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Caribbean Metaverse Development: A Literature Review Perspective

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Abstract - The Caribbean's metaverse evolution accelerated due to the Covid-19 pandemic. This paper focuses on the metaverse, XR, and NFT and emphasises the Caribbean's contribution to the virtual environment. A bibliometric analysis of metaverse-themed research identified the rapid increase in publications in 2021 and 2022 and that titles with XR (AR, VR or MR) occurred three times more than blockchain (including NFT). An evolving dataset was created based on a continuous scoping literature review of Industry 4.0 and its enabling technologies. This enables the creation of a new definition of the metaverse, understanding the UX benefits of XR and its applications' areas of foci, highlighting investment in XR-based projects, and illustrating the Caribbean-themed NFT and XR projects. This dataset revealed that UX benefits are linked to XR element features that are relevant, contextual, customised, hands-free and intuitive. It also revealed that XR applications have areas of foci that can enable machine control or data interface, designing and testing, remote support, education, customer engagement, remote collaboration or entertainment and escapism. Analysis of 54 XR papers revealed that the most popular area of focus was education (including training, learning and understanding). An evaluation of global investments in XR development showed funding ranged from USD 70K to USD 100M, and there needs to be focused financial support for Caribbean projects. This justifies continued research into factors influencing funding and encouraging Caribbean XR development. In addition, this research promotes regionally developed XR projects and NFTs. The paper's originality is the reductionist definition of the metaverse: a space designed for users by users, which can satisfy whomever, whatever, however, wherever and whenever. It manifests the user's extended reality, facilitated through XR technologies that enable Industry 4.0 (I4.0). As such, the metaverse can be considered the practical implementation of I4.0.

Keywords: Caribbean, Metaverse, Industry 4.0 (I4.0), Extended Reality (XR)

I. Introduction

There is an existing gold rush to create and dominate virtual worlds (metaverse), of which extended reality (XR) technologies (augmented reality (AR), virtual reality (VR), and mixed reality (MR) play an essential role. However, the success of its adoption will be tempered by the perceptions and efficacy of the virtualised environment, which depend on the idea that the "objects will be versatile and scalable across different surfaces and use cases like commerce and shopping" [1]. This is highlighted by the importance of the digital transformation movement captured in the 2021 PricewaterhouseCoopers "Digital Readiness survey", in which AI (artificial intelligence), IoT (Internet of Things), RPA (Robotic Process Automation) and AR (augmented reality) make up the top four emerging technologies to be prioritised [2, p. 22].

These tools are used to develop "new revenue streams and grow existing ones" and "create new experiences and products" [3, p. 5] in a metaverse in which industry sectors such as gaming (Roblox signed partnerships with NFL, Ralph Lauren, Nike), media and entertainment (Imagine Dragons and Ariana Grande had VR concerts), e-commerce and retail (Shopify merchants using 3D images had a 94% increase in conversions), manufacturing (BMW tested changes in a virtual factory), architecture and engineering (Nvidia's Omniverse facilitates the remote collaboration of 3D assets) can benefit [4]. The emphasis on shaping the utility of these new environments is being placed on 3D development (creation of assets and tools to facilitate the process). It is already common in "product visualization such as 3D shopping (product models to spin & zoom on your desktop), or AR (the same thing overlayed in your space)" [5]. This development of new value demonstrates that "creativity is a critical competency that will be humans' distinctive asset in this current time where technology is ubiquitous." [6]. Quality content directly affects user adoption through better experiences [3, p. 15], [7].

Investments from technology companies are supporting the development of creatives to populate the new worlds [1], [8], which will enable users to be outfitted with and experience similarly designed and branded products used in the real world as clothing and cosmetics [9], [10]. This trend has expanded into big box retailers, such as Walmart, who will commercialise virtual products "ranging the gamut from electronics, home decorations, children's toys and games, sporting goods, personal care products to physical fitness training services and health and nutrition classes in augmented and virtual reality" [11], [12]. Another example is the partnership between Hyundai and Unity to create a meta-factory, which will be a digital twin of the physical plant's equipment and operations "will allow Hyundai to test numerous scenarios virtually, to assess, calculate and create optimal operation conditions, without employees needing to be onsite" [13]. The fashion and beauty industry has also entered the virtual marketing and engagement platform that enables brands to demonstrate new products. For example, Estée Lauder and Lottie London's nail collection, which the latter provided visitors with a "limited-edition free wearable avatar head" with "Mega Brow, Stamp Liner Wing Edition and Freckle Tint' as well as Valdé Beauty's NFT (non-fungible token) lipstick holders which also comes with

"virtual "armor" that the NFT owners could wear on Decentraland's platform" [14]. To support these developments, Deloitte provides "services and a studio to enable creators to build virtual and augmented environments"[15]. Virtual products, such as these, can offset the limitations of supply chain bottlenecks and uncertainties of the real world.

The Covid-19 pandemic highlighted the need to accelerate the adoption of digital transformation [16] to create virtualised systems such as AR and VR that would mitigate the adverse effects of required physical social distancing protocols. This prevented persons from engaging in many Caribbean activities such as tourism, Carnival, in-person meetings, and in-person educational classes. This perspective was emphasised by Senator Hassel Bacchus, Minister in the Ministry of Public Administration and Digital Transformation (Trinidad and Tobago), who stated that "the world of AR/VR has become a staple in many sectors because of COVID" and that "AR/VR is very important to the tourism sector which can add to the educational and cultural experience for visitors" as well as noting "AR/VR could be incorporated in Carnival and any sector." [17].

As such, the Caribbean Community (CARICOM) has recognised this need for digital skills and policies that guide the development of its people to meet the evolving needs of the new environment and which is being supported by funding from the 11th European Development Fund to "fast-track digital transformation" [18].

This drive is supported through initiatives such as the Caribbean Industrial Research Institute (CARIRI) AR/VR challenge, limited to participation by citizens of Trinidad and Tobago [19], identified XR projects that focused on areas of education, healthcare, agriculture and tourism. The top five projects selected were "Roam Reality", "Carnival Universe", "Explore Tobago – Underwater", "Planet Runner", and "Konnect the Kids" [20].

EON Reality provided a broader Caribbean focus through a USD 25M grant to The University of The West Indies (The UWI), which has physical campuses located in Jamaica, Trinidad and Tobago, Barbados, Antigua and Barbuda, as well as an online campus accessible to the entire Caribbean region [21]. This sponsorship was for the development of Caribbean capacities in "digital education and professional training" using their XR platform [22].

Meta (formerly Facebook), in their partnership with the Organization of American States (OAS), is supporting content development training throughout a larger region, in Latin America and the Caribbean, using their Spark AR platform as part of their global "XR Programs and Research Fund" [8], [23].

