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Analysis of Caribbean XR Survey Creates an XR Development Strategy as a Path to the Regional Metaverse Evolution

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Abstract - XR provides benefits in innovation, competitiveness and sustainability that offset disruptions in and enhances physical reality. The Caribbean's metaverse evolution started before the pandemic with the development of XR projects and creatives' NFTs. The physical isolation during the Covid-19 pandemic accelerated the Caribbean's interest in the metaverse and XR. In 2020, only 83 participants from Trinidad and Tobago entered the CARIRI AR/VR Challenge to demonstrate their XR ideas. There is a need to encourage and accelerate regional XR development. The purpose of this research is to explore Caribbean XR developers' experiences to provide an understanding of the factors affecting their XR development. This paper addresses the question: What factors of influence will encourage the development of XR projects in the Caribbean to advance their metaverse development? Online questionnaires issued to Caribbean XR developers from July to December 2021 obtained responses from 77 participants throughout 13 regional countries. The primary data were statistically insignificant and skewed towards two countries (Jamaica and Trinidad & Tobago). Comparative and inferential analyses identified factors of influence, industry sectors, and design foci. The originality of this research is an XR development strategy that incorporates the I4.0, UX, and financial strategies. It establishes the XR project design foci (the user, the purpose and the location). The factors of influence minimum criteria and the industry sector(s) influence each design focus. An initial reference list of industry sectors is education (the preferred option), healthcare, tourism, culture, manufacturing for export, construction, entertainment, game development, agriculture, and environmental protection. The strategy's value is in enabling content creators to design XR applications to meet consumers' needs and increase the regional adoption of XR. The impact of the research on the Caribbean is to facilitate a path to the regional metaverse evolution. This research identified the need for a regional XR development policy.

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

I. INTRODUCTION

A. *The metaverse and extended reality (XR)*

a) *The metaverse*

The metaverse is not a new word. The following examples outline the origin and provide an understanding of the term. Neal Stephenson wrote about experiencing an imagined space free from the limitations of physical reality and introduced the word 'metaverse' in his 1992 published book "Snow Crash" [1]. Neil Trevett, Chair of the Metaverse Standards Forum, outlines the group's view of this environment as a platform which is "an evolution of the Web" that "combines the connectivity of the Web combined with the immersiveness of Spatial Computing" [2, pp. 3, 6]. Matthew Bell's 2022 book 'The Metaverse, And How It Will Revolutionize Everything' [3] defines the space in terms of integrating technologies that mimic real-world interactions [4]. A 2022 systematic review of metaverse literature summarised it as three core areas: Spatio-temporal extensibility, virtual-real interaction, and human-computer symbiosis [5, pp. 8–10]. Therefore, the metaverse must be immersive, persistent and interoperable [6, pp. 3–5]. It facilitates anyone accessing the environment and performing any desired activity. A common framework of the metaverse is the evolution of technology to connect humans through the integration of virtual tools (worlds, applications, and AI) that reflect the physical world or the user's imagination [7, p. 5].

A simplified conceptual understanding of the metaverse describes it 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." [8, p. 86]. This definition supports the usage of Industry 4.0 (I4.0) enabling technologies such as extended reality (XR), blockchain (such as non-fungible tokens (NFTs)), artificial intelligence, and Big Data [9, p. 577] outlined by various authors in the development of the metaverse [10]–[15], [16, pp. 11–12]. The metaverse provides a virtual and immersive experience [17, p. 1], [18, p. 20]. Thus, the metaverse is an evolving construct of human existence, imagination, and desire facilitated by emerging technologies.

Although XR enables the usage of the metaverse, it is not a critical element. The latter "offers more enduring content and social significance" whereas the former focuses on the physical to virtual interactivity [8, p. 89], [16, p. 11]. Therefore, the metaverse is virtual but requires a medium in the physical world to immerse humans in its features. The following section outlines the genesis of XR technologies, their advantages and disadvantages, and predicted future development and use.

b) Extended realities (XR) such as AR, VR or MR

The idea of accessing a different reality originates in Lewis Carroll's 1872 book 'Through the Looking Glass: And what Alice Found There' in which Alice Liddell uses a mirror to enter a different reality [19]. It provides a framework for interacting with virtual experiences [20] and earns Carroll the term "fairy godfather of virtual reality" [21]. Therefore, the concept of virtual systems evolved from this point.

The following examples highlight a few notable contributions to the technology's development, starting from the 1930s. Edward Link's 1931 patent of the Link Trainer, which is an electromechanical flight simulator; Stanley G. Weinbaum's 1935 book 'Pygmalion's Spectacles' [22] about "a pair of goggles that makes the wearer experience a fictional world through holograms, smell, taste, and touch"; and Morton Heilig's 1962 patent of the Sensorama, which coupled film with motion, sound, wind, and aromas [23, p. 1]. In 1965 Ivan Sutherland wrote 'The Ultimate Display', which credited Carroll through the statement "with appropriate programming such a display could literally be the Wonderland into which Alice walked" [24]. He expanded the window concept in his 1968 paper "A head-mounted three-dimensional display" [25] that described the visual perspective "as if looked, felt, sounded real and in which the user could act realistically" [26, pp. 1–2]. In 1989 Jaron Lanier introduced the term virtual reality (VR), and this visual immersive or interactive technology evolved in cycles to the designs and modalities used today [27].

