A Systematic Review of Virtual Commerce Solutions for the Metaverse

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***Abstract*—The metaverse, a rapidly evolving field, promises to transform online shopping through immersive technologies. This systematic review aims to explore and analyze the key design features of Virtual Commerce (v-commerce) solutions within this digital environment. By examining 24 studies that have developed immersive v-commerce applications, this review seeks to compile a taxonomy of essential design attributes necessary for creating effective and engaging v-commerce experiences. The review classifies these attributes into three primary dimensions: Product, Intelligent Services, and Functionality. The findings indicate that within the Augmented Reality (AR) category, product visualization and natural interaction were the most studied attributes. In the Virtual Reality (VR) category, intuitive affordances emerged as the most frequently investigated features. Meanwhile, Mixed Reality (MR) studies commonly focused on information quality, intuitive affordances, and shopping assistants. The insights from this review provide valuable guidance for researchers, developers, and practitioners aiming to enhance consumer engagement and satisfaction in the metaverse through well-designed v-commerce applications. By synthesizing the results of various studies, this review offers a comprehensive overview of the current state of v-commerce research, identifies existing gaps, and proposes potential directions for future development in the field.**

Keywords*—*Metaverse; v-commerce; immersive technologies; design attributes

I. Introduction

Over the past two decades, the online retail market has seen a significant increase, primarily driven by the rise of electronic commerce (e-commerce). The COVID-19 pandemic further accelerated this growth, leading to unprecedented levels of global e-commerce sales, which reached $5.7 trillion in 2022, representing a rise in market share from 18.8% to 19.7% [1]. Analysts predict that by 2026, the online segment will grow to $8.1 trillion, nearly a quarter of the total retail market share [2], [3], indicating a lasting shift in consumer behavior towards online shopping [4]. This shift is fueled by advancements in mobile and internet technologies, necessitating businesses to continuously adapt to stay competitive and enhance consumer shopping experiences.

The advent of the metaverse promises to transform online shopping into a more immersive, engaging, and seamless experience. Unlike traditional e-commerce, the metaverse allows users to interact through digital avatars in virtual storefronts, offering an enriched user experience powered by technologies like Augmented Reality (AR), Virtual Reality (VR), and Mixed Reality (MR) [5]. These immersive technologies, along with Artificial Intelligence (AI) powered chatbots and Internet of Things (IoT), enable personalized shopping experiences and provide retailers with valuable data analytics to tailor offerings to customer preferences [6]. For organizations to fully exploit these capabilities, it is crucial to select optimal v-commerce solutions that integrate the real and virtual worlds, enhance consumer engagement, and support business success. Furthermore, v-commerce attributes can also be used to assess, evaluate and compare multiple v-commerce solutions against each other to select the most optimal one.

To leverage the potential of the metaverse, organizations need to adopt v-commerce solutions that meet their specific needs and enhance consumer engagement and trust. However, there is no consensus among researchers on the effective design elements of these solutions [7]. Studies in Information Systems (IS) have explored factors influencing consumer behavior in immersive shopping environments [7], [8], [9], [10]. However, these studies often focus on behavioral intentions using self-reported data, which can be biased and require validation through more robust methodologies.

To effectively identify the essential design elements of metaverse v-commerce solutions, an investigation of Design Science (DS) research is recommended [11]. DS approach emphasizes the creation and evaluation of innovative IT artefacts and can provide a more rigorous foundation for understanding the impact of design attributes on consumer behavior [12], [13]. To the best of our knowledge, no study has comprehensively combined and presented design attributes for v-commerce solutions.

Several systematic reviews on v-commerce exist in literature [7], [9], [14]. However, the current systematic review diverges from the previous studies in several key aspects. First, the previous reviews focus on IS studies in v-commerce reporting behavioral constructs for the adoption of v-commerce solutions, and the theories applied to predict consumer purchase intentions. The aim is to inform practitioners about the essential factors needed for a v-commerce system to achieve its intended purpose. Second, previous reviews focus on a single immersive technology such as VR [7], or AR [9], [14]. This study seeks to investigate DS research to present the v-commerce attributes for all immersive environments focusing all the immersive technologies (AR, VR and MR). Furthermore, this review aims to identify the design elements for developing and evaluating v-commerce solutions.

This study employs a systematic approach to review and synthesize an analysis based on empirical studies that have implemented v-commerce solutions. The study aims to categorize literature based on immersive technologies to reveal a taxonomy of the design attributes implemented in v-commerce solutions for consumer engagement. Additionally, it aims to outline future directions and research opportunities in this field.

The rest of the study is organized as follows. Section II provides background information on the metaverse and v-commerce. Section III presents the methodology of the systematic review, while Section IV presents the results and discussion of the review. Section V presents the conclusion of the study along with the research limitations and future work.

II. Background Information

A. Metaverse

The metaverse, initially coined in Neal Stephenson's 1992 science fiction novel "Snow Crash," is a collective virtual shared space created by the convergence of physical and virtual reality [15]. Over the past three decades, technological advancements have laid the foundation for a more tangible metaverse experience [16]. While still in its infancy, ongoing research and development are shaping its potential as the successor to the Internet.