This development culminates in the creation of a virtual (digital) space that can offer Caribbean users (as well as visitors to the Caribbean) a realistic experience, which would be experienced as though it were a physical environment. A clear example of this approach is the Barbadian Ministry of Foreign Affairs and Foreign Trade developing an embassy in Decentraland [24]. This will require virtual assets to provide services to travellers, which will "open the door, using technology diplomacy, which then extends to cultural diplomacy – the trade of art, music, and culture." [25]. Another Caribbean country, St. Vincent and the Grenadines, is exploring developing a virtual Carnival for access in the metaverse [26].

The Jamaican Member of Parliament, Lisa Hanna, has advocated the importance of Caribbean-generated digital content and licensing opportunities through NFTs. She specifically noted the need for adequate infrastructures to support these developments. She also drew a comparison to the successes of the Jamaican athletic environment as a result of investments in sports training and development [27]. This would enable the Caribbean "artists, musicians, and content creators to monetise their content by leapfrogging their minds to this new reality of digital ownership, management, and sale" [28].

The Caribbean's evolution into the metaverse is being promoted by the Government of Barbados, the Caribbean Telecommunications Union (CTU) and Meta [29], [30], through the first public virtual forum, in February 2022, in which content creation was a key highlight as identified by the following statements [31]:

- Professor Avinash Persaud, Chairman of the CARICOM Commission on the Economy, stated, "Barbados is also providing opportunities for its citizens to be content creators for the digital space by providing them with the appropriate tools."
- "Presenters agreed that many opportunities exist for a variety of content creators in the sector"
- Rodney Taylor, CTU Secretary General, noted, "One thing we must never do in the region is to relinquish all technological innovation to the developed countries and simply be consumers of technology products and services residing in a distant cloud. We have too much regional talent for that to be the case. Yes, we must build global relationships and collaborate, but we must also take ownership for and be craftsmen and women of our destiny."

Thus, the ability to lower the entry barrier and give content creators greater freedom to develop and publish novel and customisable intellectual property-protected virtual assets [32] can increase the competitive advantage in the Caribbean region. This paper aggregates the Caribbean-focused work in metaverse-related areas such as NFT and XR and clearly indicates the progress made within this space.

II. Methodology

A. Bibliometric analysis of metaverse research

a) Selection of Web of Science as the bibliometric tool

A bibliometric analysis of metaverse-themed research performed on the 2nd of August 2022 identified the trend in published research [33] as there is a focused interest in the topic in the Caribbean. Web of Science (WoS) was selected as the source of data as it is "one of the world's premier scientific citation search, discovery, and analytical information platforms" [34, p. 2] and "still considered to be the most reliable sources of bibliographic data, both for the

most analyses and research evaluations and for daily tasks."[35, p. 4]. Neither Scopus nor Google Scholar was utilised. The author did not have academic access to the former platform as it is not included in the university's library subscription. The latter was omitted as it "lacks the quality control needed for its use as a bibliometric tool" [36, p. 343].

b) Identification of metaverse-themed research

The keyword (appended with the asterisk wildcard) "metaverse*" was used to capture any variations of the word [37] in two different searches (topic and title) to discover any patterns in the priority placement of the word metaverse. The topic search returns documents with the keyword in any of the following: title, abstract, author keywords, and Keyword Plus. The title search only identifies the presence of the keyword in the title.

An exhaustive search of the available WoS databases (KCI-Korean Journal Database, Web of Science Core Collection and SciELO Citation Index) was performed to identify the maximum number of documents that matched the criteria. A limitation in the number of results will occur if metaverse-themed research is present in other databases [38] to which the author's university library does not subscribe. Although WoS deduplicates data using the "All Database" search option [39], the author visually verified that the results contained unique records.

c) Priority of keywords (NFT, blockchain, AR, VR, MR and XR) within titles of metaverse-themed research

The quantities of keywords (NFT, blockchain, AR, VR, MR and XR) within the titles of the metaverse search results were identified to determine their priority. This would determine the technologies that authors frequently associate with the term metaverse in the titles. The terms selected were the digital tools identified in the Caribbean's metaverse journey. Blockchain was included as it is the platform for NFT [144, p. 3]. The following terms (and their variations) were searched within the titles: NFT (and fungible), Blockchain (and block, chain), Virtual Reality (and VR), Augmented Reality (and AR), Mixed Reality (and MR), Extended Reality (and XR).

d) Caribbean focused research

No titles contained the term "Caribbean" in the WoS dataset. This illustrated the lack of focused research on the Caribbean metaverse.

B. Exploration of Industry 4.0 and its enabling technologies

A scoping literature review [40], [41] using Google Scholar [42], [43] was used as the primary database for an exploratory search as it provided the researcher with a larger dataset (as compared to WoS) from a wide array of sources [44, p. 61], [45]. This research into Industry 4.0 and its enabling technologies, including those related to XR and blockchain (including NFT), began in 2016. This focus was to not deliberately omit or search for a specific element linked to the various technologies. Instead, these search results were continuously recorded, analysed and segmented based on thematic elements (such as the metaverse, Industry 4.0, XR, NFT, the Caribbean, and other categories). The growing dataset also included documents that matched the criteria from other sources such as websites, magazine subscriptions, newspapers (and news posts), blogs, reports, research papers, theses, references, and article suggestions from reference managers. This analysis highlights the relationship between the metaverse, XR and Industry 4.0. It also identifies the various benefits that can be achieved by implementing XR.

a) Understanding user experience (UX) benefits of XR and its applications' areas of foci

. The XR-themed documents (in the growing segmented dataset) were evaluated for UX benefits and its applications' areas of foci. A review of a sample of 54 academic sources (papers, conference publications) and 109 non-academic sources (websites, magazines, newspapers, blogs, reports, research papers) was performed to categorise the various types of applications. The latter was omitted from this paper due to its length. The aim was not to perform a gap analysis or an exhaustive search. The purpose was to categorise the types of foci present in XR-related work from selected documents and to determine a priority focus.

b) Investment in XR-based projects

The recorded data of various forms of investments into XR-themed projects were reviewed to identify the monetary value, the priority of the funding and the source of the funds. This demonstrated funding availability (and criteria) to develop virtual projects.

c) Caribbean-themed NFT and XR projects

The specific data on Caribbean-themed NFT and XR projects were extracted from the dataset. Caribbean NFT projects were evaluated to determine the product category types that creatives produced. Caribbean XR projects were evaluated and mapped with XR applications' areas of foci. These highlighted the region's progression in developing aspects of the metaverse through its application of the technologies. This work would show future researchers the contributions to the field made in the Caribbean.

