somewhere on the scale of 0-1. This suggests that consumer behaviors and consumption of marketing content cannot

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be understood as simply black and white (i.e., true/false binary absolutes) but rather from 'shades of grey' perspectives [4]. Customers are not predictable or predefined, they are fuzzy by definition. For example, just because a customer bought a specific product this week does not mean they will buy the same product again next week [7]. Therefore, instead of treating them collectively within a particular segment through signal data, fuzzy logic encourages treating customers as individuals and real people [2]. Consequently, this approach enables the creation of promotional messages that emotionally engage them and increase potential positive behaviors and outcomes [8]. A systematic bibliometric literature review (LRSB) of 96 sources was conducted to illustrate further the connection between these concepts, marketing, and fuzzy logic, to enhance marketers' efforts to achieve competitiveness in the unpredictable business environment.

2. Materials and Methods

A systematic bibliometric literature review (LRSB) was conducted to analyze and synthesize data on fuzzy logic and marketing strategies. The primary aim of this research was to illustrate how integrating fuzzy logic increases the effectiveness of a marketing strategy and its associated outcomes. Consequently, the LRSB approach was deemed desirable because it helps researchers the interrelationships and impacts of research published within the field of interest [9]. It involves analyzing large amounts of academic literature to provide diverse perspectives and findings that can be integrated to improve practice and inform policy-making and decision-making. According to Donthu et al. [10], the bibliometric analysis should be used when the scope of review and dataset are enormous. In this case, fuzzy logic is a broad concept used in multiple fields. Thus, the bibliometric analysis is an appropriate method to present the state of scholarly structure and emerging trends of a specific research topic.

The LRSB involves the screening and selection of information sources to ensure the validity and accuracy of the data presented, in a process consisting of 3 phases and 6 steps [11,12,13,14, 15] (Table 1).

Table 1. Process of systematic LRSB.

Fase	Step	Description
Exploration	Step 1	formulating the research problem
	Step 2	searching for appropriate literature
	Step 3	critical appraisal of the selected studies
	Step 4	data synthesis from individual sources
Interpretation	Step 5	reporting findings and recommendations
Communication	Step 6	Presentation of the LRSB report

The methodology approach began with a literature search on the SCOPUS indexing online database of scientific articles, the most important peer-reviewed peer in the academic world. The use of Scopus alone is due to the fact that it is the main article base for academic journals/magazines, covering around 19,500 titles from more than 5,000 international publishers, including coverage of 16,500 peer-reviewed journals in the fields scientific, technical, and medical and social sciences. Thus, providing a very real view of the researched subjects with scientific and/or academic relevance. However, we assume that the study has the limitation of considering only the SCOPUS database, excluding the other academic bases.

The procedure began with the use of the keyword "fuzzy" in the Scopus directory to identify appropriate sources. The screening was limited to the titles, abstracts, and keywords, and a total of 370,090 references were generated. However, further search limits were implemented based on Linnenluecke et al. [16] (2020) argument that only articles in journals judged as "high-quality" should be synthesized in a literature review,

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recommending researchers adopt appropriate inclusion and exclusion criteria. Xiao and Watson [17] further explain that literary analysis improves readers' understanding of the breadth and depth of existing literature. Therefore, to narrow the search to more relevant literature keyword "marketing" was added, reducing the numbers to 1,973 documents.

A further exact keyword, "marketing strategy," was added, reducing the document results to 96 scientific and/or academic documents, included documents until February 2022, 47 Conference Papers; 46 are Articles; 2 Reviews; and 1 Book Chapter (Table 2).

Table 2. Screening Methodology.

Database Scopus	Screening	Publications
Meta-search	keyword: fuzzy	370,090
Inclusion Criteria	keyword: fuzzy, marketing	1,973
	keyword: fuzzy, marketing, Marketing Strategy	96
Screening	Published until May 2022	

Source: own elaboration

3. Literature analysis: themes and trends

Peer-reviewed documents on the topic were analyzed until May 2022. The years 2009 and 2012 were the years with the highest number of peer-reviewed documents on the topic Fuzzy and marketing Strategy, with 12 publications each. Figure 1 analyzes peer-reviewed publications published through May 2022.

The publications were sorted out as follows: Expert Systems With Applications (5); Advances In Intelligent Systems And Computing (4); IEEE International Conference On Fuzzy Systems (4); Communications In Computer And Information Science (3); Journal Of Intelligent And Fuzzy Systems (3); Advanced Materials Research (2); Huazhong Ligong Daxue Xuebao Journal Huazhong Central China University Of Science And Technology (2); Marketing Intelligence Planning (2); World Scientific Proc Series On Computer Engineering And Information Science 7 Uncertainty Modeling In Knowledge Engineering And Decision Making Proceedings Of The 10th International Flins Conf (2) and with 1 the remaining publications.

We can say that between 2017 and May 2022 there has been an interest in research on Industry 4.0 and Marketing

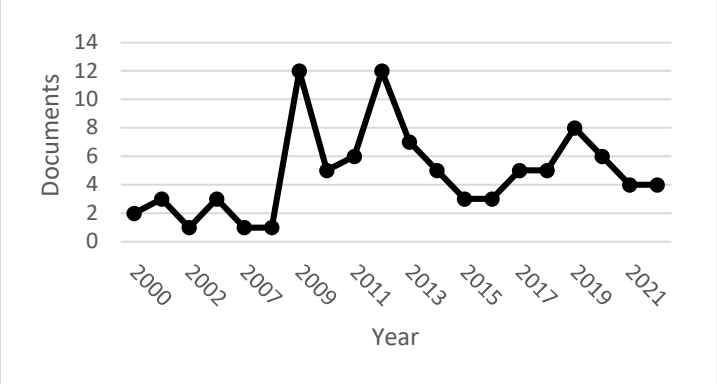

Figure 1. Documents by year. Source: own elaboration.

In Table 3 we analyze for the Scimago Journal & Country Rank (SJR), the best quartile, and the H index by publication. The Administrative Sciences with 15,100 (SJR), Q1 and H index 181.

There is a total of 53 publications on Q1,16 publications on Q2, 10 publications on Q3, and 6 publications on Q4. Publications from best quartile Q1 represent 30% of the 53 publications titles; best quartile Q2 represents 19%, best quartile Q3 represents 11%, best quartile Q4 represents 2%, data from 20 publications are not available.

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As evident from Table 3, the significant majority of articles on Industry 4.0 and marketing rank on the Q1 best quartile index.

Table 3. Scimago journal & country rank impact factor.

