NEAR EAST UNIVERSITY
INSTITUTE OF GRADUATE STUDIES
BUSINESS ADMINISTRATION PROGRAM

EFFECTS OF DIGITAL MARKETING TECHNOLOGIES ON MARKETING DECISION MAKING USING FUZZY APPROACHES

GUNEL IMANOVA

MASTER'S THESIS

NICOSIA
2021

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THESIS SUPERVISOR

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NICOSIA
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ACCEPTANCE/APPROVAL

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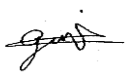

Gunel Imanova

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ABSTRACT

Effects of digital marketing technologies on marketing decision making using fuzzy approaches

Nowadays, digital marketing technologies have dramatically transformed the: products/services offered; prices provided to clients to increase profit; store locations to virtual ones; interaction and communication methods to two way communication, in order to improve customer satisfaction. Due to positive technological improvements business-customer relationships become more digital. Our study is based on the investigation of effects of digital marketing techniques of a kind that, AI-Artificial Intelligence, IoT, AR/VR - on marketing decisions of an organization using Fuzzy approach. The aim of this study is to analyze and rank the digital marketing technologies of AI, IoT, AR/VR and deciding on the optimal alternative for the strategic marketing decisions of an organization especially during pandemic outbreak. With this study, the effect of digital marketing technologies such as AI, IoT, and VR/AR on marketing decisions of an organization to understand the importance of digitalization are examined. Our study focuses on a consistency-driven model for calculating the values of 4Ps, and customer focused factors, and also range between the optimum positive and negative solutions utilizing Fuzzy and TOPSIS approaches. As a result, AI is found to be the best option to be used following by IoT and AR/VR alternatives, respectively, according to given criteria weights and decision maker’s preferences under predetermined circumstances such as pandemic outbreak.

Keywords: Artificial Intelligence (AI), decision making, Virtual Reality (VR), Augmented Reality (AR), Fuzzy logic, digital marketing, Internet of Things (IoT)

ÖZ

Bulanık yaklaşımlar kullanarak dijital pazarlama teknolojilerinin pazarlama kararları üzerindeki etkileri

Günümüzde dijital pazarlama teknolojileri birçok bilineni değişmektedir. Dijital pazarlama, örneğin, sunulan ürün/hizmetleri; karı artırmak için müşterilere sağlanan fiyatları, somut konumları sanal konumlara; çift yönlü iletişimle etkileşim ve iletişim yöntemlerini ve teknolojik gelişme vasıtasıyla müşteri memnuniyetini artırmak için firma-müşteri ilişkileri daha dijital hale geliyor. Araştırmamız, AI-Yapay Zeka, IoT-Nesnelerin İnterneti, VR/AR-Sanal ve Artırılmış Gerçeklik türündeki dijital pazarlama tekniklerinin bir organizasyonun pazarlama kararları üzerindeki etkilerinin ve hangi alternatifin en uygun olduğunu anlamaya yönelik bulanık mantık yaklaşımı kullanılarak araştırılmasına dayanmaktadır. Bu araştırmanın amacı, AI, IoT, AR/VR gibi dijital pazarlama teknolojilerini analiz etmek ve pandemi salgını koşulları dikkate alınarak önem sırasına uygun sıralamak ve organizasyonun stratejik pazarlama kararları için en uygun alternatife karar vermektir. Bu araştırma ile dijitalleşmenin önemini anlamak için AI, IoT ve VR/AR gibi dijital pazarlama teknolojilerinin şirketin pazarlama kararları üzerindeki etkisini de inceliyoruz. Araştırmamız, 4P değişenlerinin ve müşteri odaklı faktörlerin değerlendirilmesi için tutarlılık odaklı bir modele dayanmakta ve ayrıca Fuzzy ve TOPSIS yaklaşımlarını kullanan optimum olumlu ve olumsuz çözümler arasında değişmektedir. Sonuç olarak, pandemi salgını koşullarında, verilen kriter ağırlıklarına ve karar vericinin tercihlerine göre sırasıyla AI, IoT ve AR/VR alternatiflerinin kullanılabilecek en iyi seçenek olarak bulunmuştur.

Anahtar Kelimeler: Yapay Zeka (AI), Karar verme, Sanal Gerçeklik (VR), Bulanık mantık, Artırılmış Gerçeklik (AR), Dijital pazarlama, Nesnelerin İnterneti (IoT)

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ABBREVATIONS

AHP Analytic Hierarchy Process

DM Decision Maker

FNIS Fuzzy Negative Ideal Solution

FPIS Fuzzy Positive Ideal Solution

MCDM Multi-criteria Decision Making

MTD Machine Type Devices

NL Natural Language

TOPSIS Technique for Order Preference by Similarity to Ideal Situation

INTRODUCTION

In today's era digital marketing technologies which involves different promotional technologies are utilized to reach the customers. Beside the mobile and conventional TV and radio, digital marketing involves a wide range of service, product, and brand strategies which use the internet as a core promotional element (Yasmin, *et al.,* 2015). Digital marketing is essential in the competitive marketing industry, particularly during COVID-19 pandemics, for increased brand equity and company revenue. Besides, because the number of people who have access to the internet grows, businesses will have more opportunities to use digital marketing tools to better serve their customers and measure their satisfaction rates. Digital marketing creates a competitive advantage by saving money and allowing your company to communicate with your customers through two-way communication. Also, there is more relative product/service detail, better targeting abilities by targeted advertisements to impact consumers in a brief span of time, resulting in highly efficient and competitive marketing for corporations and businesses (Durmaz & Efendioglu, 2016). According to Tiago and Verissimo (2014), consumer relationships, buying habits, and interaction all change, forcing marketers to adjust by directing them to use modern digital marketing technologies. As Kotler, Armstrong and Opresnik (2017) mentioned, by better understanding consumers, building deep engagements with customers, creating more efficient and successful targeting strategies, and eventually establishing long-term relationships, technological advances in the marketing landscape will help companies gain a competitive advantage over rivals.

Every day, technology changes and as technology advances, more effective digital marketing tools emerge to be used. On the other hand, the most important thing is to assess and to choose the right one to use. There are numerous studies on how to choose the best digital marketing tool, such as gathering information on job seekers' viewpoints on the importance of using a digital marketing tool for recruitment.

With this study, the effects of digital marketing technologies to make a robust marketing decision based of organizations by choosing the best digital marketing technology among the alternatives of Artificial Intelligence (AI), Internet of Things (IoT), and Augmented/Virtual Reality (AR/VR) are aimed to assess.

Observing technological changes in the marketing environment can allow a company to gain a competitive advantage over competitors by better understanding consumers, developing more effective and efficient targeting strategies, deepening customer engagement, and, as a result, establishing long-term relationships (Kotler, *et al.,* 2017). In here, this study looks for to study how effective are the digital marketing technologies-based marketing approach on marketing decisions of an organization under fuzzy approach to enhance, understand and take actions for better decision makings to gain a competitive advantage over rivals.

Study question for this study is; which digital marketing technology (AI, IoT, AR/VR) is optimal for marketing decisions?

This study looks for digital marketing techniques of a kind that, AI-Artificial Intelligence, IoT - Internet of Things, VR/AR - Virtual and Augmented Reality. The purpose of this study is to analyze the impacts of digital marketing technologies (AI, IoT, and AR/VR) on marketing decisions of an organization and rank the alternative techniques according to priority order. This study looks for digital marketing technologies such as Artificial Intelligence (AI), Internet of Things (IoT), Virtual Reality (VR), Augmented Reality (AR). Besides, with this study it is able to show that for most of the cases using digital technologies of AI, IoT, AR/VR will positively affect the marketing decisions of an organization. Here, the use of a hybrid method which is based on fuzzy and TOPSIS approaches is proposed. By taking into consideration the uncertainty or vagueness in the decision making environment, especially with such strategic marketing decisions regarding the pandemic outbreak, fuzzy is one of the optimal ways to weight the criteria given for selecting the best alternative. Besides, alternatives are evaluated and selected using the TOPSIS method by providing the ideal positive and ideal negative solutions.

CHAPTER 1
THE DECISION MAKING PROCESS

According to Aliev and Huseynov (2014), in every day we are making decisions both consciously and unconsciously related to our daily problems such as deciding on where to go for shopping, what to eat at lunch, where to study master degree, which route to take for future career etc., which need decision making capability. Making a decision from a variety of alternatives to obtain a desired outcome is known as decision making process (Eisenfuhr, 2011). The five steps that make up decision-making theory, according to Albert and Steinberg (2011), are establishing alternative solutions, identifying the evaluation criteria of the alternatives, assessing the consequences associated with each alternative, gathering additional information and seeking help from third parties, and finally making a decision and executing the alternative. As Adair (2007) mentioned, there is a classic five-step guide to decision making that you can find incredibly useful. That isn't to suggest you can blindly follow it in any case. However, since it is a fairly natural sequence of thought, you will naturally follow this mental direction even without the formal framework. According to Saaty (2008), we are all essentially decision-makers. All we do, whether consciously or unconsciously, emerges from a decision. The information we collect is used to help us comprehend events so that we can make sound judgments and make decisions about them. Besides, decision-making, for which we collect the majority of our information, has evolved into a mathematical science. It formalizes our thinking so that everything we need to do to make better decisions is straightforward in every way. We need to have a basic understanding of this most valuable process that nature has given us in order to make decisions that will help us survive. To make a decision, we must first understand the problem, the decision's need and purpose, the decision's criteria, their subcriteria, and the alternative actions to take. Then we try to figure out which available is the best, or, in the case of resource allocation, we need priorities for the alternatives so that they can get their fair share of the resources. In other words, the decision-making process includes stages such as recognizing the problem, gathering data or information, developing alternatives to be analysed, choosing an alternative, and finally implementing the decision and reviewing the final results for consistency and effectiveness (Adair, 2000). Below there is a figure (Figure 1) that explains the process.