III. DISCUSSION

A. The Metaverse

a) Origin of the metaverse term

The origin of the word "metaverse" has been credited to the descriptive world created in Neal Stephenson's 1992 novel "Snow Crash" [46, p. 492], [47, p. 3], [48, p. 56], [49, p. 4211], [50, p. 17], [51, p. 1]. However, there is currently no consensus on a specific definition, although there are recognised technologies and features that are being adopted, such as XR (a form of human-machine interface or HMI) and blockchain that facilitate the integration of and interoperability with decentralised systems, through real-time analytics of Big Data, to create realistic, immersive virtual worlds and experiences that are accessible by anyone and by any number of concurrent users [46], [49]–[53].

b) A new definition of the metaverse

Thus, conceptually, the metaverse is an evolving state machine that can mimic the physical world as well as the

variety of human-centric interactions, such that it will become impossible to distinguish between the "created" (virtual) environment and the "natural" (real) environment. It is shaped by the specific needs of the user(s) (as engaging in life-like remote collaborations across geographies). It relies upon emerging technologies to support its various requirements (such as verifying a digital object was created by a specific person or guaranteeing the success of a financial transaction between two entities) [47], [49], [54]. Therefore, as a reductionist definition, it can be thought of as:

A space designed for users, by users (that can satisfy whomever, whatever, however, wherever and whenever). It manifests their extended reality, which is facilitated through XR technologies.

c) Metaverse themed research

Metaverse-themed research collated using WoS between 1995 and 2022 identified 644 documents (as of the 2nd August 2022). This comprised 403 documents that contained the word metaverse directly in the title and 241 that contained it in the abstract or keywords. The annual variation in the publication per year data revealed a minimal interest in the area up to 2020 (Fig. 1) as there were 56 papers (approximately 9% of the total) produced during the first 25 years (Fig. 2). This increased by a factor of 10.5 to a total of 588 (approximately 91% of the total) over two years (2021-2022) (Fig. 1).

The graphs illustrated that there was no consistent pattern in the placement of the term metaverse within the title of the article (Title: Metaverse Paper Count) or within abstracts as well as keywords (Topic (No Title): Metaverse Paper Count). However, there is a clear shift in this focus in 2021 and 2022, with the majority having metaverse directly in the title.

The citation per year data (Fig. 3) also demonstrated no annual consistency. However, unlike the publication per year data, only 2022 produced the most significant number of citations of 220, which was approximately five times the annual average between 2008 and 2021.

The data revealed a significant inverse relationship between the number of papers and the number of citations Fig. 4), such that the lowest quantity of citations (either 1 or 2) was from 44 documents. Only one paper had the highest citation (116). Those without citations accounted for most of the papers (560). This pattern was similar for papers with metaverse in the title alone and those with metaverse located in the abstract or keywords. However, a key difference was that the highest citation of a paper with metaverse in the abstract or keywords is 73, whereas the paper with metaverse in the title has 116 citations.

d) Keyword evaluation of NFT, blockchain and XR

Fig. 5 illustrates the priority of keywords (NFT, blockchain, VR, AR, MR and XR) within the titles of the metaverse publication dataset. This demonstrated a strong association with extended reality technologies (including VR, AR, MR and XR) compared to the blockchain (including NFT). The XR group occurred three times more than blockchain and NFT combined. VR was the preferred keyword amongst the group accounting for almost 64% of the XR group's total (80). The data also revealed a lower occurrence of the metaverse and any of the keywords (except MR) being in the title together. MR and metaverse are present in the titles of three out of four documents.

e) Conclusion of metaverse-focused research

Based on the bibliometric analysis and keyword evaluation of the term metaverse, it is clear that there is a rapidly increasing interest in the subject (as shown in the change in trends in 2021 and 2022). It also revealed XR is the technology most frequently associated with developing this new space. As such, this paper will focus on XR as a critical element to the metaverse development in the Caribbean. It is, therefore, essential to outline the benefits of XR.

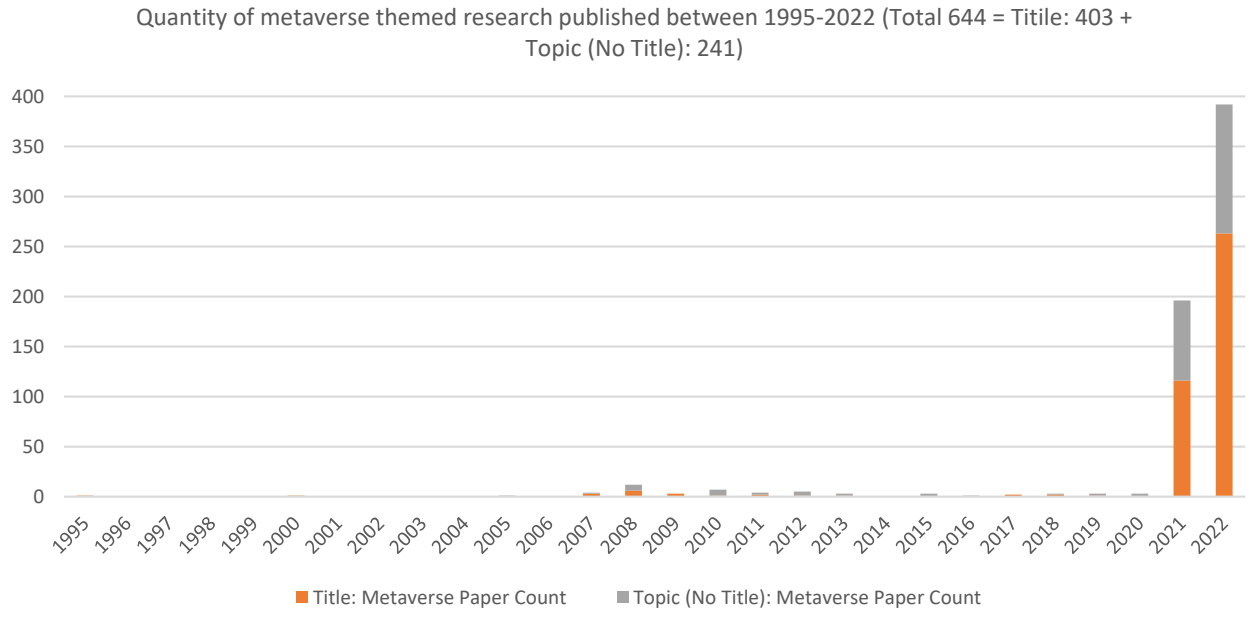

Fig. 1: Publication Per Year Data of Metaverse Themed Research Between 1995 and 2022

