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# Managing Metaverse Marketing Challenges Considering Service Quality Model: Application of Intuitionistic Fuzzy Decision Support System

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**ABSTRACT**

This study aims to explore the application of advanced decision-making frameworks for identifying and prioritizing marketing challenges in the Metaverse, with a focus on the real estate sector. It examines the integration of innovative methodologies to enhance service quality and customer experience within virtual environments. The research adopts a novel ARAS-FUCOM-SERVQUAL methodology to systematically evaluate and rank Metaverse marketing challenges. Data were collected from a cohort of international real estate agents using intuitionistic triangular fuzzy numbers to assess SERVQUAL (Service Quality) dimensions. The study employs multi-criteria decision-making (MCDM) techniques to analyze and validate the collected data, ensuring robust prioritization of the challenges. The findings reveal ten critical marketing challenges in the Metaverse, including interoperability, data privacy, customer engagement, and regulatory complexities. The results demonstrate the effectiveness of the ARAS-FUCOM-SERVQUAL framework in providing actionable insights for strategic planning and resource allocation. Key managerial recommendations are proposed to address these challenges and optimize marketing strategies in virtual environments. This research introduces an innovative combination of the Additive Ratio Assessment System (ARAS) and the Full Consistency Method (FUCOM) with SERVQUAL dimensions, tailored to the Metaverse context. It highlights the potential of these methodologies to bridge the gap between traditional service quality assessments and the evolving requirements of marketing in virtual environments. The study offers a comprehensive framework for addressing the complexities of Metaverse marketing, particularly in the dynamic real estate industry.

## 1. Introduction

The concept of the Metaverse has gained significant traction since its introduction in Neal Stephenson's 1992 novel Snow Crash [1]. Initially described as a black, spherical planet accessed

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through virtual reality terminals, the Metaverse has evolved into a broader vision for the future of the internet [2]. Hofman [3] defines the Metaverse as the convergence of the digital and physical realms facilitated by a combination of technologies, including virtual reality (VR), augmented reality (AR), blockchain, artificial intelligence, and the Internet of Things (IoT). Lovich [4] further clarifies the Metaverse as a blend of VR and mixed reality (MR) worlds, accessible through browsers or headsets, enabling real-time interactions and experiences across distances. This surge in interest surrounding the Metaverse, particularly since 2020 with the backing of major technology companies like Facebook [5], can be attributed to its potential to create a three-dimensional virtual world inhabited by avatars – essentially, a computer-mediated environment for social interaction within immersive, 360-degree virtual spaces.

The Metaverse presents itself as an interactive, collaborative virtual environment fostering real-time interactions between individuals or their avatars. This amalgamation of VR and AR technologies allows for multimodal interactions with digital products, virtual settings, and other users [6]. Marketers are particularly interested in the potential of the Metaverse, recognizing the opportunities it offers alongside the inherent challenges [6]. The vast amount of data and information generated within the Metaverse presents a valuable resource for optimizing marketing strategies and improving customer service quality. However, this potential comes with its own set of challenges, including concerns around user privacy and data consent, as well as disparities in consumer access to the necessary technologies [7]. Recognizing and addressing these challenges is crucial for organizations planning to enter the Metaverse and implement effective marketing strategies. This global trend towards the Metaverse signifies a shift towards interconnected digital spaces where users interact through computer-generated environments [8]. Once a concept confined to the realm of science fiction, the Metaverse is rapidly emerging as a significant technological frontier, blurring the lines between virtual and physical realities.

Metaverse marketing in real estate is distinct due to its reliance on spatial and visual experiences. Unlike industries such as retail or entertainment, where products or services are often intangible, real estate marketing requires potential buyers to experience the physicality of properties. The metaverse allows for immersive virtual tours and 3D visualizations, which are essential in real estate but less critical in other sectors [8].

Additionally, real estate decisions are often emotionally driven, with consumers forming strong attachments to properties, making trust and assurance critical. Other industries, such as digital retail, typically don't involve such high-stakes, emotional investments [9].

Service quality, as defined by Crosby [10], refers to the act of tailoring products or services to meet the specific needs of customers. In the dynamic residential property market, service quality plays a critical role, benefiting brokers, customers, and the entire industry . By implementing effective customer satisfaction evaluation methods, companies can gain valuable insights that lead to improved customer service and satisfaction within the real estate sector. The emergence of the Metaverse in real estate marketing necessitates a reevaluation of traditional service quality paradigms. Existing service quality assessment measures fail to account for the unique characteristics of the virtual landscape. To enhance customer experience and build trust within the Metaverse, organizations must develop innovative metrics specifically designed for this digital domain. A key question remains: how can organizations strategically optimize their approach to marketing service quality in the face of emerging challenges? Data analytics, privacy concerns, and technology accessibility are all critical aspects that need to be addressed.

The real estate industry faces unique challenges, particularly in the context of marketing, where physical space and visual experiences are crucial for engaging potential buyers. The emergence of the metaverse offers an opportunity to overcome these barriers by enabling immersive virtual tours and interactive experiences [8]. Unlike other sectors, real estate marketing heavily relies on spatial and emotional factors, making it an ideal case for exploring how digital technologies can transform service delivery. Additionally, trust and responsiveness are key concerns in real estate transactions, which are addressed through the SERVQUAL model, ensuring that virtual interactions can foster customer confidence [10, 11]. The integration of AI and data analytics further allows for highly personalized services, meeting the expectations of real estate consumers [12]. By focusing on real estate, this study highlights the significant potential of the metaverse in addressing industry-specific challenges and improving consumer management [9, 13].

Multi-Criteria Decision-Making (MCDM) techniques are now critical to help in achieving decision outcomes due to these complex decision problems which have several, frequently conflicting criteria. They have been utilized throughout the spectrum of areas such as: military decision-making, engineering design, logistics, healthcare, and sustainability assessments. For example, new research on sophisticated MCDM frameworks in a military setting has already been conducted to inform tactical and strategic decisions based on strict performance requirements and uncertainty [14]. The increasing use of MCDM approaches demonstrates their functionalities to design problem structures or to introduce expert judgment in the decision-making process and thus to provide systematic evaluation and to be transparent in the evaluation process.

Real-world decision making involves uncertain, ambiguous, and partially comprehended information. These complications are rarely captured in traditional decision models, so fuzzy, intuitionistic fuzzy, and hyper-fuzzy theories are introduced into MCDM models. Such approaches improve and make decision-makers able to predict vagueness and hesitation in a realistic manner [15]. Here, the intuitionistic fuzzy sets are also of great interest, as they enable simultaneous consideration of the membership, non-membership, and hesitation degrees, and thus yield a more holistic structure for uncertainty assessment. Fitting into the uncertainty and dynamic trends of the new digital environment, namely the Metaverse, this study will address the need of combining MCDM methodologies with the most contemporary uncertainty modeling techniques.

In recent years, multi-criteria decision-making (MCDM) techniques such as FUCOM and ARAS have been extended to various complex decision situations, which have shown that they are robust against qualitative as well as quantitative criteria. Pamučar *et al.,* [16] proposed the Full Consistency Method (FUCOM), attracted considerable attention because it is capable of producing consistent, consistent criteria weights with fewer pairwise comparisons. For instance, Stević *et al.,* [17] used an adapted ABC–FUCOM model for product classification in which its efficiency in eliminating variability is demonstrated over prior weighting. So too and in transportation strategy, risk analysis and supplier selection problem, FUCOM successfully is used, evidencing its flexibility in various decision environments. In contrast, the Additive Ratio Assessment (ARAS) method, by Zavadskas and Turskis [18], has been widely used for ranking alternatives in engineering, management and sustainability decision problems.

The importance of ARAS comes from the fact that it possesses a logic and assesses alternatives based on utility degree, making it suitable for real-life applications with multiple at odds with criteria. Previous reports have used Applying ARAS in construction project assessment, energy management, and logistics optimization have shown its efficacy in achieving stable, interpretable rankings. Hybrid MCDM frameworks based on FUCOM and ARAS are more recently proposed to exploit the best features of both models, given the uncertainty and complexity of environments. These combined methods are known to improve decision accuracy and predictability when integrated with fuzzy or intuitionistic fuzzy extensions. But while they are increasingly popular in engineering and operations research, their relevance in new digital environments, such as Metaverse marketing, remains limited. This gap in expertise drives the current study to apply a hybrid framework of FUCOM-ARAS within an intuitionistic fuzzy framework to address the market in Metaverse to meet challenging and uncertain marketing challenges.

### *1.1 Practical and Methodological Aims of the Study*

Service quality is crucial in the dynamic real estate brokerage sector, characterized by rapid and constant changes in the residential real estate market. Agents and the industry directly benefit from soliciting and obtaining service quality information [19]. SERVQUAL is a crucial aspect of marketing in the Metaverse, a virtual reality space where users interact with virtual representations of properties and engage in transactions. This paper explores the importance of service quality in the marketing metaverse of real estate and the challenges faced by organizations in improving it by choosing SERVQUAL's five dimensions as decision criteria while prioritizing metaverse marketing challenges. The Metaverse provides an unusual context in which clients get to experience virtual representations of properties and interact in virtual transactions. Organizations should, therefore, provide outstanding SERVQUAL in order to improve customer experiences and create trust within the virtual world.

Nevertheless, achieving service excellence in the Metaverse comes with unique challenges. Firms need to modify their current SERVQUAL models for the Internet, come up with new metrics and measuring methods, and address technology-related issues such as system malfunctions like technical glitches and latency, among other performance problems. Another problem is to build trust and credibility within the Metaverse. Given that this is a relatively new domain, customers might feel anxious about its authenticity and confidentiality when transactions are made. Organizations must make sure they have robust security measures and reveal key aspects employed to instill buyers' trust by overcoming negativity. To sum it up, SERVQUAL assumes paramount significance in the real estate marketing metaverse, particularly in an ever-changing, dynamic residential real estate landscape. Improving SERVQUAL has both short-term effects on homeowners or buyers and a long-lasting impact on making them realize that they are not just another number but that their concerns do count within the sector. Organizations can unlock the Metaverse's full potential as a robust marketing platform in the real estate sector when they make use of customer insights, technological advancements, and iterative improvements.

### *1.2 Motivation for Developing Intuitionistic Fuzzy Framework*

The triangular fuzzy number proves more effective in representing fuzzy problems than interval numbers. However, their application in intuitionistic fuzzy sets is relatively rare and provides an alternative way of handling information that is not precise or uncertain. Further research on intuitionistic fuzzy sets is warranted, given the complexities involved [20]. In this study, we deal with the Metaverse's complicated nature in the service industry, which is one of the most complicated segments of the business because of customer witnesses while providing service, so common decision-making approaches cannot satisfy the situation.