The realization of the metaverse is made possible by various technologies, including immersive technologies, 3D computing, 5G and edge computing, AI, blockchain, and IoT [6], [17], [18]. These advancements offer high-speed, low-latency connectivity, personalized user experiences, secure digital identities, and seamless interactions within the metaverse. AI enhances user experiences by personalizing content and enabling intelligent interactions, while blockchain ensures secure transactions and digital ownership verification [6], [17], [18]. IoT bridges the physical and virtual worlds, mirroring real-world information within the metaverse [17], [19].

At the core of the metaverse experience are immersive technologies such as VR, AR and MR, collectively known as Extended Reality (XR). These technologies create a sense of presence in digital environments, allowing users to interact with and navigate the metaverse seamlessly. Low-immersion environments offer limited sensory stimulation, while high-immersion environments provide a rich, multi-sensory experience, enhancing the realism and interactivity of virtual objects and environments. The immersion spectrum of AR and VR technology is depicted in Fig. 1.

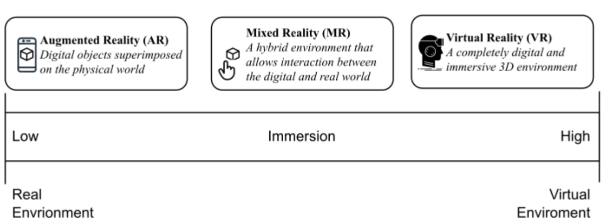

Fig. 1. Immersion spectrum of XR technologies.

Central to this immersive engagement are avatars, digital representations of users that facilitate social interactions within the metaverse [20]. Avatars range from simple 2D icons to complex 3D models and can perform various functions beyond visual representation, such as gestures and expressions. They enable users to communicate and collaborate in real-time, simulating real-world interactions [15]. The metaverse holds the potential to revolutionize socialization and interaction across various domains, including tourism [21], education, and retail [5], by providing immersive, interactive, and engaging experiences that integrate the physical and virtual worlds seamlessly. Designing v-commerce solutions in the metaverse requires addressing the challenge of creating unique, integrated experiences that enhance consumer engagement and business growth.

B. Virtual Commerce

The evolution of online shopping is rapidly transforming with the advent of new technologies that are quickly gaining traction among consumers. In this expansive digital landscape, v-commerce has emerged as a dynamic and transformative force, offering new opportunities and challenges for businesses and consumers alike. V-commerce is becoming a prominent feature of e-commerce, leveraging immersive XR technologies alongside AI to deliver captivating, three-dimensional shopping experiences [22]. These advanced digital technologies provide highly engaging and interactive experiences, immersing users in unique shopping environments [23].

V-commerce technologies allow consumers to explore virtual stores and examine products in a way that closely replicates the experience of shopping in person. This paradigm shift promises to revolutionize shopping practices by offering enhanced convenience and customer satisfaction [24]. Unlike traditional e-commerce, v-commerce provides immersive experiences that engage consumers through various sensory dimensions, including visual, auditory, kinetic, and tactile stimuli. This approach opens numerous opportunities for increased customer engagement, streamlined purchasing processes, stronger connections, and enhanced profitability.

The evolution of e-commerce towards virtual realms and encounters is evident as several stores facilitate immersive experiences for consumers. For instance, Ikea has developed a virtual reality app that allows customers to visualize furniture in their own rooms before purchasing [25]. Fashion retailer Zara introduced an AR shopping assistant app that displays clothing worn by models when customers point their cameras at the store. Additionally, brands like Sephora and L'Oreal use immersive technologies to let consumers digitally try on makeup products [26].

The convergence of v-commerce and the metaverse, which includes virtual environments where users can interact with various digital assets, offers countless possibilities for creating distinctive and immersive shopping experiences, such as virtual product explorations, virtual social interactions, virtual try-ons, and even virtual malls. In conclusion, v-commerce is poised to transform the online shopping landscape through rich, interactive, and immersive experiences.

III. Methodology

This paper uses a systematic approach to examine empirical research studies that have implemented v-commerce solutions.

For this purpose, the study adopts the systematic review framework established by [27]. This framework was selected over other frameworks, such as [28], since it provides guidelines specifically for conducting reviews in the technical field. Employing a rigorous theoretical framework is crucial for guiding the comprehensive data collection and analysis methods required for ensuring the reliability of the results. The systematic literature review guidelines by [27] offer a thorough approach to collecting, analyzing, and documenting findings from secondary data sources. By following this methodology, we aim to perform a thorough analysis of the included articles in the review and uncover the v-commerce design attributes to guide practitioners and researchers and further the study in this field.

The review process is segmented into five distinct phases: identifying the data sources, establishing the search strategy with the inclusion/exclusion criteria, selection of the articles using the PRISMA framework, performing the meta-analysis and finally reporting the results. The next subsections explain each phase and the outcomes of the phase. Results of the review are presented in Section IV.