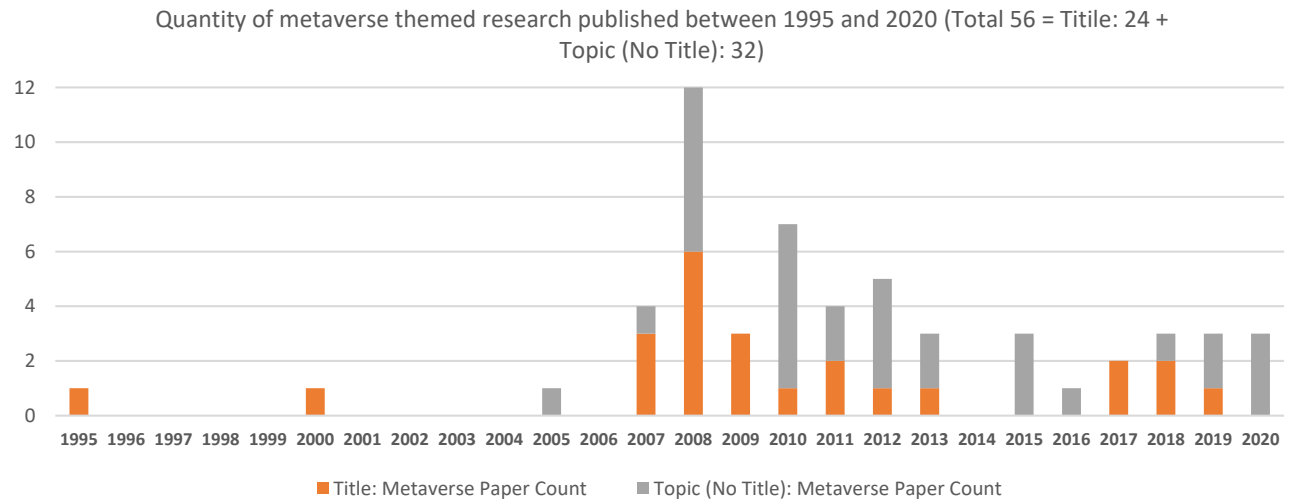

Fig. 2: Publication Per Year Data of Metaverse Themed Research Between 1995 and 2020

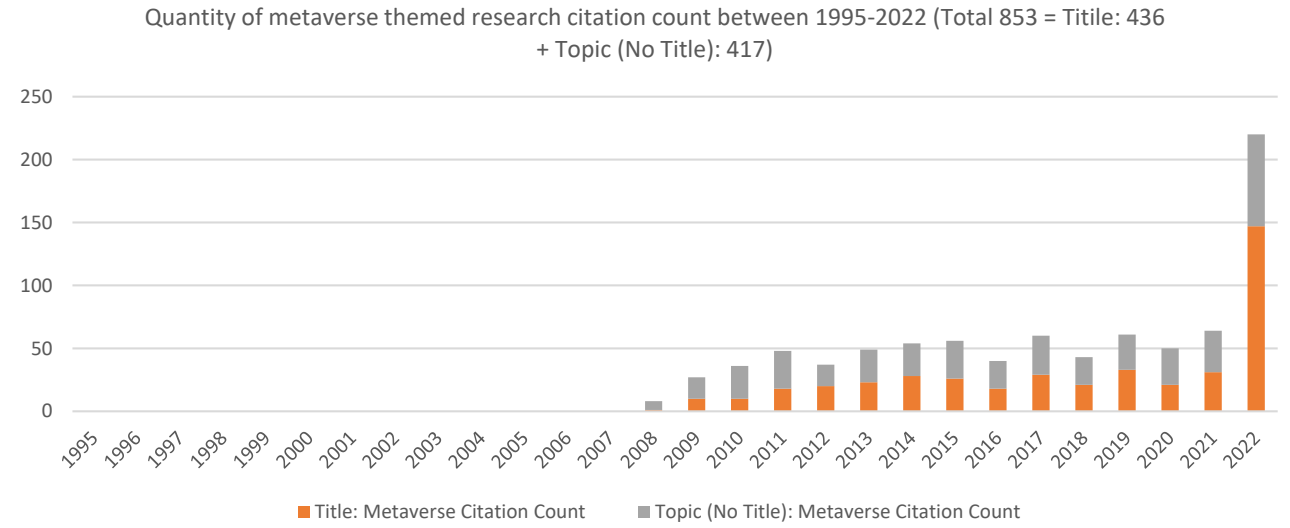

Fig. 3: Citation Per Year Data of Metaverse Themed Research Between 1995 and 2022

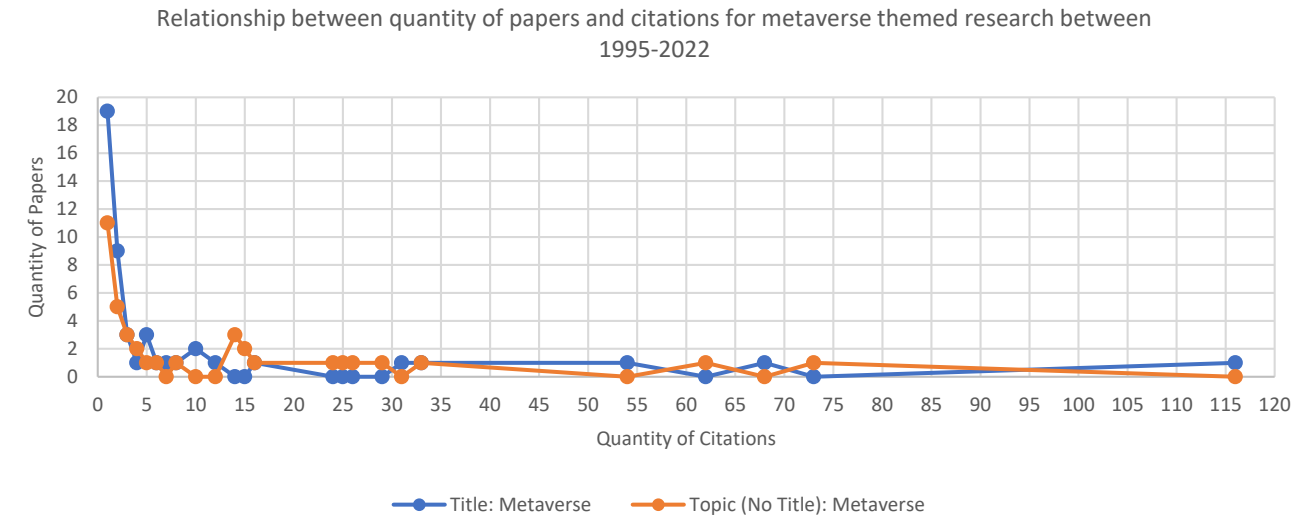

Fig. 4: Relationship Between Quantity of Papers Published and Quantity of Citations in Metaverse Themed Research Between 1995 and 2022

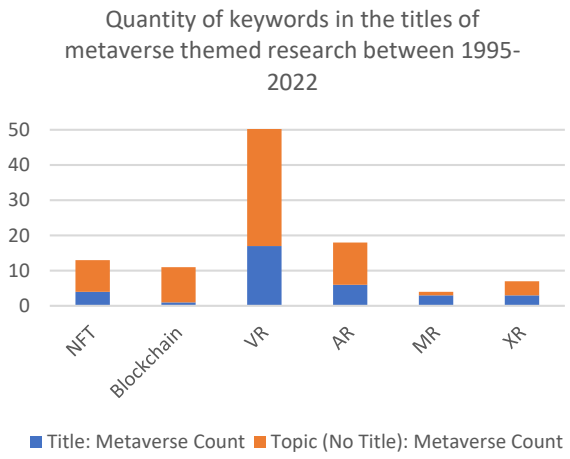

Fig. 5: Quantity of Keywords in Titles of Metaverse Themed Research Between 1995 and 2022

B. XR Enables the Benefits of Industry 4.0 to be Applied Across the Business-to-Customer Ecosystem

a) What is Industry 4.0?

