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Neutrosophic CRITIC MCDM Methodology for Ranking Factors and Needs of Customers in Product's Target Demographic in Virtual Reality Metaverse

Ahmed Sleem [1,*], Nehal Mostafa [2] and Ibrahim Elhenawy [3]

[1] Ministry of communication and information technology, Egypt; ahmedsleem8000@gmail.com, asleem@mcit.gov.eg.
[2] Misr Engineering and technology, Misr Higher Institute For commerce and computers, Egypt; nehal.mostafa24@gmail.com.
[3] Faculty of Computers and Informatics, Zagazig University, Zagazig, Sharqiyah, 44519, Egypt; ielhenawy@zu.edu.eg.

* Correspondence: asleem@mcit.gov.eg.

Abstract: Affective design has come to place a premium on customer-centric creativity, which ultimately results in the creation of a product tailored to the requirements of a certain demographic. Designing a fresh and original item that appeals to clients remains challenging, despite the abundance of literature on customer-centric creativity and impact product design. This is so because optimizing technological and aesthetical design aspects and variables for a group of consumers is highly complicated, and for the same reasons that it is hard to know a customer's choice, enable the product's functioning, etc. One of the most important parts of creating cutting-edge technological items is the technical product requirement. In reality, we can generally glean insights about a product's design by looking at the hidden desires of a comparable set of potential buyers. In this study, we provide a unique combined structure for evaluating the factors and needs of customers in product design in virtual reality (VR) metaverse by merging the CRiteria Importance Through Intercriteria Correlation (CRITIC) approach with single-valued neutrosophic sets (SVNSs). The characteristic weights in this approach are calculated using the CRITIC technique. The CRITIC method computes the rank of needs. The neutrosophic set is used to overcome the uncertain data. The application of this study shows thermal dissipation, airtight construction, weight, and control mechanisms are among the most crucial considerations.

Keywords: Metaverse; Virtual Reality; Product Design; Neutrosophic CRITIC MCDM.

1. Introduction

Even though we describe it perfectly now, the phrase "Metaverse" was originally used in 1992 by Neal Stephenson, a student at Boston University who is particularly interested in computers, in his book Snow Crash. The narrative also makes contemporary references to avatars and virtual reality goggles. There's more to life than merely chatting with friends online, and the metaverse promises to provide. Pre-metaverse platforms are a kind of promising idea. Sandbox, for instance, provides blockchain-based video games, virtual worlds, and e-commerce. Non-fungible tokens (NFTs) exist in their own universe as well. It allows users to build their own virtual environments. The 3D scanning functionality of the Metahero project shines through, allowing users to create their own avatar in 16K resolution and convert it to NFT [1], [2].

In addition to providing a fresh take on the Internet, the Metaverse is quickly becoming a lucrative market for a wide range of industries. The number of potential financial gains resulting from this is straightforward to estimate. Major investments are being made by some of the world's most prestigious IT firms in the hope that the metaverse will one day become mainstream. Companies like Meta, Microsoft, and Epic Games are good examples. To make the metaverse a reality, we need advancements in areas such as wearable gadgets, internet connection methods, etc. Research on open standards are being conducted, and a standards forum for the metaverse is currently being developed. Recent years have seen significant development in the realms of both virtual reality (VR) and augmented reality (AR). However, when using data flow from senses with different technologies and sophisticated methods, safety and confidentiality problems emerge [3]–[5].

The growth of the theory of single-valued neutrosophic sets (SVNSs) inspired us to investigate its potential use in factors and needs of customers of product design assessment in VR and metaverse associated with imprecise expertise, the inaccurate human mind, and unreliable data. In order to evaluate the factors and needs of customers of product design selection based on several criteria, this research creates a framework using the CRiteria Importance Through Intercriteria Correlation (CRITIC) method in an SVNSs setting for the first time. This is because the CRITIC method's calculation of objective attribute weights is more in line with common sense when applied to MCDM systems [6]–[8].