MCDM has become increasingly important in decision-making theories. In this paper, we employed the ARAS's ability to combine and balance qualitative and quantitative data with different metrics. This method is aimed at simplifying the decision-making process in Multi-attribute Decision Making (MADM), for instance, by mitigating and reducing effects caused by different measures used in measurements. A five-step ARAS method comprises formalizing the matrix of decisions, data normalization, calculation of the normalized weight matrix, determination of optimal function and utility degree, and derivation of final ranking. By employing a relative indicator (utility degree), the ARAS method seeks to streamline complex decision-making, identifying the "best" alternative while mitigating the influence of disparate measurement units. In the MADM field, the ARAS method has gained significant popularity because of its ease of use and efficiency. A typical problem in MCDM, such as deciding on a set of decision alternatives, consists of simultaneous examination of multiple decision criteria.

The ARAS approach assumes that the best alternative is characterized by its utility function value; hence, the overall relative efficiency of an alternative depends on the values and weights in terms of the main criteria for a project, whereas the value of utility functions implies its relative impact [21]. As in this paper, we buckle with a new concept of metaverse marketing, and we need to help managers decide which challenges are the most important ones to assign the central budget to; we need a trustworthy method for prioritizing numerous challenges extracted from the literature. This method needs the criteria weights as an input, so we applied FUCOM. The Full Consistency Method (FUCOM) was devised Pamučar *et al.,* [16] as an alternative to AHP (Analytical Hierarchy Process) and BWM (Best Worst Method) for criteria weighting. Its application has been explored in research by Nunić [22].

*1.3 Organization of the Study*

The other parts of this paper are sequenced as follows: The next part is an inclusive review of the existing literature on Metaverse marketing challenges, with a specific reference to the SERVQUAL model. In Section 3, we explain the methods used, emphasizing the application of the Intuitionistic triangular fuzzy number approach and the FUCOM-ARAS method. Section 4 then presents our findings in relation to these challenges, along with their implications. It further discusses how those results are significant (section four), linking the SERVQUAL model with the FUCOM-ARAS method, which is an effective metaverse marketing strategy. Finally, section five ends the paper by summarizing some disscotion, conclusions and suggesting what future studies can be done in this emerging field.

## 2. Methodology

In this study, a new ARAS-FUCOM-SERVQUAL technique has been creatively developed to improve the service quality assessment process. The unique benefits of this newly invented method are realized through a careful consideration of both input and output factors, which results in more precise and objective findings. The first step in the process is leveraging the advantages of the ARAS method. Firstly, criteria and alternatives are systematically identified using the ARAS approach. Expert and stakeholder opinions are then used as inputs in constructing a comprehensive decision matrix. Finally, the normalization of this matrix provides a scale for evaluation that is consistent enough. This allows for the Full Consistency Method (FUCOM), after which weights will be given to each criterion so that evaluations by process specialists can be made consistently.

The “FUCOM-ARAS” method was chosen for its efficiency in handling MCDM challenges, specifically in the complex environment of real estate marketing within the metaverse. Compared to other methods like “AHP (Analytical Hierarchy Process)”, which requires numerous pairwise comparisons that can become cumbersome, FUCOM-ARAS simplifies the weighting process and ensures consistency without excessive complexity [16]. Unlike “BWM (Best-Worst Method)”, which can introduce subjectivity, FUCOM-ARAS provides a balanced approach with fewer judgment errors, making it ideal for applications that demand both accuracy and simplicity in criteria evaluation [23]. This makes FUCOM-ARAS particularly suited to address the unique characteristics of real estate in a metaverse context.

The FUCOM approach is used to find weight values for these dimensions, hence ensuring that an evaluation procedure is reliable and consistent. This model incorporates systematic distinctions between consumer expectations and perceptions into the SERVQUAL model. Data handling capabilities prove how superior these combined techniques are over other methods such as those mentioned above since they have been modified accordingly by SERVQUAL approach, treating it like a black box that transforms customer's satisfaction score into quality gaps with respect to different dimensions but still retain its dimensionality structure while invoking certain assumptions about relationship patterns among items contained within specific dimensions such as tangibles or responsiveness. Diverse application is a characteristic of the methodology, whereas it has no limitation regarding some fields of study that are needed to carry out the research. Additionally, it is an appropriate way to assess the effectiveness and stage of selected firms through customer satisfaction, thus opening up avenues for improving strategic management. Like the methodology in that source, this established approach provides for its increased applicability and future use. It has a potential bearing on businesses, thus enhancing their overall efficiency in making strategic choices. More precise results are obtained when using these conventional quality measurement techniques as opposed to other ones because of the rigorous treatment of input factors, which guarantees a higher level of accuracy. Figure 1 Shows what the whole process should look like.

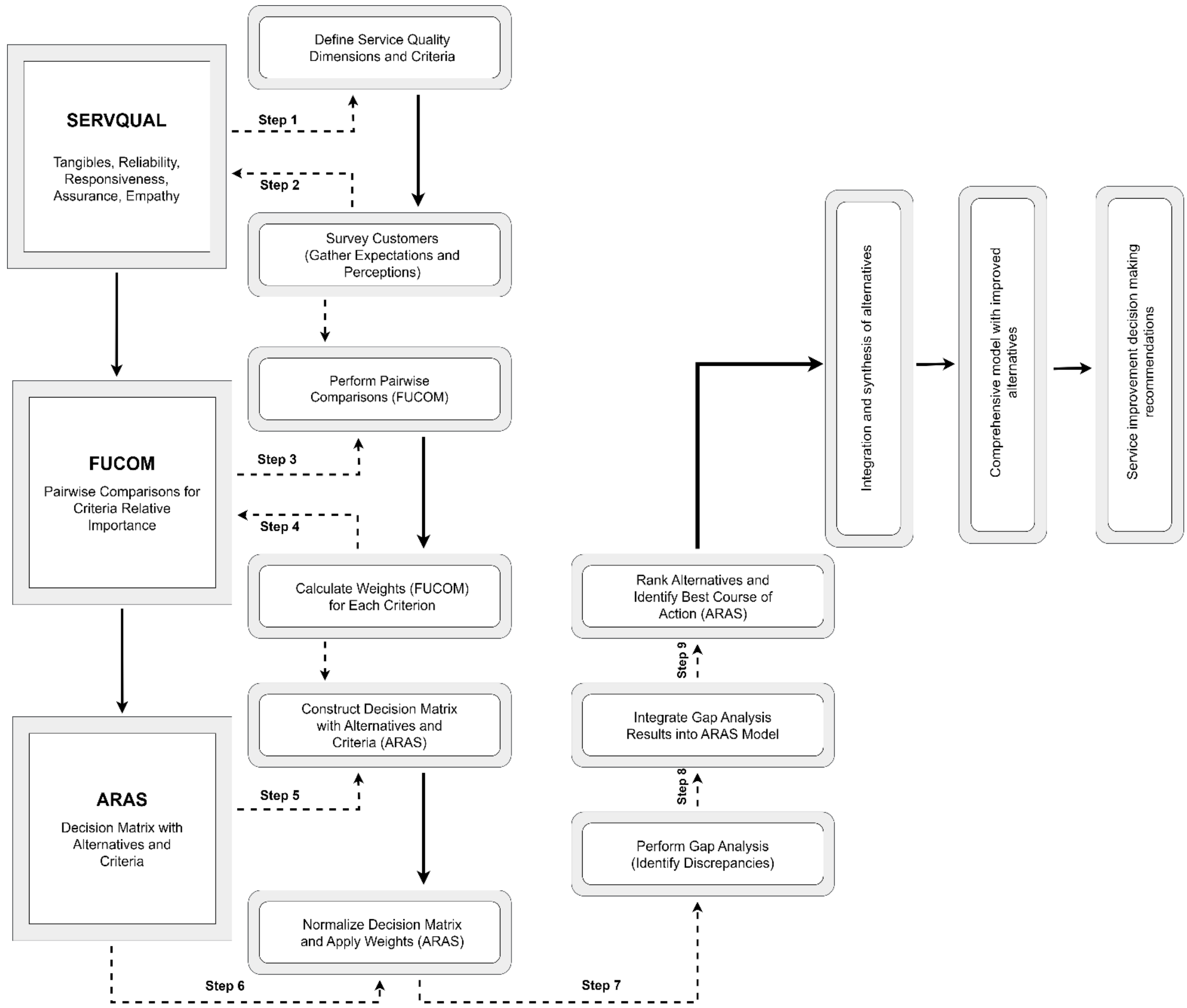


**Fig. 1.** ARAS-FUCOM SERVQUAL model flowchart

### *2.1 Preliminaries on challenges in the use of Metaverse*

The Metaverse's inception has given rise to considerable challenges in achieving interoperability, necessitating comprehensive solutions for integrating virtual environments developed by diverse entities with varying hardware and software tools. These challenges are categorized into technical, usage, and jurisdictional domains. Technical challenges encompass a range of issues, including network limitations, asset ownership, intellectual property protection, payments, identity verification, and concerns related to data privacy and security across both hardware and software. Usage interoperability challenges stress the need for a user-centric design to ensure global accessibility, inclusivity, and fairness across diverse demographics within the Metaverse. Jurisdictional interoperability challenges compound these issues, requiring the establishment of best practices and standards applicable across various industries, locations, and countries [8]. Critical technical issues involve variations in hardware, software, and network protocols, impeding effective communication between different virtual worlds and platforms. Ownership and control challenges arise due to conflicting rights concerning data, intellectual property, and governance structures. Jurisdictional disparities introduce additional impediments manifested in variations in user behavior and preferences, limiting usage interoperability. Active coordination with existing and emerging laws and paying attention to considerations and ethical principles such as user behavior and environmental responsibility are important and obvious to create and maintain the long-term success of consumer trust in the Metaverse [24]. Stakeholders engaged in metaverse development must address these multifaceted challenges, recognizing the imperative of balancing interoperability with concerns related to privacy, security, safety, and identity.

#### *2.1.1 Governance, Trust, and Privacy*

According to Yaqoob *et al.,* [8], there are interoperability issues with the Metaverse related to use, jurisdiction, and technology. Network constraints, asset ownership, safeguarding intellectual property, and security issues are examples of technical difficulties . Human-centric interoperability standards, teamwork, and putting well-being first are necessary to address them [8, 25].

#### *2.1.2 User Engagement and Experience*

The pleasure and charm of immersing and escaping from reality in Metaverse strongly attracts customers [26]. High-speed Internet, low latency, and scalable networks are necessary for real-time virtual reality experiences [27]. Managing multiple formats, synchronization, real-time rendering, and user experience optimization are some of the problems associated with user Engagement and Experience [28].