Industry 4.0 (I4.0) is a strategy paradigm change first publicised in 2011 at the Hannover Fair in Germany [55]–[57]. That is the evolutionary change in industrial automation that utilises advancements in Information and Communication Technology (ICT) systems to incorporate and analyse large volumes of data from various disparate systems in real-time. The English term "Industry 4.0" is a translation of the original German moniker "Industrie 4.0", and these are often interchangeable with the phrase "Fourth Industrial Revolution" [58, pp. 17–18] coined in 2016 by Klaus Schwab [59].

Table I defined the features of each I4.0 key concept that could be implemented into any solution (as well as service or product), which would enable it to align either fully or partially with the strategy. The various benefits and opportunities available (Table II) identified the potential outcomes that could be realised throughout the Business-to-Customer (B2C) ecosystem when I4.0 was adopted.

b) XR as an Enabling Technology of I4.0

Concerns regarding the effective use of XR tools are addressed in its ability to virtually develop and evaluate proof of concepts [60], [61]. Companies that leverage these technological changes become successful [62, p. 2], and this can create "increased trust", "increased belief in its likely usability", "increased desire to purchase", and "reduced fear of operational failures" [63, p. 1018], which accelerates the digital transformation adoption into the virtual realm. These XR systems assist humans in "information visualization, remote collaboration, human-machine-interfaces, design tools and education and training" [64, p. 153] and apply to a wide range of disciplines, industries and activities [65]–[67], [68, p. 7].

Thus, human interventions are augmented by more comprehensive sources of data to aid in solving problems and making better decisions [62, p. 4]. Furthermore, these tools achieve the various I4.0 benefits by implementing various virtual applications in the business, process and customer segments. As such, AR, VR or MR technologies satisfy the "I4.0 key concepts of evolution, connected systems, decentralised, intelligent and integration of value chains" and are recognised as enablers of I4.0 as they can facilitate its core benefits of innovation, competitiveness and sustainability through the creation of and an increase in value [69].

A potential limitation of this achievement is an unsatisfactory user experience that can affect the adoption of XR applications within the B2C system. As such, it is essential to adequately develop XR projects that can satisfy the user's experience in various application environments.

TABLE I. I4.0 KEY CONCEPTS' DEFINITIONS (ABSTRACTED FROM [50, P. 371])

I4.0 Key Concept	Definition
Evolution	Changes and adapts to a variety of conditions as different users, tasks and environments
Connected systems	Links the user to other virtual or physical systems that provide additional data
Decentralised	Ability to function without a permanent physical or digital link to other systems
Intelligent	The system is self-reliant and understands the purpose, and makes decisions based on data
Integration of value chains	Create new revenues and reduce costs through linking complementary activities in different departments, companies and geographies

TABLE II. I4.0 BENEFITS AND OPPORTUNITIES ACHIEVED IN THE BUSINESS, PROCESS AND CUSTOMER SEGMENTS OF THE B2C ECOSYSTEM (SOURCE: [56, P. 577])

Business	Process	Customer
Information	Information	Information
Quality assurance	Quality assurance	Quality assurance
Time (real-time and reduced loss time)	Time (real-time and reduced loss time)	Time (real-time and reduced loss time)
Competitive	Efficiency	Loyalty
Quantity independent price model	Optimisation	Quantity independent price model
Value creation	Value creation	Satisfaction
Expense reduction or minimisation	Expense reduction or minimisation	Growth
Flexibility	Flexibility	
Improvement	Improvement	
Decentralisation	Decentralisation	
Easily influenced	Easily influenced	
Performance	Performance	
Transparency	Transparency	
Safety	Safety	
New businesses	Reliability	
New services		
Profit		

C. UX Benefits of XR and Its Applications' Areas of Foci

a) UX Benefits of XR and the Technology Platform Requirements

XR can be used to provide a digital version of the physical world. A feature of this digitalised representation or digital twin is that it "has a level of completeness and accuracy and includes context information that allows the user to understand its behavior and performance" [70, p. 3]. It can also mimic the real entity, including responses to real-time changes in conditions [61], [71, p. 242]. Another requirement is that "the interaction between a user and a virtual scene must register faster than a blink of an eye" [68, p. 6] through "low latency with a high rate of the frame" [72, p. 81]. As such, this technology can also be used to emulate life in gamified and experiential environments [73], [74].

Thus, real-time data influences how creators develop, modify, view and interact with virtual elements [75]–[77],

[78, pp. 55–56] to effectively emulate the physical world and provide the sensation of reality. This also requires "low-latency interactions" [65, p. 4]. However, as the real world involves many different systems interacting simultaneously, this depends upon collaboration across the various decentralised systems and feedback from various users to guide the development's evolution. Thus, this virtual platform can aggregate real-time data into virtualised changes in which users can experience the effects.

The ability to anchor a virtual simulation in reality without any real-time data (i.e. without a sensor to detect the changes in the physical world and relate them to the virtual domain) can be provided by incorporating physics engines [79]–[81] into the XR development platform to enable expected realistic interactions. Therefore, this technology can improve user productivity as relevant and content-specific information, skills and experience can be accessed anywhere and at any time via mobile devices [62, p. 3] and across various types of XR [82, p. 31].

TABLE III. UX BENEFITS OF XR PLATFORMS WITH THE CORRESPONDING XR ELEMENT FEATURE

UX Benefit	XR Element Feature	Cited Authors
Critical changes in the physical or digital worlds are automatically updated to alter the virtual object that informs the user	Relevant	[67], [72], [86], [87]
Virtual objects' and environments' design features change to suit the specific task requirements	Contextual	[67], [72, p. 82], [86], [87]
Designed to fit the requirement needs of each user in each specific task	Customised	[64], [67], [87], [88]
Hands-free to perform tasks	Hands-free	[89, p. 520]
Easy and fast to understand and use	Intuitive	[72, p. 82], [88, p. 5]

Multiple use XR elements reduce cost and time and provide design consistency by enabling the virtual object(s) to be applied in various applications. For instance, in a vehicle HMI control design [78], "Assets created by product design teams working on HMI can later be repurposed for use in marketing materials. Ultimately, this makes for more efficient use of company resources and keeps the designs consistent across an entire brand." [83]. This ability improves user engagement in both the virtual and physical worlds, as exemplified in the merging of e-Commerce with brick-and-mortar stores which created phygital (physical and digital) assets to provide immersive experiences in-store [84], [85].

A summary of the user benefits experienced in using XR platforms is summarised in Table III. This linked essential experiences a user would want within the virtual environment with those of the XR technology platform (element feature), which encompasses the hardware, software and application design. It provides a reference for the ability to develop and implement immersive experiences. As each experience depends on the specific task, it requires understanding the applications' areas of foci.

b) XR Applications' Areas of Foci

The benefits of using XR can be applied to core uses of "Gaming and Entertainment", "Education and Training", and "Enhanced Navigation, Smart Infrastructure, Communications" [90, pp. 10–14], which can be separated into areas of foci, as

- Machine control, Data interface (M) - ability to control equipment or vehicles or access information about them
- Design, Planning, Testing, Evaluation (D) - create new layouts or features of buildings, equipment, products
- Remote support (RS) - view information to guide the successful completion of tasks
- Training, Education, Learning, Understanding (T)
- Customer engagement (C) - demonstrations of new product ideas
- Remote collaboration (RC) - interact with people in different locations at the same time
- Entertainment, Escapism (E) - relaxing activities such as games, movies, art.