1.1 Factors and needs of customer in product design in VR Metaverse

Recent decades have seen a rise in the importance of customer-centric innovation as a method for facilitating the production of cutting-edge manufactured goods. Innovation and product design that resonates with the intended market are propelled by a customer-centric approach. Commercial product design creates an item that not only prioritizes its functionality, dependability, manufacturability, and novelty, but also places an emphasis on the outlook, form, shape, and look that piques consumers' attention and influences their purchase decisions [9].

Marketing and selling a product that is tailored to the needs of a certain demographic requires an innovative approach that puts the consumer at the center. Given that product, perspectives are often the central problem influencing the idea development of a product, item enclosure design is crucial in the focused on client's design approach. There have been many academic articles written on customer-centric creativity and effective design for goods, but it is still difficult to create anything really novel that will find an audience among your target consumers. Knowing what a consumer wants, implementing that want into a product, etc., is difficult [10].

It is challenging to simultaneously maximize the technical and aesthetic qualities of a product's design. Immersive devices (e.g., virtual reality/mixed reality headsets), AI structures, mobile phones, Internet of Things (IoT) goods, etc. all rely heavily on the design of their respective product enclosures. The product enclosures safeguard the product's essential electromechanical parts, allowing it to function as intended per the design's requirements and specifications. Creating original tech products relies heavily on adhering to technical design specifications [11], [12].

The main contributions of this study are organized as:

- The first study applied the MCDM model to rank factors and needs of customer in product design on VR metaverse.
- This is the first study applied the neutrosophic set with the VR metaverse in product design.
- The CRITIC method is used to compute and rank the factors and needs of customer in product design in VR metaverse.
- The weights of factors are computed based on the standard deviation and correlation coefficient between factors.

2. Metaverse

In recent years, corporations have been focusing on joining the Metaverse, a permanent and decentralized online environment. The use of HMDs is crucial to the development of the Metaverse. The Metaverse will likely consist of mixed work surroundings, virtual NFT exchanges, shared and distributed immersive experiences, and immersive simulations of performances as the outcome of the combination of HMDs alongside additional immersive and novel technologies like blockchain, no fungible tokens (NFTs), artificial intelligence (AI), and Web 3.0. There are numerous potential benefits and drawbacks of exploring the immersive Metaverse and its effects on people, organizations, and society. Researchers in the field of IS will be able to learn more about these novel occurrences and determine which methods work best for conducting studies in the immersive, physically-boundless Metaverse [13], [14].

Virtual reality (VR) apps, for instance, aim to trick users into thinking they are physically experiencing the virtual environment in which they are interacting. In other words, not only does the simulation of the actual world blur the border between physical and virtual reality, but the blending of human and technical endeavors has also contributed to this phenomenon. Because of this, HMDs enable new socio-material practices in the workplace and in daily life by extending the capacities of both humans and technology. The overlapping of real and virtual identities, increased cybersecurity concerns, security, legal and moral difficulties, and VR-related technostress are all examples of potential unintended consequences that might arise from a more porous boundary among the real and virtual worlds [15], [16].

Since the Metaverse is so immersive, it provides IS researchers with unprecedented possibilities for trying out novel strategies (such as the socio-material method), techniques, and theoretical concepts. Anonymity, trust, user behavior and misbehavior, and the organizational effects of using immersive Metaverses are all areas where this framework can be fruitfully applied to further research [17].

3. Virtual Reality

The term "virtual reality" (VR) is used to describe computer-generated environments that are designed to look and feel like our everyday physical world. Virtual reality (VR) as an idea has been around for quite some time. Recent advances in consumer virtual reality head-mounted displays (HMDs) have led to a surge in the technology's popularity. Due to its superior technological features, including as high-quality picture rendering and a variety of accessories that enable unrestricted movement in the virtual world, the HMDs provide the most realistic VR experiences to date. These technology advancements pave the way for novel user and business scenarios. The $2.3 billion invested in VR startups in 2016 will grow to a $6.1 billion industry by 2020 as a result of the growing demand for head-mounted display (HMD)-based virtual reality (VR) innovation. Big Tech is shifting its attention back to virtual reality (VR) for both retail and enterprise use, and the industry is projected to grow to $20.9 billion by 2025. The virtual reality market is so promising that it is now included among the most important technological trends that governments may pursue [18], [19].