Title	SJR	Best Quartile	H index
Expert Systems With Applications	2,070	Q1	225
Advances In Intelligent Systems And Computing	0,220	Q4	48
IEEE International Conference On Fuzzy Systems	0,350	-*	61
Communications In Computer And Information Science	0,210	Q4	55
Journal Of Intelligent And Fuzzy Systems	0,390	Q2	64
Advanced Materials Research	0	-*	43
Huazhong Ligong Daxue Xuebao Journal Huazhong Central China University Of Science And Technology	0	-*	0
Marketing Intelligence Planning	-*	-*	-*
World Scientific Proc Series On Computer Engineering And Information Science 7 Uncertainty Modeling In Knowledge Engineering And Decision Making Proceedings Of The 10th International Flins Conf	-*	-*	-*
2009 International Conference On Management Science And Engineering 16th Annual Conference Proceedings Icmse 2009	-*	-*	-*
2011 International Conference On E Business And E Government Icee2011 Proceedings	0	-*	8
2012 International Conference On Fuzzy Theory And Its Applications Ifuzzy 2012	0	-*	8
2015 12th International Conference On Fuzzy Systems And Knowledge Discovery Fskd 2015	0	-*	12
2019 IEEE Symposium Series On Computational Intelligence Ssci 2019	0	-*	19
2nd International Conference On Information Science And Engineering Icise2010 Proceedings	0	-*	10
6th International Conference On Soft Computing And Intelligent Systems And 13th International Symposium On Advanced Intelligence Systems Scis Isis 2012	0	-*	11
ACM International Conference Proceeding Series	0,230	-*	128
Annual International Conference Of The American Society For Engineering Management 2012 Asem 2012 Agile Management Embracing Change And Uncertainty In Engineering Management	0	-*	4
Applied Intelligence	1,210	Q2	72
Applied Mathematical Modelling	1,110	Q1	122
Applied Mathematics And Computation	1,040	Q1	154
Applied Soft Computing Journal	1,960	Q1	156

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Asia Pacific Education Review	0,610	Q2	32
Assembly Automation	0,610	Q2	44
Computational And Mathematical Organization Theory	0,540	Q2	28
Computational Intelligence And Neuroscience	0,860	Q1	61
Computers And Industrial Engineering	1,780	Q1	136
Computers In Human Behavior	2,170	Q1	206
Conference Proceedings IEEE International Conference On Systems Man And Cybernetics	0	-*	62
Data 2019 Proceedings Of The 8th International Conference On Data Science Technology And Applications	0	-*	4
Dianwang Jishu Power System Technology	-*	-*	-*
Energy	2,040	Q1	212
Engineering Applications Of Artificial Intelligence	1,730	Q1	114
European Journal Of Operational Research	2,350	Q1	274
Frontiers In Artificial Intelligence And Applications	0,260	Q4	54
Future Generation Computer Systems	2,230	Q1	134
IFIP Advances In Information And Communication Technology	0,250	Q3	56
Icnc Fskd 2017 13th International Conference On Natural Computation Fuzzy Systems And Knowledge Discovery	0	-*	8
Ie And EM 2009 Proceedings 2009 IEEE 16th International Conference On Industrial Engineering And Engineering Management	0	-*	9
Industrial Management And Data Systems	1,010	Q1	109
Intelligent Systems Concepts Methodologies Tools And Applications	-*	-*	-*
International Journal Of Computational Intelligence Systems	0,490	Q2	45
International Journal Of Computer Integrated Manufacturing	1,100	Q1	59
International Journal Of Electronic Commerce Studies	0,290	Q3	12
International Journal Of Electronic Customer Relationship Management	0,210	Q3	14
International Journal Of Information Technology And Decision Making	0,550	Q2	46
International Journal Of Innovative Computing Information And Control	0,480	Q2	52
International Journal Of Services Technology And Management	0,120	Q4	24
International Journal Of System Assurance Engineering And Management	0,430	Q2	28
International Journal Of Technology Intelligence And Planning	0,250	Q3	17
International Review On Computers And Software	0	-*	16
Journal Of Discrete Mathematical Sciences And Cryptography	0,450	Q3	18

Journal Of Multiple Valued Logic And Soft Computing	0,230	Q4	25
Journal Of Organizational And End User Computing	1,210	Q1	36
Lecture Notes In Business Information Processing			49
Lecture Notes In Computer Science Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics	0,410	Q2	415
Lecture Notes In Electrical Engineering	0,150	Q4	36
Management Decision	1,160	Q1	106
Metallurgical And Mining Industry	0	-*	23
Nanjing Li Gong Daxue Xuebao Journal Of Nanjing University Of Science And Technology	0,220	Q3	14
Neural Computing And Applications	1,070	Q1	94
PCI 2009 13th Panhellenic Conference On Informatics	-*	-*	-*
Picmet 2016 Portland International Conference On Management Of Engineering And Technology Technology Management For Social Innovation Proceedings	0	-*	9
Proceedings 2009 Asia Pacific Conference On Information Processing Apcip 2009	0	-*	13
Proceedings 2013 4th International Conference On Digital Manufacturing And Automation Icdma 2013	0	-*	43
Proceedings 2017 2nd International Conferences On Information Technology Information Systems And Electrical Engineering Icitisee 2017	0	-*	8
Proceedings Academia Industry Working Conference On Research Challenges 2000 Next Generation Enterprises Virtual Organizations And Mobile Pervasive Technologies Aiworc 2000	-*	-*	-*
Proceedings International Conference On Management And Service Science Mass 2009	0	-*	11
Proceedings Of 2020 IEEE International Conference On Information Technology Big Data And Artificial Intelligence Iciba 2020	-*	-*	-*
Proceedings Of SPIE The International Society For Optical Engineering	-*	-*	-*
Proceedings Of The 2016 2nd International Conference On Contemporary Computing And Informatics Ic3i 2016	-*	-*	-*
Proceedings Of The 3rd International Conference On Intelligent Sustainable Systems Iciss 2020	-*	-*	-*
Proceedings Of The Universities Power Engineering Conference	0	-*	32
Research Journal Of Applied Sciences Engineering And Technology	0	-*	30

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Sustainability Switzerland	0,660	Q1	109
Uncertain Supply Chain Management	0,360	Q2	19
Wmsci 2006 The 10th World Multi Conference On Systemics Cybernetics And Informatics Jointly With The 12th International Conference On Information Systems Analysis And Synthesis Isas 2006 Proc	0	-*	4
World Academy Of Science Engineering And Technology	0	-*	31

Note: *data not available. Source: own elaboration

The thematic areas covered by the 96 scientific and/or academic documents were: Accounting (17); Decision Sciences (14); Energy (5); Environmental Science (2); Materials Science (2); Medicine (2); Social Sciences (2); and with 1 (Arts and Humanities; Earth and Planetary Sciences; Neuroscience; Physics and Astronomy; and Psychology).

The most cited article was "DEMATEL revised: resolving DEMATEL infeasibility" by Hsuan-Shih et al. with 123 citations published in Applied Mathematical Modeling and Environment with 1,110 (SJR), the best quartile (Q1) and with an H index (122). The article shows that raising the initial relation matrix to the power of infinity may not converge to zero and therefore the total influence may not converge.

In Figure 2, we can analyze the evolution of citations of documents until May 2022. The number of citations shows a positive net growth with R2 of 54% for the year 2021 with 156 citations with a total of 905 citations.

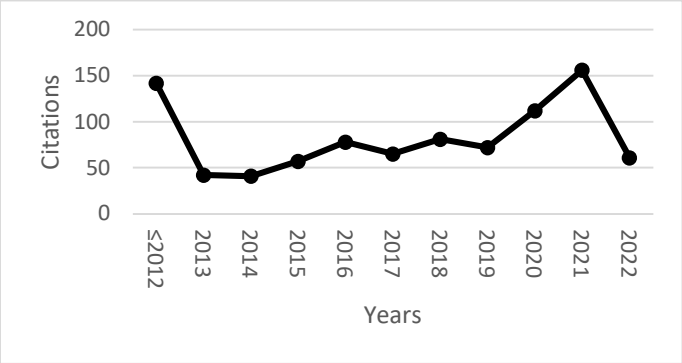

Figure 2. Evolution of citations between ≤2012 and until May 2022. Source: own elaboration.