There is ambiguity in the specific definitions of augmented reality (AR), virtual reality (VR), mixed reality (MR), and extended reality (XR) due to the spectrum of immersions, presence and interactivity a user can experience [28, p. 199], [29] and the difference between the terms alternate and extended [30]. However, XR is the general acceptance to group the technologies and encapsulate the spectrum of digitally created immersive and interactive environments [30], [31, pp. 3–5].

As such, human beings currently access two modes of reality, physical and virtual, as "however real the physical world is – which we never can really know – the virtual world is exactly as real, and achieves the same status" [27, p. 2]. It translates into differences in perception of reality. Information about physical reality uses the senses of visual, olfactory, gustatory, somatosensory, and auditory [27, p. 4]. These biological senses "protect the individual from external and internal perturbations through a contact delivery of information to the brain"[32, pp. 397–398]. Therefore, the experience of reality is through the brain's interpretation of the signals generated by the stimulated sense organs. As such, the immersive experience of the metaverse requires a mechanism to stimulate specific senses [33].

Access to the physical and virtual realities depends upon the systems that enable the transition between them and the user experience required within the spectrum [8, pp. 88–89], [30]. As such, no clear boundary exists, as it is case specific. The following provides a simplified view of each modality. VR head-mounted displays (HMDs) only enable viewing of digitally created two-dimensional (2D) or three-dimensional (3D) assets, which is the dominant perspective, and prevents the user from seeing the physical world simultaneously [6, p. 11]. This mode compromises safety as the individual does not perceive physical hazards and collides with stationary or moving objects. However, AR glasses facilitate the view of the real world. A user can safely navigate around and avoid physical objects. In this mode, 2D or 3D assets enhance the existing perspective to provide information in the form of a virtual layer of objects, scenes, or effects [6, pp. 8–9]. It augments the physical world [16, p. 15], [34, p. 28]. MR HMDs combine the benefits of VR and AR to create a mixed mode that anchors the virtual asset to a specific physical object [6, pp. 9–10] that "allows the user to perceive depth and perspective" accurately as distance to the virtual item changes [16, p. 15].

The visual perspective noted above is not the only requirement for an individual immersed in the virtual realm. The brain needs to receive signals from each sensory perception system to believe the experiences in the virtual world are real. Integrating separate sensory-specific systems forms an XR immersive experience [35, p. 277]. Additionally, providing information for other senses enables persons with impairments to perceive the virtual world the same way they would in the real world. For example, a visual-impaired person uses auditory and tactile sensations to understand reality. As such, an inclusive and equitable metaverse must be accessible to anyone.

The following examples highlight systems used within each sensory category. Noise-cancelling headphones block sounds from the physical world. It is similar to the visual isolation in VR HMDs. Thus, the user only hears the digitally created sounds that produce an immersive spatial audio experience [36]. However, real-world sounds detected by microphones and real-time data analysis enable the user to hear sounds from the real world and those digitally created to provide augmented hearing [37]. Haptic feedback devices in gloves, clothing and other physical objects (such as hand-held controllers and seats) stimulate the somatic senses to provide the ability to touch and feel virtual assets [33], [38], [39]. Olfactory technology activates the sense of smell by producing particles near the nose [40]–[42]. Rapid thermal stimulation of sections of the tongue activates receptors to produce sensations of "sweetness, fatty/oiliness, electric taste, warmness and reduces the sensibility for metallic taste" when heated and "mint taste, pleasantness, and coldness" when cooled [43, p. 1496]. A different approach uses galvanic stimulation of the tongue to produce a "metallic or electric taste" or to enhance taste without chemicals [44, p. 341]. Stimulating taste and smell simultaneously via wind, odour, and temperature enhances the virtual experience [45, p. 31]. Thus, physical manipulators provide a sense of realism for the XR user [31, p. 4]. The Sensorama device noted earlier created a multi-sensory stimulated immersive environment.

The following statements outline simplified differences between VR, AR and MR. VR technology blocks stimuli from the real world to create a completely virtual experience. As such, the user only experiences the virtual versions of light, sound, scent, taste and touch. AR enhances the physical world of the user. As such, the user must receive stimuli from the physical world and the virtual world. MR combines the benefits of AR and VR. It enables flexibility and choice of experience. It must encapsulate the user's senses whilst providing the ability to perceive external stimuli via a passthrough system. Thus, the decision to use XR depends upon the need to access an artificially created reality. It is necessary to understand the advantages and disadvantages of this technology. The following section expands on these points.

c) Advantages and disadvantages of XR

As an enabling technology of I4.0, XR provides the same benefits within the business, process, and customer segments [9, p. 577]. As such, the technology creates new value that satisfies innovation, competitiveness, and sustainability [8, pp. 83, 88]. The following generic scenario provides the baseline to evaluate the advantages and disadvantages. A user remotely views a system's parameters to make an informed decision.

This example focuses on the benefits and opportunities common to each segment. These are real-time access, reduced loss of time, quality assurance, and information.