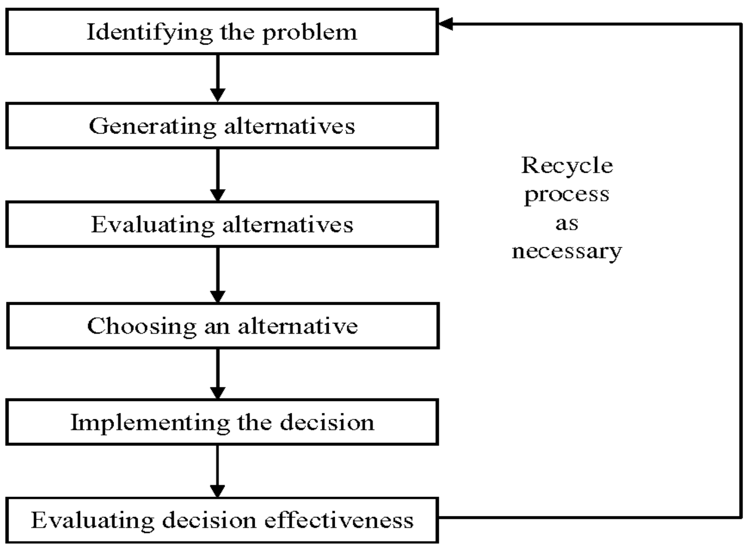

Figure 1: The Decision Making Process

(Lunenburg, 2010)

1.1 Identifying Problem/Problem Recognition

The link between two fundamental components, the desired state and the actual state, is the premise for problem recognition, according to Bruner & Pomazal (1988). That one is associated with how an individual would prefer a need to be met, whereas the second is concerned with how well a perceived need is met. As a result, problem recognition occurs when a significant gap exists between a person's desired state and actual state in relation to a certain goal or need. They have stated a good example. There are issues that arise over a long period of time when the desired and real states move apart. Being thirsty at work and running to the vending machine for a soft drink is an example of simple problem recognition. Besides, when an individual considers trading in an old car for a new one after several years of good use, this is an example of complex problem recognition. Moreover, whether a decision was able to solve the identified problem, or if the manager was able to achieve the desired goals and objectives, it is called an effective decision. According to Lunenburg (2010), a successful decision maker understands the importance of correctly identifying related problems. He also stated that recognizing a problem requires an explanation of the situation that causes the problem. As a consequence, we will arrive at the desired solution or decision. Internal and external environment assessment can help identify problems (Lunenburg, 2010). He also stated that recognizing a problem requires an explanation of the scenario that causes the problem. As a result, we can arrive at the required solution or decision. The problem is defined by the constraints that cause dissatisfaction. For that reason, managers must constantly monitor the development of their organization's activities in order to maintain a steady course that leads to the attainment of desired goals and objectives. Managers can use risk analysis methods like Scenario and SWOT analysis to find potential threats and opportunities that could affect their goals and objectives (Hillson, 2002). These assessments can be used to help make decisions like whether or not to expand the business.

1.2 Generating/Developing Alternatives

According to Stevenson (2009), the ability to make right decisions is frequently linked to the ability to generate appropriate alternatives or criteria. The decision-makers must generate and identify an alternative that can be employed as a problem-solving solution. He claims that determining alternatives or criteria is based on cost-benefit analysis, return on investment, the company's image, increased productivity, increased demand, and other factors. The further alternatives you investigate, the more informed your final decision will be. Creating a wide range of options may appear to make your decision more difficult at first, but the act of brainstorming encourages you to think about the situation in new ways. The most common approach of creating ideas is brainstorming. Also, decision-makers must tap into their creativity in order to produce viable alternatives. This can be accomplished by attempting to create as many alternatives as possible. The next phase is to broaden the search for new information, drawing on the expertise of specialists and other relevant individuals (Dessler, 2004).

1.3 Evaluating/Analyzing Alternatives

In decision making process the next step is evaluating/analysing the alternatives. Stevenson (2009) stated that different statistical or mathematical tools and approaches, such as linear programming (LP), are commonly used to improve the evaluation process.

“How do you choose an appropriate alternative given the right objectives?” As a result, it is regarded as the most challenging and complex aspect of the decision-making process that necessitates the use of future forecasting. The relevant parameters, such as stable demand for the company's products or services, and the cost of production, which have known repercussions and values for the future, are included in perfect or certain conditions and environments. Decision makers make decisions under certainty because the outcomes are known. According to Statistical Decision Theory, managers face three types of environments in their organizational problem-solving and decision-making processes: certainty, risk, and uncertainty (Dessler, 2004). Bounded rationality is a term coined by Simon (1979) to characterize decision-making under uncertainty, and it is used to replace the classical idea of human rational choice. Because of the uncertainty in the environment and the restricted computational capabilities, this novel model illustrates how decisions should be made when DM needs to search for alternatives with imperfectly known consequences. According to Simon (1979), utility maximization is not always desirable when looking for alternatives. DM, on the other hand, stops looking for additional feasible alternatives when he or she discovers one that is convenient and fits his or her desire for a good alternative. This model of selection was termed "satisficing" by him. In the decision-making approach, DM can be satisfied by either discovering the optimal or best solution by reducing the weight of mathematical computations to address a more simplified world problem, or by selecting a suitable solution that is more applicable to an actual world situation.

Both approaches are utilized alternately in management science problems, according to Simon (1979). As a result, Zadeh (1975) proposed a technique for dealing with uncertainty in real-world decision-making processes. The fuzzy set theory proposed by Zadeh (1975) can be used as the mathematical foundations for creating an eligible formal basis for bounded rationality notions for more realistic decisions (Aliev & Huseynov, 2013).

Dessler (2004) proposes three steps for evaluating alternatives effectively. To begin, DMs must mentally project themselves into the future using process analysis. Anticipating and looking into the future or tomorrow, as Dessler (2004) states, is a valuable analytical skill. He defines process analysis in his book as "solving the current problems by thinking broadly from the beginning to the finish of the process, employing the imagination at each moment to estimate what may actually happen by picking an alternative." Second, poorer alternatives should be eliminated or, in other words, removed from the list of available alternatives if they have little or no chance of succeeding.

Finally, the author proposes putting the remaining alternatives into a consequences matrix. The DM's aims (horizontally) and choices are displayed in this repercussions matrix or table (vertically). There is a short statement in each box of the table that indicates the linked implications of one alternative to the associated objective.

1.3.1 Decision Making Criteria

Decision makers or DMs, according to Stevenson (2009), create a payoff table that estimates or decides the payoff or outcome for each potential future circumstance or state of nature. Between the certainty and uncertainty-dominated environments, decision-making under risk exists. The probability of occurrence for each state of nature is known in this case. The expected monetary value criterion is commonly employed to make decisions under risk. The expected value for a given alternative is calculated by adding all the weighted payoffs (multiplying the related probability of occurrence by the payoff for each state of nature). Then, the alternative with the greatest expected value is chosen.

The process of evaluating alternatives is guided by decision criteria for uncertainty, such as; maximax which means selecting the alternative with the best payoff or outcome, disregarding any payoff that is less than the best. This is an optimistic perspective.

Next one is maximin which is choosing the best payoff alternative from one of the worst payoff alternatives. This criterion is based on a pessimistic perspective.

The Minimax regret criterion aims to reduce regret by reducing the difference between the given available payoff and the best feasible payoff alternative (for each state of nature). Besides, there is the Laplace criterion which is based on the assumption that all natural states are equally conceivable. DM chooses the alternative with the best average result or payoff among all other alternatives by using this method.

A decision tree can be used instead of payoff tables to evaluate circumstances involving sequential decisions, such as whether to grow a business after realizing a bigger demand for goods and services than anticipated. As a result of the analysis, the decision is made on the alternative with the highest expected value or return.

1.4 Making a Choice

DM has two or more feasible options after analysing and eliminating the alternatives (Lunenburg, 2010). After that, DM should make a decision based on the major stated target. Also, he states that the DM may be allowed to choose many alternatives at the same time. He uses the example of employing an English teacher to demonstrate his point. If the principal is torn between two strong applicants, he or she can propose a vacation to one while keeping the other under observation. As a result, if the first applicant fails to meet the requirements, the school administrator will have a viable alternative to replace the instructor.

1.4.1 Making Better Decisions

Dessler (2004) proposed various ways to aid the DM in improving the quality of his or her decision-making.

1.4.1.1 DM’s Intuition

Intuition, according to Dessler (2004), is a cognitive process. An individual makes instinctive decisions based on his or her accumulated knowledge and experience. Trial-and-error is used by intuitive decision makers because they tend to attempt one alternative after another until they find the best or optimal alternative based on their inner nature. In order to address a problem, systematic decision makers, on the other hand, take a more logical and step-by-step method. According to research on both types of decision makers, DMs can be systematic in instances where there is ample time to evaluate all possible alternatives. However, it is also necessary to use intuition to make better decisions.

1.4.1.2 Increasing Knowledge

More knowledge and information are necessary for more challenging decisions. DM can always ask more and more questions like "What? Who?" to expand his knowledge. When, where, and why did you do it? “How much is it?” For instance, who is purchasing the house and why?, how much can you afford to pay for it?, and so on are all objective questions. The use of consultants' or other people's experience that the DM lacks is a significant issue. The DM may be able to obtain more knowledge by conducting research related to the targeted goal. Searching for trade barriers, culture, and customs in the country the company wants to enter, for example, will provide a wealth of information about the country's economic, political, sociologic, and other issues.

1.4.2 Different Decision Making Styles

Different decision-making styles used by DMs have been studied by researchers. Different techniques or styles are used by managers and other DMs when making decisions. As a result, it's important to talk about distinct decision-making styles.

Heuristics Decision Making

The concept of rational decision making is not always a good paradigm to describe and explain human behavior in a world of limited knowledge, resources, and time. Due to a lack of time and commitment, people are more likely to take shortcuts when making judgments, according to studies (Payne *et al*. 1993). Thus, rapid and frugal heuristics have become popular as a means to express human judgments.

General Decision-Making Style (GDMS)

According to Scott and Bruce (1995), an individual's decision-making style is closely linked to his or her typical and learnt response, rather than personality traits, in a given situation. There are five types of decision makers: intuitive, rational, spontaneous, avoidant, and dependent decision makers.

- Rational: Decision makers prefer searching in depth for accurate information and weighing the pros and cons of various alternatives. The rational style's primary goal is to make logical and methodical decisions by analyzing all aspects of the alternatives considered in order to attain the desired goals and objectives.