The h-index was used to ascertain the productivity and impact of the published work, based on the largest number of articles included that had at least the same number of citations. Of the documents considered for the h-index, 17 have been cited at least 17 times.

In Annex A, Table A1, the citations of all scientific and/or academic documents up to until May 2022 are analyzed; 30 documents were not cited in this period, making a total of 905 citations.

In Figure 3, the bibliometric study is presented to investigate and identify indicators on the dynamics and evolution of scientific information. The study of bibliometric results, using the scientific software VOSviewe, aims to identify the main search keywords in studies that integrate industry 4.0 and the marketing research area.

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Figure 3. Network of all keywords.

The research was based on the articles analyzed on Industry 4.0 and Marketing. The associated keywords are shown in Figure 4, making clear the network of keywords that appear together/linked in each scientific article, thus allowing to know the themes studied by the researchers and identify future research trends. In Figure 5, a profusion of bibliographic couplings with a cited reference analysis unit is presented.

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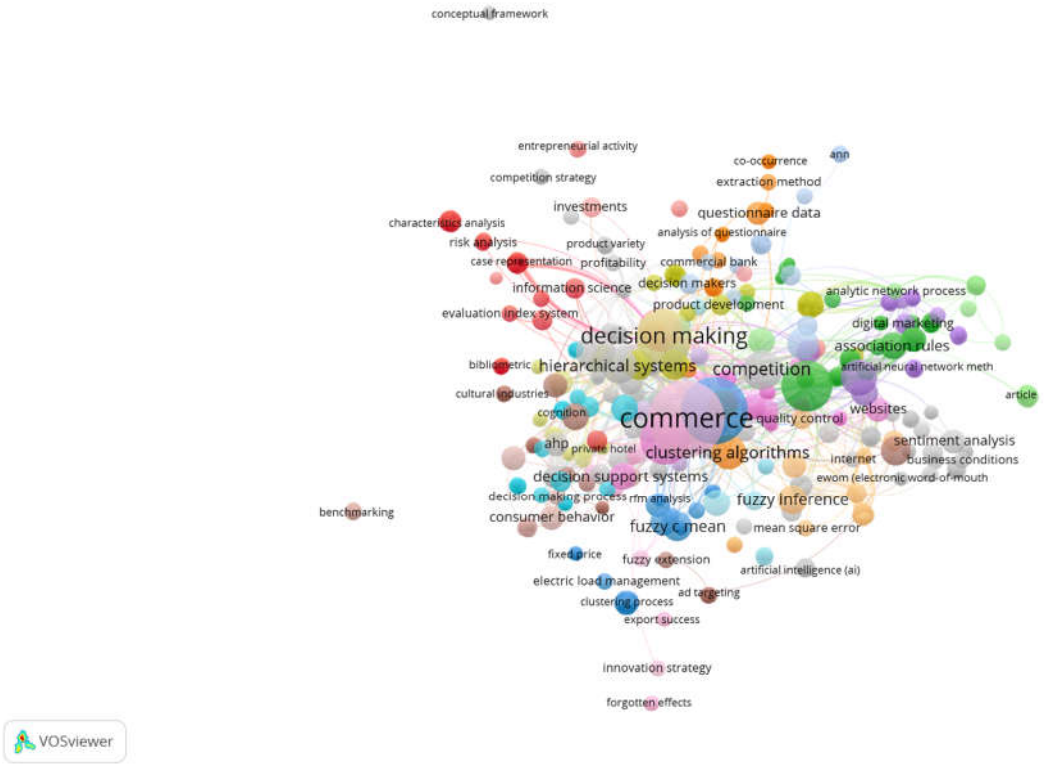

Figure 4. Network of Linked Keywords.

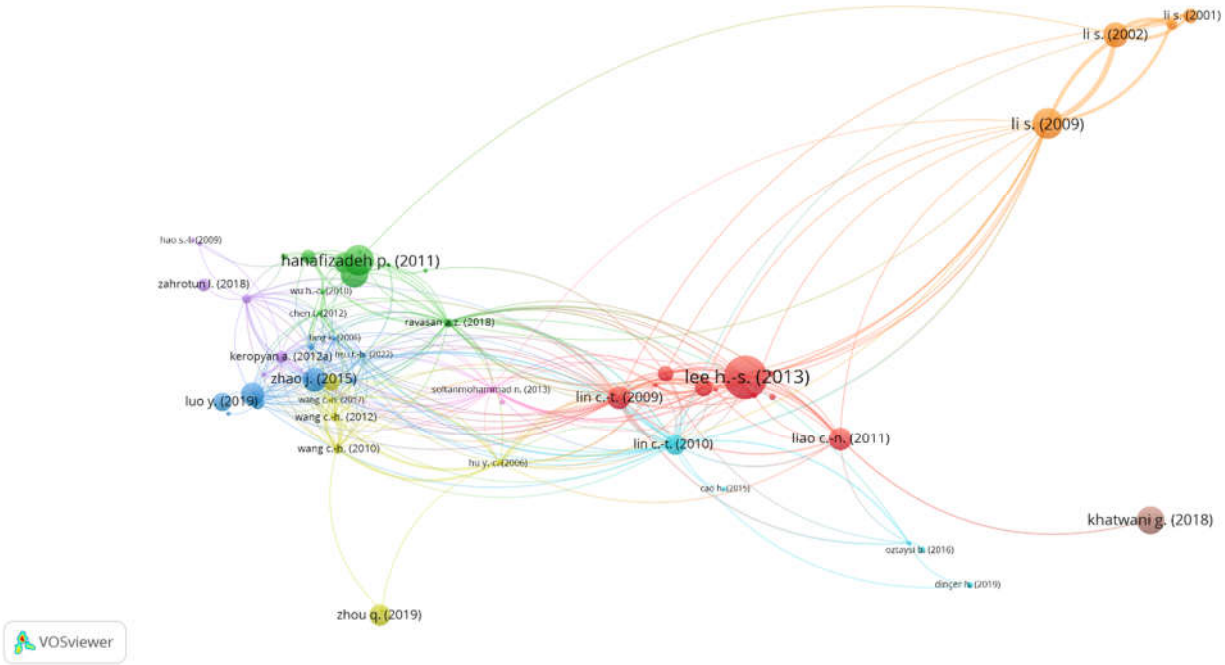

Figure 5. Networks bibliographic coupling.

4. Theoretical perspectives

4.1. The Fuzzy Logic

Fuzzy logic is a variable processing procedure that allows for processing multiple truth variables using the same variable. In this case, the researcher uses an open, imprecise

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spectrum of data and statistical approaches to make accurate conclusions [18]. It encourages the generalization of the standard logic by illustrating that a concept possesses a certain degree of truth that can range between 0.0 and 1.0. In standard logic, ideas are often believed to be either entirely true (truth value 1.0) or completely false (truth value 0.0) [19]. However, fuzzy logic suggests that some concepts humans use to define problems or analyze situations are vague and characterized by subjective or relative definitions, thus cannot be classified as either absolute truth or absolute false [20]. For example, describing someone as "beautiful" is subjective and thus cannot be categorized as indisputable facts or false. Fuzzy logic provides a flexible reasoning mechanism that can handle partial truths or determine conclusions for real-life situations that are difficult to decide whether or not they are false or true [21]. Therefore, fuzzy logic can be defined as a problem-solving technique used to evaluate all available information to make the best decisions.

