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IFAC PapersOnLine 59-10 (2025) 2892–2897

A Service Quality Model for Metaverse: An Application for Supply Chains using Interval Valued Intuitionistic Fuzzy AHP Method

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Abstract: In recent years, unstoppable developments in technology have caused radical transformations all over the world. With the introduction of spatial computing technologies such as virtual reality (VR), digital twin, augmented reality (AR), and mixed reality (MR), Metaverse has become one of the most popular topics in the business world, and people frequently talk about it. Metaverse has transformed the service provided to customers to a completely different dimension, a mixture of the real world and the virtual world, causing a change in the customers' understanding of service quality. For this reason, this study focuses on how to measure metaverse service quality. For this purpose, a generic model is proposed in the study based on a literature survey and the opinions of industrial experts. The proposed model's validity, applicability, and suitability have been tested with an application in Turkey's supply chain area. The criteria weights of the proposed model within the scope of this application were calculated using the analytical hierarchy process (AHP) method, which is one of the multi-criteria decision-making methods. However, real-life problems based on expert opinions contain complexity and uncertainty, and in addition, human perception in decision-making processes brings intuition and hesitation. For this reason, the classical AHP method was expanded to interval-valued intuitionistic fuzzy (IVIF) sets. The study's results reveal that immersive interaction and experience dimension is a priority, and supply chains should primarily consider issues such as customer centricity, blockchain-enabled traceability, and social interaction to increase their metaverse service quality performance.

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Keywords: Digital service quality, metaverse service quality, IVIF AHP, SERVQUAL, supply chain

1. INTRODUCTION

Today, technologies are evolving together. This allows the metaverse to play an active role in creating many new channels of interaction between consumers, customers and businesses. Thus, unlimited opportunities arise for the development of the service sector through the metaverse (Dwivedi et al., 2022; Jung et al., 2024). The metaverse is an evolution of the internet that allows for the "participation and living" of a permanent shared experience beyond "navigating" between an utterly virtual world encompassing the real world and the physically existing world. Therefore, it is much more than a virtual playground. Therefore, this evolution has the potential to reinvent consumerism, business models, platforms, partnerships, and more (Canham et al., 2022).

Metaverse is still in its early stages of development and implementation. However, it can potentially revolutionize how businesses interact with customers by bringing the virtual and real worlds together. The opportunities the metaverse can provide to deliver engaging, immersive, and interactive customer experiences excite service industries (Jung et al., 2024). The structure and features of the Metaverse, which brings together the physical and virtual worlds, lead to the development of service delivery methods of businesses. New service boundaries are enabled by advances in supporting technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), digital twins, and blockchain. Metaverse offers service providers the opportunity to seamlessly blend the best experience elements of the physical and digital worlds through its digital nature and immersive digital technologies, merging the physical world with the borderless virtual world. Thence, it enables service providers to create new and unique experiences for customers (Gleim et al., 2024).

In an environment like the metaverse, expectations, quality perception, and satisfaction regarding the service provided will transform. Measuring service quality in the metaverse, as it is always and everywhere, is critical for companies that carry their products and services to the virtual environment to make a profit and be competitive. Changing service quality landscape with the offered services by metaverse has led to questions about the suitability of existing service quality scales and models for the nature of the metaverse and their adequacy for service quality measurements (Gleim et al., 2024). Therefore, this study focuses on service quality in metaverse by considering the changing service quality perception. In this regard, a new service quality model is proposed. The applicability, suitability, and validity of the proposed model have been tested with an application in supply chain in Turkey. The reason for this application is that supply chains have an important place in the business world as network-like structures that connect the whole world and have a global impact. Supply chains, which serve the manufacturing and service industries and form the backbone of the entire business world, are one of the areas affected by this change. Since, analyzing metaverse service quality for supply chains requires considering more than one criterion a multi-criteria decision-

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Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2025.09.486

making (MCDM) approach was adopted in this study. The weights of the criteria are computed using the analytic hierarchy process (AHP) (Saaty, 1980). However, modeling and solving decision-making problems in real life may contain uncertainty, complexity. Furthermore, the decision-making processes conducted by decision-makers (DMs) may involve human perception, hesitation, and intuition. To eliminate that problem the AHP method is expanded to interval-valued intuitionistic fuzzy (IVIF) sets (Atanassov and Gargov, 1989).