Many academic disciplines, from computer science to the health sciences, have taken an interest in virtual reality. Despite recommendations for greater study in this area, the majority of VR-related articles published in mainstream IS journals have dealt with non-immersive VR (i.e. desktop-based VR) topics such as virtual worlds and 3D objects. Journals in fields including medicine, retail, travel, HCMI, and educational technology are where you'll find the bulk of the known and expanding literature on immersive VR [20], [21].

Virtual reality (VR) is distinguished by its immersive qualities. The ability of virtual reality (VR) gear and software to fool the senses into thinking they are in a different environment is what we mean when we talk about immersion. The favorable impact that immersion has on the user's sense of presence in a virtual environment makes it crucial. Awareness, on the other hand, is a subjective feeling of being fully immersed in a certain place or situation. Users' actions in virtual reality become increasingly consistent with those in the real world as their sense of presence increases, erasing the barriers among the two worlds. Therefore, being immersed in a virtual environment is not just VR's ultimate objective, but also its distinguishing characteristic [22], [23].

4. Single Valued Neutrosophic Sets and MCDM

To cope with the ensuing ambiguity in a variety of fields, the notion of fuzzy sets (FSs) has been widely used. Pattern recognition, making choices, computational imaging, and other fields have all benefited from the various generalizations of FSs that have been described and applied over the last several decades [24]. However, FSs and their expansions are only capable of dealing with partial and inaccurate data, and not the indeterminate and unreliable information that arises in practical MCDM issues [25], [26]. Smarandache devised the neutrosophic set (NS) notion to sidestep this difficulty. Standalone and residing in are the truth, the indeterminacy, and the falsity. The NS is the generalization of FSs as stated by Smarandache. As a result, it has found widespread use in a variety of contexts [27], [28]. Figure 1 shows the SVNSs with the CRIRIC method. The proposed method is starting by using VR and metaverse to rank the customer needs and factors in product design.