- Spontaneous: Decision makers are impulsive by nature when it comes to making decisions. They make snap decisions that appear natural or native to them. Because time is of the essence, decision makers must act quickly to complete the decision-making phase as soon as possible.

- Intuitive: Rather than looking for a reasonable source of reason to make a conclusion, this approach depends on an individual's inner sensations or sentiments of what is right. Intuitive decision makers, according to Scott and Bruce (1995), prefer to make decisions based on their "guesses and feelings."

- Dependent: Before making major decisions, a dependent decision maker will frequently consult or seek advice from others. A decision maker's ability to make decisions is dependent on the support of others.

- Avoidant: When confronted with pressure, decision-makers have a proclivity to delay or cancel the decision-making process as much as possible. They also have a proclivity to make last-minute appeal decisions. He or she is likely to have uneasy thoughts about making decisions, which is why he or she avoids making them.

1.5 Conclusion for Chapter 1

This chapter explains the fundamental concepts and basic information for the decision-making process, which includes every day and administrative decisions made in conditions of certainty, risk, and ambiguity, as well as with imperfect information. Decision making occurs at every step of our lives, thus in order to think different, we must overcome the restrictions or psychological traps that stand in the way of our creativity in order to make more effective and efficient decisions.

CHAPTER 2
DIGITAL MARKETING TECHNIQUES/TOOLS

2.1 Digital Marketing

Digital marketing is a form of marketing that is commonly used to promote goods or services and reach out to customers across digital channels. It is broad term that encompasses a wide range of promotional strategies that make use of digital technologies to reach customers. It comprises a wide range of service, product, and brand marketing methods that predominantly use the Internet as a core promotional tool, in addition to mobile and traditional TV and radio. (Yasmin, *et al.,* 2015). As a result of today's problems and increased competition, marketers must consider cost-cutting budgets and showing up with something special in order to be customer-oriented. As a result, digital marketing is the one that assists marketers with both cost-effectiveness and a new way of connecting with customers (Tamanna, T., 2021). Mobile marketing, programmatic advertising (i.e. automated media buying), and social media (SM) are increasingly being used by organizations to gain a competitive advantage. These technologies are changing the face of integrated marketing communication (IMC), resulting in a growing number of new digital IMC choices. In today's dynamic corporate world, a well-designed social media strategy that develops and curates compelling content is critical to maintaining competitiveness. Various studies have been conducted to aid in the selection of the finest digital marketing tool, such as gathering information on job seekers' viewpoints on the use of vital digital marketing tools for recruiting (Anute N.B, *et al*., 2019). For example, there are techniques as social media marketing, search engine optimization, pay-per-click and etc. On the other hand, in this study 3 major and mostly used digital marketing techniques were used (AI, IoT, AR/VR) as these are the mostly important techniques in today's circumstances such as pandemic outbreak. Nowadays, most of the companies use the AI, IoT, AR/VR algorithm to reach the customers more easily and in an effective way according to researches. Customers would like to use the easiest and user-friendly applications. Thus, these stated techniques are considered as the most used techniques for the applications' algorithms among the customers on the pandemic outbreak (Keller, 2016).

2.2. Artificial Intelligence-AI

Mishkoff (1986) stated that a machine, software, or computer that can quickly copy or simulate a person's decision-making process and provide good outcomes in a short amount of time is known as AI. It is transforming the way people work, eat, sleep, and so on. AI, or AI adoption, is method that process human being intelligence in order to solve issues or make good decisions. Take into account the variety of AI interactions that consumers have throughout the day, from Fitbit's health tracker and Alibaba's Tmall Genie smart speaker to Google Photo's editing tips and Spotify's music playlists (Puntoni *et al*., 2021). For instance, during the peak demand times through AI, Uber tries to match the demand with their right price strategy and this is a good example for AI based pricing strategy (Forbes, 2018). Also, chatbots are AI-based computers that communicate with customers through natural language-based user interfaces on internet and social network like Facebook. So, chatbot has ability to improve customer relationships by allowing for interactive conversation and prompt responses, resulting in higher customer satisfaction (Brandtzaeg & Følstad, 2017). Alshaikhi and Khayyat (2021) stated that AI introduces numerous new tools and techniques to ensure improved quality and cost-effectiveness in the business environment, all under the scope of an Information and Communication Technology world revolution. AI provides cost-effectiveness, reliability, and permanence, as well as addressing some uncertainty issues by reaching a conclusion or solving a problem. As shown in [Fig. 1], AI applications are progressively incorporating these new technology advancements, and this trend is expected to continue at a rapid pace in the future.

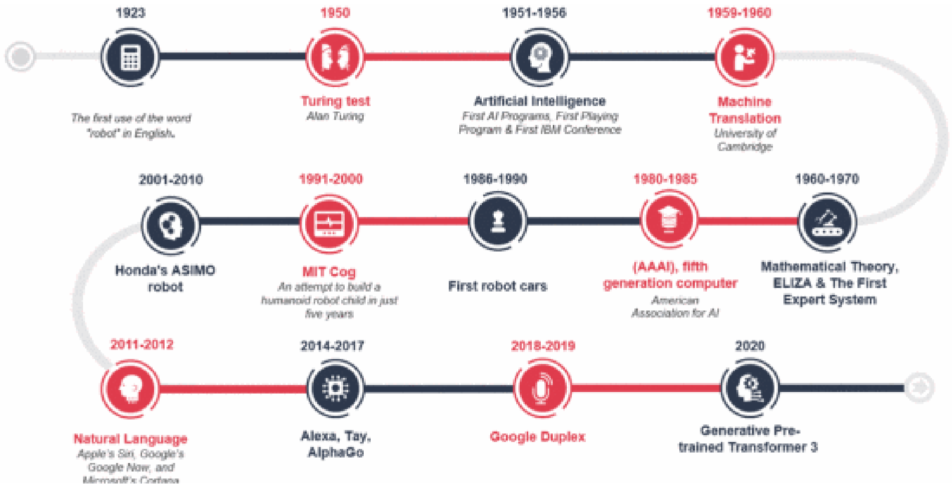

Figure 2: Evolution of AI

(Alshaikhi and Khayyat, 2021)

2.2.1 Artificial Intelligence Implementation Barriers and Challenges

On the other hand, there are some barriers and drawbacks of using AI. Firstly, data availability is one of the most significant obstacles to AI implementation. Due to poor quality, data is inconsistent and compartmentalized. AI can only accomplish the sorts and jobs that have been programmed or built for it. Due to high operating costs and equipment, AI adoption and implementation are difficult to achieve. Implementing, repairing, rebuilding, and creating take a long time. As the majority of the industry's personnel and workers are replaced by AI robots, the rate of unemployment will rise. Similarly, AI adoption will make humans lethargic because the majority of tasks will be handled by machines in a very short amount of time (Bhbosale *et al*., 2020). To operate and deploy AI in the business, well-trained and experienced technical staff is required. The company will not be able to gain a long implementation time if they are unable to operate. Integration issues and a lack of understanding of state systems.

2.3 Internet of Things-IoT

It is collection of interconnected programs or systems that work together to deliver an advanced commodity and boost customer engagement and loyalty by sending customised messages (Spilotro, 2016). IoT is attracting a huge amount of attention right now, and its first practical applications are being seen in real-world contexts. The term "Internet of Things" encompasses both the real and virtual worlds. The Internet of Things (IoT) is an ecosystem that connects a large number of machine type devices (MTDs), everyday objects, tablets, people, and smartphones to the internet (Trnka, & Cerny, 2016). Smart homes and autos, home security, smart TVs, wearables, and healthcare gadgets like MRI scanners all use IoT. Companies use the Internet of Things to repair or improve devices by sending signals to suppliers if the product requires immediate adjustment. For example, a Tesla car must update itself every time a new software version is released (Spilotro, 2016). Individual preferences are combined with information gathered from the internet, website, or mobile app to tailor promotion through communication. Pricing strategies for IoT connected programs or devices may be based on smart data pricing models based on actual consumer behavior, although they are not as well developed as AI pricing strategies (Niyato, 2016).

2.3.1 IoT Security Concerns

The importance of wireless infrastructure in IoT applications is projected to expand as mobile nodes and wireless sensor networks become more common. As wireless sensor networks link to the internet, they become more vulnerable to attackers from around the world (Jiang *et al*., 2014). Insecure network services, insecure online interfaces, insecure mobile interfaces, insecure cloud interfaces, insufficient authentication, insufficient permission, and a lack of security configuration are all important security concerns in the IoT, as previously discussed. The number of security problems directly related to IoT devices has increased in recent years.

2.4 AR-VR

AR is computer-assisted technology that enables digital information, like audio, 2D or 3D objects, and video files to interact in real-time with real-world information or the consumers' side of the reality. (Yuen, *et al.,* 2011). We can use it in a variety of situations, including e-commerce, entertainment, games, medical, marketing, and so on. It's also used to advertise a commodity in digital marketing. For example, IKEA, a prominent furniture store, lets customers to visualize their desired furniture by showing how it might seem in their home

(Scholz & Smith, 2016). Companies that use those tools aim to improve effective marketing decision makings by improving contact and spreading positive word-of-mouth. VR is a simulation-like user experience that allows customers to feel as though they are visiting or remotely engaging with a product, service, or brand (Crittenden, *et al.,* 2019). Car brands with virtual test drives, 3D product shows, remotely visiting various locations, and so on are some popular examples which boost the powerful marketing decisions of an organization. In addition, Apple has talked about the prospects of augmented reality for several years, and there have recently been reports that the company is getting ready to take its ambitions to the next level by producing a device that combines augmented reality, virtual reality, or both. Consider an augmented reality headset—hopefully in the form of lightweight glasses—that gives you a heads-up display of your vitals while working out, similar to how your Apple Watch gives you that information at a look, but more practical. Alternatively, an augmented reality projection of your trainer who can keep you on track even if you aren't looking at a screen. Apple has spent a lot of effort and money enhancing its mapping service over the last few years. Back in 2012, the company first moved away from Google Maps. The new mapping data includes bike routes, elevation, and even “Look Around” data that allows you to visually move around any street.

Whether you're walking, jogging, or cycling, an augmented reality headset might be able to use that data not only to assist you determine out where you are, but also to provide simple directions displayed on the world around you.