The study consists of the following sections. Section 2 explains the implications of metaverse in different industries including supply chains. Following this, the study focuses on metaverse service quality in Section 3. Section 4 gives details regarding the utilized methodology. Section 5 explains the details of the application with obtained results before the study is concluded in Section 6.

2. METAVERSE AND ITS IMPLICATIONS

The lightning-fast pace of change is making today's landscape more dynamic and unpredictable than ever before, while creating new demands. At this point, the metaverse evolution is much more than a virtual playground, as it promises to reinvent consumerism, business models, platforms, partnerships, and more (Canham et al., 2022). The Metaverse is a point where various immersive technologies intersect, offering the promise of dramatically new consumer interactions and experiences (Monsanto et al., 2022).

Immersive experiences benefit operations in different industrial areas such as aerospace and defense, automotive, healthcare, insurance, finance, telecommunication, banking, education, retail and manufacturing (Dwivedi et al., 2022; Monsanto et al., 2022). The use and purpose of immersive implementations in industries can be summarized as follows (Monsanto et al., 2022): Media and entertainment uses immersive technologies to develop facial and movement tracking for characters. Furthermore, this industry uses technologies such as AR/VR to develop costume production, avatars, and designs. Telecom industry offers on-field support and remote assistance using immersive technologies. Manufacturers harnesses various technologies including IoT and XR to reduce costs, conduct simulation-based scenarios, and improve time to market, optimize production time and employee safety. Supply chains utilize industrial metaverse to strength digitalization, to monitor supply flow, to reduce vehicle delivery time and carbon footprint, achieve innovation cycle reduction, host all off the supply chain data. Finance sector uses the metaverse and immersive technologies to offer financial support and advise and visualize the financial data.

The applications of the metaverse in supply chains have attracted the attention of scientific literature. The metaverse applications provide numerous benefits for supply chains as follows (Trivedi and Negi, 2023):

- Reduced cost and returns, improved production quality, collaboration and transparency in sourcing and procurement,
- Reduced downtime and waste, improved sustainability, resource utilization and simulation in manufacturing,
- Improved customer satisfaction, virtual experiences and digital commerce, and reduced overhead expenses in retailing,
- Optimized operations and spaces, improved inventory management and speed of adjustments in logistics operations.

3. METAVERSE AND SERVICE QUALITY

The proliferation of digital technologies has caused consumers to adapt to digital consumption, and the focus of the service sector has shifted, and this has largely reshaped the typical service journey (Jung et al., 2024). In metaverse environments, service providers and customers exist in various forms, both as physical humans and as avatars representing individuals, robots, and digital humans. These environments enable the digital delivery of services (Lyu et al., 2024).

Studies show that consumers and customers prefer online channels more than traditional business-consumer interaction channels (Elmasry et al., 2022; Jung et al., 2024). Consumers and customers today are hyper-connected with the use of digital technologies. In this way, they demand seamless and personalized experiences at every touchpoint with a company. The future of customer experience and meeting these expectations is critical to success. Therefore, businesses need to pay attention to the latest trends in technology and offer an improved consumer and customer experience journey that integrates technology to achieve their goals. The potential of the emergence of the metaverse to further revolutionize the service sector, the opportunities it can provide, and the interest in it have been proven by many studies (Jung et al., 2024).