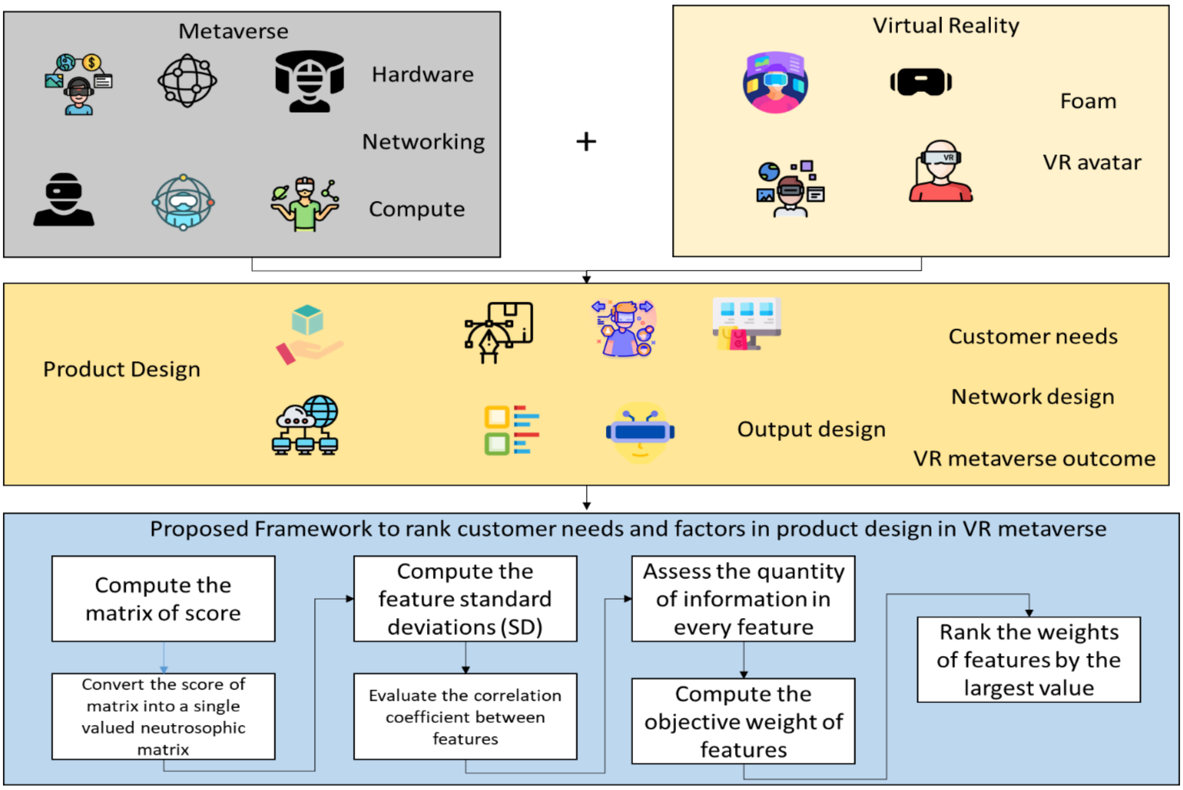

Figure 1. The VR metaverse in product design with the neutrosophic CRITIC method.

5. Metaverse and Authentication

Some people dismiss the enhanced virtual reality technology known as the Metaverse as pure fantasy. However, verses are virtual worlds, and the metaverse is the overarching word for the future Internet. Video games also include digital environments, but the metaverse differs in important ways. In order to draw in a diverse audience, Metaverse should provide engaging content.

The greatest possible user experience requires that all user actions occur simultaneously and in real time. The token economy is the key to ensuring the system's long-term viability. The security of the network, token economy, and decentralized identities all depend on decentralization. Wallets will be used to store and access the digital assets across platforms. The need to safeguard user histories and digital assets will grow. We'll need stronger protections in metaverse, notably during the authentication process[29], [30].

Users and programs must go through authentication before being granted access to a protected area. After successfully authenticating, the user should have access to all resources; nevertheless, security and privacy must be guaranteed. Security refers to the safeguarding of people and their belongings against any and all threats to life and limb. When information, transaction data, or communication belonging to the parties engaged in a transaction is shielded from third parties, we say that the parties have privacy. As our lives grow increasingly intertwined with technological systems, protecting the confidentiality of private information becomes more challenging. Some methods that may be used to verify a user's identity in the metaverse include full-body scanning, face recognition software, DNA identification, and retinal recognition. Because of the sensitive nature of this information, protecting the privacy and security of biometric data is more important than ever before[31], [32].

6. The CRITIC Method

The CRITIC method evaluates the relative importance of factors in MCDM problems based on hard data. The objective weights do this by combining a measure of correlation coefficient (CRC) between qualities with an evaluation of the intensity contrast standard deviation (SD) between features[33], [34]. The weights are $e = (e_1, e_2, \ldots\ldots e_n)^T, and\ \sum_{j=1}^{n} e_j = 1, e_j \in [0,1]$. The steps involved in configuring single-valued neutrosophic sets are outlined below.

(i) Compute the matrix of score

$$S(b_{ij}) = \frac{3+T_{ij}-2I_{ij}-F_{ij}}{4} \quad (1)$$

(ii) Convert the score of matrix into a single valued neutrosophic matrix.

$$\tilde{B}_{ij} = \begin{cases} \frac{B_{ij}-\min_j B_{ij}}{\max_j B_{ij}-\min_j B_{ij}} & for\ positive\ criteria \\ \frac{\max_j B_{ij}-B_{ij}}{\max_j B_{ij}-\min_j B_{ij}} & for\ cost\ criteria \end{cases} \quad (2)$$

(iii) $$SD_j = \sqrt{\frac{\sum_{i=1}^{m}\left(\tilde{B}_{ij}-\sum_{i=1}^{m}\frac{\tilde{B}_{ij}}{m}\right)^2}{m}} \quad (3)$$

(iv) Evaluate the correlation coefficient between features.