The ability of XR to "potentially enable scenarios otherwise inaccessible or unreachable" and "improve already existing practices" [31, p. 14] that "lie in enhancing visual and spatial experience" [31, p. 20] with reduced risks of being in the physical environment [46, p. 3] determine the advantages. The following identifies specific cases. XR removes the health and safety risks of physically travelling to and interacting with the system. It also eliminates the travel time and fuel expense to visit the system. The reduced wear and tear extend the vehicle's reliability. The elimination of vehicle emissions contributes to climate change mitigation. XR allows the user to easily and quickly identify and understand relevant data about the system. The XR environment facilitates the user to recognise and encourage changes created by the virtual disruption of existing conditions [47, p. 372]. XR enables the user to evaluate potential solutions to make a knowledgeable time-dependent decision about multiple options. Brick-and-mortar institutions that adopt this feature can offer new markets the convenience, safety, and affordability of accessing their products and services.

The disadvantages related to XR are “primarily related to technical usability issues, undeveloped practices of technology applications, and lack of resources” [31, p. 14]. The following points outline these areas. In the previous scenario, there are equipment and application development costs [48, p. 17]. Also, a user can experience health effects such as eyestrain, nausea, faintness, simulator sickness, and headaches from prolonged usage of the XR system [49, p. 11]. Accessing remote data can compromise cybersecurity and lead to unauthorised access to the system's confidential data or unwanted manipulation of the data [50]. Electricity consumption increases during the time of XR usage [51]. Low Internet bandwidth can reduce the visual quality of the virtual images and increase the time to access the data [52].

However, the specific type of XR used determines the advantages and disadvantages. A disadvantage of VR is that the user does not perceive the real world [53, p. 364] and would collide with obstacles. A benefit is that it provides a higher level of focus due to complete immersion [54, p. 82]. AR adds the data as an overlay onto the physical worldview so the user can operate safer but may cause confusion in a remote scenario as the virtual image is present with any real object the user sees [53, p. 365]. MR anchors the virtual data to specific physical items to provide greater clarity and perspective as the user position changes. The disadvantages would be the additional costs (hardware, software, and development) required to lock the virtual image onto the physical object and make it dynamic. These examples illustrate the ability to custom-make each viewer's reality based on specific information related to the user [46, p. 4].

However, incorrect or insufficient data is a disadvantage that offsets advantages. It can affect the user's perspective within the environment, create conflict with the user's expectation, or result in a wrong user decision. An example is a user trying on a virtual watch before purchasing [55, p. 13], [56, p. 42]. A virtual wristwatch larger than a virtual car can alter the viewer's perception of the distance between objects. Differences between the design of the virtual watch and the physical watch will lead to unsatisfied customers, product returns, and reduced sales when customers receive the physical item. Missing or poorly rendered details on the virtual version can lead to low interest and potential customers failing to purchase. The example outlines the issue in the retail industry. However, erroneous data in an XR environment can compromise safety in industry sectors such as manufacturing, health, and construction. An example in the health sector is where XR can "mislead surgical operations from a desired outcome" [31, p. 15]. A surgeon can damage a patient’s heart due to the incorrect or missing virtual image of the laser and internal organs. The operation's risk increases (possibly leading to the patient's death) if the position of the virtual laser is on the correct tissue to be lacerated but physically positioned on the main artery supplying blood. In the example, the user believes the reality of the immersive virtual environment.

The context of use and the XR type determine the pros and cons. Therefore, there is no exhaustive list of advantages or disadvantages that apply equally to AR, VR or MR. As such, future research should focus on a systematic review of existing benefits and issues of applications to build a reference catalogue. It is beneficial to use a proof-of-concept to evaluate the pros vs cons of each use case to determine whether adoption should occur [9, p. 581], [31, pp. 20–21], [57, p. 11]. Covid-19 created a specific use case of remote work due to forced isolation. This increased XR development and usage [28, p. 206]. Therefore, the need for XR after the pandemic will depend upon the use cases. The subsequent section offers a look-ahead at the post-pandemic future of XR.

d) XR in a post-pandemic world

Currently, "XR applications have areas of foci that can enable machine control or a data interface, designing and testing, remote support, education, customer engagement, remote collaboration, or entertainment and escapism" [8, p. 83]. The required physical isolation during the pandemic would influence the future novelty of XR applications with a focus on areas of remote accessibility [31, p. 20]. Therefore, XR removes the boundaries defined by the physical environment. Thus, without any physical limitations, a user can perform any task. As such, the future of XR cases appears limitless.

Physical engagement would resume after the pandemic. Thus, XR can offset the limitations and enhance the experiences in the physical world. As such, a hybrid strategy provides the benefits of both realities. Therefore, users will have the flexibility of choice. The assessment of the task, risks, timeframe and costs determines whether to engage the physical, the virtual, or both realities. It involves a comparison of the advantages and disadvantages of each reality within the context, such as:

- Select the physical reality when XR risks are higher
- Select XR when the physical reality risks are higher
- Blended mode of the physical reality and XR when the risks are the same

An example of a consumer purchasing groceries in a post-pandemic world illustrates a low risk in the latter point. The AR mode enables the consumer to verify the fruit's visual quality via an application that compares the item with the supplier's data. The need to inspect the firmness and physically orient the fruit to check for bad parts occurs in physical reality. There are minimal risks in the physical and extended realities. The time of AR use is low. There is no additional hardware expense as the AR application is on the user's smartphone. There are no health effects from AR or infected persons. There are no gas savings as the grocery was along the route to the user's home. There is no cybersecurity risk, as the user does not access confidential data.