A. Data Sources

Choosing the appropriate data sources is a crucial step in an Systematic Literature Review (SLR) process. To this end, three multidisciplinary databases were utilized as sources for collecting relevant articles – Web of Science (WoS), Scopus and ScienceDirect. The suitability and relevance of these databases has been acknowledged in numerous SLR articles published in well-regarded journals and in scientific research articles, demonstrating their resilience and scholarly evaluation [29]. All the selected databases encompass multiple publications across diverse scientific research domains and from various academic disciplines. Both Scopus and WoS are multidisciplinary databases encompassing peer-reviewed literature in science, medicine, social science, technology, arts and humanities, making them valuable for accessing a broad spectrum of research. ScienceDirect is a comprehensive resource for articles in the scientific, technical and medical fields.

B. Search Process

The search was conducted in two iterative rounds, the first in December 2023 and second in Jan 2024, to ensure that the latest articles are not left out. Additional studies were also sourced using a snowballing technique. The keywords representing immersive technologies such as ‘virtual reality’, ‘augmented reality’, ‘mixed reality’, ‘virtual world’ and ‘virtual environment’ were combined with the keywords ‘virtual commerce’, ‘virtual shopping’, ‘virtual store’ using Boolean operators to limit the search to the respective domain. Moreover, the search encompassed the title, abstract, and keywords to broaden the search space and ensure the inclusion of relevant studies. The formulated keywords search string is given below:

("virtual commerce" or "virtual shop*" or "virtual store") AND ((virtual AND (reality OR environment OR world)) OR ((mixed OR augmented) AND reality)).

A set of inclusion exclusion criteria, presented in Table I, was established to outline the crucial characteristics of the studies incorporated in the research.

TABLE I. INCLUSION / EXCLUSION CRITERIA

Inclusion Criteria	Exclusion Criteria
Must be an empirical study focused on the development of v-commerce applications.	Studies that are qualitative or unrelated to v-commerce application development
Must detail characteristics or design features of the developed application	Studies that do not describe or include any attribute of v-commerce application
Must be published in a peer-reviewed journal or conference proceedings	Publications such as books, book chapters, reviews, or articles not yet published
Must be written in English	Papers written in languages other than English
Must have been published between 2011 and 2024	Papers published before 2011

This study delves into the trends of research by analyzing keywords present in literature, particularly focusing on v-commerce solutions utilizing immersive technologies. After conducting the initial search, which yielded 525 results, the key terms from these findings were visualized using VOSviewer to identify prominent themes in the literature. VOSviewer is an advanced software tool designed for visualizing and analyzing scientific literature [30]. By examining the external characteristics of the data, it enables statistical and mathematical analysis to uncover trends and features within specific disciplines. Fig. 2 illustrates the visualization results. The diagram highlights the significance and interconnections among frequently occurring terms extracted from the abstracts, titles, and keywords of the search results. The size and label of each term indicate its importance, while the color represents clusters in the visualization. Each cluster comprises terms related to one another within the group, and the distance between clusters signifies their relatedness.

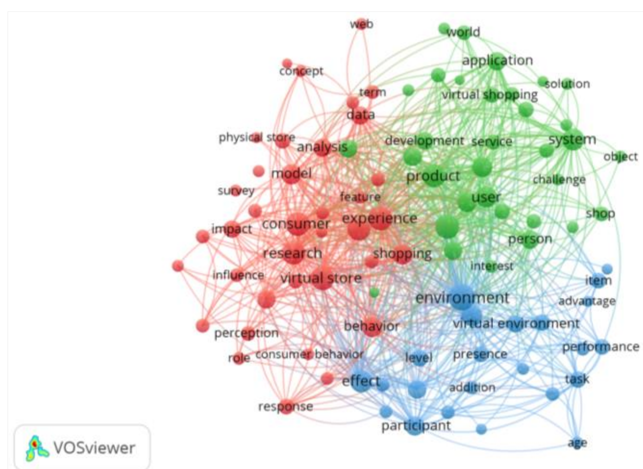

Fig. 2. Visualization of key terms in search results.

The visualization of key terms present in the titles and abstracts reveal three primary clusters, which clearly indicates the divide in the extant literature between IS and DS research. The red cluster encompasses keywords like consumer behavior, purchase intention, perception, influence, relationship, and model, indicating a research focus on behavioral outcomes concerning v-commerce and purchase intentions arising from IS studies. The green cluster, on the other hand, features terms such as product, solution, service, application, technology, interaction, and development, showcasing a trend towards DS research for v-commerce solution development. Lastly, the blue cluster includes terms like performance, time, advantage, reflecting the evaluation of both IS and DS studies. This differentiation between IS and DS research underscores the need for mapping findings between the two domains.