The metaverse offers a new paradigm for customer experience and provides an opportunity for service researchers to advance this emerging field. Technological developments have enabled the growth and development of the service sector in the metaverse and have led to the emergence of an enormous amount of information to be examined (Gleim et al., 2024). The metaverse has unique characteristics. Moreover, providing high quality and consistent service in the metaverse is difficult because the entire service experience is a touchpoint (Jaakkola and Terho, 2021). To understand and manage customer expectations in the metaverse, re-evaluation of current strategies is a necessity for companies (Westerman, 2022). For this reason, it has become a necessity to review and re-examine existing theories. Furthermore, both existing theories, current and future service offerings should be thoroughly examined for their compatibility and relevance. Dwivedi et al. (2022) emphasized that customer experience, brand satisfaction and brand loyalty through user engagement in the metaverse is a possible future research area. Digital nature of the metaverse provides valuable advantages in terms service offerings such as available real-time data, personalized experiences, improved engagement and connections, seamless blend of physical and digital worlds. However, the lack of tangibility in the metaverse brings both opportunities and challenges for firms. Satisfaction and service quality have changed significantly with the Metaverse, reaching a point where further research is required. Since metaverse offers dynamic service offerings and redefines the boundaries of service quality, alternative approaches should be proposed to

conduct and continue service research in the metaverse (Gleim et al., 2024). From this point of view, this study proposes a new service quality model for metaverse.

The proposed model relies on the digital service quality proposed model by Büyüközkan et al. (2020). They emphasized in their studies that customers who use digital technologies have become digital customers, and even the expectations of these customers regarding digital products and services have become digital. In their study, the classical SERVQUAL model (Parasuraman et al., 1988) was rearranged, modified and adapted to digital transformation. This is proving that changing technological conditions changes the service quality perception and there is a need for new service quality measurement for metaverse. The proposed model consists of four dimensions which are intangibles (Gleim et al., 2024), reliability, digital trust (Büyüközkan et al., 2020), and immersive interaction and experience (Monsanto et al., 2022; Cheng, 2023). Here, each dimension consists of four criteria which are collected through a literature survey. The details regarding the criteria of the model are given in Table 1.

Table 1. The details of the proposed model

Criteria of the Dimensions	Sources
Intangibles	
Interoperability	(Büyüközkan et al., 2020)
Spatio-temporal consistency	(Wang et al., 2023)
Social computing	(Wang et al., 2023)
Frictionless and user centric design	(Canham et al., 2022)
Reliability	
Robustness	(Papagiannidis et al., 2025)
Compatibility	(Wang et al., 2023)
Omni-channel integration	(Monsanto et al., 2022)
Accessibility	(Zallio and Clarkson, 2022; Papagiannidis et al., 2025)
Immersive interaction and experience	
Gamification	(Büyüközkan et al., 2020)
Virtual interaction	(Alabau et al., 2024)
Social interaction	(Monsanto et al., 2022; Zallio & Clarkson, 2022)
Customer centricity	(Büyüközkan et al., 2020)
Digital Trust	
Responsible AI	(Papagiannidis et al., 2025)
Blockchain-enabled traceability	(Curtis et al., 2024)
Privacy and security	(Büyüközkan et al., 2020)
Inclusivity	(Zallio and Clarkson, 2022)

4. THE IVIF AHP METHOD

This section explains the preliminaries for IVIF sets and explains the steps of the IVIF AHP method, respectively. The details are given below.

IVIF sets were proposed by Atanassov and Gargov (1989) as an extension of IF sets to deal with uncertainty, complexity, hesitancy, and intuition due to human perception in the decision-making processes. Let $\tilde{A}$ be an IVIF set. Then, $\tilde{A}$ is represented as in (1).

$$\tilde{A} = \{\langle x, \tilde{\mu}_{\tilde{A}}(x), \tilde{\nu}_{\tilde{A}}(x)\rangle | x \in E\} \quad (1)$$