4.2. The Origin of the Fuzzy Logic

Although Lotfi Zadeh introduced the concept of fuzzy logic in 1995, its history and development are rooted in earlier theories of logic that examined the structure and principles of correct reasoning. For instance, Aristotle and his predecessors developed ideas of logic and mathematics, including the Law of Excluded Middle, which insinuates that every proposition can either be true or false [22]. However, the Greek philosopher Plato disagreed with this notion, arguing that a third domain exists beyond true and false where the concepts 'tumbled out' [23]. These different perspectives influenced the mathematical study of logic and later led to the development of fuzzy logic [24]. For instance, in the 19th century, George Boole used the Aristotelian perspective to develop an algebra and set theory that mathematically dealt with the two-valued Aristotle logic by mapping true and false to 1 and 0, respectively. Jan Lukasiewicz developed a three-valued logic (true, possible, false) in the early 20th century. However, it failed to gain approval from other mathematicians and philosophers.

Other philosophers studied principles of uncertainty and vagueness before the theory of fuzzy sets was embraced in mainstream research and practice. For instance, Bertrand Russell proposed the paradox of "all sets that do not contain themselves" [25] (p.72). Similarly, Max Black, a German philosopher, and scientist introduced the theory of "vague sets" that analyzed the problem of vagueness. Max Black argued that Russell's theory confused vagueness with generality, thus suggesting that vagueness should be represented with appropriate details such as terms and symbols that describe borderline cases [26]. The German philosopher proposed that a curve or a consistency profile should be used to analyze the ambiguity of a symbol or word. These curves resemble the membership functions of (type-1)-fuzzy sets in Lofti Zadeh's theory of fuzzy sets [27]. Therefore, fuzzy logic's concepts and ideologies developed over time from various thinkers in different fields who recognized the shortcomings of the traditional two-value truth logic.

The concept was officially recognized in 1965 when Professor Lotfi A. Zadeh of the University of California at Berkeley published "Fuzzy Sets." The professor based the notion of a fuzzy set on the concept of partially belonging or gradually belonging to a set [28]. Zadeh explained that most objects do not have precise membership criteria in the real physical world, even though they play a critical role in human thinking. For instance, these imprecise categories influence various aspects of recognizing patterns [29], as well as communicating and abstracting information [30]. An example of a real-life situation is that suppose someone is considered tall if they are 180cm and above and short if they are 140 cm and below. How would we classify someone who is 178 cm? Under the two-valued logic, the degree of belonging to the tall group is zero even though such a person is closer to the tall requirements than the short ones. Such a representation may be inaccurate given that some people may consider 178 cm to be tall rather than short. Thus, an intermediate degree of truth is necessary in this case to provide appropriate conclusions by accommodating the imprecision of human reasoning [31]. In this case, the concept of fuzziness

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understands that a proposition can be partially true or false simultaneously and is based on human thought and communication processes.

4.3. Fuzzy Expert Systems (FES)

An expert system is a computer program that uses knowledge and inference steps to handle complex problems and provide decision-making capabilities comparable to a human expert. The smart program uses reasoning and inference rules based on the user queries to extract knowledge from its knowledge base [32]. The first expert system was developed in 1970 as part of artificial intelligence (AI) to solve complex issues like an expert [33]. It uses heuristics and facts stored in the knowledge base to facilitate decision-making and improve performance [34]. It has three primary components, as illustrated in Figure 6, user interface, inference engine, and knowledge base [35]. The user interface is the component used by the expert system to interact with the user by taking the user query as an input and displaying the query's results as output [36]. Thus, it helps the user communicate with the expert system to find a solution. The inference engine is the brain of the expert system that takes the query and processes it by applying the inference rules or the rules of the engine to the knowledge base to deduce new information or derive a conclusion [37]. An inference engine based on facts and rules is called a deterministic inference engine and provides conclusions assumed to be true. On the contrary, a probabilistic inference engine is based on probability and contains uncertainties in the solutions [38]. The third component of the expert system, the knowledge base, is a type of storage used to store knowledge from multiple experts in a particular field and solve problems [39]. The knowledge can either be factual, i.e., based on facts, or heuristic, i.e., based on practice, assessments, and experiences [40]. The expert system increases efficiency and expertise in a particular domain by allowing automated access to vast amounts of knowledge from multiple experts and fast processing to acquire desired, high-quality solutions.

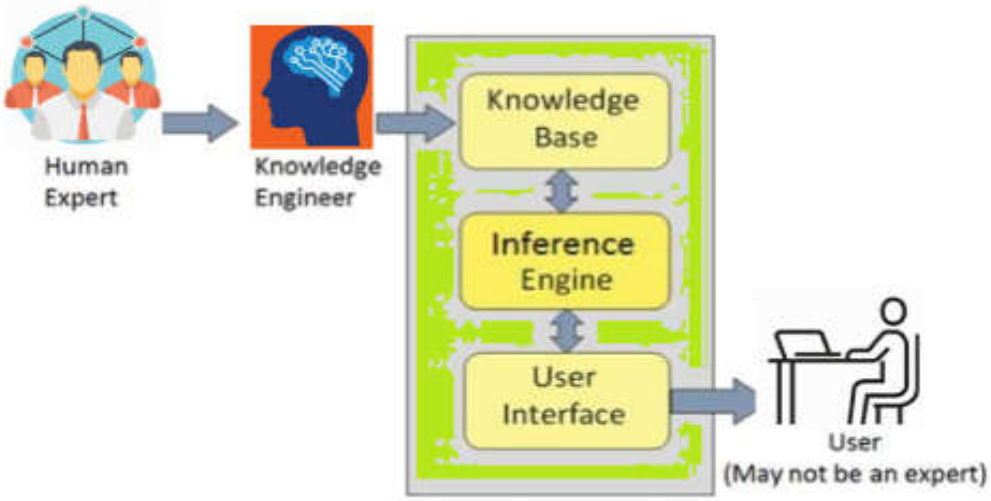

Figure 6. Structure of the Expert System [35].

A fuzzy expert system (FES) is an expert system used to interpret vague or incomplete information to overcome data challenges by utilizing fuzzy sets and logic. This type of expert system is used to solve decision-making problems with no exact algorithm by utilizing human-like mechanisms of approximate reasoning expressed in fuzzy IF-THEN rules [41]. Integrating the fuzzy set theory into the FES increases its ability to describe a particular process or phenomena linguistically and represent it with few flexible rules [42]. One primary advantage of the FES is that the use of specified steps, mathematical formulas, and interconnected subsystems makes it possible to explain how results are derived [43]. The subsystems or components making up the FES are: fuzzification, inference rules, knowledge database, and defuzzification, as shown in Figure 7 [44]. Therefore, FES

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is well-suited for solving challenges resulting from vagueness, inexactness, and subjectivity.