C. Study Selection

The selection of articles for the systematic review was processed using the PRISMA framework [31] depicted in Fig. 3. This framework offers comprehensive guidelines and an organized method for reviewing documents. It consists of four main phases after performing the keyword search. The first phase is the identification phase in which the articles are retrieved from the identified databases and the duplicate articles are removed. Second is the initial screening phase, in which the inclusion/exclusion criteria are utilized to screen the articles based on the abstracts. Third is the eligibility phase in which a thorough full-text screening is performed to assess the relevance of the articles and to ensure that the article meets the requirements of the SLR. Finally, the last phase involves performing a quality assessment of the articles to ensure reliability of the findings. The application of each of the four phases using the PRISMA model is discussed next.

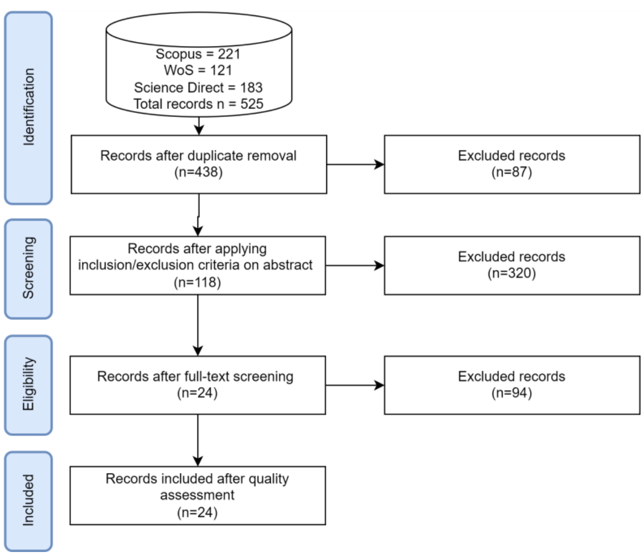

Fig. 3. PRISMA framework.

First, the search yielded 525 results across all databases. The removal of duplicate articles reduced the number of studies to n=438. Next, the abstract screening process was used to screen irrelevant articles which further reduced the number of studies to n=118. During the abstract screening process, numerous studies were excluded as they did not contribute to the context of this research such as the studies which were not empirical research in the field of v-commerce solutions development. In the eligibility phase a full-text screening of the articles led to the removal of all irrelevant studies that did not meet the inclusion criteria requirement thereby reducing the number of articles to n=24. A through screening of the articles revealed that several studies were irrelevant due to multiple reasons such as review articles, articles not in English, unavailability of full-text, articles not related to v-commerce application or solution development.

Finally, a quality assessment was conducted to ensure the reliability and validity of the included articles. It is important to note that the purpose of the quality assessment is to evaluate the relevance of the selected articles to this study's objectives, rather than to critique individual studies or their findings. Ensuring the validity of results and minimizing bias are crucial aspects of systematic reviews, highlighting the importance of quality assessment [32]. Additionally, quality assessment helps refine inclusion and exclusion criteria and contributes to the overall rigor of the review process [27]. The quality assessment checklist, was adapted from an extant SLR study [29]. It comprises of criteria that are crucial for the encoding process such as detailed description of the design elements and evaluation of the application design. The quality assessment also considers the credibility of the source and relevance of the publication to the research community. Each reviewed article was assessed using a quality checklist by assigning a score of 1 when the criteria is met, 0.5 if it is partially met or 0 if it is not met. The total score was converted to a percentage value. Only studies scoring 75% and above are considered for the review. Notably, all the studies passed the quality assessment check and were included in the meta-analysis.

D. Data Analysis and Coding

The objective of this phase is to thoroughly document the systematic review findings by gathering meta-data from the primary studies included in the review, with a focus on the research questions. A thorough data analysis of the relevant features identified during the planning phase is conducted to achieve this objective. The meta-data analysis encompasses various characteristics crucial for achieving the objective of the study such as identifying the design attribute implemented in the study and categorizing the attribute to its respective dimension.

E. Reporting the Review

In the concluding phase of the systematic review, the study results are unveiled. Section IV presents a comprehensive analysis of the meta-data extracted from the full-text review, with the aim of revealing the v-commerce design attribute implemented in the studies. This analysis presents and discusses the insights from the collected data, providing a thorough understanding of the findings and their implications within the context of the objectives of the study.

IV. Results and Discussion

The scope of the SLR included a qualitative analysis of 24 studies. The studies were categorized based on the immersive technologies utilized in the experimental design. Out of the 24 studies, nine studies developed AR solutions; nine studies developed VR solutions while six studies developed MR solutions. The meta-analysis aimed to uncover the design features in v-commerce applications implemented for respective immersive technologies. This section presents the design attributes extracted from all the reviewed studies and presents a critical review of the implementation leading to a taxonomy of v-commerce design attributes.

A. V-Commerce Design Attributes

The results of the analysis revealed a total of 13 design attributes that were used to enhance shopping experience in v-commerce solutions. The design attributes were further categorized into three main dimensions: Product, Intelligent Services and Functionality. The definition of each attribute within each dimension is summarized below.