In this equation, E shows a crisp set and $\tilde{A}$ is defined by $\tilde{\mu}_{\tilde{A}}(x)$, and $\tilde{\nu}_{\tilde{A}}(x)$. Here, $\tilde{\mu}_{\tilde{A}}(x)$ indicates the interval-valued membership function and $\tilde{\nu}_{\tilde{A}}(x)$ represents the interval-valued non-membership function. This IVIF set is characterized by $\tilde{\mu}_{\tilde{A}}(x) = \left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right] \subset [0,1]$ and $\tilde{\nu}_{\tilde{A}}(x) = \left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right] \subset [0,1]$, $\forall\, x \in E$. Additionally, $\tilde{\mu}_{\tilde{A}}(x)$ and $\tilde{\nu}_{\tilde{A}}(x)$ intervals are based on following conditions: $\mu_{\tilde{A}}^{L} = \inf\left(\tilde{\mu}_{\tilde{A}}(x)\right)$, $\mu_{\tilde{A}}^{U} = sup\left(\tilde{\mu}_{\tilde{A}}(x)\right)$ and $\nu_{\tilde{A}}^{L} = inf\left(\tilde{\nu}_{\tilde{A}}(x)\right), \nu_{\tilde{A}}^{U} = sup\left(\tilde{\nu}_{\tilde{A}}(x)\right)$. Here, $0 \leq sup\left(\tilde{\mu}_{\tilde{A}}(x)\right) + sup\left(\tilde{\nu}_{\tilde{A}}(x)\right) \leq 1$, and $\tilde{\pi}_{\tilde{A}}(x) = \left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right], x \in E$. The degree of uncertainty is represented by $\pi_{\tilde{A}}$ and its lower and upper points can be calculated by using (2) and (3), respectively.

$$\pi_{\tilde{A}}^{L} = 1 - \mu_{\tilde{A}}^{U} - \nu_{\tilde{A}}^{U} \quad (2)$$

$$\pi_{\tilde{A}}^{U} = 1 - \mu_{\tilde{A}}^{L} - \nu_{\tilde{A}}^{L} \quad (3)$$

Furthermore, the IVIF set $\tilde{A}$ can be indicated as in (4) based on lower and upper end points.

$$\tilde{A} = \langle \left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right], \left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right], \left[\pi_{\tilde{A}}^{L}, \pi_{\tilde{A}}^{U}\right] \rangle \quad (4)$$

The computational steps of the IVIF AHP methodology are given as follows (Büyüközkan et al., 2020):

Step 1. *Select the DMs, determine the evaluation scales:* The structure of the decision-making problem directly affects the selection process of the DMs. Additionally, the experience, academic background, knowledge level and willingness to share opinions are considered as the criteria to select the appropriate DMs for the decision-making process. Furthermore, the linguistic scales are determined for both importance degree of the DMs and the evaluation of the criteria. Determined linguistic scales are given in the related steps.

Step 2. *Construct a hierarchical model:* A hierarchical model is constructed based on main dimensions, criteria or sub-criteria. Here, dimensions, and criteria are identified through literature survey and the opinions of the DMs.

Step 3. *Calculate the DMs' weights:* In this step, linguistic terms of the linguistic scale presented in Table 2 are used to calculate the weights of the DMs. This step is supported by the utilization of the formula given in (5).

$$\lambda^{(k)} = \frac{\sqrt{\frac{1}{2}\left[\left(1-\pi_{\tilde{A}}^{L(k)}\right)^2 + \left(1-\pi_{\tilde{A}}^{U(k)}\right)^2\right]}}{\sum_{k=1}^{K}\sqrt{\frac{1}{2}\left[\left(1-\pi_{\tilde{A}}^{L(k)}\right)^2 + \left(1-\pi_{\tilde{A}}^{U(k)}\right)^2\right]}} \quad (5)$$

Here, $\lambda^{(k)}$ indicates the weight of the kth DM where $\lambda^{(k)} = \left\{\lambda^{(1)}, \lambda^{(2)}, \ldots, \lambda^{(K)}\right\}$ represents the sets of the weights of the K number of DMs and $\sum_{k=1}^{k} \lambda^{(k)} = 1$.

Table 2. Linguistic scale for DMs (Büyüközkan et al., 2018)

Linguistic Terms	IVIF Values	
	$\left[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}\right]$	$\left[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}\right]$
Extremely qualified (EQ)	[0.95, 1.00]	[0.00, 0.00]
Very qualified (VQ)	[0.80, 0.85]	[0.05, 0.10]
Qualified (Q)	[0.60, 0.65]	[0.10, 0.15]
Less qualified (LQ)	[0.30, 0.35]	[0.25, 0.30]
Very less qualified (VLQ)	[0.20, 0.25]	[0.30, 0.35]
Extremely less qualified (ELQ)	[0.00, 0.05]	[0.45, 0.50]

Step 4. *Evaluate the criteria:* In this step, DMs evaluate the criteria by prioritizing that is based on pairwise comparison using the linguistic terms introduced in Table 3.