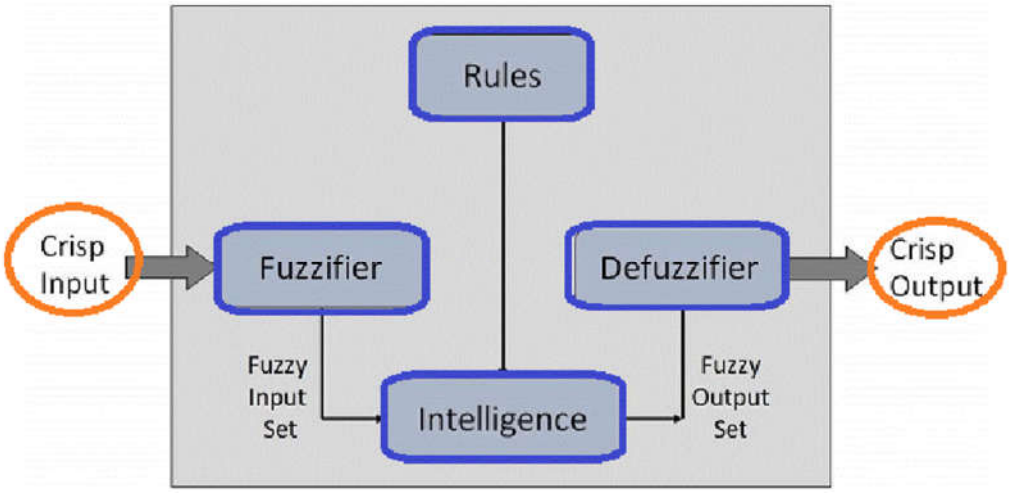

Figure 7. Fuzzy Expert System (FES) Architecture [35].

The Rules base contains all the rules and if-then conditions provided by experts to regulate the decision-making process. Fuzzy inputs and rules must be provided for the inference generator to produce fuzzy productions [45]. However, recent updates in fuzzy theory demand a significant decrease in rules and conditions by providing various methods of designing and tuning fuzzy controllers. The fuzzification process converts inputs by turning crisp numbers into fuzzy sets [41]. Under this subsystem, sensors measure the crisp numbers before passing them into the control system for further processing [46]. The inference engine is the subsystem used to determine the degree of match between the rules and the fuzzy input [47]. After deciding the % match, the inference engine identifies the specific rules to be applied to develop the control actions [48]. The final component of the fuzzy expert system is the defuzzification which performs the crisp yield operations that involve converting the fuzzy sets to crisp value that indicates the degree of truth.

The FES can be designed for implementation in multiple fields, including marketing, medicine, and automotive [49]. While the factors and variables tested are different depending on the area, the successful design of a good FES follows the following steps identified by Ghaderi and Maihami [50]:

i) Identifying the problem and selecting the appropriate type of fuzzy system: Identifying the issues that need solving helps determine the required fuzzy system based on the problem requirements. It is recommended to adopt a modular system since it can be configured in multiple ways to serve various purposes and satisfy multiple needs [51]. Besides, the system's modules can be improved over time to accommodate changes and new challenges, thus improving performance;

ii) Defining the input and output variables: In this case, it is critical to identify the input parameters and classify the crisp values based on ambiguity indices into different fuzzy sets [52]. Some aspects considered include their membership function and linguistic attributes;

iii) Defining the fuzzy heuristic rules: the if-then rules provide a convenient way of expressing knowledge by providing interpretations that can process information in a specific way at the inference level [53]. For instance, some rules express certainty or obligation, while others describe possibility or feasibility [54]. Various types of fuzzy rules considered in this step include gradual inference rules, certainty rules, and possibility rules, depending on intended applications and uses;

iv) Selecting the fuzzy inference method: fuzzy inference refers to the process of formulating the mapping from a specific input to output using fuzzy logic [55]. It thus

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involves determining the aggregation operators for preconditions and conclusions [56]. This procedure creates the foundation from which decisions are made and patterns identified;

v) Defuzzification methods: this step involves converting the fuzzy output into a crisp value. Examples of ways that can be used for this procedure include center-of-maximum (CoM), center-of-area (CoA), smallest-of-maximum (SoM), weighted average (WA), and largest-of maximum (LoM);

vi) Test the fuzzy system prototype to ensure it functions appropriately and make appropriate adjustments in membership functions, fuzzy rules, and goal function between input and fuzzy output variables.

4.4. Marketing Strategy

Developing and implementing a marketing strategy is critical in marketing practice. For any successful business seeking long-term participation in a market, it is essential to have a clear marketing strategy that organizes marketing activities and resources to enhance an organization's capability to achieve competitive advantage [57]. Morgan et al. [58] (2019) define a marketing strategy as a company's integrated pattern of decisions that specifically identify the products and services it offers, target markets, marketing activities, and resources. Keropyan and Gil-Lafuente [56] (2012) further indicate that it involves exchange, communication, and relationships to achieve specific objectives. Marketing literature broadly suggests that a company's economic performance within a particular marketplace is determined by its marketing strategy, which guides critical marketing activities such as resource deployment [59]. In addition, the marketing strategy identifies the specific marketing objectives that help streamline organizational business processes, marketing efforts, customer needs, and other stakeholders' expectations to enhance performance in the competitive business environment.

The formulation-implementation dichotomy of marketing strategy encourages establishing long-term decision-making frameworks that look into the future of the company. From this perspective, formulating the marketing strategy requires managers and their teams to make precise "what" decisions regarding the goals they aim to achieve. Similarly, Khatwani and Srivastava [60] (2016) state that it also identifies techniques they intend to apply to achieve them, including selecting the target market, scheduling, positioning, and determining the value offerings [61]. This marketing strategy thus involves executing a set of detailed marketing techniques and accompanying them with necessary resources and actions to enact the previously made marketing decisions. The success of the marketing strategy formulation and implementation processes is determined by the appropriate use of strategy content and strategy process [62]. The marketing strategy content should specifically identify various aspects, including specifying the target segments, the company's value proposition, selecting the marketing communication media, and planning the sales-force incentive [63]. In this case, the marketing strategy content indicates the specific strategic decisions and identifies appropriate tactical marketing program decisions to ensure the success of the marketing efforts. Contrary, the marketing strategy process identifies the organizational mechanisms that lead to these decisions [64]. Examples of these processes include situation assessment, marketing mix planning, performance evaluation and monitoring, top-down vs. bottom-up strategic planning process, budgeting, and goal-setting [65]. Therefore, a competitive marketing strategy encompasses decisions, activities, and procedures required to achieve a company's desired goals over time, including the means to develop, deliver, and communicate its offerings to target markets.

4.4.1. Classification of Marketing Strategies

Organizations adopt different marketing strategies depending on multiple factors, including objectives, marketing relationships, products or services offered, target markets, and resources. Igor Ansoff, in 1957, identified four broad categories of marketing strategies; marketing penetration strategy, market development strategy, product

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development strategy, and market diversification strategy [66]. These classifications are based on the firm's nature of existing and new products and customers.

4.4.2. Market penetration strategy

Market penetration strategy begins with evaluating the size of the market and the percentage of consumers within it that buy the company's products and services. From this aspect, marketing creates and implements a strategy that aims to overtake competitors to acquire a larger market share [67]. Therefore, market penetration strategy refers to a firm's initiatives to make its existing products and services to an already thriving market to boost sales and organizational performance [68]. According to Hussain et al. [66], the market penetration strategy improves business performance by either increasing the number of sales among existing customers or looking for new customers for the existing products or services. Various tactics can be adopted to achieve these goals, including lowering prices to compete with alternative products, acquiring competitors, and revamping the digital marketing roadmap to increase brand awareness among target markets [68]. Therefore, the primary goal of this marketing approach is to generate more income by promoting or repositioning existing products to existing or new customers who fit the target market.