1) Product attributes: Product attributes encompass the richness and presentation of product information within an immersive environment. These design features are crucial for users to access detailed product information and interact effectively, enabling informed decisions. Through the literature review product attributes were categorized into four sub-attributes namely information quality (IQ), product visualization (PV), intuitive affordance (IA), and realistic modeling (RM). Each sub-attribute is described below.

a) Information Quality (IQ): Refers to the richness and presentation of the product information in the application. Information quality in a 3D environment may be defined as the quality of product information provided as direct information as well as indirect information revealed through interactions [33]. The richness and abundance of product information empowers consumers to make well-informed purchasing decisions. Utilizing 3D environments, simulations, or augmented reality can optimize the depth of information provided and elevate brand interaction and purchasing intent by improving perceived information accuracy and fostering positive brand perceptions [34]. Interaction with the product can also assist the consumer to gather more information while in an immersive environment.

b) Product Visualization (PV): PV, often implemented as Virtual try-on feature, in an immersive environment fosters customer involvement and provides an opportunity to test the items in order to make an informed purchase decision by reducing product ambiguity [35]. Several studies use algorithms to track the position of the surroundings or the human body to accurately display virtual accessories such as eyeglasses and clothing.

*c) Intuitive Affordance (IA)***:** IA refers to designing user interfaces that facilitate natural interactions with virtual objects, including actions like gaze, pinch, touch, grab, and hand gesture recognition, among others [36]. An immersive environment engages multiple human senses. To fully engage users in an immersive environment, the application must cater to their natural expectations for varied sensory experiences [37]. Therefore, virtual interactions that aligned with human perceptions of physical interactions create a more natural interaction.

d) Realistic Modelling (RM): Methods to render a product and/or the virtual environment in such a way that it is perceived to be realistic by users. Realistic modelling enhances perceived presence in the immersive environment [38], [39] and enhances the level of satisfaction [39].

2) Intelligent services: Intelligent Services within v-commerce applications leverage AI, machine learning, and data analytics to enhance the shopping experience. These services encompass the integration of agents that aid users in navigating the online environment, recommend products, and simulate the assistance provided by in-store human assistants. Additionally, AI technologies like computer vision and geolocation features can be integrated to offer a more intuitive and seamless interactive experience within the environment. Five sub-attributes were identified in this category, which include Natural Interaction (NI), Navigation Agent (NA), Recommendation Agent (RA), Shopping Assistant (SA) and Personalization (PS). Each sub-attribute is described below.

a) Natural Interaction (NI): NI involves utilizing technologies that enable users to engage with the application in intuitive and expected ways, for example using computer vision for face or body detection instead of using markers or silhouettes in AR [40], facial expression detection, natural language conversations, gesture recognition in a VR environment [41].

b) Navigation Agent (NA): A smart digital assistant that aids users in navigating a virtual space by providing guidance and directing them on how to interact with objects [42]. Navigation agents may take the shape of an embodied agent with an avatar or a virtual tour.

c) Shopping Assistant (SA): A virtual agent that provides information about the products or services in the virtual environment. The goal of the shopping assistant is to provide a new digital dimension to shopping mimicking the in-store assistants by answering basic FAQs, providing information on deals, coupons, and subscriptions [43].

d) Recommendation Agent (RA): RA utilize AI technologies to suggest products based on user preferences and behaviors. [44]. Product recommendations offer an efficient search option for end users and thereby enhance the brand attitude, user satisfaction and attitude towards technology [45].

e) Personalization (PS): Providing customized information to users based on characteristics, or preferences. Studies reveal that tailoring content to an individual's needs and interests is associated has a greater appeal and convincing impact on the consumer [46]. Moreover, increased personalization enhances brand attitude and user satisfaction [46].

3) Functionality design: Functionality attributes in v-commerce applications refer to the design features that aim to enhance interactivity, engagement, and control in an immersive environment. Interactive features are known to positively influence consumer satisfaction [47], [48] and provide an enjoyable shopping experience [38], [49], [50]. Four design attributes were identified in this category, namely Customization (CS), Navigability (NV), Seller Reputation

(SR) and Social Commerce (SC). Each sub-attribute is described below.

a) Customization (CS): CS is a feature of immersive technology that allows the user to manipulate and customize the product and/or the virtual environment. Incorporating VR technology for product customization is expected to improve task-related factors and enhance the perceived value of the user experience [51]. Moreover, these systems may enable users to personalize a 3D layout and adjust specific properties of virtual objects.

b) Navigability (NV): NV refers to the design of functions to enable user navigation or movement through the immersive environment [11]. It enhances the system's ease of use and is essential for creating a sense of physical presence within the immersive environment [52], [53], [54].

c) Seller Reputation (SR): SR is a technique for objectively measuring a seller's credibility based on customer feedback and personal ratings. A mechanism to rate seller's reputation promotes transparency and enhances repurchase intentions in an online environment [55].

d) Social Commerce (SC): Enabling social presence by adding features of collaborative shopping and social activities such as sharing reviews, voting, likes and more [56]. Social commerce uses technologies to blend shopping with social activities to develop a sense of connection with the e-retailer and thereby enhancing the degree of social presences in a digital environment.