Table 3. Linguistic scale for criteria (Abdullah and Najib, 2016)

Linguistic Terms	IVIF values		Reciprocals	
	$[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}]$	$[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}]$	$[\mu_{\tilde{A}}^{L}, \mu_{\tilde{A}}^{U}]$	$[\nu_{\tilde{A}}^{L}, \nu_{\tilde{A}}^{U}]$
Equally important	[0.38, 0.42]	[0.22, 0.58]	[0.22, 0.58]	[0.38, 0.42]
Intermediate value	[0.29, 0.41]	[0.12, 0.58]	[0.12, 0.58]	[0.29, 0.41]
Moderately more important	[0.10, 0.43]	[0.03, 0.57]	[0.03, 0.57]	[0.10, 0.43]
Intermediate value	[0.03, 0.47]	[0.03, 0.53]	[0.03, 0.53]	[0.03, 0.47]
Strongly more important	[0.13, 0.53]	[0.07, 0.47]	[0.07, 0.47]	[0.13, 0.53]
Intermediate value	[0.32, 0.62]	[0.08, 0.38]	[0.08, 0.38]	[0.32, 0.62]
Very strongly more important	[0.52, 0.72]	[0.08, 0.28]	[0.08, 0.28]	[0.52, 0.72]
Intermediate value	[0.75, 0.85]	[0.05, 0.15]	[0.05, 0.15]	[0.75, 0.85]
Extremely more important	[1.00, 1.00]	[0.00, 0.00]	[0.00, 0.00]	[1.00, 1.00]

Step 5. *Obtain group decision values:* The IIFWA operator (Xu and Cai, 2012) that is given in (6) is employed to aggregate the IVIF values of the individual linguistic evaluations of the DMs into group decision values.

$$IIFWA = \left(\begin{bmatrix} 1 - \prod_{k=1}^{K} \left(1 - \mu_{\tilde{A}}^{L}\right)^{\lambda^{(k)}}, \\ 1 - \prod_{k=1}^{K} \left(1 - \mu_{\tilde{A}}^{U}\right)^{\lambda^{(k)}} \end{bmatrix}, \begin{bmatrix} \prod_{k=1}^{K} \left(\nu_{\tilde{A}}^{L}\right)^{\lambda^{(k)}}, \\ \prod_{k=1}^{K} \left(\nu_{\tilde{A}}^{U}\right)^{\lambda^{(k)}} \end{bmatrix} \right) \quad (6)$$

where $\sum_{k=1}^{K} \lambda^{(k)} = 1$.

Step 6. *Check the consistency:* The consistency ratio $(C.R.)$ that is adopted from Abdullah and Najib (2016) and given in (7) is used to check the consistency of the judgments of the DMs.

$$C.R. = \frac{RI - \frac{\sum \pi_{ij}^{U}(x)}{z}}{z-1} \quad (7)$$

Here, the evaluations are consistent when $C.R. \leq 0.1$. Therefore, revision of the evaluation is not necessary. Otherwise, the evaluation process contains inconsistency, and this requires the revision of the evaluation process. The number of the criteria is represented by z while RI indicates the randomness indices that are shown in Table 4. Here, $\pi_{ij}^{U}(x)$ indicates the hesitation value (Abdullah and Najib, 2016).