This example outlines the case when physical and XR risks are high. A surgeon uses an MR HMD during a complex surgery to view patient data and remotely collaborate with medical experts. The high XR risks involve the system costs, reliability and accuracy of the data, and fatigue and nausea from prolonged use. Without the MR device, the patient's risk is high due to increased human error without simultaneous access to patient data and experts within the field of view.

Therefore, in the post-pandemic period, the future use of XR depends upon the risk assessment of the application. Continuous development in XR will create additional use cases, each evaluated as a proof-of-concept. The practicality of this future depends upon the combinations of various complementary technologies continually evolving to facilitate the development of XR. This non-exhaustive list identifies some of the enablers that drive this change: lowered costs, display resolution, artificial intelligence, miniaturisation of wearables and sensory devices, democratised development of XR applications, rendering applications and algorithms, Cloud computing, Wi-Fi 6 and 6G, WebXR, open standards, brain-computer interface, hand and eye tracking, haptics, GPS and other location systems, and hardware specifically optimised for XR [6, pp. 12–16], [50]–[52], [58]–[62].

e) Future scope of XR

The theoretical end of the XR evolution is the inability to sense a different reality. The user is unable to differentiate stimuli from the real and virtual worlds. It is no longer an alternate or an extension of physical reality (not virtual, not augmented, and not mixed). It will simply be one reality [27, p. 37]. Thus, "there must always be some aspect of the VR that does not conform with reality" as users "are directly perceiving physical reality, then they are perceiving their own physical reality" [27, p. 37]. Therefore, ideas that defy reality, thus unreality, ensure the continuation of development where the ultimate "goal is to shape it to create moments that enhance the lives of people and maybe help secure the future of the planet" [27, p. 38]. Human imagination coupled with artificial intelligence can fuel this development. They can form a symbiotic relationship influencing each other in a continuous feedforward evolution. The initial stages of this process exist with text-to-image and text-to-3D platforms where users suggest a text as the seed for artificially generated art or 3D objects [63]–[67]. XR becomes an amalgam of technologies and modalities that create this future.

To explore this idea of AI assistance, the researcher asked OpenAI's ChatGPT, 'How does XR help in a post-pandemic world'. After one generation, the model identified the following results: virtual meetings, remote training, virtual events, and virtual tourism. The descriptions focused on areas of improving accessibility, safety, and convenience. It also stated, "Overall, XR has the potential to help people stay connected and engaged in a post-pandemic world, even when it is not possible or safe to be physically present." [68].

However, the researcher notes a caveat with the AI-generated response. The cut-off date for training the large language model was 2021 [69]. Thus, it is beneficial to perform a longitudinal study of the XR benefits post-pandemic and compare it to the earlier predictions.

The metaverse and XR can offset effects from disruptions within the physical reality, such as those experienced in the Covid-19 pandemic. During this period, the Caribbean region increased its attention to virtual environments and activities. The following section focuses on the Caribbean's evolution in the metaverse and XR.

B. The Caribbean's metaverse evolution

The enforced social distancing and physical isolation during the Covid-19 pandemic demonstrated the need for virtual environments that would allow a degree of normalcy in people's lives to facilitate remote activities such as shopping, education, entertainment, and working from home [70]. Caribbean countries promoted entering the virtual realm during this isolation period.

The following regional examples illustrate the country-specific activities involving the metaverse and XR. Senator Hassel Bacchus noted the importance of AR and VR in Trinidad and Tobago to continue engagement in tourism, Carnival, and education [71]. The Caribbean Industrial Research Institute (CARIRI) launched a competition to encourage AR and VR development in 2020, which attracted 83 participants from Trinidad and Tobago [72], [73]. Jamaican Minister of Parliament Lisa Hanna advocated for NFTs in her country as a revenue-generating mechanism [74], [75]. St. Vincent and the Grenadines' planned to create a Carnival metaverse [76]. Barbados started their development of an embassy in Decentraland [77] and actively promoted content creatives' needs of the metaverse [78]. These examples highlight the importance of the virtual realm to the Caribbean and the need for creatives to build virtual systems that continue to develop the regional metaverse.

On a regional scale, XR companies created relationships within the Caribbean to develop competencies. It is part of the regional response to the need for virtual development. EON Reality provided a grant to The University of the West Indies (The UWI) for training and educating the Caribbean on their EON-XR platform [79]. Meta partnered with the Organization of American States (OAS) to provide training in developing AR using their Spark AR platform [80].

These activities occurred during the pandemic period. However, it was not the start of the Caribbean's metaverse evolution. The following examples identify XR projects before the pandemic. Trinbagonian company Dingole launched the virtual reality steel pan in 2017 [81]. In 2018, the Caribbean Agricultural Research and Development Institute (CARDI) launched the Caribbean Coconut Industry Development Project (CCIDP) project to increase awareness of coconut products via AR [82]. Next Generation Creators used AR to create audience engagement with art in a 2018 Jamaican art show [83].