B. Critical Review of V-Commerce Attribute Implementation

This section presents a summary of the design attribute implementation within the respective immersive technology (AR, VR, MR) and develops a taxonomy of the design attributes. Out of the 24 reviewed studies, nine studies belonged to the AR category, nine to the VR category and six to the MR category. Fig. 4 presents the taxonomy, which illustrates the mapping of the design attributes implemented in the reviewed studies.

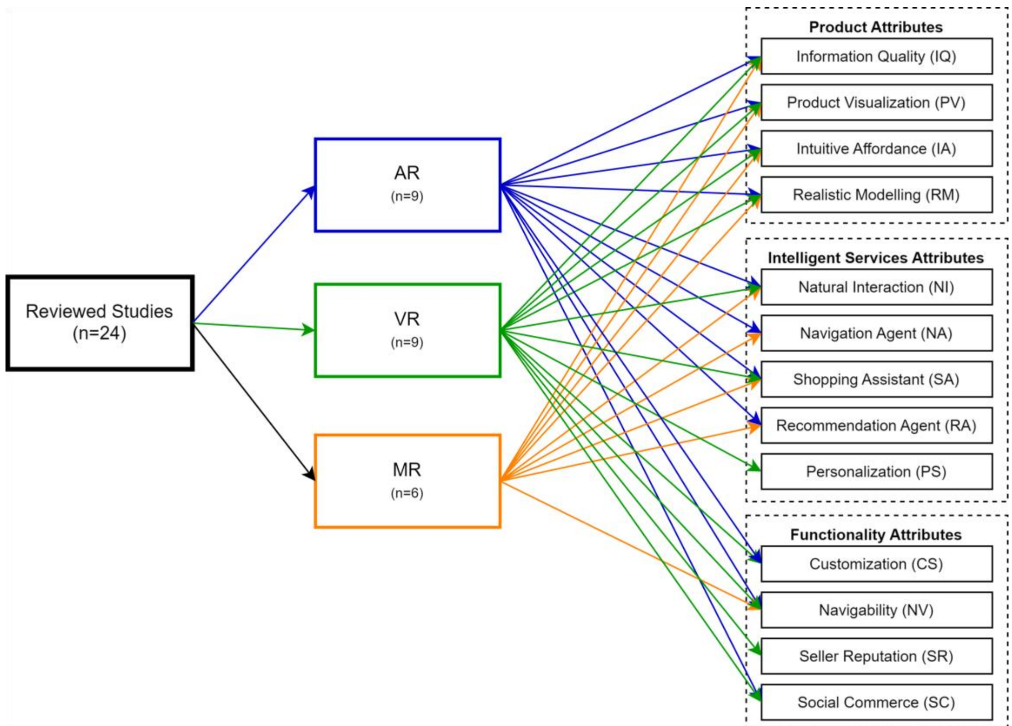

Fig. 4. Taxonomy of v-commerce design attributes.

1) AR studies: AR technologies superimpose digital information onto the real physical environment creating a new, combined experience that can be interactive and dynamic [57]. AR uses various devices such as smartphones, tablets, or specialized glasses to display computer-generated images, videos, or other virtual content in real time [14]. AR has the potential to offer new and innovative ways of engaging users in the shopping experience through product visualization, virtual try-ons and more [38], thereby providing consumers with a more immersive, engaging, and interactive shopping experience, leading to increased customer satisfaction and sales.

An analysis of the reviewed studies under the AR category revealed that numerous researchers focused on multiple design features of AR applications to enhance the consumer's shopping experience. Under the product dimension, product visualization and virtual try-ons (PV) were the most investigated design attributes by multiple researchers in the form of trying on clothes, glasses and visualizing furniture and toys [35], [40], [58], [59], [60]. Several studies enhanced the Information Quality (IQ) of the products by providing detailed product information [58], [61], information placement, and provision of additional relevant information [61], [62], while [63] enhanced Information quality by using explainable recommendations, and product comparisons. Intuitive Affordance (IA) was a focus of four out of nine studies in AR.

The research in [62] and [60] implemented intuitive affordance features by adding product rotating, zooming capabilities. The research in [58] implemented a direct selection feature that allows consumers to pick and try on glasses published by other users. While [63] added intuitive visual elements to ease navigation and discovery. Only two studies [62], [64] focused on enhancing the 3D quality ad Realistic Modelling (RM) of the product.

In the Intelligent Services dimension, Natural Interaction (NI) was among the highly researched design areas, and the focus of six out of nine studies. Computer vision used to naturally detect users' body [40], facial data [35], [58], or perform a product search [60]. On the other hand, [62] used deep learning to detect users current in-store location. The research in [60] also focused on other intelligent services such as a Navigation Agent (NA), shopping assistant (SA). Both [60] and [63] added product recommendations using Recommendation Agents (RA) to enhance the user's shopping experience.