#### *2.1.3 Market Research and Cost*

To effectively market in the Metaverse, a thorough understanding of customer wants and preferences must be obtained via market research [29]. Additional expenditures are needed for technical resources like AR and VR, which might be difficult for Small and Medium Enterprises (SME)s [30]. Business models are challenged by the uncertainty surrounding customer spending patterns [29]. Businesses could find it challenging to translate metaverse experiences into tangible purchases, which would need them to conduct iterative experiments.

#### *2.1.4 Undesired Behaviors and Identity Vulnerability*

Identity theft, social engineering, and polarization are examples of metaverse security threats. Voice, video, and face recognition systems leave users open to assaults. The use of Metaverse technology to steal identities and Deviant behaviors like harassment, racism, and hate speech presents serious difficulties. User behavior, digital literacy, and privacy laws must all be prioritized in order to allay these worries [8].

### *2.1.5 Data and Interoperability Issues*

The issues associated with metaverse data include managing various data formats, real-time display, and data synchronization . Scalable infrastructure, effective data management, enhanced compression methods, and smooth integration of various data kinds are necessary to meet these problems [28]. Regulation observance and cooperation are required due to ethical concerns about cyberbullying and data privacy [30, 31].

### *2.1.6 Supply Chain and Logistics*

The Metaverse presents legal issues in relation to virtual currency transactions and cross-border law enforcement [32]. Regulations and controls are necessary for business operations due to jurisdictional difficulties and virtual crimes [32]. Regulations are necessary to safeguard users in virtual environments because of ethical concerns about possible exploitation and misrepresentation [6].

### *2.1.7 Energy Industry and Smart Grid*

As a result of increasing energy use, emerging metaverse technologies lead to environmental contamination . Carbon emissions are an issue due to cloud computing utilization and high computational power requirements. To reduce the environmental effects of metaverse technologies, creative solutions are required, such as new techniques for computation and technological developments [33, 34].

### *2.1.8 Rights, IP, and Governance*

Enforcing laws across borders and virtual transactions with cryptocurrency are two legal obstacles in the Metaverse [32]. Regulations and controls are necessary for business operations due to jurisdictional difficulties and virtual crimes. It is necessary to address ethical issues and put robust security mechanisms in place in order to protect user safety in the Metaverse [8].

### *2.1.9 Privacy Regulations and Data Ownership and Integration*

Data security, openness, and virtual identity protection are privacy concerns in the Metaverse. In order to resolve these problems, marketers must work with Information and Communication Technology (ICT) and follow privacy rules and regulations [12, 30]. Managing several data formats, real-time rendering, and data synchronization are among the issues associated with metaverse data. Scalable infrastructure, effective data management, and smooth integration of various kinds of data are required for solutions [28]. The ethical implications of data privacy and cyberbullying highlight the need for cooperative endeavors and adherence to regulations [30, 31].

### *2.1.10 Connectivity and Data Management*

The significance of personalization in enhancing consumer satisfaction and fostering repeat business transactions is well-documented. However, the process of deducing individual consumer preferences from available data is frequently hampered by the issue of data sparsity. This challenge arises due to the fact that the transactional history of any given consumer represents only a minuscule fraction of the aggregate data pool [35]. Handling bandwidth, latency, and network capacities is necessary to provide uninterrupted communication in the Metaverse [36]. High-speed Internet, low latency, and scalable networks are necessary for real-time virtual reality experiences [27]. Robust and advanced communication networks are necessary to deliver the best possible metaverse experience.

*2.1.11 Digital Usage Concerns*

In the Metaverse, digital addiction may lead to compulsive thinking, loss of control, and detrimental effects on one's mental, physical, emotional, financial, and social well-being [37]. The transition from in-person to virtual contact may exacerbate loneliness, impair social skills, and result in mental health problems [37]. Raising awareness, creating support networks, and using technology breakthroughs like virtual reality treatment are all necessary to address these issues [8, 38].

*2.1.12 Virtual World Complexity*

Given the complexity of the Metaverse, issues with user behavior, preferences, and the risk of extremism and polarization must be addressed . User activity inside the shared virtual environment is a source of privacy and security problems, including trolling and cyberbullying [38]. Creating a secure and inclusive Metaverse necessitates balancing limitations on unwanted activities and encouraging positive interactions among users.

*2.1.13 Technology and Environmental Impact*

Growing metaverse technologies lead to higher pollution levels and greenhouse gas emissions in the environment [34]. Carbon emissions are an issue due to cloud computing utilization and high computational power requirements [33]. To reduce the energy consumption of the Metaverse and lessen its adverse environmental effects, cooperative efforts and creative thinking are needed [8].

*2.1.4 Brand Building*

Uncertainty regarding consumer expectations and the conversion of virtual brand experiences to offline sales provide difficulties for businesses trying to establish their brands in the Metaverse . Measuring the influence of metaverse brand creation on long-term consumer behavior and its efficacy provides measurement issues [29].

*2.1.15 Customer Behavior and Spending*

Businesses' capacity to project revenues and get a favorable return on investment is hampered by the uncertainty surrounding client spending habits in the Metaverse . It is challenging to translate metaverse experiences into real-world purchases; in order to successfully target consumers, iterative testing is necessary [29, 39].

*2.1.16 Return on Investment (ROI) and Identity Linkage*

Marketers have difficulties when attempting to link the results of their metaverse brand development initiatives to long-term consumer behavior, return on investment, and in-person sales. It is still unclear if user behavior in the Metaverse and the real world are related [29].

*2.1.17 Influencer Marketing*

In the Metaverse, where virtual influencers may not connect with consumers, finding relevant influencers and calculating their good return on investment continues to be complex tasks [29]. Influencer marketing tactics are made more difficult by the fuzziness of consumer preferences in the Metaverse and the real world.

*2.1.18 Virtual Addiction and Exploitation of Vulnerable Users*

Overuse of metaverse gadgets may result in addiction, which can affect relationships, hygiene, sleep, job, and education . Therapies, medicines, and support groups are necessary to treat the detrimental impacts of addiction on one's emotional, physical, and social well-being [37]. Concerning the possible exploitation of susceptible consumers via deceptive marketing strategies, the Metaverse poses ethical issues [13]. In order to safeguard people in virtual settings, marketers need to steer clear of fake material and invasive strategies.

*2.1.19 Inaccurate Representations*

When consumers or companies develop virtual representations that do not accurately reflect their real-world identities, it raises ethical questions [6, 30]. Ethical practices need to refrain from using invasive methods and gather superfluous information.

*2.1.20 Advanced Technologies and Integration*

Adding cutting-edge technology to the Metaverse, such as blockchains, Non fungible Token (NFT)s, AI, AR, and VR, requires a lot of processing power and bandwidth and pollutes the environment [34]. To minimize energy use and tackle any problems related to electronic waste, creative approaches are necessary [8, 33].

*2.1.21 Lack of Standardization*

The Metaverse's lack of standards compromises marketers' capacity to guarantee interoperability across many platforms [6]. The difficulties with standardization have an impact on monitoring and evaluating the performance of marketing campaigns, highlighting the need of teamwork and legal compliance [6].

The extracted challenges of metaverse marketing from the studied literature are shortlisted in Table 1.

**Table 1**
Marketing Challenges in the Metaverse

| Dimension | Indicators | Challenges | References |
|---|---|---|---|
| Comprehensive challenges | Governance, Trust, and Privacy | C1: Concerns about governance, trust, and data privacy | [40] |
| | User Engagement and Experience | C2: Limited sensory appeal, impeding immersion<br>C3: Boredom in virtual activities<br>C4: Detachment from reality and potential addiction | [9] |
| | Market Research and Cost | C5: It is expensive for firms to study virtual worlds<br>C6: Limited availability of high-end metaverse gears | [9] |
| | Undesired Behaviors and Identity Vulnerability | C7: Deviant behaviors like harassment, racism, and hate speech<br>C8: Possibility of consumer addiction leading to impulsive buying<br>C9: Vulnerability to identity theft and harassment | [9, 31] |
| | Data and Interoperability Issues | C10: Difficulty in transporting real-world consumer data to the Metaverse<br>C11: Interoperability, complexity, and low personalization issues | [9, 41] |
| | Supply Chain and Logistics | C12: Hard to identify gaps or loopholes in supply chain design | [3, 42, 43] |
| | Energy Industry and Smart Grid | C13: Issues related to maintenance, energy management, and accessibility | [44] |

**Table 1**
Continued

| Dimension | Indicators | Challenges | References |
|---|---|---|---|
| Legal and Governance Challenges | Rights, IP, and Governance | C14: Competing rights, intellectual property, and governance challenges | [25] |
| | Privacy Regulations Data Ownership and Integration | C15: Lack of privacy regulations<br>C16: Intrusive and extensive data collection<br>C17: Lack of users' data rights and ownership<br>C18: Difficulty interpreting current regulations in the metaverse world | [45-47] |
| Technical Issues | Connectivity and Data Management | C19: High responsiveness and high bandwidth connectivity requirements for a seamless user experience<br>C20: Various data formats, heterogeneous storage needs, and lack of integration solutions<br>C21: Difficulty in collecting customer data beyond metadata | [9, 27, 28, 29, 36] |
| | Digital Usage Concerns | C22: Overusing digital devices, obsessively thinking about digital use, and replacing face-to-face communication | [37, 48] |
| | Virtual World Complexity | C23: Virtual nature, anonymity of avatars, and challenges in determining laws for intangible assets | [32] |
| | Technology and Environmental Impact | C24: High computing power and bandwidth requirements<br>C25: Growing use of cloud computing and advancements in VR leading to e-waste | [34, 49] |
| Market challenges | Brand Building | C26: Effectiveness compared to physical and traditional online efforts | [29] |
| | Customer Behavior and Spending | C27: Difficulty in measuring long-term effects on behavior<br>C28: Unclear customer spending and demand<br>C29: Customer service and retention issues | [29, 39] |
| | ROI and Identity Linkage | C30: Challenges in achieving positive ROI<br>C31: Reluctance in linking virtual and physical identities | [29] |
| | Influencer Marketing | C32: Identifying appropriate influencers<br>C33: Challenges with non-human virtual influencers | [29] |
| | Virtual Addiction Exploitation of Vulnerable Users | C34: Concerns about users becoming addicted to immersive experiences<br>C35: Ethical issues related to the potential exploitation of vulnerable users | [13, 50] |
| | Inaccurate Representations | C36: Brands/users creating virtual representations that may not reflect real-world identities accurately | [6, 30] |
| Technical Implementation Challenges | Advanced Technologies and Integration | C37: Need for advanced technologies in marketing<br>C38: Integration challenges with metaverse platforms<br>C39: Many technologies are not yet integrated with metaverse platforms due to early development stages | [30, 51] |
| | Lack of Standardization | C40: Lack of standardization as a significant challenge | [6] |

### *2.2. SERVQUAL model*

Service quality is a nuanced concept, ranging from high-quality performance to completely unacceptable quality [52]. Crosby [10] Defines quality as adjustments made according to customer specifications, with product quality involving alterations based on customer preferences. While extensive research has focused on product quality and its benefits, service quality, being more challenging to define and measure, requires further exploration. The model was initially developed in 1985 [53] and subsequently refined and enhanced in 1988 [11] and 1994 [54]. At present, it has become one of the most essential models in relation to service quality. The algorithm used is the "perception minus expectation" algorithm. Also, The conceptualization and operationalization of service quality theory were advanced [55] through the development of the SERVQUAL scale. This multiple-item instrument aimed to measure perceptions and expectations of service quality, explicitly addressing the critical fifth quality gap. The goal was to provide firms with a quantifiable construct of "service quality," enabling them to identify areas for improvement and enhance customer satisfaction.