$$q_{ij} = \frac{\sum_{i=1}^{m}\left(\tilde{B}_{ij}-\sum_{j=1}^{m}\frac{\tilde{B}_j}{m}\right)\left(\tilde{B}_{ij}-\sum_{i=1}^{m}\frac{\tilde{B}_i}{m}\right)}{\sqrt{\sum_{i=1}^{m}\left(\tilde{B}_{ij}-\sum_{j=1}^{m}\frac{\tilde{B}_j}{m}\right)^2\left(\tilde{B}_{ij}-\sum_{i=1}^{m}\frac{\tilde{B}_i}{m}\right)^2}} \quad (4)$$

(v) Assess the quantity of information in every feature.

$$P_j = SD_j \sum_{t=1}^{n} (1 - q_{jt}) \quad (5)$$

(vi) Compute the objective weight of features.

$$e_j = \frac{P_j}{\sum_{j=1}^{n} P_j} \quad (6)$$

(vii) Rank the weights of features by the largest value.

7. Application

As the metaverse industry evolves rapidly, so are the technical standards for the gear used in it. The proposed hybrid approach is useful for evaluating the design of any technology item since it takes into account both technological and aesthetic factors. To show how the suggested hybrid MCDM technique may be utilized to rank the factors and needs of customers in designing products in the VR metaverse.

It is important to give each element and sub-factor enough consideration when ranking the factors and needs of the customer in product design in the VR metaverse. The variables and sub-factor weights were determined by polling an expert panel. Stakeholders were polled via the use of questionnaires.

Brainstorming sessions or in-depth interviews with prospective customers, key consumers, and technical teams are often used to assess consumer requirements. Next, the requirements need to be weighted based on how important they are. To achieve this objective, it is helpful to ask participants to compare various design elements in a survey by having them rank them on a scale of importance using SVNSs CRITIC. The technical design aspects that are most significant to VR head-mounted systems are identified via market analysis of technical requirements.

The SVNSs CRITIC is used to compute the weights of factors and needs of customers in product design in the VR metaverse. We collected four main factors and 14 sub-factors in the needs of customers to compute the weight as shown in Figure 2.

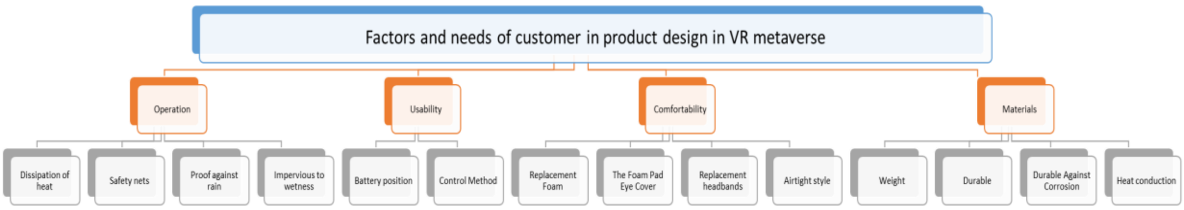

Figure 2. The needs and factors of customer in product design in VR metaverse.

The SVNSs CRITIC method is applied in the data, which collected from survey and previous studies. We collect experts have expertise in product design and VR metaverse to assess the factors and needs of customer in product design in VR metaverse. The experts build the score matrix by using single valued neutrosophic numbers by using Eq. (1). Then compute the normalization score matrix by using Eq. (2). Then compute the standard deviation by using Eq. (3). Then compute the correlation between features by using Eq. (4) as shown in Table 1. Then assess the information by all features by using Eq. (5) as shown in Table 2. Then compute the objective weight by using Eq. (6) as shown in Figure 3. The rank the weights of features. From Figure 3, thermal dissipation, airtight construction, weight, and control mechanisms are among the most crucial considerations.

Table 1. Correlation coefficient of all features.