In the functionality dimension three studies [40], [59], [62] added Customization (CS) features on the AR shopping app such by allowing users to customize the product size, color, type or more. Four out of nine studies focused on navigability (NV) by providing easy search features and filter features for products [58], [59], [60] or easy in-store navigation [62]. The research in [40], [58] and [59] enhanced the social presence in the AR shopping app by adding the feature allowing users to share their try-ons with others, thus promoting Social Commerce (SC).

Overall, in the AR category, NA and PV were among the most investigated design attributes with 67% (n=6) and 56% (n=5) studies experimenting with these features respectively. The IQ, IA attributes were studied by 44% (n=4) studies, while the PS and SR attribute were not investigated by any study.

2) VR studies: VR technologies simulate realistic and immersive experience in a three-dimensional environment. VR allows consumers to see and interact with a product in a virtual environment, providing a more immersive and realistic experience than traditional 2D images or videos. With VR, businesses can create virtual storefronts and showrooms, allowing customers to browse and providing a multisensory purchase experience [10].

Among the reviewed studies in the VR category, several researchers focused on multiple VR design attributes to applications to enrich the consumer's shopping experience. In the product dimension, Intuitive Affordance (IA) and information quality (IQ) were the most investigated criteria. Three studies, [65], [66] and [67] focused on product presentation and information to enhance the information quality of the user experience. In addition, [67] also provided detailed product information with price comparisons to enhance the quality of information. Intuitive affordance was investigated by four studies by incorporating features such as grabbing, picking, rotating and adding items to the cart [65], [66], [67], [68]. Two studies focused on Realistic Modelling (RM) of the products [66], [68], while only one study incorporated the product visualization (PV) feature as virtual try on for clothes [67].

In the intelligent services dimension, natural interaction (NI) in a shopping environment was investigated by five researchers in the form of using speech, eye and gaze interaction and virtual touch features [65], [66], [68], [69]. Moreover, [67], [70] also included the feature of an intelligent shopping assistant (SA) in the virtual environment. The research in [71] incorporated the feature of a personalization (PS) based on users shopping profile. Navigation agents (NA) and recommendation agents (RA) were not studied in a virtual shopping environment by any of the studies.

Navigability (NV) was the most investigated criteria in the functionality dimension. Navigability was implemented with the use of controllers to ease navigation [67], simple and easy environment with clear signs [68], 3D navigation for ease of movement and turns [65], [66]. The research in [72] investigated the feature of customizing (CS) the virtual store. Fang et al. (2014) implemented the seller reputation (SR) feature by using a five senses reputation mechanism to assess the reputation of the seller in the virtual environment. The research in [67] added a social commerce feature by providing users a sense of shopping with other users by showing their online presence.

In the VR category, the NI design attribute is one of the highest investigated design features investigated in 44% (n=4) studies. In addition, IA and navigability NV were also investigated by 44% (n=4) studies. The IQ feature was investigated by 33% (n=3) studies. Furthermore, in the VR studies category the NA and RA attributes were not investigated by any study.

3) MR studies: MR is an emerging technology that integrates both virtual and augmented reality elements to create a blended, hybrid environment which includes both real and virtual objects [74]. Unlike AR, MR enables virtual objects to interact with the physical world. MR offers all the benefits of AR with an addition of interaction. Consumers can not just visualize or try the product before purchase, but also interact with it in real-time. Thus, MR allows for a more natural and intuitive interaction between the consumers and the digital products, leading to a more immersive experience.

From the reviewed studies in the MR category, four studies investigated the online shopping experience using MR technology. The research in [75] implemented a total of six design attributes. The study included three product attributes in the form of virtual try-ons (PV), intuitive affordance (IA) using with a full hand manipulation feature and enhanced product information. Furthermore, [75] also added intelligent services with natural interaction (NI) using computer vision for a smart product detection feature and recommendation engine (RA). Navigability (NV) was enhanced by incorporating ease of searching.

The research in [76] applied eight design attributes to an immersive shopping environment. In the product category, all the attributes were implemented (information quality (IQ), virtual try on (PV), intuitive affordance (IA), realistic modelling (RM)). The research in [76] also applied intelligent services to the shopping application in the form of a navigation agent (NA) that provides a tour of the application, a shopping assistant (SA) that answers users queries and a product recommendation (RA) system that suggests products based on user's traits. Finally, navigability (NV) of the system was enhanced by an avatar-based guidance system and providing a 360 view of shopping center with free walking and movement.

The research in [77] on the other hand implemented three design attributes (product visualization (PV), natural interaction (NI) and a voice-based shopping assistant (SA)) for a fashion store. The research in [78] implemented two design attributes, intuitive affordance (IA) using a feature to interact with a virtual hand, and realistic modelling (RM) by incorporating a sense of agency on the virtual hand to make it appear realistic. The research in [79] developed an MR shopping assistant using Microsoft HoloLens, which offers product information, reviews, and recommendations to the shopper. In a later study [80] enhanced the shopping assistant application to include more features. Their prototype incorporated features such as providing product information using textual and video-based formats to enhance the Information Quality (IQ), product reviews from other consumers (SC), recommendations (RA). The study also Intuitive Affordance (IA) using gesture-based interactions such as air tap, touch, drag and hand menu. Moreover, natural interaction (NI) was employed using computer vision technology to recognize images in the user's field of vision.