There is a growing development of metaverse and XR-based projects generated by Caribbean nationals that cover areas such as art, music, and collectables; entertainment and escapism; customer engagement; remote collaboration; and education [8, pp. 91, 93]. These innovative digital products and services strengthen the Caribbean's competitiveness and sustainability and contribute to the continued evolution of the metaverse [8].

C. Conclusion

The metaverse is a limitless virtual space that allows users to perform any desired activity, such as shopping, education, entertainment, and working from home. The continuous evolution of technological innovations coupled with human imagination shapes the users' virtual experiences. VR, AR, or MR systems allow users to exist within a spectrum between the physical and the virtual realities and engage in the metaverse. XR is the collective term for these alternatives or extensions of physical reality. It is a mechanism to explore and engage in various immersive environments. As such, the virtual world mirrors many activities performed in the real world. It provides opportunities for expanding beyond the restrictions of the physical world to create novel experiences.

The Caribbean's development of XR projects occurred before the pandemic. However, the Covid-19 isolation requirements accelerated the region's metaverse evolution. After the pandemic, these developments can provide new products and services that benefit from physical and virtual realities to connect people, visit places, and perform tasks. Therefore, there is an opportunity for Caribbean XR developers to create their vision of the future, generate new sources of revenue and establish a system to offset the effects of future disruptions within the physical reality.

The purpose of this research is to explore Caribbean XR developers' experiences to provide an understanding of the factors affecting their XR development. This paper addresses the question: "What factors of influence will encourage the development of XR projects in the Caribbean to advance their metaverse development?" [8, p. 93]. An online survey of qualitative categorical and free-response questions, issued from July 2021 to December 2021, captured answers from 77 Caribbean XR developers within the region to answer the question. The previous research on the evolving Caribbean metaverse development [8] provided the basis for the questionnaire. This study formulates a strategy for Caribbean XR development. It can encourage and accelerate the metaverse evolution in the region.

The following section outlines the methods to target respondents, collect data, develop the survey questions, and study the data. The remainder of the paper's structure is as follows: Section III contains the results and analysis that summarise the findings from the survey. Section IV is the discussion that identifies the factors of influence and creates the XR development strategy. In the last section, the conclusion introduces the need for a policy to support XR development in the region.

II. Methodology

A. Identification and Collection of Primary Survey Data

a) Target Audiences

The 83-person cohort of the CARIRI AR/VR challenge was the target, as it was the only public event on XR development in the Caribbean as of July 2021. CARIRI issued the questionnaire each month in July, August, and September of 2021. It only received fifteen responses, which is a response rate of 18%. The Raosoft online calculator [84], [85, p. 3], [86, p. 11] recommends a sample size of 45 for a population size of 83. The calculation uses the minimum accepted values of 10% precision and 95% confidence level [87, pp. 80–81], [88], [89, p. 053], [90, pp. 27–28], [91, pp. 740–741].

The low response rate and focus on Trinidad and Tobago created the need to capture a broader Caribbean response. The researcher modified the questionnaire and issued it in October, November, and December of 2021. The new target was anyone in the Caribbean involved in XR development. The following Internet-based methods targeted respondents:

- Direct messaging to the researcher’s email and LinkedIn contacts involved or associated with virtual developments
- Mass messaging via LinkedIn groups’ posts, The UWI marketing email service, and SurveyTandem

It was impossible to obtain an exhaustive list of persons developing XR-based applications in the Caribbean, as projects may not be publicly discoverable. Thus, the population size of Caribbean XR developers is unknown. The Rasoft sample size evaluation informs us that any population above 250,152 has a minimum sample size, for statistical validity, of 97 respondents. The survey distribution channels for both questionnaires resulted in 77 valid responses.

b) Data Collection

Each respondent viewed a message that contained a link to a Google Forms questionnaire. The Google Forms application collected the anonymous responses and collated the primary data into a spreadsheet [70, p. 5], [92]. It received responses from a broader geographic audience than could have been achieved by an in-person survey and mitigated the limitations of the Covid-19 restrictions. This method also eliminated the costs associated with phone calls or travel.

c) Survey Limitations

The limitations summarised below provide reasons for the low response rate:

- Dissemination of an English-only questionnaire in a multi-lingual region
- Only using Internet messaging platforms to reach potential candidates
- Issuing each questionnaire for only three months
- Only accepting responses from persons over 18 years of age
- Concerns raised by potential respondents that providing the information would attract foreign stakeholders to advance the XR environment in the Caribbean and not benefit the local developers

B. Survey Questionnaire Development

The first part of the questionnaire recorded the respondent’s country and consent. The questionnaire comprised twenty-three qualitative questions segmented into six thematic sections about the respondent’s experience developing an XR project. The sections are status updates, developmental costs, applications of the idea, process and tools, skills, and participation in other activities. Twenty questions contained categorical options (in the form of multiple choices or checkboxes) for respondents to select. Questions #9, #17 and #23 required free responses.

The first section, "Status update of your AR, VR or MR idea”, contained one question which provides insight into the existing developmental stages of XR projects. In addition, it is a summary progress report of XR development approximately five months after the CARIRI AR/VR challenge award ceremony in February 2021 [93].

The second section, "Development costs of your AR, VR or MR idea”, grouped questions #2 to #6. It highlighted the core resources (such as time, financial, and human capital) required to be competitive in the global development marketplace to sustain Caribbean XR development. The basis of this section was the financial sources for XR development [8, pp. 91–92] and lessons of a democratised developmental environment [94].