2.5 Other digital marketing techniques/tools

2.5.1 Social Media Marketing (SMM)

‘A series of internet-based applications that build on the ideological and technological foundations of Web 2.0 and enables the creation and exchange of user created content,' according to the definition (Kaplan & Haenlein, 2010). Marketers can utilize social media as another form of digital marketing channel to engage with consumers through advertising. However, we can think of social media in a broader sense, considering it less as digital media and specialized technical services, and more as a kind of communication and more as digital gathering places where significant portions of people's life are conducted. From this standpoint, social media becomes less about specific technology or platforms and more about what people do in these circumstances (Appel, *et al.,* 2020). Traditional marketing activities and strategies fall short of meeting specific requirements for efficient and effective social media marketing (SMM) operations because they seek to sell through multiple channels, whereas SMM focuses on making individual connections and developing long-term relationships. For a more meaningful and focused marketing choice, SMM customizes and personalizes marketing (Erdoğmuş & Cicek, 2012). With the rise in internet access and smartphone availability, social media marketing has become increasingly important as part of digital marketing. Using communicating effectively, social media marketing facilitates the sharing of information and knowledge, as well as the marketing of goods and services (Kotler, *et al.,* 2017). Marketing professionals now employ social media as part of their marketing plan. Customer experience, views, inclinations toward brands and campaigns, past preferences, personality features of customers, and brand loyalty may all be gleaned through social media. This section contains the most important facts for comprehending the target consumer for better addressing them (Tuten, T.L., & Solomon, M., 2014). For example, Facebook, Twitter, Instagram and etc.

2.5.2 Search Engine Optimization (SEO)

Search engine optimization (SEO) is the process of improving a website's ranking on search engines for certain search terms by managing inbound links and website characteristics (Malaga 2010). Search engine optimization is the art and science of convincing search engines like Google, Bing, and Yahoo to promote your material as the best solution to their consumers' problems (Barnard, 2020). Inbound marketing, or marketing that focuses on being found by customers, includes SEO. That is the most significant distinction from typical outbound marketing (TV ads, calling and etc.), in which the process of obtaining a consumer works in the opposite direction, with organizations focusing on finding new customers on their own. On-page SEO (altering the structure of a website) and off-page SEO (techniques unrelated to the structure of a website) are the two types of SEO. External website optimization includes adding a website to a site guide, using social media features, and exploiting links from other optimized websites to a connected webpage (Yalçın & Köse, 2010). In terms of internal website optimization, Bar-Ilan *et al*. (2006) stated that by developing and rebuilding webpages, websites can get high rankings for specific search keywords within specific search engines. Prior to optimization, it is critical to understand the consumer, market, and one's own competencies. It is hard to optimize every word on a website for search engines; therefore, it is critical to choose seven to ten keywords that most properly represent the content. Furthermore, optimization is always done in response to a specific query that is likely to be searched by a user.

2.5.3 Pay-per-click (PPL)

Digital marketing is commonly used to sell products and services more efficiently and effectively in order to improve sales and revenue. It enables organizations to communicate desired material to their customers more efficiently. Pay-per-click (PPC) advertising is an example of this type of digital marketing (Kapoor *et al.,* 2016). This kind of computerized showcasing methodology is additionally alluded to as cost-per-click promoting (CPC). Inside this, the proprietor of a website page,otherwise called the web distributer, permits organizations to promote items/administrations on the proprietor's page. Each time a guest on the distributer's website page taps on that commercial, the business will pay a specific add up to the distributer, thus the name pay-per-click/cost-per-click promoting (Farris *et al.,* 2010). PPC schemes, which provide non-organic rankings, are systems that display adverts alongside organic results on a search result screen, but rank them independently. These advertising are usually displayed to the right of and above the organic search engine results. PPC, as the name implies, charges the advertiser the bid amount each time a user clicks on an advertisement on the Internet. Each term has a different level of competition, and the more popular a keyword is, the greater the cost (Chen *et al*. 2011). Many companies, particularly the tourism industry, have taken use of this marketing opportunity to great effect. Even small firms have gone to great lengths to conduct research in order to choose the best search engine PPC strategy to employ (Kennedy & Kennedy 2008).

2.6 Conclusion for Chapter 2

This chapter explain the digital marketing and digital marketing techniques/tools such as AI, IoT, AR-VR and other techniques. The purpose of this chapter is to assess the impacts of those digital marketing technologies on the marketing decisions of an organization with real life examples of companies.

CHAPTER 3
Fuzzy Approach in Digital Marketing

3.1 Fuzzy numbers: In a real-world decision-making context, experts or decision-makers are frequently unsure about the plausibility of given values, and they are also oblivious of the degrees of imprecision or uncertainty, according to Aliev (2015). In a fuzzy set, a degree is assigned to each potential value of x, (x)[0,1].

$$x_0 \in R, \text{ where } \mu_M(x_0) = 1 \qquad (1)$$

For any 0 ≤ α ≤ 1, $A_\alpha = \left[x, \mu_{A_\alpha}(x) \geq \alpha\right]$ is a closed interval, where F(R)

3.2 Random variables: Continuous random variables and discrete random variables are the two types of random variables. The continuous one, denoted by X, can produce an infinite number of numerical outputs. In contrast, a discrete random variable can only take countable different values (Aliev *et al.,* 2015).

3.3 Triangular Fuzzy Numbers: According to Aliev, R. A., & Aliev, R. R. (2001), triangular fuzzy number which is denoted by Ã as a triplet, shown as (a_1, a_2, a_3), where the membership is determined utilizing the following formula (2).

$$\mu_{\tilde{A}}(x) = \begin{cases} 0 & x\epsilon(-\infty, a_1) \\ \frac{x-a_1}{a_2-a_1} & x\epsilon[a_1, a_2] \\ \frac{c-x}{a_3-a_2} & x\epsilon[a_2, a_3] \\ 0 & x\epsilon(a_3, +\infty) \end{cases} \qquad (2)$$

3.4 Preliminaries

The basics of fuzzy preferences, linguistic variables for self-confidence (Aliev & Aliev, 2001), and fuzzy preferences will be gone over. Also, in this part the procedure of finding Eigenvalues and Eigenvectors using DE is covered.

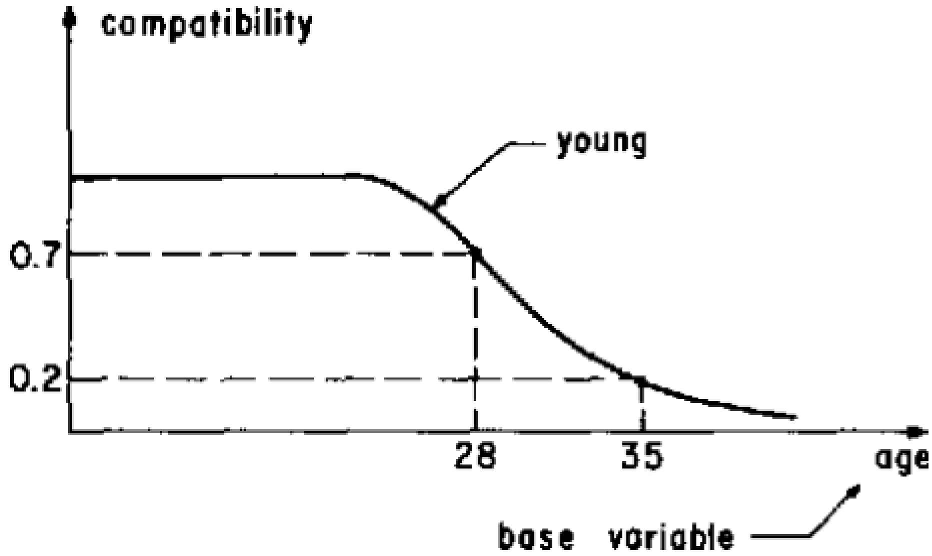

Figure 3: Compatibility Function Example for ‘young’ Labeled Fuzzy Restriction

(Zadeh, 1975)

Zadeh (1975), proposed fuzzy set theory as a mathematical foundation for developing an eligible formal basis for restricted rationality notions for more realistic decision-making (Aliev & Huseynov, 2013). This relationship is stated by Aliev and Huseynov (2013), on the basis of human beings' imperfect or constrained information understanding (which is the main focal point of bounded rationality) and their desire to evaluate information in linguistic variables. Information that is ambiguous, uncertain, unreliable, indefinite/incomplete, imprecise, or partly true is referred to as imperfect information (Zadeh, 2009).

Imperfect information described linguistically is included in fuzzy set theory. A linguistic variable, according to Zadeh (1975), has values in the form of words or phrases in an artificial or natural language (NL). This is due to human beings' limited computational ability, as they think and reason in natural language propositions rather than complicated mathematical statements. Humans with

limited and imperfect knowledge, on the other hand, favor linguistic evaluations that allow for ambiguity, uncertainty, and imprecision in decisions. As a result, DMs yield reasonable and approximate outcomes and, approximate reasoning in fuzzy logic is referred to as such (Aliev & Huseynov, 2013). Zadeh (1975) gives some instances of linguistic variables, such as age, temperature, and height, which are linguistic variables if the given values are linguistic (qualitative) rather than numerical. Instead of 21, 22, 23, 24, etc., age has values such as young, not young, very young, old, not very young, not very old, etc. As a result, the values (young, old) of linguistic variables (e.g. Age) are derived from the fundamental terms (age), a collection of hedges (very, slightly, extremely, quietly, etc.), and connectives of ‘and' and ‘or'. However, because age is often a numerical variable, a compatibility function that associates the provided variable's linguistic value is applied. For example, the linguistic value ‘old' A, A(u), A: U [0, 1], associates any age within a specific age interval (e.g. [0, 100]) a real number between 0 and 1 indicating compatibility or grade of membership of any age u in the linguistic value ‘old' A, A(u), A: U [0, 1]. The compatibility of age 80 with the term "old" may be 0.8; on the other hand, the compatibility of age 27 with the term "old" may be 0.2.
In our study, each of the three alternatives, $A = \{a_1, a_2, a_3\}$,, is specified by five criteria. $C = \{c_1, c_2, c_3, c_4, c_5.\}$.