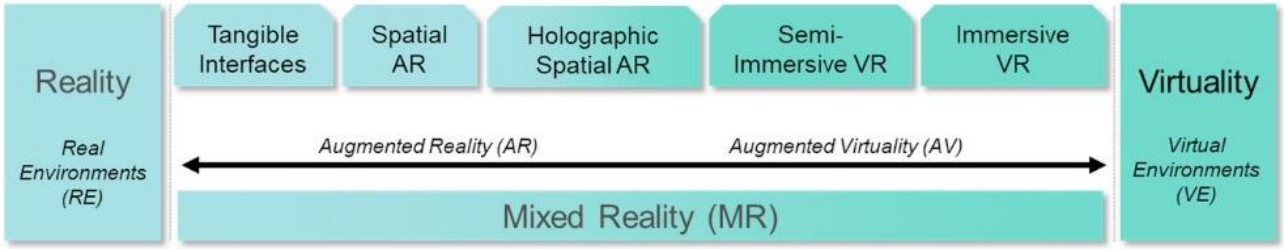

Fig. 6: Spectrum of the Transition from Real to Virtual Environments (source: [64, p. 154]*)*

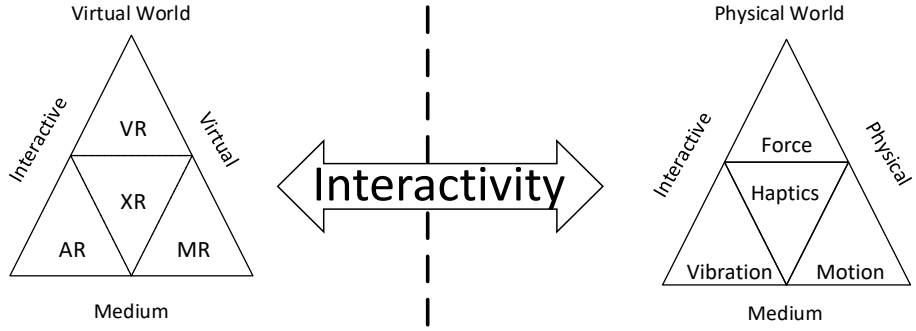

Fig. 7: Relationship of User Interactivity Transitioning Between the Real and Virtual Worlds (source: [92, p. 115]*)*

TABLE IV: XR APPLICATIONS' AREAS OF FOCI IDENTIFIED BASED ON SCOPING LITERATURE REVIEW OF SAMPLED JOURNAL PAPERS

Cited Authors	M	D	RS	T	C	RC	E
[93]				✓			✓
[94]				✓			
[72]	✓	✓		✓			✓
[95]				✓			
[86]	✓	✓	✓	✓			✓
[96]				✓			
[97]				✓			
[63]	✓						
[98]				✓		✓	
[89]	✓	✓	✓	✓			
[99]				✓			
[100]			✓				
[101]	✓		✓	✓			
[82]		✓	✓	✓		✓	
[102]			✓	✓	✓		
[103]				✓			
[104]				✓			
[105]		✓					
[106]				✓			
[61]		✓		✓			
[107]				✓			
[67]				✓			
[108]	✓						
[109]				✓			
[64]	✓	✓		✓	✓	✓	
[110]				✓			
[111]				✓			✓
[112]				✓		✓	✓
[113]				✓			
[114]				✓			
[115]				✓			
[116]				✓		✓	
[117]				✓			✓
[118]		✓					
[119]					✓	✓	
[120]		✓		✓		✓	
[78]		✓		✓	✓	✓	
[121]				✓			
[122]				✓			
[123]				✓			
[124]				✓			
[88]				✓			
[125]		✓		✓			
[126]				✓			
[76]				✓			
[87]				✓			
[71]	✓			✓			
[65]				✓		✓	✓
[127]				✓			
[128]				✓			
[129]			✓				
[130]				✓			
[131]				✓			
[132]				✓			
Total	8	11	7	47	4	9	7
Percentage	14.8	20.4	13.0	87.0	7.4	16.7	13.0

Table IV highlights the XR applications' areas of foci identified through a review of a sample of 54 academic journal papers. This determined that training, education, learning or understanding was a popular objective, thus identifying it as a core focus of an XR application. Different areas of foci may be better performed by a specific type of XR technology. As the range of XR applications' areas of foci is varied, it is essential to understand the scope of the terms AR, VR and MR [91] as they apply across the spectrum of transition from the real to the virtual worlds (Fig. 6) and the interactivity that a user experience in moving between them (Fig. 7). This would determine the specific XR application feature set that is required for various environments and tasks.

Therefore, XR application parameters depend on the UX benefits needed, XR applications' areas of foci of the specific task, the type of XR user interface being used, and the level of interactivity required between the real and digital worlds. Furthermore, the level of immersion depends upon the user, environment (or location) and task (or purpose). Thus, XR content development becomes an essential factor in this process.

D. XR Content Development

There is an ever-growing demand for innovative and creative content for the virtual space. This is demonstrated in the competitive space amongst meetings and other remote collaborative XR-based software environments constructed from various virtual elements to form exciting digital spaces [133]. These assets can be created as 2D or 3D objects. However, the choice between development in 2D vs 3D must be related to the context in which the information will be accessed, understood and applied to the task [134]–[136].

Content development of XR elements usually requires complex and expensive programming skills, and there is a need to democratise this process, expand the user accessibility base, and be platform-agnostic [137], [138]. Thus, the benefit is that XR immersive environments can be created by and experienced by anyone, anywhere and using any device. Furthermore, it will "make XR acceptable and available to larger audience at affordable cost" [65, p. 3].

As part of this approach, Seek developed "a system for converting "any type" of a 3D model into a platform-agnostic augmented reality asset", which will enable 3D content to be created and modified using their technology and then democratise the publishing and viewing of AR content on any platform [139]. The core benefit is the production cost and time saved in converting assets into formats that specific AR platforms can read. However, this will make Seek a critical link in the create-modify part of the development chain.

Thus, development platforms such as Unity [140], Unreal Engine [141], Blender [142] and Roblox [143] are some examples that have a low barrier to entry. This is either through being free or having a free commercial tier, which would be an essential component for developers and would encourage novices to enter this domain to start creating.