Table 4. Randomness indices (Saaty, 1977)

z	1-2	3	4	5	6	7	8	9
RI	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Step 7. *Calculate the criteria weights:* In this step, (8) is used to compute the local weights of the criteria.

$$w_j = \frac{1 - \tilde{w}_j}{n - \sum_{j=1}^{n} \tilde{w}_j} \quad (8)$$

where

$$\tilde{w}_j = 1 - \frac{\sum_{k=1}^{K} \frac{\lambda^{(k)} \left(\mu_{\tilde{A}_j}^{L} + \mu_{\tilde{A}_j}^{U}\right)}{2}}{\sqrt{\sum_{k=1}^{K} \frac{\lambda^{(k)} \left(\mu_{\tilde{A}_j}^{L\,2} + \mu_{\tilde{A}_j}^{U\,2} + \nu_{\tilde{A}_j}^{L\,2} + \nu_{\tilde{A}_j}^{U\,2}\right)}{2}}} \quad (9)$$

Here, the set of the criteria weights is shown as $w = \{w_1, w_2, \ldots w_n\}$ where $w_j \geq 0, j = 1,2, \ldots, n$ and $\sum_{j=1}^{n} w_j = 1$.

Step 8. *Prioritize the criteria:* The criteria are prioritized based on their global weights that are calculated by using the local weights.

5. APPLICATION IN SUPPLY CHAIN

In this section, the validity, usability, and applicability of the proposed model given in Table 1 has been tested with an application in Turkey's supply chain sector. In this context, the computational steps of the IVIF AHP method given in the section above have been applied. The details regarding the applied steps are given below.

Three supply chain experts (DMs) were selected from industry and academia based on the selection criteria such as academic backgrounds, knowledge levels, experiences. However, no further information can be provided due to privacy concerns and confidentiality. To proceed the application, a hierarchical model based on the dimensions and criteria has been constructed as shown in Fig. 1.

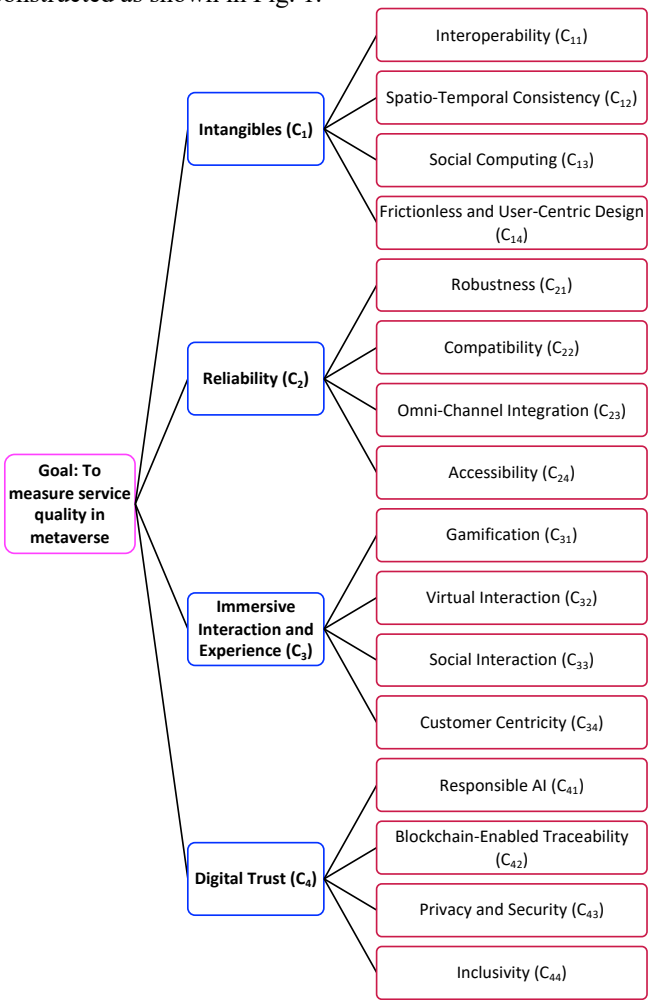

Figure 1. Hierarchical model of proposed service quality model

The weights of the DMs were computed using (5) based on the linguistic terms given in Table 1. The importance of the DMs and their weights are shown in Table 5.