The five fundamental dimensions of SERVQUAL are Tangibles, reliability, responsiveness, assurance, and empathy. Each of these dimensions has specific attributes. The quality function of the model SERVQUAL is expressed by equation (1).

$$SQ_i = \Sigma W_j \left(P_{ij} - E_j\right) \tag{1}$$

The equation represents the perceived quality of a dimension. In this equation, $SQ_i$ −refers to the perceived dimension quality, $W_j$ −represents the attribute importance factor, $P_{ij}$ −represents the perception of dimension $i$ in respect to attribute $j$, $E_{ij}$ −represents the expected level of the attribute, and $j$ is a normative factor for dimension $i$.

The five SERVQUAL dimensions shown in Figure 2 (reliability, responsiveness, assurance, empathy, and tangibles) succinctly capture a fundamental criterion employed by customers to evaluate the quality of services. The significance of the dimensions in a conventional SERVQUAL model is founded on a survey having 44 quality indicators, where 22 measure expectations (E) while the others measure perceptions(P).

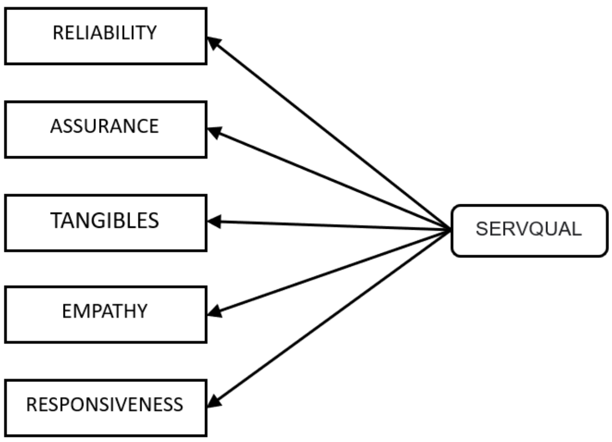


**Fig. 2.** SERVQUAL Model [53]

### *2.3 FUCOM decision-making method*

It is essential to mention that the FUCOM was presented by Pamučar *et al.,* [16] as an alternative to AHP (analytical hierarchy process) and BWM (best worst method) for weighting the criteria. The researchers of Nunić [22] have also studied its application. Three steps comprise FUCOM:

Step 1. Criteria from the predefined set $C = (C_1, C_2, \dots, C_n)$ are ranked based on their anticipated significance, establishing a hierarchy denoted as:

$$C_{j(1)} > C_{j(2)} > \cdots > C_{J(K)} \quad (2)$$

Here, $k$ is the position or level of the observed criteria. If two or more criteria are deemed equally significant, the sign of equality is used instead of the $'' >''$ Symbol in expression (2).

Step 2. In the second phase, a comparison of the ranking criteria is carried out, and the comparative priority ($\varphi_{K/(k+1)}$, $k = 1, 2, \dots, n$, where $k$ denotes the rank of the criteria) of the assessment criteria is calculated. The comparative priority of the assessment criteria ($\varphi_{k/(k+1)}$) is an advantage of the criterion of the $C_{j(k)}$ rank compared to the criterion of the $C_{j(k+1)}$ Rank. Thus, the vectors of the comparative priority of the assessment criteria are determined, as in the statement (3):

$$\Phi = (\varphi_{1/3}, \varphi_{2/3}, \dots, \varphi_{k/(k+1)}) \quad (3)$$

where ($\varphi_{k/(k+1)}$ reflects the relevance (priority) that the criteria of the $C_{j(k)}$ Rank has been compared to the criterion of the $C_{j(k)}$Rank.

Step 3. Final weight coefficients $(w_1, w_2, \dots w_n)^T$ Are computed, adhering to two conditions: first, the ratio of weight coefficients must equal the comparative priority ($\varphi_{k/(k+1)}$), expressed as

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \quad (4)$$

second, mathematical transitivity must be satisfied

$$\frac{w_k}{w_{k+2}} = \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(K+2)} \quad (5)$$

Complete consistency, indicating minimal Deviation from Full Consistency (DFC) ($\chi$), is achieved when transitivity is fully observed. The model for determining the final weight coefficients and DFC degree is defined as follows:

$$\begin{gathered} minimize\ \chi \\ subject\ to \\ \left| \frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)} \right| \leq x, \forall j \\ \left| \frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(K+2)} \right| \leq x, \forall j \\ \sum_{j=1}^{n} w_j = 1, \forall j \\ w_j \geq 0, \forall j \end{gathered} \quad (6)$$

Solving this model yields the final weight coefficients. $(w_1, w_2, \dots w_n)^T$ And the DFC degree ($\chi$).

### *2.4 Additive Ratio Assessment (ARAS) Method*

The first step involves constructing a decision-making matrix (DMM). In discrete optimization problem's MCDM, preferences for m possible alternatives (rows) evaluated on n relevant criteria (columns) can be expressed as DMM:

$$X = \begin{bmatrix} x_{01} & \cdots & x_{0j} & \cdots & x_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{ij} & \cdots & x_{ij} & \cdots & x_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mj} & \cdots & x_{mn} \end{bmatrix}; \ i = \overline{0, m}; \ j = \overline{1, n}, \quad (7)$$

where $m$ — number of alternatives, $n$ — number of criteria describing each alternative, $x_{ij}$ — a value representing the performance value of the $i$ alternative in terms of the $j$ criterion, $x_{0j}$ — the optimal value of $j$ criterion. If the optimal value of $j$ criterion is unknown, then

$$x_{0j} = \max_i x_{ij}, if \max_i x_{ij} \ is\ perferable \tag{8}$$

$$x_{0j} = \min_i x_{ij}^* \ , if \min_i x_{ij}^* \ is\ perferable$$

A common way to represent performance values $x_{ij}$ and the criteria weights $w_j$ Is to use a DMM. Experts usually determine the system of criteria and the values and initial weights of criteria. The interested parties can adjust the information according to their objectives and possibilities. The next step is to rank the alternatives based on the criteria. Since the criteria may have different units, the next stage is to obtain unitless weighted values from the comparative criteria. To overcome the challenges of different units of the criteria, the ratio to the optimal value is applied. Different theories exist to describe the ratio to the optimal value. However, the normalization of a DMM maps the values either on the interval $[0, 1]$ or the interval $[0, \infty]$. In the second stage, the initial values of all the criteria are normalized — obtaining values. $\bar{x}_{ij}$ of normalized decision-making matrix $\bar{X}$ .

$$\bar{X} = \begin{bmatrix} \bar{x}_{01} & \cdots & \bar{x}_{0j} & \cdots & \bar{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{i1} & \cdots & \bar{x}_{ij} & \cdots & \bar{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \bar{x}_{mj} & \cdots & \bar{x}_{mj} & \cdots & \bar{x}_{mn} \end{bmatrix}; \ i = \overline{0,m}; \ j = \overline{1,n}, \tag{9}$$

The criteria, which have optimal values of maxima, are normalized in the following manner:

$$\bar{x}_{ij} = \frac{\bar{x}_{ij}}{\sum_{i=0}^{m} x_{ij}} . \tag{10}$$

The criteria, which have optimal values at the minimum, are normalized using a two-stage procedure:

$$x_{ij} = \frac{1}{x_{ij}^*}; \ \bar{x}_{ij} = \frac{\bar{x}_{ij}}{\sum_{i=0}^{m} x_{ij}} . \tag{11}$$

When all criteria are known in dimensionless values, they may be compared since their dimensions were not the same previously.

The third stage is defining—$\hat{X}$ Normalized-weighted matrix. It is possible to evaluate the criterion with weights $0 < w_j < 1$. Only well-founded weights should be used because the weights are subjective, and they always affect the result. The values of weight $w_j$They are generally decided by the expert evaluation method. The sum of weights $w_j$ It would be limited as follows:

$$\sum_{j=1}^{n} w_j = 1 . \tag{12}$$

$$\hat{X} = \begin{bmatrix} \hat{x}_{01} & \cdots & \hat{x}_{0j} & \cdots & \hat{x}_{0n} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{i1} & \cdots & \hat{x}_{ij} & \cdots & \hat{x}_{in} \\ \vdots & \ddots & \vdots & \ddots & \vdots \\ \hat{x}_{m1} & \cdots & \hat{x}_{mj} & \cdots & \hat{x}_{mn} \end{bmatrix}; \ i = \overline{0,m}; \ j = \overline{1,n},$$

Normalized-weighted values of all the criteria are calculated as follows:

$$\hat{x}_{ij} = \bar{x}_{ij} w_j \ ; i = \overline{0,m} , \tag{13}$$

where $w_j$ is the weight (importance) of the $j$ criterion, and $\bar{x}_{ij}$ Is the normalized rating of the $j$ criterion.

where $\bar{x}_{ij}$ is a normalized rating of the $j$ criterion and $w_j$ Is $j$ weight (importance).

The following task is to ascertain the values of the optimality function:

$S_i = \sum_{j=1}^{n} \bar{x}_{ij}\, ; i = \overline{0,m}\,,$ (14)

where $S_i$ Is the value of the optimality function of $i$ alternative.

The most significant value is the best, while the least one is the worst. Taking into account the calculation process, the optimality function $S_i$ has a direct and proportionate relationship with the values $x_{ij}$ and weights $w_i$ Of the studied criteria and their respective influence on the outcome. Therefore, the bigger the value of the optimality function $S_i$, the more influential the alternative. The priority of alternatives can be selected according to their value. $S_i$. Consequently, it is convenient to analyze and rank choice options when this method is utilized.