	VRM_1	VRM_2	VRM_3	VRM_4	VRM_5	VRM_6	VRM_7	VRM_8	VRM_9	VRM_{10}	VRM_{11}	VRM_{12}	VRM_{13}	VRM_{14}
VRM_1	1	0.066872	0.122363	-0.00619	-0.72244	0.315618	-0.09081	0.151651	0.310365	0.251944	0.320882	0.643458	0.290807	0.331133
VRM_2	0.066872	1	-0.58167	0.013252	-0.08454	-0.32151	-0.20769	0.040565	0.536038	-0.28328	0.258597	-0.55979	0.360556	0.596401
VRM_3	0.122363	-0.58167	1	-0.76654	0.205529	0.637387	-0.61338	-0.38597	-0.06301	0.240776	-0.48929	0.623583	-0.55511	-0.04538
VRM_4	-0.00619	0.013252	-0.76654	1	-0.30576	-0.47856	0.768982	0.701272	-0.38212	-0.02174	0.638936	-0.25582	0.684383	-0.44129
VRM_5	-0.72244	-0.08454	0.205529	-0.30576	1	-0.40293	-0.24295	-0.15749	0.139099	-0.53968	-0.11869	-0.60432	-0.43863	0.001495
VRM_6	0.315618	-0.32151	0.637387	-0.47856	-0.40293	1	-0.32274	-0.43155	-0.15148	0.863602	-0.61363	0.746693	-0.27668	0.058412
VRM_7	-0.09081	-0.20769	-0.61338	0.768982	-0.24295	-0.32274	1	0.121191	-0.1641	0.116103	0.13875	-0.14608	0.094001	-0.2111
VRM_8	0.151651	0.040565	-0.38597	0.701272	-0.15749	-0.43155	0.121191	1	-0.44436	-0.2482	0.895879	-0.12301	0.892859	-0.54417
VRM_9	0.310365	0.536038	-0.06301	-0.38212	0.139099	-0.15148	-0.1641	-0.44436	1	-0.26232	-0.01759	-0.24655	-0.31766	0.96073
VRM_{10}	0.251944	-0.28328	0.240776	-0.02174	-0.53968	0.863602	0.116103	-0.2482	-0.26232	1	-0.4526	0.57702	-0.05055	-0.04129
VRM_{11}	0.320882	0.258597	-0.48929	0.638936	-0.11869	-0.61363	0.13875	0.895879	-0.01759	-0.4526	1	-0.24777	0.814418	-0.16837
VRM_{12}	0.643458	-0.55979	0.623583	-0.25582	-0.60432	0.746693	-0.14608	-0.12301	-0.24655	0.57702	-0.24777	1	-0.11328	-0.16477
VRM_{13}	0.290807	0.360556	-0.55511	0.684383	-0.43863	-0.27668	0.094001	0.892859	-0.31766	-0.05055	0.814418	-0.11328	1	-0.31543
VRM_{14}	0.331133	0.596401	-0.04538	-0.44129	0.001495	0.058412	-0.2111	-0.54417	0.96073	-0.04129	-0.16837	-0.16477	-0.31543	1

Table 2. The evaluation of information of every feature.

	VRM_1	VRM_2	VRM_3	VRM_4	VRM_5	VRM_6	VRM_7	VRM_8	VRM_9	VRM_{10}	VRM_{11}	VRM_{12}	VRM_{13}	VRM_{14}
VRM_1	0	0.933128	0.877637	1.006193	1.722438	0.684382	1.090812	0.848349	0.689635	0.748056	0.679118	0.356542	0.709193	0.668867
VRM_2	0.933128	0	1.58167	0.986748	1.084544	1.321506	1.207689	0.959435	0.463962	1.283275	0.741403	1.559792	0.639444	0.403599
VRM_3	0.877637	1.58167	0	1.766544	0.794471	0.362613	1.613379	1.385973	1.063014	0.759224	1.489289	0.376417	1.555109	1.045381
VRM_4	1.006193	0.986748	1.766544	0	1.305759	1.478565	0.231018	0.298728	1.382121	1.021737	0.361064	1.25582	0.315617	1.44129
VRM_5	1.722438	1.084544	0.794471	1.305759	0	1.40293	1.242946	1.15749	0.860901	1.539678	1.118695	1.604316	1.438634	0.998505
VRM_6	0.684382	1.321506	0.362613	1.478565	1.40293	0	1.32274	1.431549	1.151483	0.136398	1.613633	0.253307	1.276678	0.941588
VRM_7	1.090812	1.207689	1.613379	0.231018	1.242946	1.32274	0	0.878809	1.164098	0.883897	0.86125	1.146084	0.905999	1.211096
VRM_8	0.848349	0.959435	1.385973	0.298728	1.15749	1.431549	0.878809	0	1.444365	1.248201	0.104121	1.123011	0.107141	1.544165
VRM_9	0.689635	0.463962	1.063014	1.382121	0.860901	1.151483	1.164098	1.444365	0	1.262317	1.017591	1.246552	1.317659	0.03927
VRM_{10}	0.748056	1.283275	0.759224	1.021737	1.539678	0.136398	0.883897	1.248201	1.262317	0	1.4526	0.42298	1.050545	1.041289
VRM_{11}	0.679118	0.741403	1.489289	0.361064	1.118695	1.613633	0.86125	0.104121	1.017591	1.4526	0	1.247769	0.185582	1.168373
VRM_{12}	0.356542	1.559792	0.376417	1.25582	1.604316	0.253307	1.146084	1.123011	1.246552	0.42298	1.247769	0	1.113285	1.164774
VRM_{13}	0.709193	0.639444	1.555109	0.315617	1.438634	1.276678	0.905999	0.107141	1.317659	1.050545	0.185582	1.113285	0	1.315434
VRM_{14}	0.668867	0.403599	1.045381	1.44129	0.998505	0.941588	1.211096	1.544165	0.03927	1.041289	1.168373	1.164774	1.315434	0