As such, these summarised lessons in developing virtual worlds can be applied within the development process [144]:

- Proper selection of content development platform based on technology limitations for accessibility, ease of customising existing templates or creating new 3D assets
- Design considerations to determine the look and "feel" of the virtual space as whether it should be a digital twin (replica of a physical asset) or based on limitless imagination ("castle in the sky")
- Focus on human-centred UX/UI features "abilities, goals and expectations of the intended users"

They can be used to identify core features of a democratised development platform that are:

- Easy to use in developing (including creating or modifying) 2D or 3D assets
- Low cost or zero capital investment (free application tools, free tiers of platform use or costs applied only when minimum sales level is achieved)
- Fast development (from concept idea to implementation of a minimum viable product (MVP))
- Low technical requirement (enable anyone to develop 2D or 3D assets without the need for high-level programming skills)
- Can be integrated into and used on various platforms (develop content for AR, VR or MR applications and published on various systems)

E. Financial Sources to Support XR Development

Although there are low-cost or free software development platforms (as noted in Section D: XR Content Development), finances are required to procure hardware, Internet access, and developers' time. As such, monetising virtual assets and investments are two options.

a) *NFTs as a mechanism to monetise Virtual Assets*

Creatives can generate both active and passive revenue by selling virtual assets to consumers who utilise them for various foci (such as collaborations, entertainment, data interface and training). It provides a symbiotic relationship between producer and consumer which encourages the adoption and permanent use of the "metaverse where creators can earn a living and people can purchase digital goods, services, and experiences" [145], [146].

NFTs are a mechanism to facilitate this process via their unique digitalised smart contracts that enable secure transactions based on the blockchain protocol [147, p. 3], [148]–[150]. The NFT of the virtual asset is permanently linked to the creator. Moreover, it contains rules of sale to enable both active incomes (direct development of the asset for sale to a user) and passive income (NFT-linked virtual assets can be resold by various entities with the creator receiving a percentage based on the specifics of the smart contract) [151], [152, p. 3].

The popularity of NFTs is demonstrated by companies expanding their customer engagement through customisation and delivery of unique or limited experiences or products through this platform. One example is Gap's use of the Tezos platform to create NFTs designed by Brandon Sines to embed "community, creativity, and self-expression" into the retailer's marketing strategy [153]. Another example is Perfect Corp which developed NFT AR assets to facilitate "beauty and fashion brands with new revenue stream opportunities, while providing customers with an interactive and personalised element" [154].

Various Caribbean creatives have entered this realm to generate revenue and engage customers through unique art, music, fashion and various collectables. A sample of these products is summarised in Table V to demonstrate that regional entities can accomplish it. This drive to facilitate creators' development of NFTs could be accomplished by connecting consumers into this ecosystem that enables a supply-demand relationship and thus provide sustainability for the innovators [146].

TABLE V: CARIBBEAN THEMED NFT PRODUCTS

Caribbean Creative Works	NFT Product Category	Cited Authors
Jamaican Bay-C's reggae music	Art, music, collectables	[155], [156]
Art auction of works by Jamaican-born-Caymanian Shane Aquârt 'dready'	Art	[157]
Barbadian Haleek Maul record sale	Music	[158]
Barbadian Shain "Rudy Vuitton" Clarke's artistic piece "Mojos Dome"	Art	[158]
"Views from 6 Roads" Digital Artwork meme	Art	[158]
NFT platform for Caribbean artists	Art, music, collectables	[159]
Barbadadian Shontelle Layne NFTs comprised customised artwork, a cameo in the music video, and a dubplate that would include a shout-out to the top buyers, among other exclusive opportunities	Art, music, collectables	[156]
Caribbean fashion NFT WYLD TING	Art, music, fashion	[156]

b) XR Investment

Funding directly applied to XR projects would alleviate creators' need to consistently engage with potential buyers and reduce the financial uncertainty of selling their virtual assets based on a global supply-demand marketplace. In addition, this would enable them to focus on developing the application.

A sample of various global investment initiatives is identified in Table VI to illustrate the availability and range of funds and the variety of the critical criteria for awarding monetary support. These programmes will help to develop the metaverse, various XR applications and developer competencies. However, there are a few shortcomings: they do not all focus directly on the creator; they may be platform specific and not allow an agnostic development; funding may be geographic specific.

CARIRI addressed many of these issues through an investment competition launched in 2020 to assist XR developers in commercialising their projects, with first place receiving TTD 40,000 (approximately USD 5,890 on the 19th of February 2021 [160]) to complete the project and other prizes being TTD 20,000 (approximately USD 2,945 on the 19th February 2021 [160]) worth of devices [161]. However, this programme only focused on the citizens of Trinidad and Tobago. As such, there is a need to support XR developers throughout the Caribbean and provide a higher capital investment into AR, VR or MR-based projects.

The potential access to funding from global or regional sources raises the following concerns: Is it possible for regional XR developers to compete for global XR funding? Is a better strategy a focused regional investment? Will more significant opportunities exist through a combination of the two options? This question would focus future research on Caribbean XR developers to understand their needs and factors that affect their XR project development. It is, therefore, useful to identify the types of Caribbean XR applications that have already been developed.

TABLE VI: GLOBAL INVESTMENT IN METAVERSE AND XR DEVELOPMENT

Value ($USD)	Fund Focus	Funder	Cited Authors
100M	Approximately 31 XR projects (out of 390 recipients) focusing on "games to simulation to education" were able to access parts of the Epic MegaGrants program fund using Epic Games' development platform Unreal Engine	Epic Games	[162]
100M	Snapdragon Metaverse Fund will support projects that use the Qualcomm Snapdragon platform ecosystem to focus on "building unique, immersive XR experiences, as well as associated core augmented reality (AR) and related artificial intelligence (AI) technologies"	Qualcomm	[163], [164]
50M	Meta's various platforms will be utilised through partnerships "with organizations like Women in Immersive Tech, Africa No Filter, Electric South, and the Organization of American States" to develop elements of the metaverse to provide "compatibility with other services, as well as inclusivity, privacy, safety, and "economic opportunity""	Meta	[8]
50M	The fund focuses on global investments in "virtual reality games and related areas like the metaverse"	Tower 26 venture fund	[165]
27.5M	Total of FOV's first fund will "focus on Europe-based metaverse startups" "working specifically in the areas of 'Avatars & Identity', 'Retail & Digital Commerce', 'Immersive Social', 'Future of Work', and 'Tools & Infrastructure'."	FOV Ventures	[166]
25M	"Caribbean digital education and professional training" using EON Reality's EON-XR platform	EON Reality	[22]
20M	Niantic's Lightsight AR Development Kit (ARDK) for Unity will be used to "accelerate the growth of AR applications and experiences"	Niantic	[167]
15M	Fund provided "seed investments in gaming VR and AR"	GC Tracker Fund	[165]
10M	Meta's Horizon VR platform (Horizon Worlds) will be used to "build "the very best worlds"; "give people from diverse backgrounds an advanced crash course in Horizon Worlds creation"; and "making "experiences""	Meta	[168]
0.7M	Meta's Spark AR and Presence Platform will be used to "build something cool and useful" with user privacy in mind	Meta	[169]
0.5M	Meta's Horizon Worlds will be used for "creating unique, innovative, and engaging worlds"	Meta	[170]
0.07M	NASA MarsXR Challenge "to create new assets and scenarios to create realistic research, development, and testing environments" using the Epic Games' Unreal Engine 5 platform	HeroX	[171]

F. Caribbean XR Projects

Table VII highlights some XR projects developed for use within the Caribbean or focusing on a Caribbean element (such as marketing a locally produced product or experiencing a tour of part of a country). This sampled variety demonstrates the importance of Caribbean creatives to develop content and applications that will attract, engage and retain users. This ability to extend Caribbean-centric products and services to the global market using virtual domains can strengthen its economic viability using XR as a mechanism for diversification which will be unaffected by disruptions to the physical supply chain infrastructure.