The third section, "Applications of your AR, VR or MR idea”, captured information about XR applications from responses to questions #7 to #17. It encompassed the XR applications’ areas of foci [8, pp. 89–90], Caribbean-based XR projects [8, pp. 92–93], user experience (UX) benefits [8, pp. 88–89], user interactivity within the virtual and physical worlds [95, p. 115], and I4.0 strategy and its key concepts [8, p. 88].

The fourth section, “Process and tools to develop your AR, VR or MR idea", contained questions #18 and #19. These focused on XR developers' approach to building XR applications and linked them to human resource requirements.

There was only one question (#20) in the fifth section, "Skills needed to develop your AR, VR or MR idea". The developers identified areas to enhance their competencies in 2D, 3D, AR, VR, and MR. It covered creating content, modifying content, developing virtual scenes, creating applications, and using XR developmental applications.

The final sixth section, "Participation in Caribbean AR, VR or MR events or competitions”, was not included in the first questionnaire sent to the CARIRI AR/VR challenge participants. Instead, the answers to Q#21 identified the respondents who participated in the CARIRI AR/VR challenge competition. Submissions to Q#22 determined whether there were any duplications between the two questionnaires. Responses to Q#23 identified the existence of other Caribbean XR-related events.

Questions #1, #2 and #5 focused on specific phases of the XR application development process. For simplicity, the four stages used as categories in these questions were product concept idea, visual representation of the product and its features, proof-of-concept or minimum viable product, and final working product. In addition, this segmentation captured responses about incomplete projects and the financial and human resources needed within each tier.

C. Analysis of Data

These data represent responses received during the period from July 2021 to January 2022. The raw data, converted into a percentage of the consented Caribbean sample, enabled a comparative and inferential analysis of the responses. In addition, it facilitated the identification of selections made by at least 50% of the survey, the most popular answer, and the least popular option.

The researcher omitted vague responses from Q#9 from the study as it was difficult to determine the use case to link with the XR applications' areas of foci. The researcher evaluated the open-ended answers of Q#17 for similarities in keywords, context and theme to combine respondents' answers.

Responses to Q#22 identified three persons who submitted both questionnaires. Without any duplicated email addresses, it was not possible to identify specific submissions in the CARIRI-submitted questionnaire. Thus, comparing the responses of the seven persons from the CARIRI submissions, without an email address, to the answers from the three who submitted both questionnaires revealed that none contained the same answers to each question. Furthermore, it showed that the developers used different XR projects to answer each questionnaire. Thus, these data were still valid for this study.

III. Results and Analysis

The authors arranged this section to maintain the order and grouping of the questionnaire to separate the different types of information. The section titles from section III B onwards are the same as in the questionnaire. It provides the reader with the same format experienced by the respondents. It provides additional clarity to their responses.

A. *Geographic Segmentation of Survey Participants*

Only 77 persons from 13 Caribbean countries consented to participate in the survey. Fig. 1 illustrates the disparity in the geographic representation. The two most significant contributions were from Trinidad and Tobago and Jamaica, representing approximately 73% of respondents. No single country had 50% or more respondents.

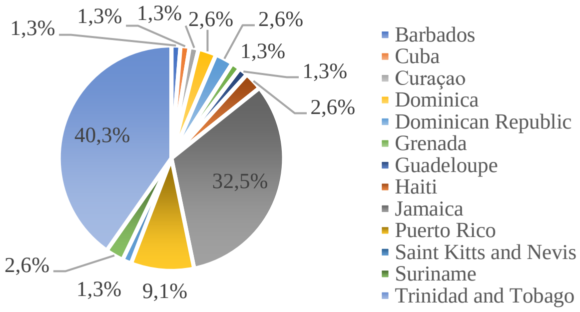

Fig. 1: Survey Participants Segmented by Country

B. *Status Update of Your AR, VR or MR Idea*

a) *Q# 1. Identify the Stages of Development for Your AR, VR or MR Idea*

Fig. 2 illustrates the percentages of the combined Caribbean responses segmented by the status of each project phase category. Approximately 27% of the Caribbean respondents were already working on various project phases. An average of 41% planned to work on each segment. Only 15.6% and 6.5% of developers were ready to present their proof-of-concept and final working product. Persons uninterested in completing those last two phases averaged 17.5%. Therefore, most developers would not have viable demonstrations. The data demonstrate the need to encourage and assist in completing XR projects. It also raises the question of the resources required to accomplish that goal. The following section addresses this area.