In the MR category, IQ, IA and SA were the most investigated design attributes by 67% (n=4) of the studies, while the attribute of PV was implemented by 50% (n=3) of the studies. The attributes of CS and SR were not investigated in any of the MR application design studies. Table II summarizes the design attributes implemented in the reviewed studies.

TABLE II. SUMMARY OF IMPLEMENTED V-COMMERCE ATTRIBUTES

		Product				Intelligent Services					Functionality			
	Reviewed Studies	*IQ*	*PV*	*IA*	*RM*	*NI*	*NA*	*SA*	*RA*	*PS*	*CS*	*NV*	*SR*	*SC*
AR	[40]	×	✓	×	×	✓	×	×	×	×	✓	×	×	✓
	[61]	✓	×	×	×	×	×	×	×	×	×	×	×	×
	[35]	×	✓	×	×	✓	×	×	×	×	×	×	×	×
	[58]	✓	✓	✓	×	✓	×	×	×	×	×	✓	×	✓
	[64]	×	×	×	✓	✓	×	×	×	×	×	×	×	×
	[62]	✓	×	✓	✓	✓	×	×	×	×	✓	✓	×	×
	[59]	×	✓	×	×	×	×	×	×	×	✓	✓	×	✓
	[63]	✓	×	✓	×	×	×	×	✓	×	×	×	×	×
	[60]	×	✓	✓	×	✓	✓	✓	✓	×	×	✓	×	×
VR	[65]	✓	×	✓	×	×	×	×	×	×	×	✓	×	×
	[73]	×	×	×	×	×	×	×	×	×	×	×	✓	×
	[68]	×	×	✓	✓	✓	×	×	×	×	×	✓	×	×
	[66]	✓	×	✓	✓	✓	×	×	×	×	×	✓	×	×
	[71]	×	×	×	×	×	×	×	×	✓	×	×	×	×
	[67]	✓	✓	✓	×	✓	×	✓	×	×	×	✓	×	✓
	[70]	×	×	×	×	×	×	✓	×	×	×	×	×	×
	[69]	×	×	×	×	✓	×	×	×	×	×	×	×	×
	[81]	×	×	×	×	×	×	×	×	×	✓	×	×	×
MR	[75]	✓	✓	✓	×	✓	×	×	✓	×	×	✓	×	×
	[77]	×	✓	×	×	✓	×	✓	×	×	×	×	×	×
	[76]	✓	✓	✓	✓	×	✓	✓	✓	×	×	✓	×	×
	[78]	×	×	✓	✓	×	×	×	×	×	×	×	×	×
	[79]	✓	×	×	×	×	×	✓	✓	×	×	×	×	✓
	[80]	✓	×	✓	×	✓	×	✓	✓	✓	×	×	×	✓

V. CONCLUSION

This systematic review has identified and synthesized the essential design attributes of v-commerce solutions within the metaverse. The study reviewed twenty-four empirical studies which have implemented v-commerce solutions and categorized them based on the three immersive technologies – AR, VR, and MR. The meta-analysis of the reviewed studies revealed thirteen v-commerce design attributes. The attributes were further classified into these attributes into three main dimensions: Product, Intelligent Services, and Functionality. Each dimension encompasses specific design features that collectively enhance consumer engagement, satisfaction, and overall shopping experience in immersive environments. Results of the systematic review revealed that In AR category, the most investigated attributes were PV and NI. In the VR category, IA and NI were the most frequently investigated features. Lastly, in the MR studies, IQ, IA, and SA were the most common.

This comprehensive taxonomy of design attributes not only provides valuable insights for researchers and practitioners but also sets the stage for future innovations in v-commerce. By leveraging these attributes, businesses can create more engaging and effective v-commerce solutions that meet the evolving needs of consumers in the metaverse.

A. Limitations and Future Directions

Despite the comprehensive nature of this review, several limitations must be acknowledged. First, the scope of the review was limited to empirical studies published between 2011 and 2024, which may exclude relevant research outside this timeframe. Second, the reliance on peer-reviewed journal articles and conference proceedings may have omitted valuable insights from industry reports, white papers, and other non-academic sources. Third, the review primarily focused on studies written in English, potentially overlooking significant contributions in other languages. Additionally, the variability in methodologies and contexts of the included studies may affect the generalizability of the findings.

Future research should address these limitations by expanding the scope to include a broader range of sources and languages. Further research could focus on developing and testing comprehensive frameworks that combine design science and information systems research can provide more robust insights into the effective design and implementation of v-commerce solutions in the metaverse. Finally, incorporating the design attributes in decision-making processes can help businesses create more engaging and effective v-commerce solutions. Researchers can apply decision making methods to evaluate v-commerce solutions using the identified attributes as evaluation criteria. By addressing these future directions, researchers and practitioners can build on the foundation laid by this review, advancing v-commerce and shaping the future of online shopping through immersive and interactive experiences.

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