The degree of the alternative utility is determined by a comparison of the variant that is studied, with the ideally best one $S_0$. The equation used for the computation of the utility degree $K_i$ of an alternative $a_i$ Is given below:

$k_i = \frac{S_i}{S_0}; i = \overline{0,m}\,,$ (15)

where $S_i$ and $S_0$ are the optimality criteria values, determined from Eq. (9). It is evident that the calculated values $k_i$ Are in the interval $[0, 1]$ and can be ordered in an increasing sequence, which is the intended order of precedence. The complicated relative efficiency of the feasible option can be determined according to the utility function values. The whole algorithm is shown in Figure 3.

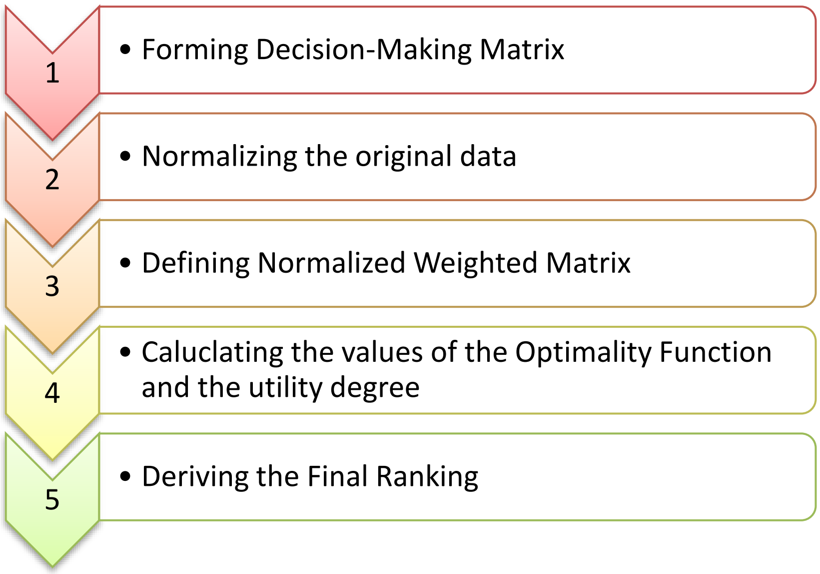


**Fig. 3.** ARAS method model [18]

*2.5 Intuitionistic triangular fuzzy number*

In 1965, Professor Zadeh introduced fuzzy set theory [56], which is a valuable research tool for FMCDM problems. Gau and Buehrer [57] later proposed the term vague sets. Bustince and Burillo [58] observed that vague sets are also intuitionistic fuzzy sets whose main advantage lies in their capability to consider membership degree, non-membership degree, and hesitancy simultaneously when modeling vagueness or uncertainty.

Atanassov and Stoeva [59] extended intuitionistic fuzzy sets to interval intuitionistic fuzzy sets with basic operations defined by Atanassov [60]. Bustince and Burillo [61] studied the correlation degree of interval intuitionistic fuzzy set and the decomposition theorem of interval intuitionistic fuzzy set. Hung and Wu [62] evaluated correlation coefficients by the centroid method, while Deschrijver and Kerre [63] investigated the connection between interval intuitionistic fuzzy sets, L-fuzzy sets, intuitionistic fuzzy sets, and interval type-2 fuzzy sets. Xu [64] proposed approaches to aggregating information given in terms of Interval-valued Intuitionistic Fuzzy Sets.

Let us consider a nonempty set $X$. An intuitionistic fuzzy set A, as defined by Atanassov and Stoeva [60], is given by $A = \{< x, \mu_A(x), v_A(x) > x \in X\}$, where, $\mu_A(x)$ is the membership degree of $x$ belongs to $X$ and $v_A(x)$ is the non-membership degree of $x$ belongs to X, $\mu_A : X \longrightarrow [0,1]$, $v_A : X \longrightarrow [0,1]$ and $0 \le \mu_A(x)+v_A(x) \le 1$, $\forall x \in X$ .In addition, $1-\mu_A(x)-v_A(x)$ signifies the hesitancy degree of $x$ in $X$.

Now, consider two intuitionistic fuzzy numbers $A = \{< x, \mu_A(x), v_A(x) > x \in X\}$ and $B = \{< x, \mu_B(x), v_B(x) > x \in X\}$. The operation rules for these intuitionistic fuzzy numbers, as per [60, 65], are as follows:

$$A + B = \{< x, \mu_A(x) + \mu_B(x) - \mu_A(x)\mu_B(x), v_A(x)v_B(x) > x \in X\}; \tag{16}$$

$$A.B = \{< x, \mu_A(x)\mu_B(x), v_A(x) + v_B(x) - v_A(x)v_B(x) > x \in X\}; \tag{17}$$

$$nA = \{< x, 1 - [1-\mu_A(x)]^n, [v_A(x)]^n > x \in X\}; \tag{18}$$

$$A^n = \{< x, [\mu_A(x)]^n, 1 - [1 - v_A(x)]^n > x \in X, n > 0\}. \tag{19}$$

Intuitionistic fuzzy sets offer a flexible and practical approach to handling fuzzy and uncertain information. However, due to the inherent complexity and uncertainty of most situations, expressing membership and non-membership degrees with precise real numbers can be challenging [66]. A viable solution is to represent these degrees using triangular fuzzy numbers.

This paper broadens intuitionistic fuzzy sets with triangular fuzzy numbers representing the degree of membership $\bar{\mu}_A(x)$ and non-membership degree $\bar{v}_A(x)$. This results in an intuitionistic fuzzy number based on the triangular fuzzy number termed a triangular intuitionistic fuzzy number. Its general form is denoted as $([a^L, a^M, a^U], [b^L, b^M, b^U])$, where $[a^L, a^M, a^U]$ and $[b^L, b^M, b^U]$ are triangular fuzzy numbers.

Consider two triangular intuitionistic fuzzy numbers, $I_1 = ([a_1^L, a_1^M, a_1^U], [b_1^L, b_1^M, b_1^U])$, and $I_2 = ([a_2^L, a_2^M, a_2^U], [b_2^L, b_2^M, b_2^U])$. According to formulas $(20)-(23)$ and the operation rules of triangular fuzzy numbers, we have:

$$I_1 + I_2 = ([a_1^L, a_1^M, a_1^U], [b_1^L, b_1^M, b_1^U]) + ([a_2^L, a_2^M, a_2^U], [b_2^L, b_2^M, b_2^U]) = ([a_1^L + a_2^L - a_1^L a_2^L, a_1^M + a_2^M - a_1^M a_2^M, a_1^U + a_2^U - a_1^U a_2^U], [b_1^L b_2^L, b_1^M b_2^M, b_1^U b_2^U]) \tag{20}$$

$$I_1.I_2 = ([a_1^L, a_1^M, a_1^U], [b_1^L, b_1^M, b_1^U]) + ([a_2^L, a_2^M, a_2^U], [b_2^L, b_2^M, b_2^U]) = ([a_1^L a_2^L, a_1^M a_2^M, a_1^U a_2^U], [b_1^L + b_2^L - b_1^L b_2^L, b_1^M + b_2^M - b_1^M b_2^M, b_1^U + b_2^U - b_1^U b_2^U]); \tag{21}$$

$$\lambda I_1 = \lambda([a_1^L, a_1^M, a_1^U], [b_1^L, b_1^M, b_1^U]) = ([1-(1-a_1^L)^\lambda, 1-(1-a_1^M)^\lambda, 1-(1-a_1^U)^\lambda], [(b_1^L)^\lambda, (b_1^M)^\lambda, (b_1^U)^\lambda])\lambda \ge 0; \tag{22}$$

$$I_1^\lambda = ([a_1^L, a_1^M, a_1^U], [b_1^L, b_1^M, b_1^U])^\lambda = ([(a_1^L)^\lambda, (a_1^M)^\lambda, (a_1^U)^\lambda][1-(1-b_1^L)^\lambda, 1-\left(1-b_1^M\right)^\lambda, 1-\left(1-b_1^U\right)^\lambda]), \lambda \ge 0; \tag{23}$$

The results of these calculations are triangular, intuitionistic fuzzy numbers. From equations $(24)-(28)$, we can derive the following calculation rules

$$I_1 + I_2 = I_2 + I_1; \tag{24}$$

$$I_1 . I_2 = I_2 . I_1; \tag{25}$$

$$\lambda(I_1 + I_2) = \lambda I_1 + \lambda I_2, \lambda \ge 0; \tag{26}$$

$$\lambda_1 I_1 + \lambda_2 I_1 = (\lambda_1 + \lambda_2) I_1, \lambda_1, \lambda_2 \ge 0; \tag{27}$$

$$I_1^{\lambda_1} . I_1^{\lambda_2} = (I_1)^{\lambda_1 + \lambda_2}, \lambda_1, \lambda_2 \ge 0. \tag{28}$$

## 3. Case Study

The primary purpose of this study is to recognize and introduce metaverse marketing challenges in service industries and help companies in this business segment better manage their exitance and roleplaying in the new technological era. One of the most progressive industries in this field is the real estate industry; as explained before, the use of Metaverse in this industry can facilitate both service provider and service receiver, mostly in international situations where the home seeker and real estate consultant are in different geographical places which makes it challenging to show/see the suggested houses. However, as listed in Table 1, there are many challenges for companies to deal with. Usually, CEOs cancel new projects when they come to know a long list of challenges, so we propose a decision-making method to prioritize the listed challenges, which makes the CEOs and board members to assign limited budgets better to deal with challenges and deploy new technologies.

We selected 35 international real estate agents, considering some characteristics to make sure they can understand our research purpose and might be able to answer our questionnaires: first, having an online website and second, having chain stores in different countries and cities.

In the first step, we asked our sample to score SERVQUAL dimensions using the seven-point Likert scale mentioned in Table 2.

**Table 2**
Seven-point Likert scale

| Linguistic term | Extra low | Very low | Low | Medium | High | Very high | Extra high |
|---|---|---|---|---|---|---|---|
| Equivalent number | 1 | 2 | 3 | 4 | 5 | 6 | 7 |

The seven-point Likert scale is widely used in SERVQUAL and MCDM studies to quantify subjective judgments, enabling their integration into quantitative analysis [11]. The aggregation of responses through arithmetic mean is a common approach in group decision-making to represent collective expert opinion. The results are shown in Table 3.