Table 5. Importance degree and weights of the DMs

DMs	Importance	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$\pi_{\tilde{A}}^{L}$	$\pi_{\tilde{A}}^{U}$	$\lambda^{(k)}$
DM_1	Q	0.600	0.650	0.100	0.150	0.200	0.300	0.313
DM_2	VQ	0.800	0.850	0.050	0.100	0.050	0.150	0.375
DM_3	Q	0.600	0.650	0.100	0.150	0.200	0.300	0.313

Following this, DMs conducted pairwise comparisons using the linguistic terms given in Table 3 to evaluate the criteria. Individual evaluations of the DMs were aggregated using (6) to obtain group decision values. After this, group decision values were aggregated one more time to obtain main aggregated values. Obtaining main aggregated IVIF values allow to check the consistency. $C.R.$ values were computed using (7). Both main aggregated values and $C.R.$ values are given in Table 6. Table 6 shows that all the computed $C.R.$ values are less than 0.1. Therefore, there is no need for revising the DMs' evaluations.

Table 6. Main aggregated IVIF values and $C.R.$ values

Criteria	$\mu_{\tilde{A}}^{L}$	$\mu_{\tilde{A}}^{U}$	$\nu_{\tilde{A}}^{L}$	$\nu_{\tilde{A}}^{U}$	$C.R. \leq 0.1$
C_1	0.306	0.595	0.096	0.405	0.095
C_2	0.203	0.532	0.114	0.468	
C_3	0.409	0.666	0.032	0.334	
C_4	0.317	0.588	0.059	0.412	
C_{11}	0.396	0.663	0.063	0.337	0.099
C_{12}	0.205	0.543	0.057	0.457	
C_{13}	0.193	0.531	0.121	0.469	
C_{14}	0.500	0.669	0.051	0.331	
C_{21}	0.403	0.624	0.047	0.376	0.098
C_{22}	0.193	0.588	0.056	0.412	
C_{23}	0.491	0.701	0.062	0.299	
C_{24}	0.208	0.497	0.116	0.503	
C_{31}	0.205	0.477	0.176	0.523	0.099
C_{32}	0.218	0.607	0.050	0.391	
C_{33}	0.336	0.625	0.059	0.373	
C_{34}	0.506	0.692	0.039	0.307	
C_{41}	0.260	0.558	0.045	0.441	0.098
C_{42}	0.639	0.797	0.037	0.203	
C_{43}	0.206	0.526	0.097	0.473	
C_{44}	0.198	0.522	0.095	0.478	

Finally, the weights of the criteria were computed using (8) and (9) and the criteria were prioritized based on the calculated weights which are given in Table 7.

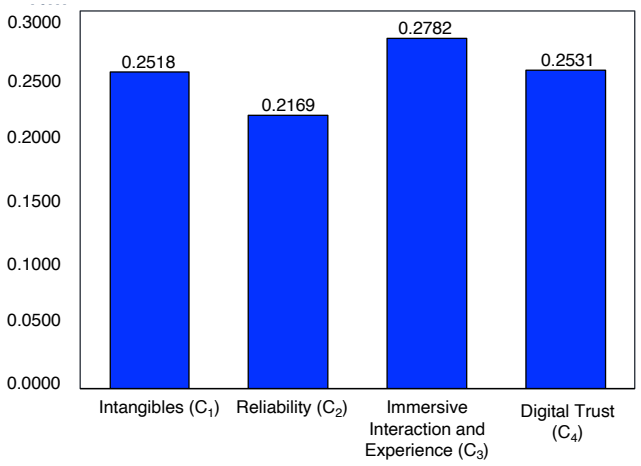

Figure 2. Importance degree of main dimension of mode

The obtained results that are summarized in Fig. 2 show that the most critical dimension in metaverse service quality for supply chains is immersive interaction and experience and it is followed by digital trust. After that the dimension of digital tangibles comes which is followed by reliability. The global weights of the criteria show that customer centricity must be the priority. After that companies should look for better traceability through blockchain technology. In this concept, social interaction was included in top three criteria. Frictionless and user-centric design and interoperability follow social interaction, respectively. Companies in metaverse supply chain should comply with the requirements regarding these issues for better service quality offerings.