4.4.3. Market development strategy

A market development strategy is a marketing approach that companies use to introduce existing products or services to new markets. Once a firm achieves maturity in its current market, it is essential to explore new markets for an ongoing product to increase sales and ensure organizational performance and stability [69]. The product remains the same, but it is promoted to new targeted customers to facilitate corporate growth [70]. For example, a company can choose to market a product in new geographical regions or develop channels for exporting the products to other markets [71]. A market development strategy is an essential marketing tool in that it helps companies reach a wider audience of potential customers, especially in the modern-day globalized business environment [72]. Other than acquiring new customers, it can be used to improve the quality of products or services, reduce production cost per unit, increase brand awareness, build organizational resilience, generate more leads and sales, and reinforce long-term corporate growth and financial performance [73]. However, businesses must conduct market research to identify development opportunities, develop a marketing plan, and allocate appropriate resources to ensure the success of the market development strategy.

4.4.4. Product development strategy

The product development strategy refers to an organization's tactics of launching new products to a market or modifying the existing ones to meet customer demands and expectations. Hussain et al. [66] explain that this strategy involves developing organized methods of guiding all processes concerned with introducing a new item to the target market. Product development strategy can be applied in multiple situations [74]. For instance, companies can develop new products when they notice a decline in the demand for an existing product in current marketing segments to ensure growth and improve financial performance [75]. In addition, companies can develop new products that offer solutions to target customers' specific problems by basing their entire production processes and activities on a comprehensive analysis of their needs, wants, and demands [76]. Demand for specific items or services creates business opportunities that can be exploited to achieve higher organizational performance. One major strength of product development strategy is that it uses market research to create a plan for successfully launching products or services in particular markets. In this case, the planning can help businesses overcome multiple challenges by adopting appropriate methods and techniques throughout the product development process [77]. Various tactics can be used under this marketing strategy to maintain competitiveness within the market, including changing product ideas,

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modifying existing and creating new products, specializing and customizing, finding new markets, and increasing product value [72]. A solid and clear product development strategy can help an organization turn an idea into a profitable product and enable modifications to remain competitive in the market.

4.4.5. Market diversification strategy

Companies used market diversification as a strategy to expand their market share or enhance their market presence by acquiring or launching new products or tapping into new markets. Some techniques used in this strategy include licensing, acquisitions, and mergers [73]. The primary goal of this strategy is to increase an organization's profitability by expanding into markets and industries that it hasn't currently explored [78]. Other than higher profitability, companies can diversify to reduce the risks of an industry downturn, improve brand awareness and image, and a defense against the increased competition in local markets [73]. There are various forms of diversification strategies adopted based on the company's goals and business offerings. These include horizontal, concentric, conglomerate, and vertical diversification.

Horizontal diversification is the strategy used when companies decide to expand their market presence by introducing products and services unrelated to their original offerings but meeting the needs of existing customers. This marketing strategy has minimal risks in most cases since the company is working within familiar market segments and customers [79]. Vertical diversification is a strategy used when a company decides to take some or all functions associated with the production and distribution of its core products [78]. In this case, the company moves up or down the supply chain by combining various activities previously done by different companies. For example, a retailer can employ vertical diversification by manufacturing the products they currently sell in-house instead of outsourcing from other manufacturers [80]. Concentric diversification is a strategy used to enter a new market with a new product that is technologically similar to the company's current. This approach allows the company to gain multiple advantages by leveraging its industry experience, manufacturing processes already in place, and technical know-how [66]. A conglomerate diversification strategy occurs when a company decides to diversify into entirely new markets offering new products unrelated to those it currently sells to reach new consumer bases. A conglomerate is a single corporate group that owns multiple business entities in different sectors [81]. Regardless of a company's choice of a diversification strategy, these approaches, if employed correctly, can help organizations offer a more comprehensive range of products and services, build a stronger brand image, and enhance the firm's profitability.

4.5. Application of Fuzzy Logic and Fuzzy Methods in Marketing Strategies

In this era of data-driven marketing, most companies are missing out on human marketing opportunities by losing sight of marketing's nuanced human context. In this context, signal data-driven promotional messages are often misleading and inappropriate due to the often generalized information regarding market segments [82,83]. Integrating the fuzzy logic and fuzzy methods solves this problem by allowing marketers to assess to what degree an individual customer fits into a market segment [84]. Modern customers want to be treated like real people instead of being wholly identified with a particular market segment and defined by their signal data [85]. Rather than using binary yes/no analysis of customers' past behaviors to determine their lifestyles and consumption decisions, fuzzy marketing allows considerations of multiple perspectives and variables that enable marketers to create marketing messages that emotionally engage customers and make them feel understood and valued [86]. Fuzzy marketing demonstrates that customers are not mere datasets and should not just be targeted; instead, they should be recognized and treated like nuanced, unpredictable, imprecise human beings.

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4.5.1. Fuzzy Marketing Model

The fuzzy marketing model helps refine the marketing campaigns by allowing the exact classification of objects and optimal allocation of resources. In traditional marketing management, companies embraced strategies such as RFM (Recency, Frequency, Monetary value) model, ABC, and portfolio analysis to analyze, assess, and segment customers based on their value to the company [87]. These methods enabled marketers to improve marketing performance, increase organizational profitability, and build customer relationships [88,89]. However, reports and decisions based on these methods are often misleading due to misclassifications resulting from assigning values to predefined classes [90]. The fuzzy marketing model eliminates these problems by enabling marketers to accurately classify objects and allocate resources accordingly [91]. Instead of categorizing variables in binary terms {0 or 1, yes/no}, fuzzy methods allow marketers to assess various degrees of contexts ranging from 0 to 1 [92]. This means that variables can be accurately classified based on how they influence marketing performance, as shown in Figure 8 below.

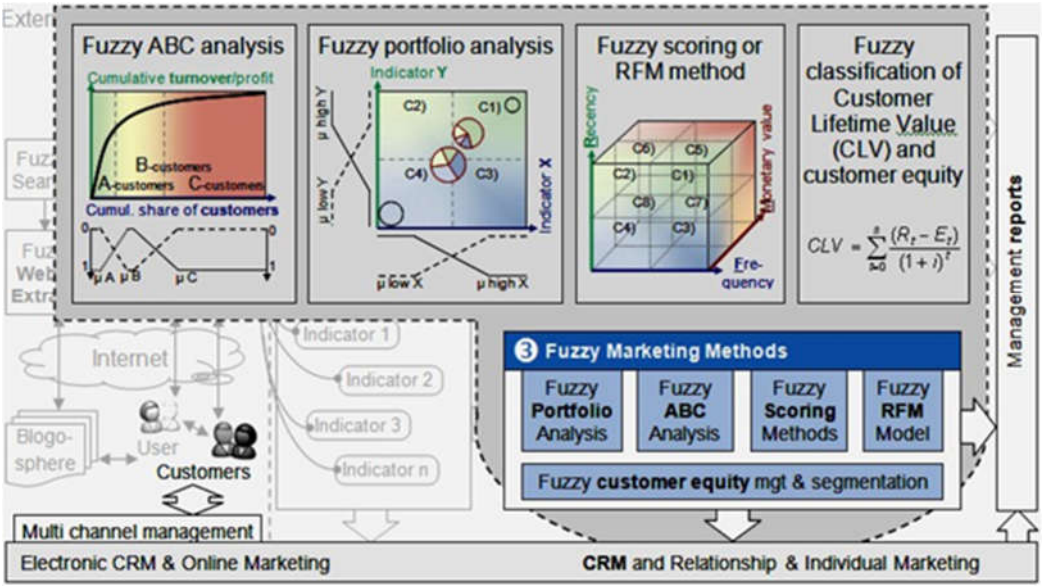

Figure 8. Fuzzy Marketing Model [87].