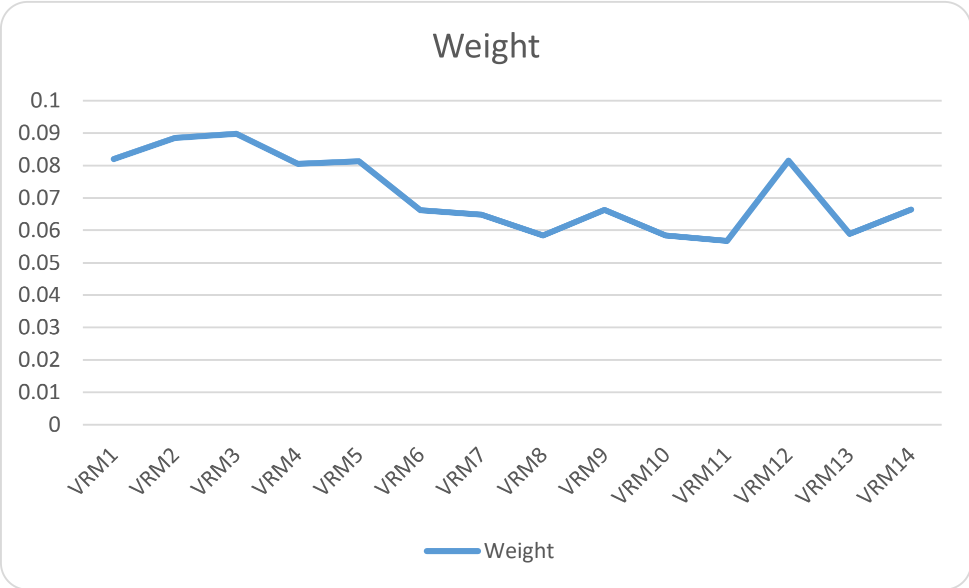

Figure 3. The objective weight of all features.

8. Conclusion

As technology firms shift their focus to immersive VR as a strategic chance, the VR sector is quickly developing increasingly powerful and adaptable HMDs and VR accessories. The VR metaverse has a big attention in product design, so many firms seek to obtain the needs of customers to improve their product design. So this paper used the MCDM method to rank factors and needs of customers in product design in the VR metaverse. The purpose of this research is to propose a novel decision-making approach to evaluating and ranking factors and needs of customers in product design in the VR metaverse in an SVNSs setting. First, a novel approach was presented that used the CRITIC technique while also making use of SVNSs. The CRITIC approach was used to calculate the relative importance of each criterion in this technique. The needs of customers are ranked based on the CRITIC method. The neutrosophic set is used to overcome incomplete and vague data. Thermal dissipation, airtight construction, weight, and control mechanisms are among the most crucial considerations.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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