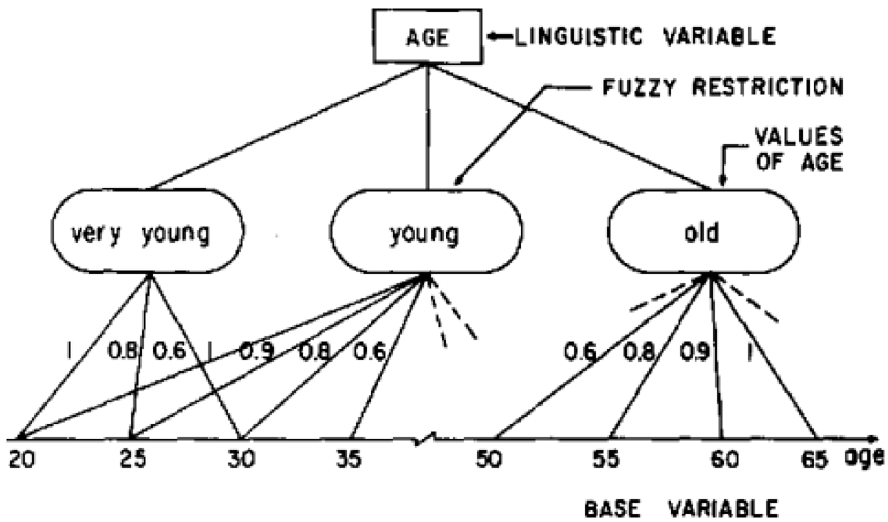

Figure 4: A Linguistic Variable's Hierarchical Structure and Values with Associated Compatibility

(Zadeh, 1975)

According to Pal and Mandal (1991), as stated in Zadeh (1975), Boolean logic's two-valued logic of truth values or propositions that can be either 0 or 1 (false or true, respectively) is confined to crisp binary values and unacceptable to imprecise and incomplete information. Fuzzy logic, on the other hand, provides intermediate values between the crisp values of 0 and 1. The three basic qualification types of fuzzy logic are truth qualifications such as very true, not very true, false; possibility qualifications such as possible, almost possible, almost impossible; and probability qualifications such as likely, unlikely, more likely, extremely likely, probable, improbable. For example is the weather hot?, and the answer may be not very true, fairly true, quite true, and so on.

Chen enhanced TOPSIS with triangular fuzzy numbers to compute the distance between two triangular fuzzy numbers, and fuzzy TOPSIS is established. Fuzzy TOPSIS, which is one of the Multi-Criteria Decision Making methods (MCDM), ranks the alternatives based on relative similarity with the ideal solution.

The goal of this study is to analyze digital marketing technologies in order to make an informed decision by choosing the best digital marketing technology from among the alternatives of AI, IoT, and AR/VR that fulfills five of following criteria, using the fuzzy and TOPSIS approaches:

Here, methodology for solution is based on consistency driven approach for identification of criteria weights that are explained below, and identification of distance between ideal positive and negative solution based on TOPSIS method (Lai, Liu, Hwang, 1994).

• C1-Product: Mix of goods and services proposed.

• C2- Price: The amount of money that customers must pay in order to get product or service, also known as the consumer's cost of purchasing.

• C3- Place: The most essential decisions are those that are made to make the product available to the consumer, such as where to sell it and how to distribute it.

• C4-Promotion: To persuade and motivate individuals to buy the supplied goods or service, use communication methods.

• C5- Targeting customer segments: Identifying segments or groups of customers to engage successfully and efficiently (Mukul, *et al.,* 2019).

These 5 criteria are the major criteria for strategic marketing decisions. Marketing mix plan is one of the important concepts to be used by marketers. Mix of product, price, place and promotion with right targeting plan can make the company better than competitors.

3.5 Procedure of finding Eigenvalues and Eigenvectors using DE

1. **Obtaining maximum Eigenvectors and Eigenvalues**
    a) Solve the equation: $\det(A-\lambda I)=0$ to find maximum Eigenvalue. Only medium values of fuzzy elements are present in matrix A. DE objective function minimization $CF(\lambda)= D^2(\lambda)-\varepsilon\lambda$, where λ is the parameter to optimize, $D(\lambda)=\det(A-\lambda I)$ is a function dependent of λ, ε is a constant (which may need to be altered for specific problem, in this case $\varepsilon=100$). (The DE search space has a dimension of one)
    b) To find Eigenvectors, create a new DE objective function: CF(X)= Vector Distance($AX,\lambda X$). The search parameters are the (N-1) elements of vector X. (except the 1st one, which is set to 1). (The dimension of the DE search space is N-1)

2. **Finding fuzzy Eigenvalues**

    Make use of a fuzzy A matrix. Create a new DE objective function like this: $CF(\lambda_L,\lambda_R)$= FuzzyDistance(AX, $(\lambda_L, \ ,\lambda_M\ \lambda_R)$X), where "FuzzyDistance" is the sum of fuzzy distances between corresponding elements of vectors. Vector X made up of fuzzy singletons, derivied from crisp Eigenvectors of step 1. The left and right components of fuzzy Eigenvalues are the only ones that can be optimized. (Step 1's medium component is used.) (The dimension of the DE search space is 2)

3. **Finding fuzzy Eigenvectors**

    Make use of a fuzzy A matrix as well as fuzzy Eigenvalues. Create the following DE objective function: CF(X)=FuzzyDistance(AX, λX). N elements of the fuzzy vector X are the search parameters. Only the left and right components are looked for, while the central component is obtained from the first phase. (The DE search space is 2*N in size.)

CHAPTER 4

METHODOLOGY

Here, pairwise comparison for each of the above-stated criterion is given in table 1. The following calculations are given for obtaining maximum Eigenvectors and Eigenvalues using the program MATLAB.

	C_1	C_2	C_3	C_4	C_5
C_1	(1,1,1)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/3,1/2,1/1)	(1,2,3)
C_2	(2,3,4)	(1,1,1)	(1,2,3)	(1,2,3)	(2,3,4)
C_3	(1,2,3)	(1/3,1/2,1/1)	(1,1,1)	(2,3,4)	(2,3,4)
C_4	(1,2,3)	(1/3,1/2,1/1)	(1/4,1/3,1/2)	(1,1,1)	(2,3,4)
C_5	(1/3,1/2,1/1)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1/4,1/3,1/2)	(1,1,1)

Table 1: Pairwise comparison matrix

Calculations

Initializing DE vector space...

Done.

Starting DE...

Initial Cost (and Error) Function value:

-43.7934549381415

Generation, Cost (and Error) Function Progress:

3 -47.0426419083874

4 -47.1389073058411

4 -47.4513445066048

4 -47.500854486146

4	-194.218760461218
16	-261.595264412823
18	-456.526260365979
23	-481.69033743008
27	-484.570819885441
27	-513.294462941244
29	-514.211559408092
30	-514.543514610905
32	-514.579147674423
34	-514.600727106478
35	-514.600798500375
38	-514.600799145285
38	-514.600803878088
38	-514.600805601565
43	-514.600806730684
43	-514.600806778972
46	-514.600807126951
47	-514.600807233003
47	-514.600807233212
48	-514.600807234417
48	-514.600807234422
48	-514.600807234503
51	-514.600807234594
52	-514.600807234728
56	-514.600807234728

60 -514.600807234728

10000

DE stopped.

Initializing DE vector space...

Done.

Starting DE...

Initial Cost (and Error) Function value:

144.33047119287

Generation, Cost (and Error) Function Progress:

1 132.183185966935

3 86.4265186907011

5 85.1427145023423

7 78.8546634632057

7 36.9146378805526

9 21.2205775605854

11 18.8739948486548

11 16.3729980433074

13 14.6690300699516

14 7.53831209690684

16 6.62384432817419

18 3.37903210566323

20 1.93541969809631

21 1.54786794000788

22 0.707747041850293

26	0.42461813838873
29	0.368325029611137
30	0.2082618048855
30	0.0102461790390463
44	0.00441408320162356
49	0.00430691608700888
49	0.00146177247205794
54	0.000703354700496585
56	0.000242424490148893
61	0.000224775503052578
61	0.000214741691498795
63	0.000213982139904157
63	0.000183490258181682
63	0.000110338480981718
65	5.17990813374019E-05
68	5.05107664782511E-05
70	1.16316801033131E-05
70	4.69263429531983E-06
78	4.39207977846257E-06
79	2.6694148773478E-06
80	8.84936233835745E-07
84	8.69526922997921E-07
85	4.77236954884565E-07
87	1.53341795297634E-07
92	1.03419485000178E-07

95	9.29534643468927E-08
99	7.19071819109754E-08
99	6.71839427862853E-08
102	6.18754032313507E-08
108	5.63509009513493E-08
112	5.61968566287182E-08
114	5.60778701475261E-08
116	5.58701033357974E-08
116	5.55865510571819E-08
117	5.53058585275059E-08
119	5.52926104598768E-08
122	5.52370386368868E-08
125	5.51572843635232E-08
128	5.51030347441465E-08
128	5.50887687837176E-08
131	5.50760216759864E-08
133	5.50730328411556E-08
134	5.50699036386776E-08
136	5.50658989631659E-08
138	5.50657847274148E-08
138	5.50649468099912E-08
139	5.50589995571291E-08
141	5.50555532759477E-08
149	5.50554241841271E-08
152	5.50552400794852E-08

164	5.50552130245455E-08
170	5.50552122040444E-08
172	5.5055210605868E-08
176	5.50552078028212E-08
177	5.50552074635052E-08
179	5.50552065818957E-08
180	5.50552056952489E-08
182	5.50552047243403E-08
188	5.50552046249408E-08
190	5.50552045847553E-08
193	5.50552045792345E-08
194	5.50552045333111E-08
194	5.50552045066953E-08
204	5.50552045015917E-08
208	5.50552045000615E-08
212	5.5055204499789E-08
213	5.50552044992786E-08
213	5.50552044986886E-08
224	5.50552044986633E-08
224	5.50552044986572E-08
225	5.50552044986364E-08
225	5.50552044985217E-08
226	5.50552044984968E-08
226	5.50552044984522E-08
227	5.50552044984359E-08

228	5.5055204498429E-08
230	5.50552044983523E-08
230	5.50552044982695E-08
246	5.50552044981702E-08
266	5.50552044981382E-08
292	5.50552044981156E-08
294	5.50552044980403E-08
403	5.5055204498008E-08
612	5.50552044979642E-08
719	5.50552044979233E-08
1250	5.50552044979106E-08
1259	5.50552044978953E-08
1366	5.50552044978786E-08
1393	5.50552044978747E-08
1399	5.50552044978742E-08
1401	5.50552044978702E-08
1411	5.50552044978701E-08
1423	5.50552044978697E-08
1424	5.50552044978696E-08
1427	5.50552044978689E-08
1442	5.50552044978685E-08
1456	5.50552044978682E-08
1466	5.5055204497868E-08
1480	5.5055204497868E-08
1490	5.50552044978678E-08

10000

DE stopped.