One significant advantage of fuzzy classifications is that one element can be assigned to multiple classes, expanding the degrees of analysis and accurate representation. For example, Figure 4 shows that customers under the fuzzy ABC analysis can partly be classified into three classes, four classes under the fuzzy portfolio analysis, and multiple classes at the same time under the fuzzy scoring methods. Statistical analyses allow marketers to compute the membership degree to each class and measure [93]. For example, fuzzy methods can analyze, categorize, assess, and manage multiple marketing indicators [94]. In addition, it can be used to analyze various measures, including customer lifetime value (CLV) and customer value, which are used to improve organizational marketing initiatives.

4.5.2. Fuzzy Marketing-Mix Model

Most companies struggle with the marketing mix problem due to uncertain and vague elements and dynamic, nonlinear relationships. These issues undermine the companies' capability to make appropriate decisions that lead to positive, measurable marketing outcomes [95]. For example, input variables such as sales forecasts are uncertain since it is difficult to know what will happen to specific products' markets in the future [96]. In addition, estimating competitor sales, distribution expenditures, and advertising to determine the level of competition can be difficult and lead to inaccurate assumptions [97]. In

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this case, most of the data used in developing and employing the classical marketing mix model are based on estimations and pure reliance on expert judgment, which can be vague and unreliable [98,99]. Other issues that make up the marketing mix problem are changing market environmental conditions, availability of financial resources, market performance, uncertainties with the organization's competitive strength, and estimating market response and economic variations [100]. However, the fuzzy marketing mix model solves these problems by allowing marketers to apply experts' If-Then decision rules.

The fuzzy logic sets allow marketers and marketing researchers to analyze and deduct accurate conclusions from vague, uncertain, subjective inputs, facilitating enhanced decision-making. In addition, the fuzzy methods can explore nonlinear relationships between problem inputs and outputs, allowing the marketers to understand how a change in one variable affects the rest of the marketing aspects [101]. Aly and Vrana [7] (2005) created a fuzzy marketing mix model based on the Fuzzy decision-making system (FDMS) that can be used to illustrate the integration of fuzzy logic and fuzzy methods in marketing, as shown in Figure 5 below. Thus, using fuzzy logic and strategies, which leverage experts' knowledge, intuition, and experience in marketing in the form of if-then rules, provides a more convenient analysis technique.

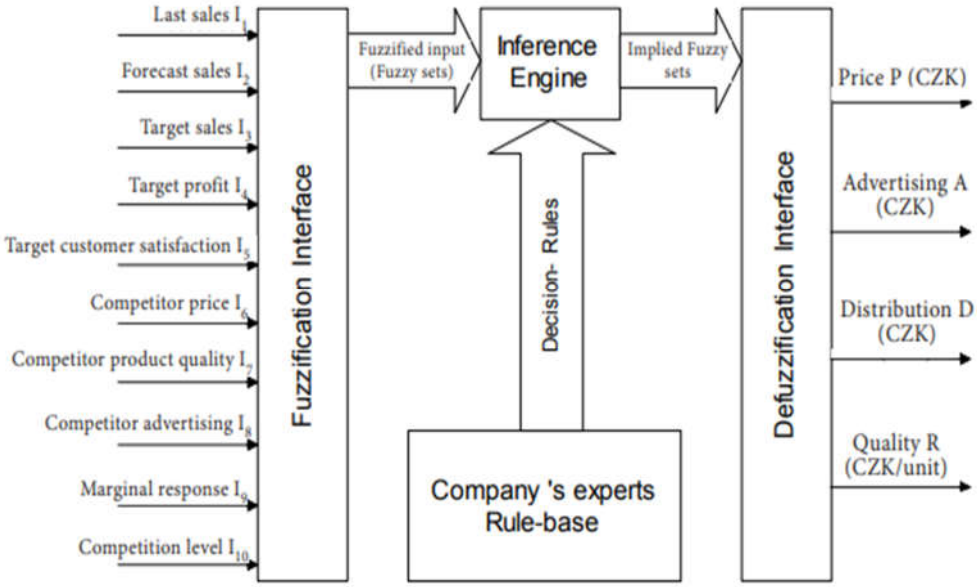

Figure 9. Fuzzy Marketing Mix Model [7].

The input variables considered are the aspects that often affect the marketing decision-making processes in most organizations as identified through experts' viewpoints and knowledge of their market environment. These factors affect the fixed output variables that make up the marketing mix settings: price (P), advertising (A), distribution (D), and product quality (R) [102]. The fuzzification interface transforms the input data gathered from experts and analysts into fuzzy variables. The rule-base encompasses experts' decision rules to guide the input variables' transformation into the marketing mix settings [103]. The inference engine is used to match the consequents of the inferring rules to the knowledge base to deduce new information that is the deffuzified to obtain the crisp values of the outputs [104]. This process enables the company to determine the marketing initiatives that accurately and approximately indicate all the requirements associated with the factors affecting performance within a specific market environment (Wu et al., 2010) [105]. Classifying elements into multiple classes throughout the analysis period enables marketers to avoid strategic failures and economic loss since they have access to more accurate and representative data [106]. Leveraging such reports enhances marketing decision-making, planning, allocation of resources, and implementation of marketing

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initiatives and campaigns [107]. Therefore, integrating fuzzy logic and fuzzy methods into marketing strategies can help improve a company's competitiveness and lead to higher performance and productivity in the modern-day turbulently changing business environment.

5. Conclusions

Globalization and diversification have increased the competition in local and international markets, prompting companies to adopt consumer-centered marketing approaches. One significant way that they have embraced is using data-driven marketing strategies to enhance targeting and customization. However, data overload and the reduction of customers into mere datasets have undermined these companies' capability to optimize human marketing approaches achievable through the appropriate use of data and information technologies. For instance, in a standard marketing strategy, customers within a particular market segment are targeted collectively regardless of their differences. This approach leads to companies missing opportunities to emotionally engage their customers for long-term, mutually beneficial relationships that increase their competitive advantage. Integrating fuzzy logic and fuzzy methods into marketing strategies solves this problem by encouraging marketers to understand their customers as unpredictable, imprecise individuals. Unlike the classical logic that clarifies contents as either absolutely truth or absolutely false, fuzzy logic recognizes that most information used in real life is subjective or relative. It does not have a definite definition or truth value. Thus, under fuzzy logic, truth values can be anything between 0 and 1. In this case, the fuzzy reasoning recognizes that yes/no answers do not necessarily reflect on the customer's behaviors or intentions, encouraging consideration of the 'maybe's' and 'if's' that occur when customers do not have absolute answers. Fuzzy marketing involves analyzing how a customer fits into a specific market segment. In this case, instead of sending mass customized promotional messages, the companies prioritize personalized marketing efforts that make the customer feel understood and appreciated.