These projects are part of the evolving Caribbean metaverse and can advance the region's innovative and sustainable competencies that improve its sustainability. As such, a system must be developed to encourage the continued development of various virtual and immersive environments that can be linked together and satisfy various applications' areas of foci.

IV. CONCLUSION

A bibliometric analysis of metaverse-themed research illustrated the rapid increase in interest during the 2021-2022 period, which accounted for 91% of the 644 documents. Furthermore, analysis of the titles revealed that the XR group (AR, VR and MR) occurred three times more than blockchain and NFT combined. It infers an association between the development of the metaverse and the application of XR technology platforms.

Thus, the metaverse will become an extension of human interactivity that bridges the gap between the physical and virtual environments. It is facilitated through emerging technologies that enable the integration, visualisation and manipulation of Big Data generated within the real and virtual worlds. This exchange of information between the two decentralised systems is provided through various user interfaces (such as XR and haptics) that interconnect people with anything to do anything. Thus, the metaverse can be thought of as the practical implementation of I4.0, defined as "the evolutionary change in decentralised connected systems to enable the intelligent integration of the horizontal and vertical value chains of an organisation" [69, p. 370].

As an enabling technology of I4.0, XR becomes a key component in this strategy which develops innovation, competitiveness and sustainability by providing benefits in the business, process and customer segments. Therefore, the metaverse will be shaped by XR. It highlights the importance of a democratised developmental platform that lowers the barrier to entry to allow anyone to create AR, VR or MR applications. Furthermore, its adoption can be encouraged through direct investments in XR projects and competency development.

XR application element features as relevant, contextual, customised, hands-free and intuitive are applied across various focus areas such as machine control and data interface; design and testing; remote support; education; customer engagement; remote collaboration; and entertainment and escapism. These create respective UX benefits as critical changes in the virtual or physical world updated in the user's virtual object; virtual design features adaptable to specific tasks; fit the user needs in each specific task; free hands to perform tasks; as well as easy and fast to understand and use. The popularity of implementing the core focus area of education (including training, learning and understanding) infers that most developers include this feature in their XR projects. However, a future survey would be needed to validate the importance of this area of focus before it is considered for inclusion as part of a reference guide to aid developers in determining the goal(s) of their XR project.

TABLE VII: SAMPLE OF CARIBBEAN XR APPLICATIONS WITH THEIR XR APPLICATIONS' AREAS OF FOCI

Caribbean XR Examples	XR Applications' Areas of Foci	Cited Authors
Augmented reality web series accessed through scanning the QR code on Shandy Carib labels	Entertainment, Escapism; Customer engagement	[172]
Virtual reality experience of a Caesar's Army Carnival atmosphere	Entertainment, Escapism; Customer engagement; Remote collaboration	[173]
Augmented Reality gaming tourism and advertising app	Entertainment, Escapism; Customer engagement	[17]
Virtual tour of industrial estates and ports	Entertainment, Escapism; Customer engagement	[174]
Virtual reality steel pan	Entertainment, Escapism; Training, Education, Learning, Understanding	[175]
Virtual reality experience "of Prime Minister Eric Williams delivering his first Independence Day address to the T&T Parliament at the Red House in 1962"	Entertainment, Escapism; Training, Education, Learning, Understanding	[176]
Augmented reality steelpan	Entertainment, Escapism;	[177]
AR filter to wear virtual team kits and hats in Republic Bank -Caribbean League Tournament	Entertainment, Escapism;	[177]
AR filter to wear Carnival headpiece	Entertainment, Escapism;	[177]
Central Bank museum virtual art exhibition	Entertainment, Escapism;	[178]
Virtual Reality recreation of Plymouth, Montserrat	Training, Education, Learning, Understanding; Entertainment, Escapism;	[179], [180]
Marriott tourism promotions of Caribbean vacations spots	Entertainment, Escapism; Customer engagement	[181]
Haiti AR virtual tours	Training, Education, Learning, Understanding; Entertainment, Escapism;	[181], [182]
Grenada AR tourism marketing advert via Stylist magazine	Entertainment, Escapism; Customer engagement	[181]
CocoBay, Bahamas AR and VR marketing	Entertainment, Escapism; Customer engagement	[181]
Diving with sharks	Entertainment, Escapism;	[181]
Exploring Havana, Cuba	Entertainment, Escapism;	[181]
Experience Bahamas culture and heritage	Training, Education, Learning, Understanding; Entertainment, Escapism;	[181]
Experiencing 360-degree views of beaches of Pinel Island, St. Maarten & St. Barts	Entertainment, Escapism;	[181]
Caribbean Coconut Industry Development Project (CCIDP) uses AR to raise awareness of all coconut products	Training, Education, Learning, Understanding;	[183]
"Tropic Shades" "Island Life" AR filter for Instagram	Entertainment, Escapism;	[184]
AR mural	Entertainment, Escapism;	[185]
AR brings art to life	Entertainment, Escapism;	[186]
VR experience of "walking down Frederick Street as a woman and being heckled"	Training, Education, Learning, Understanding;	[187]
VR ""Behind The Wheel," where you drive and have to deal with distractions and end up in an accident"	Training, Education, Learning, Understanding;	[187]
Maracas Beach experience	Entertainment, Escapism;	[187]
Hope for Haiti VR world "social VR platform to hold events and guided tours through some of the projects, people, and stories of people working for their non-profit"	Training, Education, Learning, Understanding; Remote collaboration	[188]

The Caribbean has demonstrated an interest in the utility of the metaverse, a history of XR project development and encouragement in creating and using virtual elements. It is manifested through the various Caribbean-themed XR projects (such as wearing a Carnival headpiece, visiting islands' beaches and heritage sites or playing the steelpan). EON Reality and Meta investments increase regional XR competencies using their platforms (EON-XR and Spark AR). Generation and sale of NFTs that monetise creatives' fashion, art, music and collectables. The launch of the CARIRI AR/VR challenge.

This review paper raises the question: What factors of influence will encourage the development of XR projects in the Caribbean to advance their metaverse development? Future research on a survey of Caribbean XR developers would answer this question.

There is an insufficient amount of literature explicitly focused on the Caribbean metaverse. This research illustrates the impact the Caribbean is having on its evolution in areas of XR and NFT. It adds to the literature to encourage future research in this area as a mechanism to develop strategies that promote the region's innovation, competitiveness and sustainability.

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