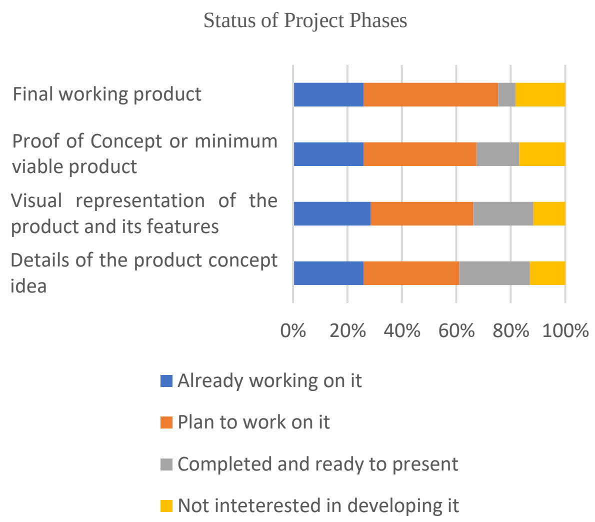

Fig. 2: Percentage of Combined Caribbean Responses that Identified the Status of their Project Phases

C. *Development Costs of Your AR, VR or MR Idea*

a) *Q# 2. Are You Able To Fund Various Parts of Your AR, VR or MR Idea?*

Fig. 3 provides a visual breakdown of the fund allocation priorities at different project phases. Approximately 23% identified funding for the project concept phase. An average of 32.5% wanted funding to develop a visual representation or proof-of-concept. More than half of the respondents (58.4%) required financial assistance to complete their XR project. The data show an increase in the funding needs as the project evolves from the concept to the final working product. It demonstrated that more funding opportunities should target completing the final phase of the XR project. An average of 51% of not requiring funding during the first two phases supports the recommendation.

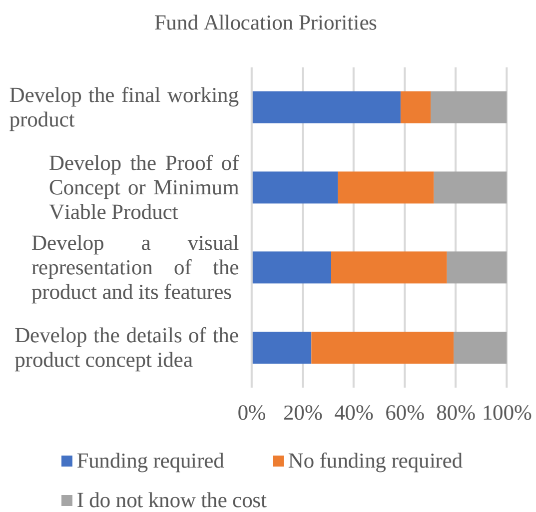

Fig. 3: Percentage of Combined Caribbean Responses that Identified Fund Allocation Priorities at Different Project Phases

The 50% criteria limit revealed two funding priorities below. The percentage of persons who did not need funding for the concept stage was approximately equal to those who required it during the final working product stage. It suggests that any funds allocated for the initial phase should shift towards the end of the project. However, this decision depends on what the funds procure.

- No funding is needed to develop the details of the product concept idea (55.8%)
- Funding required to develop the final working product (58.4%)

b) Q# 3. What is the Type of Software Licence that Was or Will be Used to Develop the Proof-of-concept or Minimum Viable Product?

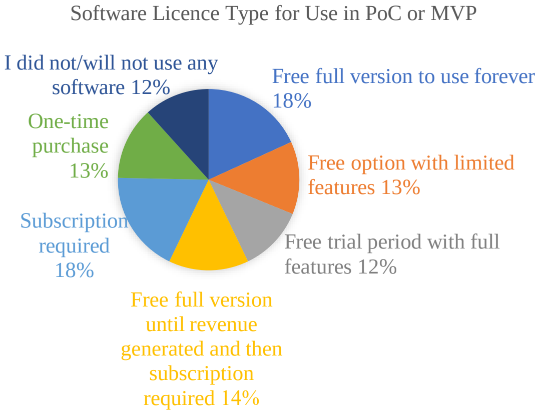

FIG. 4: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED SOFTWARE LICENCE PURCHASE TYPES FOR USE IN PROOF-OF-CONCEPT OR MINIMUM VIABLE PRODUCT

The Fig. 4 pie chart illustrates the responses' selection of software licence types. The data demonstrated that an average of 15.6% required a financial investment to make a one-time payment or lease the software's licence. It also identified that 11.7% did not or will not use software to develop an XR-based project. Understanding how to build a virtual application without software needs further research.

The respondents' choices of free software licence categories consist of the free version to use forever (18.2%), a free option with limited features (13%), a free trial period with full features (11.7%), and a free full version without generating revenue, after which requires a subscription (14.3%). A combined value of 57.1% of respondents shows a clear preference for free software. However, it varies in the specific features and the time of use. It raises the question of the type of features that developers prefer. The only selection made by at least 50% of the group was the amalgamation of various categories of free software.

c) Q# 4. What Features Do You Look for in Software Used to Create Your AR, VR or MR Idea?

Based on the data, the priority of software feature selections would first be easy-to-use, then the ability to integrate into various hardware and software platforms, followed by low-cost or free, with fast deployment and low-technical requirements being the final choices.

The two selections under 50% were fast development (48.1%) and low-technical requirements (46.8%). The low priority of these features raises questions about human resource requirements throughout the project and the time to complete a working prototype. The characteristics identified by 50% or more of the responses highlighted the minimum needs of the software:

- Easy to use (71.4%)
- Integrated into various hardware and software platforms (66.2%)
- Low-cost or free (51.9%)

d) Q# 5. What Human Resources Do You Expect to Need to Develop Your AR, VR or MR Concept?