MAX LAMBDA = 5.14605236150391

Eigen Vector = 1 3.23272232962209 2.5401079704875 1.59222967350729 0.712773857545091

Correctness Check:

A*X =

5.14594 16.63572 13.07148 8.19362 3.66779

Lambda*X =

5.14605 16.63576 13.07153 8.19370 3.66797

Initializing DE vector space...

Done.

Starting DE...

Initial Cost (and Error) Function value:

1.09533763568105

Generation, Cost (and Error) Function Progress:

3 1.08990340685457

4 0.944834524756581

5 0.831108478823954

18 0.827704319592333

28 0.82742435010865

35 0.826954889655553

36 0.826658927138127

46	0.82661501017562
51	0.826601729381538
56	0.826533286067852
74	0.826531701520516
79	0.826531025966975
85	0.826530702206657
88	0.826530525942985
88	0.826530187278663
93	0.826530147227532
96	0.826530044170471
96	0.826530026495658
97	0.826530005543788
97	0.826529997017297
98	0.826529980994695
99	0.826529958439817
100	0.826529953592645
102	0.826529949800168
103	0.826529948886765
105	0.826529948664517
106	0.826529936407671
107	0.826529934572223
110	0.82652993438434
112	0.826529934237803
112	0.826529932478273
113	0.82652993188005

113	0.826529931828623
114	0.826529931409916
115	0.826529930764511
115	0.82652993067699
118	0.826529930569862
119	0.826529930412913
121	0.826529930186243
123	0.826529930183022
124	0.82652993015803
127	0.82652993005156
127	0.82652993003657
130	0.826529930024713
136	0.826529930021659
137	0.826529930014427
137	0.826529930012183
138	0.82652993001042
140	0.826529930009797
141	0.826529930009303
141	0.826529930009106
141	0.826529930007782
142	0.826529930005717
147	0.826529930005158
147	0.826529930005061
151	0.826529930004933
152	0.826529930004876

155 0.826529930004841

158 0.826529930004841

159 0.826529930004823

160 0.826529930004815

161 0.826529930004793

165 0.826529930004788

165 0.826529930004785

167 0.826529930004779

168 0.826529930004778

170 0.826529930004777

172 0.826529930004777

173 0.826529930004777

180 0.826529930004776

181 0.826529930004776

181 0.826529930004776

187 0.826529930004775

1000

DE stopped.

Fuzzy LAMBDA = [3.59896476396572, 5.14605236150391, 7.08349591173713]

Initializing DE vector space...

Done.

Starting DE...

Initial Cost (and Error) Function value:

44.0180402336172

Generation, Cost (and Error) Function Progress:

3 28.7163112540988

3 19.3381380882838

7 18.1822765883424

9 9.01078351407212

14 7.87193460795663

18 6.13514903294738

23 5.45430641456171

27 4.79738964976423

29 4.23185679196675

36 3.93143947779054

38 2.9858557972666

42 2.82317046296927

45 2.20616884273906

51 1.8447379508822

62 1.69605585579767

69 1.66572159761908

69 1.53089129723174

72 1.44041304809154

74 1.31361184722932

77 1.10939026151092

85 1.09910986222764

85 1.00605900453613

86 0.981587325392942

87	0.963481964804764
87	0.574022660713879
98	0.520664320502449
111	0.502845536901831
113	0.473934991897074
121	0.472049336943572
128	0.412379746891528
145	0.409270056499232
147	0.400547180420607
153	0.385960228779121
162	0.381482115296014
173	0.372499966096731
179	0.371623803461166
181	0.366909111068162
190	0.365199662932307
191	0.361237784765538
194	0.354194019111489
202	0.35368053070398
204	0.352911462111164
205	0.348892741937748
207	0.340481958506986
213	0.340214130720126
214	0.334841382292648
219	0.333227160184719
221	0.330427121189481

235	0.328446769805704
245	0.327567821737157
245	0.324899733028453
259	0.324792324389281
259	0.324635015854815
262	0.323423387387595
264	0.323371611726125
265	0.323004134300905
272	0.322443832815773
273	0.318402939563213
277	0.318106440919681
283	0.318032882772405
287	0.316572176251734
301	0.31568608250998
305	0.315250580141208
307	0.315052093232892
320	0.314749534983412
330	0.314146522399453
344	0.31412914188312
345	0.314110005462194
346	0.313923230540849
356	0.313911473701743
357	0.31381073132968
359	0.31362554054876
362	0.313533191357771

365	0.313381389511761
372	0.313259552822642
387	0.313252304494162
390	0.313245365308822
391	0.313179830785543
393	0.313139703363178
400	0.31308999789782
404	0.313025299130059
416	0.313022146740191
420	0.313017523849111
421	0.312997070335266
421	0.312971861077856
426	0.312951760422487
436	0.312950178276168
440	0.312946049788794
441	0.312932072362674
447	0.31293062642273
450	0.312927551480303
451	0.312922761268858
454	0.312922108345328
454	0.312920110950597
456	0.312908588430196
462	0.312904915982267
463	0.312898478887275
468	0.312887958139993

474	0.312887455694491
476	0.312884871366855
480	0.312882609800718
481	0.312881436191193
481	0.312878985539105
486	0.312869584194411
492	0.312867270124128
501	0.312866960978955
502	0.312865089027428
510	0.312864818516694
515	0.312862183934387
516	0.312861300945411
520	0.312860794328945
527	0.312860350725258
527	0.31286001222696
527	0.312858104085019
532	0.312857788874163
538	0.31285757465584
541	0.312856888193489
546	0.312855924958634
549	0.312855837210713
555	0.312855542464724
561	0.312854981108775
564	0.312854337134403
569	0.312853785880916

577	0.312853416021437
579	0.312853061068107
584	0.312853033214116
585	0.312852824526113
587	0.31285241428097
597	0.312852051731722
610	0.312851975292924
613	0.312851837106181
615	0.312851767930452
621	0.312851360950807
631	0.312851215914893
640	0.312851148693063
646	0.312851051881827
650	0.312851032692299
656	0.312850951899063
656	0.312850950369731
658	0.31285092905788
659	0.312850905080392
669	0.312850864611194
670	0.312850846994986
672	0.312850844192721
673	0.312850837909894
675	0.312850833015325
676	0.312850823564954
676	0.312850791324735

677	0.312850781607151
677	0.312850772748745
685	0.312850721057614
686	0.312850705134674
693	0.312850692859863
695	0.312850690982155
695	0.31285068940218
699	0.312850688674777
700	0.312850672824134
702	0.312850662333886
702	0.312850650808063
706	0.312850646298275
707	0.312850639592935
709	0.312850634294505
715	0.312850629430805
718	0.3128506132909
718	0.31285060088341
725	0.312850598577187
727	0.312850582499246
739	0.312850580303973
742	0.312850565310585
746	0.312850562484535
751	0.312850549097751
761	0.312850548956123
770	0.312850546043562

778	0.312850545495795
783	0.312850540878854
792	0.31285053794706
799	0.312850535856546
800	0.312850534629902
809	0.31285053322274
812	0.312850532560839
816	0.312850532210845
824	0.312850531852691
827	0.31285053151129
834	0.312850530788814
839	0.312850530716586
845	0.312850530161692
847	0.312850529672601
849	0.312850529633634
854	0.312850529466335
859	0.312850529435744
859	0.312850529093618
862	0.312850529072373
866	0.31285052889175
869	0.312850528788637
870	0.312850528698465
870	0.312850528612644
873	0.312850528567668
877	0.312850528415089

881	0.31285052832405
885	0.312850528262088
892	0.312850528081678
895	0.312850528056924
900	0.312850527920471
901	0.312850527854843
912	0.312850527761568
918	0.312850527709585
924	0.31285052761805
925	0.312850527559172
928	0.312850527458994
934	0.312850527453372
934	0.312850527381904
945	0.31285052732503
946	0.312850527306803
951	0.312850527285635
963	0.31285052726789
968	0.312850527249238
969	0.312850527231976
972	0.312850527222027
974	0.312850527219477
974	0.312850527180039
981	0.312850527179394
981	0.31285052716472
986	0.31285052716172

988	0.312850527153461
995	0.312850527148441
995	0.312850527144843
995	0.312850527104489
1017	0.312850527098958
1021	0.312850527092664
1022	0.312850527081836
1026	0.312850527070212
1038	0.31285052706111
1041	0.312850527060595
1047	0.31285052706051
1048	0.312850527057545
1049	0.312850527054915
1051	0.312850527054514
1053	0.312850527053052
1055	0.312850527051339
1056	0.312850527050374
1057	0.312850527050012
1059	0.312850527046963
1060	0.312850527043464
1071	0.312850527042735
1072	0.312850527040317
1074	0.312850527038792
1078	0.312850527033547
1085	0.312850527032841

1087	0.312850527032298
1092	0.312850527029165
1094	0.31285052702521
1114	0.312850527023804
1123	0.312850527023022
1142	0.312850527022726
1143	0.312850527022287
1145	0.312850527022038
1154	0.312850527021895
1155	0.312850527021844
1157	0.312850527021728
1158	0.312850527021413
1161	0.312850527021168
1164	0.312850527021018
1165	0.312850527020835
1167	0.312850527020104
1173	0.312850527020092
1173	0.31285052701926
1185	0.312850527019164
1188	0.312850527019157
1188	0.312850527019125
1190	0.312850527019125
1192	0.312850527019095
1193	0.312850527019015
1197	0.312850527018881