Table 7. Computed weights and priorities (order)

Dimension	Weight	Criteria	Local Weight	Global Weight	Order
Intangibles (C_1)	0.2518	**Interoperability (C_{11})**	**0.2764**	**0.0696**	**5**
		Spatio-temporal consistency (C_{12})	0.2227	0.0561	11
		Social computing (C_{13})	0.2146	0.0540	14
		Frictionless and user-centric design (C_{14})	**0.2864**	**0.0721**	**4**
Reliability (C_2)	0.2169	Robustness (C_{21})	0.2715	0.0589	9
		Compatibility (C_{22})	0.2309	0.0501	15
		Omni-channel integration (C_{23})	0.2892	0.0627	7
		Accessibility (C_{24})	0.2084	0.0452	16
Immersive Interaction & Experience (C_3)	**0.2782**	Gamification (C_{31})	0.1999	0.0556	13
		Virtual interaction (C_{32})	0.2425	0.0675	6
		Social interaction (C_{33})	**0.2656**	**0.0739**	**3**
		Customer centricity (C_{34})	**0.2920**	**0.0812**	**1**
Digital Trust (C_4)	0.2531	Responsible AI (C_{41})	0.2444	0.0618	8
		Blockchain-enabled traceability (C_{42})	**0.3123**	**0.0790**	**2**
		Privacy and security (C_{43})	0.2232	0.0565	10
		Inclusivity (C_{44})	0.2202	0.0557	12

As businesses bring their operations to the metaverse and the metaverse evolves, user satisfaction and premium services are more important than ever. From that vision, values of customer centricity, blockchain-driven transparency, social collaboration, frictionless user-centric design, and interoperability drive value in key areas for operational effectiveness, service delivery excellence, customer satisfaction, profitability, and sustainability. Customer centricity raises business-consumer interactivity by gathering user behavior, needs, and expectations and constructing pertinent, personalized, and interactive customer experiences. Traceability is one of the applications that blockchain offers companies for risk mitigation and enabling consumer trust due to transparency, reliability, and authenticity verification. Social interaction creates a vibrant and dynamic cooperative context with the target community, providing a feedback loop through which personalized experiences can be provided. Frictionless and user-centered design reduces cognitive and computing burdens and provides users with ease of use, transparent digital processes, and operational and time efficiency, which raises the success level in the metaverse. Interoperability allows for sharing data and experience between the different virtual platforms in the metaverse. It offers flexibility, seamless customer experience, cooperation among stakeholders, and the potential to reach more individuals.

6. CONCLUSION AND PERSPECTIVES

Metaverse uses applications based on new operational models to improve the experience of customers and suppliers. These applications leverage virtual and augmented reality. Metaverse can be used for a variety of purposes in supply chains, including training, collaboration, visualization, and simulation. Advanced technologies and virtual reality can provide benefits in creating immersive and flexible platforms in supply chains. In addition, the efficiency, resilience, and effectiveness of supply chains can be improved with new

opportunities that can be created with the metaverse (Trivedi and Negi, 2023). In today's globalized business world, supply chains are interconnected and complex. Even so, many businesses continue to manage their processes in traditional ways. However, unforeseen obstacles such as pandemics can cause supply chain shocks. The immersive features of the metaverse have great potential to be useful in dealing with such complex and dynamic conditions (Trivedi and Negi, 2023). The metaverse has changed the perception of service quality. Since, there is a need for the measurement of service quality in metaverse, this study proposes a model, and it applies it into the supply chain area of Turkey to check the suitability, applicability, and validity of it. The reason behind of the selection of the application area is the critical role of supply chains in business world and economy. The IVIF AHP method was utilized to prioritize the service quality criteria based on their weights. The obtained results of the study provide valuable insights regarding a need for such a model in both academia and industry. Furthermore, study shows the applicability of analytical methods in measurement of service quality. The study proposes a generic model that can be adopted to different industrial areas and applications. In future studies, the proposed model can be expanded by increasing the number of dimensions and criteria. The number of the DMs can be increased. As another application, the model can be adapted to different industries to evaluate service quality performance in metaverse. Scenario analyses and/or sensitivity analyses can be performed. More complex fuzzy set extensions can be used, and the results can be compared.

ACKNOWLEDGEMENTS

The authors express gratitude for the contributions made by the experts. This paper has been financially supported by Özyeğin University.

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