**Table 3**
Scores given to SERVQUAL dimensions

| Dimension | Tangibility | Reliability | Responsiveness | Assurance | Empathy |
|---|---|---|---|---|---|
| Respondents | D1 | D2 | D3 | D4 | D5 |
| 1 | 2 | 7 | 7 | 4 | 2 |
| 2 | 2 | 7 | 7 | 7 | 3 |
| 3 | 2 | 5 | 4 | 5 | 2 |
| 4 | 4 | 3 | 5 | 3 | 3 |
| 5 | 4 | 3 | 4 | 2 | 4 |
| 6 | 2 | 6 | 5 | 2 | 2 |
| 7 | 5 | 7 | 4 | 6 | 4 |
| 8 | 3 | 5 | 4 | 7 | 2 |
| 9 | 4 | 3 | 5 | 3 | 2 |
| 10 | 1 | 5 | 7 | 3 | 4 |
| 11 | 4 | 5 | 6 | 5 | 4 |
| 12 | 5 | 6 | 6 | 4 | 3 |
| 13 | 5 | 7 | 4 | 7 | 3 |
| 14 | 3 | 4 | 5 | 2 | 2 |
| 15 | 1 | 6 | 4 | 6 | 1 |
| 16 | 4 | 4 | 7 | 6 | 2 |
| 17 | 5 | 6 | 6 | 2 | 1 |
| 18 | 5 | 6 | 6 | 6 | 2 |

**Table 3**
Continued

| Dimension | Tangibility | Reliability | Responsiveness | Assurance | Empathy |
|---|---|---|---|---|---|
| Respondents | D1 | D2 | D3 | D4 | D5 |
| 19 | 5 | 6 | 6 | 6 | 1 |
| 20 | 1 | 3 | 7 | 6 | 2 |
| 21 | 2 | 3 | 6 | 4 | 2 |
| 22 | 3 | 7 | 7 | 2 | 4 |
| 23 | 4 | 7 | 4 | 5 | 4 |
| 24 | 2 | 4 | 6 | 7 | 4 |
| 25 | 4 | 4 | 5 | 7 | 4 |
| 26 | 1 | 3 | 5 | 6 | 2 |
| 27 | 4 | 7 | 7 | 6 | 1 |
| 28 | 3 | 4 | 6 | 6 | 2 |
| 29 | 2 | 6 | 6 | 5 | 4 |
| 30 | 1 | 6 | 5 | 3 | 3 |
| 31 | 4 | 5 | 7 | 4 | 4 |
| 32 | 3 | 3 | 6 | 2 | 2 |
| 33 | 2 | 5 | 7 | 3 | 4 |
| 34 | 2 | 6 | 5 | 6 | 1 |
| 35 | 1 | 6 | 5 | 2 | 4 |
| Average | 3 | 5.142857 | 5.6 | 4.571429 | 2.68571 |

The last row of Table 3 shows the average score of the group of our respondents. According to these results, we have $D_3 > D_2 > D_4 > D_1 > D_5$, now by the use of the FUCOM method, we find the weights of each dimension, which is going to be used as decision criteria for the next step of the algorithm.

Comparative importance of the criteria is:

$$\varphi_{\left(\frac{D_3}{D_2}\right)} = \frac{5.6}{5.142857} = 1.09, \varphi_{\left(\frac{D_2}{D_4}\right)} = \frac{5.142857}{4.571429} = 1.12,$$

$$\varphi_{\left(\frac{D_4}{D_1}\right)} = \frac{4.571429}{3} = 1.52, \varphi_{\left(\frac{D_1}{D_5}\right)} = \frac{3}{2.68571} = 1.18$$

Which construct the constraints of the optimization model as:

$$\frac{w_3}{w_2} = 1.09, \frac{w_2}{w_4} = 1.12, \frac{w_4}{w_1} = 1.52, \frac{w_1}{w_5} = 1.18$$

$$\frac{w_3}{w_4} = \frac{w_3}{w_2} * \frac{w_2}{w_4} = 1.09 * 1.12 = 1.2208$$

$$\frac{w_2}{w_1} = \frac{w_2}{w_4} * \frac{w_4}{w_1} = 1.12 * 1.52 = 1.7024$$

$$\frac{w_4}{w_5} = \frac{w_4}{w_1} * \frac{w_1}{w_5} = 1.52 * 1.18 = 1.7936$$

We can finalize the optimization model to find criteria weights such as:

$Min$ X

Sub to:

$$\left|\frac{w_3}{w_2} - 1.09\right| \leq X;$$
$$\left|\frac{w_2}{w_4} - 1.12\right| \leq X;$$
$$\left|\frac{w_4}{w_1} - 1.52\right| \leq X;$$
$$\left|\frac{w_1}{w_5} - 1.18\right| \leq X;$$
$$\left|\frac{w_3}{w_4} - 1.2208\right| \leq X;$$
$$\left|\frac{w_2}{w_1} - 1.7024\right| \leq X;$$
$$\left|\frac{w_4}{w_5} - 1.7936\right| \leq X;$$
$$w_j \geq 0 \qquad \forall j;$$
$$\sum_{j=1}^{5} w_j = 1;$$

By using LINGO18 software Solving the constructed non-linear programming model, the weight coefficients are obtained; results are reported in Table 4 and shown in Figure 4.

**Table 4**
Criterion Weights

| Criterion | Weight |
|---|---|
| D3 | 0.2679407 |
| D2 | 0.2458171 |
| D4 | 0.2194796 |
| D1 | 0.1443945 |
| D5 | 0.1223682 |

Moreover, the objective function is $X = 0$.

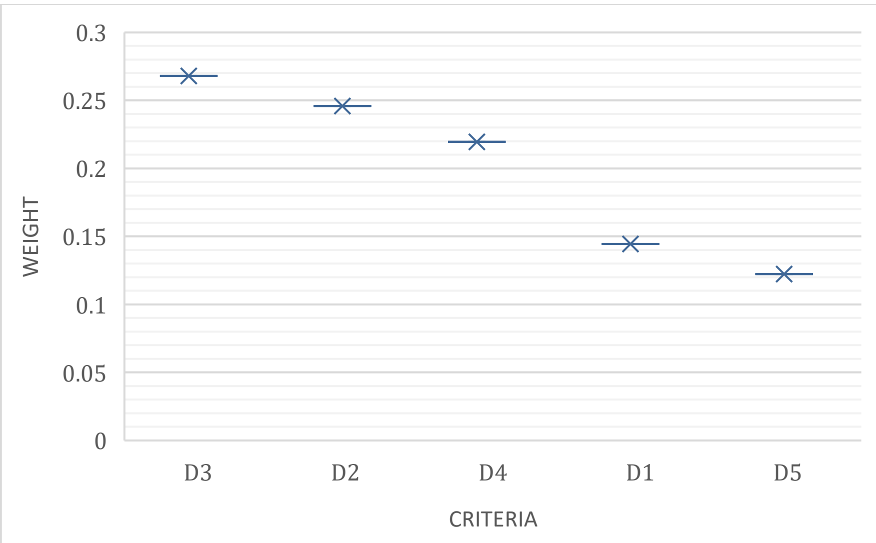


**Fig. 4.** Weight of the Decision Criteria

During our interviews to gather the respondents' opinions, we came to know that it is not easy for experts in this industry to give us exact answers or evaluate the dimensions as we needed to demonstrate the decision matrix for the next step, preferred to choose fuzzy numbers to simplify data gathering.

Topics related to the Metaverse are not familiar to most people, and it becomes more complicated when you ask them about their professional fields because they feel more responsible for their answers. The intuitionistic triangular fuzzy numbers are one of the suitable devices that can be applied to make respondents give us more realistic answers. We use seven-point Likert scale intuitionistic triangular fuzzy numbers as defined in Table 5 [20].

**Table 5**
Seven-point Likert scale intuitionistic triangular fuzzy number

| Code | Linguistic term | Equivalent term |
|---|---|---|
| $A_1$ | Extra low | ([0,0,1/6],[2/6,3/6,4/6]) |
| $A_2$ | Very low | ([0,1/6,2/6],[3/6,4/6,5/6]) |
| $A_3$ | Low | ([1/6,2/6,3/6],[4/6,5/6,6/6]) |
| $A_4$ | Medium | ([2/6,3/6,4/6],[5/6,6/6,6/6]) |
| $A_5$ | High | ([3/6,4/6,5/6],[0,1/6,2/6]) |
| $A_6$ | Very high | ([4/6,5/6,6/6],[1/6,2/6,3/6]) |
| $A_7$ | Extra high | ([5/6,6/6,6/6],[2/6,3/6,4/6]) |

To better visualize the selected Likert scale (Figure 5), it is presented in [67].

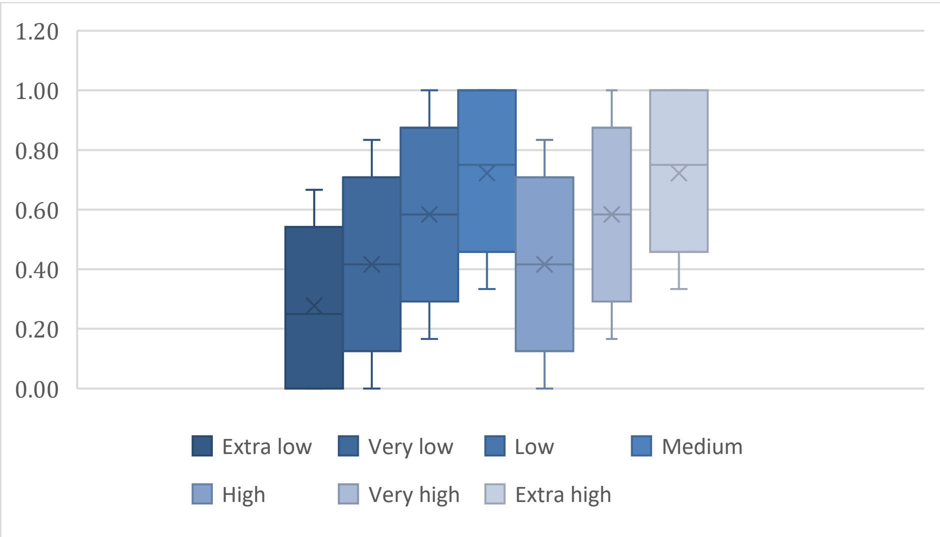


**Fig. 5.** Seven-point Likert scale intuitionistic triangular fuzzy number

Then, the average of $n$ respondents for each decision matrix element can be calculated using:

$$X_j = \frac{1}{n} \boxtimes (X_1 \boxplus X_2 \boxplus \dots \boxplus X_n) =$$
$$([\frac{1}{n}\sum_{i=1}^{n} a_{1i}\ ,\frac{1}{n}\sum_{i=1}^{n} a_{2i}\ ,\frac{1}{n}\sum_{i=1}^{n} a_{3i}], [\frac{1}{n}\sum_{i=1}^{n} \acute{a}_{1i}\ ,\frac{1}{n}\sum_{i=1}^{n} \acute{a}_{2i}\ ,\frac{1}{n}\sum_{i=1}^{n} \acute{a}_{3i}]) \tag{29}$$

Which is also an intuitionistic triangular fuzzy number $([a_1, a_2, a_3], [\acute{a}_1, \acute{a}_2, \acute{a}_3])$. Then the average should be defuzzified by [68]:

$$Defuzzified(X_j) = \frac{(a_1+4a_2+a_3)+(\acute{a}_1+4\acute{a}_2+\acute{a}_3)}{12} \tag{30}$$

The selected 35 respondents were asked to fill our ARAS decision matrix, scoring forty Metaverse marketing challenges listed in Table 1 according to each of five SERVQUAL dimensions as decision criteria, using the Seven-point Likert scale intuitionistic triangular fuzzy numbers defined in Table 5.