1198	0.312850527018766
1203	0.312850527018752
1206	0.312850527018733
1210	0.312850527018706
1212	0.312850527018654
1218	0.312850527018599
1223	0.312850527018534
1225	0.312850527018493
1231	0.312850527018428
1237	0.3128505270184
1242	0.312850527018343
1246	0.312850527018317
1253	0.312850527018274
1259	0.312850527018212
1259	0.312850527018195
1262	0.312850527018171
1268	0.31285052701817
1270	0.312850527018148
1272	0.312850527018129
1274	0.312850527018089
1279	0.312850527018078
1279	0.312850527018078
1283	0.312850527018061
1284	0.312850527018044
1289	0.312850527017988

1303	0.31285052701798
1303	0.312850527017978
1305	0.312850527017973
1307	0.312850527017964
1308	0.312850527017954
1313	0.312850527017941
1322	0.312850527017938
1327	0.312850527017937
1328	0.312850527017936
1330	0.312850527017924
1335	0.312850527017922
1335	0.312850527017919
1338	0.312850527017917
1340	0.312850527017912
1345	0.312850527017911
1346	0.31285052701791
1347	0.312850527017905
1351	0.312850527017904
1353	0.312850527017894
1358	0.312850527017893
1360	0.31285052701789
1365	0.312850527017888
1370	0.312850527017883
1375	0.312850527017879
1380	0.312850527017874

1393 0.312850527017871

1401 0.312850527017869

1421 0.312850527017869

1426 0.312850527017869

1431 0.312850527017869

1431 0.312850527017869

1432 0.312850527017867

1460 0.312850527017867

1466 0.312850527017867

1471 0.312850527017867

1476 0.312850527017866

1483 0.312850527017865

1516 0.312850527017865

1547 0.312850527017864

1557 0.312850527017864

1561 0.312850527017864

1564 0.312850527017864

1570 0.312850527017864

1599 0.312850527017864

5000

DE stopped.

Fuzzy LAMBDA = [3.59896476396572, 5.14605236150391, 7.08349591173713]

Fuzzy Eigen Vectors = [0.98021 1.00000 1.19852] [2.83861 3.23272 3.62010] [2.46467 2.54011 2.89949] [1.52681 1.59223 1.89307] [0.71277 0.71277 0.71277]

Correctness Check:

A*X =

[3.52774 5.14594 8.48971] [10.21605 16.63572 25.64297] [8.87025 13.07148 20.53854] [5.49494 8.19362 13.40958] [2.74703 3.66779 6.11763]

Lambda*X =

[3.52774 5.14605 8.48971] [10.21605 16.63576 25.64297] [8.87025 13.07153 20.53854] [5.49494 8.19370 13.40958] [2.56525 3.66797 5.04893]

```
// Crisp eigenvalues and eigenvectors

public class ExNumber
{
        double value;
        //public
        public double Value{ get{ return value; } }

        public ExNumber(double x)
        {
```

```
    value= x;
}

public static implicit operator ExNumber(double x)
{
    return new ExNumber(x);
}

public static explicit operator double(ExNumber x)
{
    return x.ToDouble();
}

public static bool operator<(ExNumber x1, ExNumber x2)
{
    return x1.Value<x2.Value;
}

public static bool operator<=(ExNumber x1, ExNumber x2)
{
    return x1.Value<=x2.Value;
}

public static bool operator>(ExNumber x1, ExNumber x2)
{
```

```
        return x1.Value>x2.Value;
}

public static bool operator>=(ExNumber x1, ExNumber x2)
{
        return x1.Value>=x2.Value;
}

public static ExNumber Min(ExNumber x1, ExNumber x2)
{
        return (x1<=x2)? x1 : x2;
}

public static ExNumber Max(ExNumber x1, ExNumber x2)
{
        return (x1<=x2)? x2 : x1;
}

public static ExNumber operator+(ExNumber a, ExNumber b)
{
        return new ExNumber(a.Value+b.Value);
}

public static ExNumber operator-(ExNumber a, ExNumber b)
{
```

```
        return new ExNumber(a.Value-b.Value);
}

public static ExNumber operator*(ExNumber a, ExNumber b)
{
        return new ExNumber(a.Value*b.Value);
}

public static ExNumber operator/(ExNumber a, ExNumber b)
{
        return new ExNumber(a.Value/b.Value);
}

public double ToDouble()
{
        return Value;
}

public override string ToString()
{
        return Value.ToString();
}

public string ToString(string format)
{
```

```
        return Value.ToString(format);
    }
}

public class Eigen//: DE.Problem
{

    public static ExNumber[] Multiply(ExNumber[,] a, ExNumber[] x, int n)
    {
        ExNumber[] col= new ExNumber[n];
        for(int i= 0; i<n; i++){
            col[i]= 0.0;
            for(int j= 0; j<n; j++) col[i]+= a[i,j]*x[j];
        }
        return col;
    }

    public static ExNumber[] Multiply(ExNumber lambda, ExNumber[] x, int
n)
    {
        ExNumber[] col= new ExNumber[n];
        for(int i= 0; i<n; i++) col[i]= lambda*x[i];
        return col;
    }
```

```
static double Distance(ExNumber[] a1, ExNumber[] a2, int n)
{
    double dis= 0.0;
    for(int i= 0; i<n; i++){
        double diff= (a1[i]-a2[i]).ToDouble();
        dis+= diff*diff;
    }
    return dis;
}

static ExNumber[,] DetMatrix(ExNumber[,] x, int n, int c)
{
    int k= 0;
    int l= 0;
    ExNumber[,] y= new ExNumber[n-1,n-1];
    for(int i= 1; i<n; i++){
        l= 0;
        for(int j= 0; j<n; j++){
            if(j==c) continue;
            y[k,l]= x[i,j];
            l++;
        }
        k++;
    }
    return y;
```

```
}

public static ExNumber Determinant(ExNumber[,] x, int n)
{
    if(n==1) return x[0,0];
    if(n==2) return x[0,0]*x[1,1]-x[0,1]*x[1,0];
    if(n==3) return
        x[0,0]*Determinant(DetMatrix(x, n, 0), n-1)-
        x[0,1]*Determinant(DetMatrix(x, n, 1), n-1)+
        x[0,2]*Determinant(DetMatrix(x, n, 2), n-1);
    if(n==4) return
        x[0,0]*Determinant(DetMatrix(x, n, 0), n-1)-
        x[0,1]*Determinant(DetMatrix(x, n, 1), n-1)+
        x[0,2]*Determinant(DetMatrix(x, n, 2), n-1)-
        x[0,3]*Determinant(DetMatrix(x, n, 3), n-1);
    if(n==5) return
        x[0,0]*Determinant(DetMatrix(x, n, 0), n-1)-
        x[0,1]*Determinant(DetMatrix(x, n, 1), n-1)+
        x[0,2]*Determinant(DetMatrix(x, n, 2), n-1)-
        x[0,3]*Determinant(DetMatrix(x, n, 3), n-1)+
        x[0,4]*Determinant(DetMatrix(x, n, 4), n-1);
    return 0;
}

public double EigenValueDECost(double[] x)
```

```
{
        EigenValueDELoad(x);
        ExNumber[,] A_= new ExNumber[N,N];
        for(int i= 0; i<N; i++){
                for(int j= 0; j<N; j++){
                        if(i==j) A_[i,i]= A[i,i]-Lambda;
                        else A_[i,j]= A[i,j];
                }
        }
        double det= Determinant(A_, N).ToDouble();
        return det*det-100*Lambda.ToDouble();
}

void EigenValueDELoad(double[] x)
{
        Lambda= new ExNumber(x[0]);
}

public double EigenVectorDECost(double[] x)
{
        EigenVectorDELoad(x);
        ExNumber[,] A_= new ExNumber[N,N];
        for(int i= 0; i<N; i++){
                for(int j= 0; j<N; j++){
                        if(i==j) A_[i,i]= A[i,i]-Lambda;
```

```
                    else A_[i,j]= A[i,j];
            }
        }
        ExNumber[] Z= Multiply(A_, X, N);
        double s= 0.0;
        for(int i= 0; i<N; i++) s+= (Z[i]*Z[i]).ToDouble();
        return s;
}

void EigenVectorDELoad(double[] x)
{
        X[0]= new ExNumber(1.0);
        for(int i= 1; i<N; i++) X[i]= new ExNumber(x[i-1]);
}

public ExNumber[,] A;
int N;

public Eigen(ExNumber[,] a, int n)
{
        A= a;
        N= n;
        //NPars= 1;
        X= new ExNumber[N];
}
```

```
public ExNumber[] X;
public ExNumber Lambda;

public void FindEigenVal()
{
    DE.Problem dep1= new DE.Problem(EigenValueDECost, 1);
    dep1.Optimize(
        10000,
        new DE.AdaptiveControls(),
        new DE.RandStrategy(),
        new DE.Ranges(new double[]{ 0, 0, 0, 0, 0 }, new double[]{
10, 10, 10, 10, 10 })
    );
    //
    EigenValueDELoad(dep1.Solution);
    //
    DE.Problem dep2= new DE.Problem(EigenVectorDECost, N-1);
    dep2.Optimize(
        10000,
        new DE.AdaptiveControls(),
        new DE.RandStrategy(),
        new DE.Ranges(new double[]{ 0, 0, 0, 0, 0 }, new double[]{
10, 10, 10, 10, 10 })
    );
```

```
                EigenVectorDELoad(dep2.Solution);
        }

}
class Program
{
        static void Main()
        {
                ExNumber[,] A= {
                        { new ExNumber(1), new ExNumber(1.0/3.0), new ExNumber(1.0/3.0), new ExNumber(1.0/2.0), new ExNumber(2) },
                        { new ExNumber(3), new ExNumber(1), new ExNumber(2), new ExNumber(2), new ExNumber(3) },
                        { new ExNumber(2), new ExNumber(1.0/2.0), new ExNumber(1), new ExNumber(3), new ExNumber(3) },
                        { new ExNumber(2), new ExNumber(1.0/2.0), new ExNumber(1.0/3.0), new ExNumber(1), new ExNumber(3) },
                        { new ExNumber(1.0/2.0), new ExNumber(1.0/3.0), new ExNumber(1.0/3.0), new ExNumber(1.0/3.0), new ExNumber(1) }
                };

                Eigen e= new Eigen(A, 5);
                e.FindEigenVal();
                System.Console.WriteLine("MAX LAMBDA = "+e.Lambda);
```

```
System.Console.WriteLine("Eigen Vector = "+e.X[0]+"\t"+e.X[1]+"\t"+e.X[2]+"\t"+e.X[3]+"\t"+e.X[4]);
System.Console.WriteLine("\nCorrectness Check:");
System.Console.WriteLine(
    "A*X =\n"+
    Eigen.Multiply(e.A, e.X, 5)[0].ToString("0.00000")+"  "+
    Eigen.Multiply(e.A, e.X, 5)[1].ToString("0.00000")+"  "+
    Eigen.Multiply(e.A, e.X, 5)[2].ToString("0.00000")+"  "+
    Eigen.Multiply(e.A, e.X, 5)[3].ToString("0.00000")+"  "+
    Eigen.Multiply(e.A, e.X, 5)[4].ToString("0.00000")
);
System.Console.WriteLine(
    "Lambda*X =\n"+
    Eigen.Multiply(e.Lambda, e.X, 5)[0].ToString("0.00000")+"  "+
    Eigen.Multiply(e.Lambda, e.X, 5)[1].ToString("0.00000")+"  "+
    Eigen.Multiply(e.Lambda, e.X, 5)[2].ToString("0.00000")+"  "+
    Eigen.Multiply(e.Lambda, e.X, 5)[3].ToString("0.00000")+"  "+
    Eigen.Multiply(e.Lambda, e.X, 5)[4].ToString("0.00000")
);
System.Console.ReadKey();
```