Marketing strategies are concerned with organizational plans and activities related to promoting and selling products or services to consumers. Therefore, adopting approaches such as the fuzzy marketing model or the fuzzy marketing mix model enhances the company's capability to build stronger customer relationships, enhance profitability, and improve marketing performance. For instance, with a fuzzy marketing model, marketers and researchers can accurately classify objects and allocate resources using fuzzy methods that indicate the degree to which a particular factor or indicator contributes to the marketing effort. Suppose a competitor's advertising expenditure is deemed to have minimal impact on a company's marketing performance. In classical logic, it will be assigned an absolute 0 value. In contrast, in fuzzy logic, a specific value, for example, 0.3, will be given to indicate that even though the impact is low, it does affect the company's performance. In this case, the management using fuzzy logic, will assign appropriate resources to increase the company's competitive strength. Therefore, fuzzy logic and fuzzy methods provide a more explicit representation of reality, enabling companies to make informed, accurate decisions.

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Appendix A

Table A1. Overview of document citations period 2012 to 2022.

Documents		2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Total
Research and implementation ofthe customer-oriented modem ...	2021										1	1	2
Fine-Grained Context-aware Ad Targeting on Social Media Plat...	2020										1		1
Modified dynamic fuzzy c-means clustering algorithm -Applic. ..	2020									1	6	6	13
Evaluation of entrepreneurial support projects by using IFS ...	2020										1		1
[Bidding Strategy ofComprehensive Energy Based Power Sellin ...	2019									5	1	1	7
User sentiment analysis based on social network information ...	2019							2	3	10	10	5	30
Predicting the helpfulness of online restaurant reviews usin ...	2019								1	4	12	5	22
Exploring eWOM in online customer reviews: Sentiment analysi ...	2019								4	11	18	2	35
lnnovative capacity-based approach to blue ocean strategies ...	2019										2		2
Comparative analysis of store clustering tech niques in the r ...	2019									1			1
A fuzzy DEMATEL method for analyzing key factors of the prod ...	2018									3	1		4
lmpact ofinformation technology on information search chann ...	2018								2	9	28	10	49
Optimal marketing strategy for electricity retailer consider ...	2018								2				2
A Fuzzy ANP based weighted RFM model for customer segmentati ...	2018							1		4	1		6
lmplementation of data mining technique for customer relatio ...	2018							1	2	4	4		11
A fuzzy optimisation method for product variety selection un ...	2017								1	2	1		4
An intelligent cloud-based customer relationship management ...	2017							1			2		3
Application of artificial neural network method to analyze u ...	2017								1				1
Predicting the influence of group buying on the restaurant's ...	2016								1				1
Target marketing strategy determination for shopping malls u ...	2016							2				1	3

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Using fuzzy logic approach in estimating individual guest lo ...	2015							1			1		2
Pricing and retail service decisions in fuzzy uncertainty en ...	2015				1	7	9	5	6	2	7	2	39
A study on extraction of minority groups in questionnaire da ...	2014								1	1			2
Study of collective user behaviour in twitter: A fuzzy appro ...	2014					4	2	1	2	3			12
A group decision support system for selecting a SocialCRM	2014						1						1
Analysis of user behaviors by mining large network data sets	2014			1	2	4	7	6	2	2	4		28
Criteria Weighting and 4P's Planning in Marketing Using a Fu ...	2014			2	4	2		2		2	2	2	16
Revised DEMATEL: Resolving the infeasibility of DEMATEL	2013		1	4	8	9	15	16	15	14	30	11	123
Ranking important factors influencing organizational strateg ...	2013					1	1			1			3
Formulating an optimal strategic marketing model by integral...	2013				1	1	1						3
The risk assessment of marketing management system on the ba ...	2013			2							1		3
Mining association rules uses fuzzy weighted FP-growth	2012			1	1		1			2			5
Derivations of factors influencing the word-of-mouth marketi ...	2012	1					1					1	3
A fuzzy decision support method for customer preferences ana ...	2012		1	1		1	2				2		7
Fuzzy evaluating management performance and marketing strate ...	2012			1		1	1						3
Customer loyalty programs to sustain consumer fidelity in mo ...	2012				2	2	2		2	1	1		10
Applying cluster-based fuzzy association rules mining framew ...	2012			3	1	4		4	1	1	4		18
Evaluation of children's afler-school programs in Taiwan: FA ...	2012					1			1				2
Future oriented positioning analysis with Bayesian networks	2012									1			1
The RFM-FCM approach for customer clustering	2012				1								1
A neuro-lFS intelligent system for marketing strategy select ...	2011					1	1						2
Applying Fuzzy Data Mining to Telecom Churn Management	2011					1		2	1	1		1	6
"Made-in" Nigeria or "owned-by" lreland?: Country-of-origin ...	2011			1	1		1	3		1			7
Fuzzy analytical hierarchy process and multi-segment geai pr ...	2011	4	4	4	3	6	6	1	3	3	1	1	36
Visualizing rnarket segmentation using self-organizing rnaps a ...	2011	8	7	5	5	5	4	7	9	4	2	4	60

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Power customer credit rating based on FCM and the differenti ...	2010	1											1
Applications and extensions of quality function deployment	2010	2	3		5	4		6					20
Analyzing customer sales data with a fuzzy set approach	2010	1				1							2
Applying fuzzy FP-growth to mine fuzzy association rules	2010	1	1		1	1				1			5
Fuzzy group decision making in pursuit of a competitive rnark ...	2010	14	1	3	1	5	1		1	1			27
Study on analysis of questionnaire data based on interactive ...	2009								1				1
Extraction ofimportant keywords in free text of questionnai ...	2009	2	1						1				4
Two-stage fuzzy clustering approach for load profiling	2009	4	3	2	1	3		4					17
The customer marketing strategy of commercial banks based on ...	2009		1										1
Personal credit scoring model based on integration of rough ...	2009			1									1
Hybridising hurnan judgment, AHP, simulation anda fuzzy expe ...	2009	19	5	6	7	5	3	3	4	3	4	1	60
Optimizing a marketing expert decision process for the priva ...	2009	8	2	2		3	1	2	2	8	3	5	36
A case study of applying data mining techniques in an outfit ...	2009	12	8	5	3	8	2	3	2	4	2	2	51
Fuzzy logic: a realistic toei for management of customer rei. ..	2008	1					2						3
Effective marketing of a closed-loop supply chain network: A. ..	2006	1		1									2
A knowledge acquisition method for determining utilities of ...	2006	2						1					3
lntegrating group Delphi, fuzzy logic and expert systems for ...	2002	24	3		4	2	2	4	1	1			41
GloStra - A hybrid system for developing global strategy and ...	2001	13					1						14
Developing marketing strategy with MarStra: the support syst...	2000	8									1		9
Neural networks and customer grouping in e-commerce: ...	2000	12			1					1	2		16
	Total	138	41	45	53	82	67	78	72	112	156	61	905

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