Then, the average of their answers was calculated by the equations 29 and 30. The result is reported in Table 6.

**Table 6**
The initial ARAS decision matrix

| Challenges | Tangibility | Reliability | Responsiveness | Assurance | Empathy |
|---|---|---|---|---|---|
| max | 0.584524 | 0.588889 | 0.606349206 | 0.597222 | 0.58016 |
| C1 | 0.538492 | 0.528968 | 0.525396825 | 0.529762 | 0.55635 |
| C2 | 0.584524 | 0.520238 | 0.538095238 | 0.555952 | 0.55238 |
| C3 | 0.569841 | 0.543651 | 0.578571429 | 0.559921 | 0.56548 |
| C4 | 0.574206 | 0.565476 | 0.575 | 0.507143 | 0.55238 |
| C5 | 0.510714 | 0.54246 | 0.525396825 | 0.488492 | 0.54722 |
| C6 | 0.520635 | 0.560714 | 0.524206349 | 0.520238 | 0.54722 |
| C7 | 0.520238 | 0.533333 | 0.487301587 | 0.538889 | 0.49365 |
| C8 | 0.565079 | 0.542063 | 0.551190476 | 0.597222 | 0.52421 |
| C9 | 0.565873 | 0.528571 | 0.502380952 | 0.552381 | 0.56111 |
| C10 | 0.514683 | 0.501984 | 0.510714286 | 0.479762 | 0.56587 |
| C11 | 0.55119 | 0.588889 | 0.606349206 | 0.538889 | 0.57857 |
| C12 | 0.520238 | 0.529365 | 0.528571429 | 0.473413 | 0.52381 |
| C13 | 0.538095 | 0.553175 | 0.500793651 | 0.524603 | 0.47976 |
| C14 | 0.488095 | 0.496825 | 0.515873016 | 0.53373 | 0.53294 |
| C15 | 0.51627 | 0.528571 | 0.511904762 | 0.588492 | 0.5246 |
| C16 | 0.520238 | 0.497222 | 0.538492063 | 0.529365 | 0.5127 |
| C17 | 0.534127 | 0.511508 | 0.597619048 | 0.542857 | 0.50675 |
| C18 | 0.565476 | 0.52381 | 0.583333333 | 0.556746 | 0.54762 |
| C19 | 0.560714 | 0.484524 | 0.56031746 | 0.520635 | 0.56032 |
| C20 | 0.578968 | 0.538889 | 0.479761905 | 0.578571 | 0.49802 |
| C21 | 0.546825 | 0.533333 | 0.510714286 | 0.560317 | 0.54762 |
| C22 | 0.529762 | 0.565873 | 0.551984127 | 0.548016 | 0.48413 |
| C23 | 0.478968 | 0.505952 | 0.520634921 | 0.519841 | 0.53373 |
| C24 | 0.569444 | 0.569841 | 0.551190476 | 0.525397 | 0.53413 |
| C25 | 0.547619 | 0.569841 | 0.529761905 | 0.501984 | 0.52857 |
| C26 | 0.528968 | 0.511111 | 0.528571429 | 0.533333 | 0.57857 |
| C27 | 0.575 | 0.569841 | 0.534126984 | 0.511508 | 0.51587 |
| C28 | 0.529762 | 0.556746 | 0.605555556 | 0.569444 | 0.58016 |
| C29 | 0.53373 | 0.547222 | 0.510714286 | 0.532937 | 0.55079 |
| C30 | 0.501984 | 0.520238 | 0.475 | 0.560714 | 0.4746 |
| C31 | 0.537698 | 0.501587 | 0.489285714 | 0.533333 | 0.47937 |
| C32 | 0.546825 | 0.525397 | 0.501984127 | 0.584127 | 0.52937 |
| C33 | 0.528968 | 0.537698 | 0.510714286 | 0.571429 | 0.51468 |
| C34 | 0.525397 | 0.533333 | 0.515079365 | 0.542857 | 0.57421 |
| C35 | 0.528968 | 0.542063 | 0.501984127 | 0.498016 | 0.50714 |
| C36 | 0.55119 | 0.569444 | 0.532936508 | 0.552778 | 0.52024 |
| C37 | 0.555952 | 0.524206 | 0.532936508 | 0.551587 | 0.4746 |
| C38 | 0.515873 | 0.511508 | 0.469444444 | 0.555159 | 0.5246 |
| C39 | 0.56627 | 0.528968 | 0.56031746 | 0.497222 | 0.50238 |
| C40 | 0.556746 | 0.55119 | 0.492857143 | 0.574206 | 0.5381 |

The average scores given to each challenge according to each SERVQUAL dimension (criteria) are shown in Figure 6. The diversity of scores is clearly seen in the diagram.

Now, using the ARAS algorithm, the final weighted normalized decision matrix is determined. Then, the value of the optimality function, utility degree, and the rank of the challenges are calculated. The results are shown in Table 7.