Fuzzy LAMBDA = [3.59896476396572, 5.14605236150391, 7.08349591173713]

Fuzzy Eigen Vectors = [0.98021 **1.00000** 1.19852] [2.83861 **3.23272** 3.62010] [2.46467 **2.54011** 2.89949] [1.52681 **1.59223** 1.89307] [0.71277 **0.71277** 0.71277]

Criteria weights are found by normalizing eigenvectors using the following formula:

$$Z = \frac{X - X\,min}{X\,max - X\,min} \quad (3)$$

Normalized Fuzzy Eigenvectors =

[0.125804 0.113982 0.437662], [1.00000 1.00000 1.00000]

[0.82410 0.725149 0.75214028] [0.3829263 0.348999 0.4059739] [0.00000 0.00000 0.00000]

The calculated fuzzy criteria weights are indicated in table 2, which presents the overall fuzzy decision matrix. Alternatives are evaluated according to the preidentified criteria. Normalized criteria weights show the importance of each criterion. Here the criteria 2-price is the most important one because of the pandemic outbreak, companies try to gain more profit with the lowest possible cost, as the customers. Also, purchasing power has decreased and, consumers spend less money to save more. Place which is criteria 3 is the second important criteria (according to subjective thoughts and experience of DM) as the pandemic outbreak force many stores to close up. Virtual places instead of brick and mortars are the inevitable marketing solutions. (For example; IKEA, you can take store into your house with a single application.)

	C_1-product	C_2-price	C_3-place	C_4-promotion	C_5-targeting
w	0.095	0.433	0.329	0.165	0.00
a_1 - AI	0.7, 0.8, 0.9	0.7, 0.8, 0.9	0.2,0.3, 0.4	0.6, 0.7, 0.8	0.7, 0.8, 0.9
a_2 - IoT	0.8, 0.9, 1	0.4, 0.5, 0.6	0.4, 0.5, 0.6	0.5, 0.6, 0.7	0.6, 0.7, 0.8
a_3- VR/AR	0.5, 0.6, 0.7	0.0, 0.1, 0.2	0.7, 0.8, 0.9	0.8, 0.9, 1	0.2,0.3, 0.4

Table 2: Fuzzy decision matrix

Accordingly, fuzzy normalized decision matrix is constructed in table 3. Moreover, FPIS (Fuzzy Positive Ideal Solution) a^*, and FNIS (Fuzzy Negative Ideal Solution) a^-, solutions are identified using TOPSIS approach as in table 4.

	C_1-product	C_2-price	C_3-place	C_4-promotion	C_5-targeting
a_1 - AI	0.07, 0.08 0.09	0.301, 0.344, 0.387	0.064, 0.096, 0.128	0.102, 0.119, 0.136	0.00, 0.00, 0.00
a_2 - IoT	0.08, 0.09, 0.1	0.172, 0.215, 0.258	0.128, 0.16, 0.192	0.085, 0.102, 0.119	0.00, 0.00, 0.00
a_3-VR/AR	0.05, 0.06, 0.07	0.0, 0.043, 0.086	0.224, 0.256, 0.288	0.136, 0.153, 0.017	0.00, 0.00, 0.00

Table 3: Fuzzy normalized decision matrix

	C_1-product	C_2-price	C_3-place	C_4-promotion	C_5-targeting
a^*	0.08, 0.09, 0.1	0.301, 0.344, 0.387	0.224, 0.256, 0.288	0.136, 0.153, 0.017	0.00, 0.00, 0.00
a^-	0.05, 0.06, 0.07	0.0, 0.043, 0.086	0.064, 0.096, 0.128	0.085, 0.102, 0.119	0.00, 0.00, 0.00

Table 4: Fuzzy positive ideal and negative ideal solutions

Closeness of each alternative to the fuzzy positive ideal solution is calculated as:

$$C_1^* = S_1^- / (S_1^* + S_1^-) \qquad (4)$$

Alternatives	S_i^*	S_i^-	CC_i	Ranking
$a_1 - AI$	0.244	0.338	0.58	1
$a_2 -$ IoT	0.297	0.266	0.47	2
$a_3 -$ VR/AR	0.331	0.232	0.41	3

Table 5: Closeness coefficient of each alternative and ranking

As a consequence, AI is the best digital marketing technique to be used with the achieved results. The last necessary selection may be AR/VR, but during pandemic outbreak these techniques may also be useful to reach the consumers. Results are shown as; $a_1 > a_2 > a_3$.

DISCUSSION AND CONCLUSION

Digital marketing has become a crucial component of marketing strategies. In this study, the existing literature on fuzzy logic in relation to digital marketing is examined. The fundamental problem with the reviewed literature is the lack of data certainty and reliability. As a result, a method for decision-making connected to digital marketing usage is proposed in this study for future practices. By taking into account the uncertainty of the decision-making environment, the suggested method may improve the decision-making capability of experts or DMs in a more robust and certain way.

Why to use fuzzy logic in decision making (business management) in this research? Fuzzy logic is highly close to human logic and because most of the times problems are solved through human judgement fuzzy approach is more appropriate to use in decision making process. Decision makers and expert managers could use the fuzzy logic to make effective and efficient decisions as this logic is very close to human logic. Besides, fuzzy logic enables DM to make marketing decisions of an organization to enhance, understand and take actions for better decision makings to gain a competitive advantage over rivals. Organizations could take this advantage to establish long-term relationship with their customers by increasing two-way communication, loyalty and customer satisfaction and so increase their profit and revenue accordingly.

As the digital marketing becomes more useful, it is a crucial decision to select an important digital marketing technology. In this study, AI is selected as an optimal technique that precedes IoT and AR/VR, respectively.

The main problem related to simple AHP, TOPSIS, ELECTRE, or CORPAS methods is the uncertainty of the considered variables and the ignored reliability and the perfectness of the information given.

Here, the use of a hybrid method which is based on fuzzy and TOPSIS approaches is proposed. By taking into consideration the uncertainty or vagueness in the decision making environment, especially with such strategic marketing decisions regarding the pandemic outbreak, fuzzy is one of the optimal ways to weight the criteria given for selecting the best alternative. Besides, alternatives are evaluated and selected using the TOPSIS method by providing the ideal positive and ideal negative solutions.

The ideal positive solution maximizes benefit criteria while minimizing cost criteria, as for ideal negative solution maximizes cost while minimizing benefit criteria (Roszkowska, 2011). The chosen alternative should have the smallest distance to the Positive Ideal Solution (PIS) (the solution that minimizes the cost criteria while maximizing the benefit criteria) and the greatest distance to the Negative Ideal Solution (NIS). Chen enhanced TOPSIS with triangular fuzzy numbers to compute the distance between two triangular fuzzy numbers, and fuzzy TOPSIS is established. Fuzzy TOPSIS, which is one of the Multi-Criteria Decision Making methods (MCDM), ranks the alternatives based on relative similarity with the ideal solution. There are many reasons for the using of fuzzy TOPSIS method in this study. Because of its simplicity, computational efficiency, and especially the ability to deal with the uncertainty, or imperfect information given the using of the fuzzy TOPSIS method for alternative evaluation and ranking is proposed. As a result, combination of these two MCDM methods will provide a more robust decision making ability for the decision makers who try to find the optimal digital marketing tool for their companies to increase the efficiency and effectiveness of the marketing and organizational decisions. The chosen alternative digital marketing tool should have the smallest distance to the Fuzzy Positive Ideal Solution (FPIS) (the solution that minimizes the cost criteria while maximizing the benefit criteria) and the greatest distance to the Fuzzy Negative Ideal Solution (FNIS).

The results can be compared with the research based on Z-numbers instead of fuzzy. Here, it can be stated that the achieved results are similar which also confirm that the solution is reliable (Research is given with the same criteria and alternatives but with different solution method based on Z-numbers).

Future researches may involve different criteria and alternatives for different purposes of different companies.

Limitations

In our study the using only three main digital marketing techniques as the alternatives in order to ease the process is preferred. Similarly, only five criteria are mentioned which can be further extended. Last but not least, the given criteria weights are based on the intuition and experience of decision makers, so, this can also be considered as a limitation.

Recommendations

The increasing the number of alternatives for the future researches is proposed, because, more alternatives provide more accurate decisions. Furthermore, the number of criteria and decision makers or experts to provide better aggregated decisions could be increased. Also, for future researches trapezoid fuzzy number can be used (scale with 4 fuzzy numbers). Lastly, more than one decision maker can be used such as group decision making which is compatible with fuzzy TOPSIS.

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