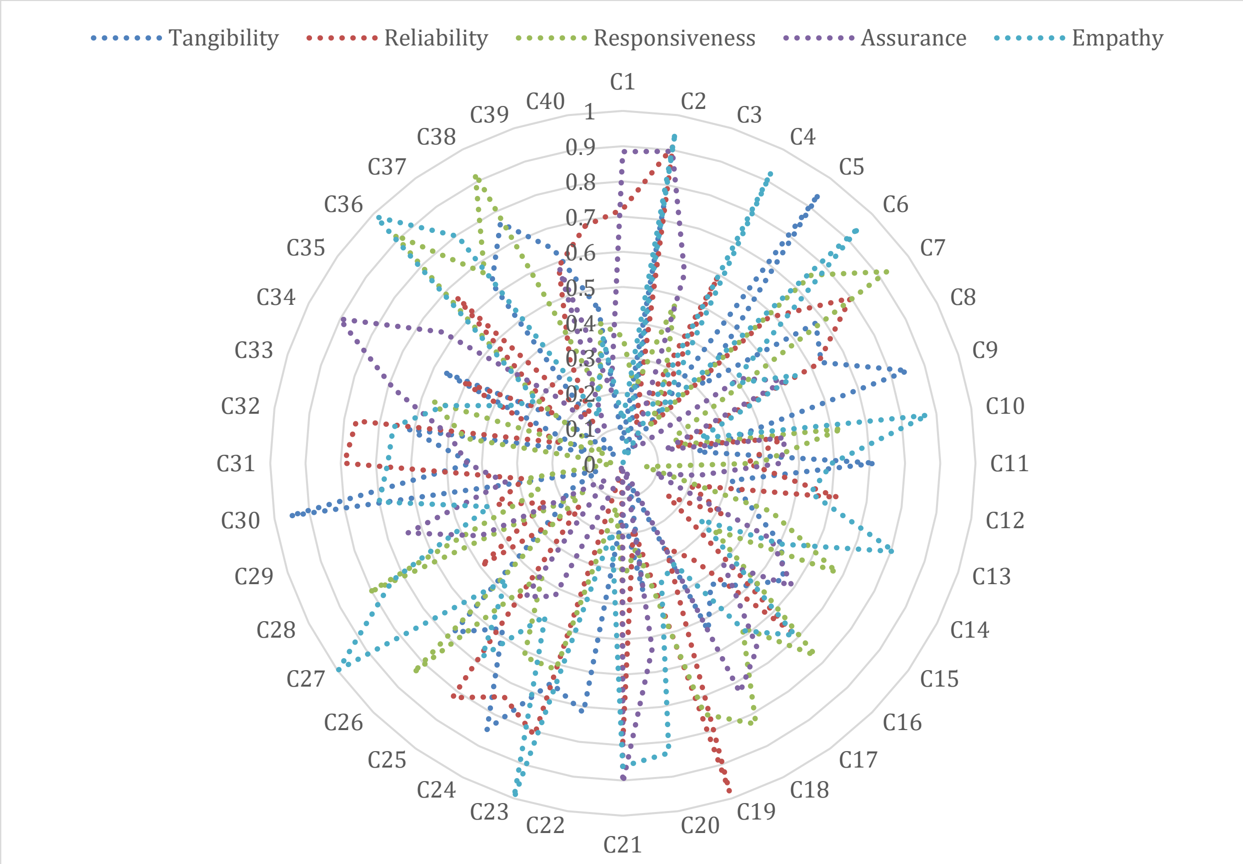


**Fig. 6.** The given score to each alternative according to each criteria

**Table 7**
The ARAS final decision matrix

| Challenges | Tangibility | Reliability | Responsiveness | Assurance | Empathy | $S_i$ | Utility degree | rank |
|---|---|---|---|---|---|---|---|---|
| max | 0.003806 | 0.006585 | 0.007462 | 0.005921 | 0.003256 | 0.027029 | | |
| C1 | 0.003506 | 0.005915 | 0.006465 | 0.005252 | 0.003122 | 0.02426 | 0.89757902 | 23 |
| C2 | 0.003806 | 0.005817 | 0.006622 | 0.005512 | 0.0031 | 0.024856 | 0.91961958 | 9 |
| C3 | 0.00371 | 0.006079 | 0.00712 | 0.005551 | 0.003174 | 0.025633 | 0.94837134 | 3 |
| C4 | 0.003738 | 0.006323 | 0.007076 | 0.005028 | 0.0031 | 0.025265 | 0.934748 | 6 |
| C5 | 0.003325 | 0.006065 | 0.006465 | 0.004843 | 0.003071 | 0.02377 | 0.87943676 | 29 |
| C6 | 0.00339 | 0.00627 | 0.006451 | 0.005158 | 0.003071 | 0.024339 | 0.90048007 | 19 |
| C7 | 0.003387 | 0.005963 | 0.005997 | 0.005343 | 0.00277 | 0.02346 | 0.86797251 | 33 |
| C8 | 0.003679 | 0.006061 | 0.006783 | 0.005921 | 0.002942 | 0.025386 | 0.93921415 | 4 |
| C9 | 0.003684 | 0.00591 | 0.006182 | 0.005476 | 0.003149 | 0.024402 | 0.90281676 | 15 |
| C10 | 0.003351 | 0.005613 | 0.006285 | 0.004756 | 0.003176 | 0.023181 | 0.85763387 | 38 |
| C11 | 0.003589 | 0.006585 | 0.007462 | 0.005343 | 0.003247 | 0.026224 | 0.9702448 | 1 |
| C12 | 0.003387 | 0.005919 | 0.006505 | 0.004693 | 0.00294 | 0.023444 | 0.86736651 | 34 |
| C13 | 0.003503 | 0.006185 | 0.006163 | 0.005201 | 0.002693 | 0.023745 | 0.878501 | 30 |
| C14 | 0.003178 | 0.005555 | 0.006348 | 0.005291 | 0.002991 | 0.023364 | 0.86440045 | 35 |
| C15 | 0.003361 | 0.00591 | 0.006299 | 0.005834 | 0.002944 | 0.024349 | 0.90086931 | 18 |
| C16 | 0.003387 | 0.00556 | 0.006627 | 0.005248 | 0.002877 | 0.023699 | 0.8768021 | 31 |
| C17 | 0.003478 | 0.005719 | 0.007354 | 0.005382 | 0.002844 | 0.024777 | 0.9166902 | 10 |
| C18 | 0.003682 | 0.005857 | 0.007178 | 0.00552 | 0.003073 | 0.02531 | 0.93640762 | 5 |
| C19 | 0.003651 | 0.005418 | 0.006895 | 0.005162 | 0.003145 | 0.02427 | 0.89792111 | 22 |
| C20 | 0.003769 | 0.006026 | 0.005904 | 0.005736 | 0.002795 | 0.02423 | 0.89644659 | 26 |
| C21 | 0.00356 | 0.005963 | 0.006285 | 0.005555 | 0.003073 | 0.024437 | 0.90410217 | 14 |

**Table 7**
Continued

| Challenges | Tangibility | Reliability | Responsiveness | Assurance | Empathy | $S_i$ | Utility degree | rank |
|---|---|---|---|---|---|---|---|---|
| max | 0.003806 | 0.006585 | 0.007462 | 0.005921 | 0.003256 | 0.027029 | | |
| C22 | 0.003449 | 0.006327 | 0.006793 | 0.005433 | 0.002717 | 0.024719 | 0.91454729 | 11 |
| C23 | 0.003118 | 0.005657 | 0.006407 | 0.005154 | 0.002995 | 0.023332 | 0.86321614 | 36 |
| C24 | 0.003707 | 0.006372 | 0.006783 | 0.005209 | 0.002998 | 0.025068 | 0.9274717 | 7 |
| C25 | 0.003565 | 0.006372 | 0.006519 | 0.004977 | 0.002966 | 0.024399 | 0.90271703 | 16 |
| C26 | 0.003444 | 0.005715 | 0.006505 | 0.005287 | 0.003247 | 0.024198 | 0.89526721 | 27 |
| C27 | 0.003744 | 0.006372 | 0.006573 | 0.005071 | 0.002895 | 0.024654 | 0.91215651 | 12 |
| C28 | 0.003449 | 0.006225 | 0.007452 | 0.005645 | 0.003256 | 0.026028 | 0.96296188 | 2 |
| C29 | 0.003475 | 0.006119 | 0.006285 | 0.005283 | 0.003091 | 0.024253 | 0.89730944 | 24 |
| C30 | 0.003268 | 0.005817 | 0.005845 | 0.005559 | 0.002664 | 0.023153 | 0.85660779 | 39 |
| C31 | 0.003501 | 0.005608 | 0.006021 | 0.005287 | 0.00269 | 0.023108 | 0.85494481 | 40 |
| C32 | 0.00356 | 0.005875 | 0.006177 | 0.005791 | 0.002971 | 0.024374 | 0.90178715 | 17 |
| C33 | 0.003444 | 0.006012 | 0.006285 | 0.005665 | 0.002889 | 0.024295 | 0.8988431 | 21 |
| C34 | 0.003421 | 0.005963 | 0.006338 | 0.005382 | 0.003223 | 0.024327 | 0.90004406 | 20 |
| C35 | 0.003444 | 0.006061 | 0.006177 | 0.004937 | 0.002846 | 0.023466 | 0.8681813 | 32 |
| C36 | 0.003589 | 0.006367 | 0.006558 | 0.00548 | 0.00292 | 0.024914 | 0.92175897 | 8 |
| C37 | 0.00362 | 0.005861 | 0.006558 | 0.005468 | 0.002664 | 0.024171 | 0.89427943 | 28 |
| C38 | 0.003359 | 0.005719 | 0.005777 | 0.005504 | 0.002944 | 0.023303 | 0.86215661 | 37 |
| C39 | 0.003687 | 0.005915 | 0.006895 | 0.004929 | 0.002819 | 0.024245 | 0.89702787 | 25 |
| C40 | 0.003625 | 0.006163 | 0.006065 | 0.005693 | 0.00302 | 0.024565 | 0.90886577 | 13 |

## 4. Discussion

The findings of this research highlight critical marketing challenges within the Metaverse real estate sector and propose innovative solutions using the SERVQUAL model, FUCOM-ARAS methodology, and intuitionistic fuzzy frameworks. These contributions are especially relevant given the emerging research landscape on Metaverse marketing and service quality assessment. Below, the study's findings are discussed in relation to existing research, focusing on alignment, distinctions, and implications for future research and practice.

Studies such as Lu and Mintz [29] emphasize the multifaceted challenges of marketing in the Metaverse, including consumer privacy concerns, high infrastructure costs, and limited technological accessibility. These findings align with the challenges identified in this research, particularly those related to governance, trust, privacy, connectivity, and data management. However, this study contributes uniquely by prioritizing challenges specific to the real estate sector. For example, it explores the importance of immersive experiences and virtual property tours, which are less prominent in general Metaverse marketing literature.

Prior work by Parasuraman *et al.,* [11] on the SERVQUAL model focused primarily on traditional service environments. More recent adaptations, such as those by Rajamanickam [27], have applied SERVQUAL in digital contexts, but these studies lack a comprehensive integration with decision-making tools like FUCOM and ARAS. This research addresses this gap by combining SERVQUAL with FUCOM-ARAS, providing a structured, quantitative approach to assessing and prioritizing Metaverse marketing challenges. This integration ensures both theoretical rigor and practical applicability.

Recent studies by Rasheed *et al.,* [20] highlight the growing utility of intuitionistic fuzzy sets in handling uncertainty and vagueness in decision-making processes. These studies focus broadly on MCDM without tailoring their applications to industry-specific challenges.

This research builds on these foundations by introducing triangular intuitionistic fuzzy numbers to improve the accuracy and reliability of stakeholder assessments in the real estate Metaverse. This application offers a novel perspective on leveraging fuzzy logic for practical industry challenges. The unique characteristics of real estate marketing in the Metaverse—such as the necessity for immersive experiences, reliable visualization tools, and legal clarity—are underexplored in existing literature. This study bridges this gap by providing tailored recommendations for addressing these sector-specific challenges. For instance, it proposes creative virtual property tours and robust regulatory frameworks to enhance user trust and engagement. These insights complement recent findings by Hofman [3] on the importance of sector-specific adaptations in digital transformation strategies.

This research provides actionable insights for managers navigating the Metaverse's complexities. The integration of SERVQUAL and FUCOM-ARAS offers a structured approach to prioritizing challenges, enabling resource allocation that aligns with organizational objectives. By adopting these frameworks, managers can:

- Enhance service quality through targeted improvements in customer experience dimensions, such as responsiveness and assurance.
- Address governance and privacy concerns with tailored solutions that foster trust and transparency.
- Leverage fuzzy decision-making tools to navigate uncertainty and make data-driven strategic decisions.

However, limitations to the proposed framework do exist. First, the outcomes are based on expert decisions, so may be subject to bias, but FUCOM is employed to ensure consistency in weight estimation. Second, the study is context-bound, specifically by examining the real estate industry under the Metaverse setting, which might reduce its wider relevance. Third, though intuitionistic fuzzy sets contribute to the model of uncertainty, they are built on existing linguistic scales. Future research may extend this framework to other industries and explore alternative MCDM methods to further validate the stability of the results.

## 5. Conclusions

The Metaverse presents a labyrinthine landscape for real estate marketing, fraught with challenges and brimming with possibilities. By prioritizing these challenges, we identified ten critical ones demanding immediate attention. These challenges encompass interoperability, complexity, lack of customization, unclear customer spending patterns, potential for user addiction, difficulties interpreting regulations, dissociation from reality, high computing power requirements, inauthentic virtual representations, and limitations in sensory experiences.

By implementing the recommended managerial solutions, organizations can navigate these challenges and enhance service quality, ultimately increasing customer satisfaction. The integration of the SERVQUAL model within a FUCOM-ARAS framework represents the core innovation of this study. The application of Intuitionistic triangular fuzzy numbers ensures the accuracy of respondent perceptions, leading to improved decision-making and resource allocation within Metaverse marketing strategies. This novel approach emphasizes the scientific underpinnings of the study by adapting traditional service quality models to the Metaverse context and fostering objectivity in decision-making via the FUCOM-ARAS method. In practical terms, this framework empowers managers with a robust resource allocation strategy, promoting operational efficiency and a competitive edge within the Metaverse marketplace. The empirical validation of the methodology underscores its effectiveness in resource allocation for tackling marketing challenges in the Metaverse. These findings hold significance not only for real estate organizations venturing into the Metaverse but also for digital marketing scholars by introducing a pioneering decision-making tool adaptable to diverse marketing contexts.

This research paves the way for future investigations. Building on these findings, future research can:

i. Explore cross-industry applications of the FUCOM-ARAS framework in the Metaverse to validate its versatility.
ii. Conduct longitudinal studies to assess the long-term impacts of service quality enhancements on customer satisfaction and business performance in the Metaverse.
iii. Investigate the interplay between technological advancements (e.g., AI, blockchain) and service quality in virtual environments.

By situating this research within the broader research context and addressing sector-specific challenges, it provides a robust foundation for both academic inquiry and practical implementation.

The findings of this study are based on a sample of 35 international real estate agents, which may limit the generalizability of the results. The small sample size, while diverse, may not fully represent the wide variety of practices across different countries and regions. Cultural, regulatory, and economic differences could lead to variations in the effectiveness of metaverse marketing strategies in real estate. Future research should consider a larger and more geographically diverse sample to enhance generalizability, as well as comparative studies between countries with different technological adoption rates.

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## Conflicts of Interest
The authors declare no conflicts of interest.

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