Fig. 5 illustrates the human resource requirements in each project phase. In the initial project phase of the concept development, 53.2% of respondents identified that they could develop it by themselves. However, the percentage decreased in the subsequent steps to 9.1% in the final phase. The choice to hire developers increased from 10.4% in the first phase to 48.1% in the final stage. The decrease in doing the project alone corresponds to a simultaneous increase in the decision to hire developers (either from within the CARICOM region or the international market). Nevertheless, in each stage, the reliance on a partner or team remains essential. An average of 43.5% of users selected this option for each phase.

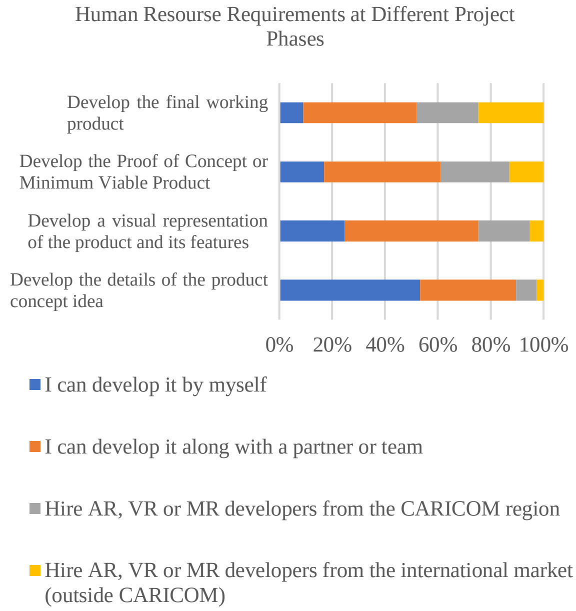

FIG. 5: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED HUMAN RESOURCE REQUIREMENTS AT DIFFERENT PROJECT PHASES

Thus, a single person can perform the initial concept development. However, progress towards the visual representation of the product requires assistance. The data demonstrated that specialist developers became vital for completing the XR project as its complexity increased. It also highlighted the importance of choosing partners or team members with the requisite skills to assist in the various phases to prevent the need to employ developers. Only two choices captured at least 50% of the responses, which were:

- Development of the product concept idea by oneself (53.2%)
- Development of a visual representation with a team or a partner (50.6%)

e) Q# 6. In Your Assessment, How Much Time is Needed to Develop Your Proof-of-concept or Minimum Viable Product?

Approximately 80% of people could not provide a feasible working prototype within eight hours. It is highlighted by the selection of each of the following time frames: 8-40 hours (14.3%), 40-160 hours (18.2%), 160-480 hours (23.4%), and over 480 hours (23.4%). It shows that there is no specific time range that a majority of developers would take. However, a small percentage of responses (1.3%) noted that a proof-of-concept would be completed within 8 hours, thus highlighting the possibility of a fast turnaround. The range of responses indicated that the time to develop an XR project's working prototype depends on other factors and would require further exploration. At least 50% of the respondents identified no option.

D. Applications of your AR, VR or MR idea

a) Q# 7. What Type of XR Project Do You Want to Create?

An average of 25% of the respondents selected VR or MR, and only 14.3% selected AR. Projects with only two combinations of XR types were not a priority for many respondents, which comprised 10.4% for AR and VR, 3.9% for AR and MR and 2.6% for VR and MR. However, this contrasted with the 18.2% that selected a focus on projects that covered all XR types. These data raise the question of which industry would benefit from XR. However, at least 50% of respondents did not select the XR type.

b) Q# 8. Select ANY of the Economic Areas in Which Your AR, VR or MR Idea Will Be Used

The top ten respondent percentages identified a priority list of industries, such as education (63.6%), tourism (42.9%), information and communication (39%), human health and social work activities (37.7%), professional, scientific and technical activities (31.2%), real estate activities (23.4%), construction (22.1%), manufacturing (18.2%), agriculture, forestry and fishing (16.9%), other service activities (16.9%), arts, entertainment and recreation (15.6%) and accommodation and food service activities (15.6%). However, the last selected area was electricity, gas, steam and air conditioning supply (1.3%). This grouping demonstrates the possibility of developing XR applications in any economic area. Therefore, determining whether an AR, VR, or MR project adds value to that sector should be the deciding factor. It raises questions about the types of usage, areas of focus, and core benefits of XR applications.

c) Q# 9. What Will Your AR, VR or MR Idea Be Used For?

Table I presents respondents' answers with clear and unique details of the project examples. It shows the range of projects and the identified XR applications' areas of foci. The respondents' ideas demonstrated that XR projects could focus on the following specific categories:

- *People*: tourists, travellers, students, women in art, financially challenged, local businesspeople, laboratory technicians, deaf people, YouTube streamers and viewers
- *Locations:* the coral reef, heritage sites, the Moon, Mars, Earth
- *Purpose:* as practical (hands-on) training and preparation, monitoring, measurement, planning, development (of land, building and infrastructure), peaceful conflict resolution, inspiring, entertainment, creating supportive communities, advertising and promotion, shared remote experiences, picturing sound as text, exploration, locate and access critical services

In Table I, Vtubing identified by a respondent refers to using avatars as a replacement for using an actual image of a streamer on YouTube, in which motion capture or keyboard input provides the image's animation [96], [97].

TABLE I: EXTRACTED FREE RESPONSES HIGHLIGHTING CLEAR AND UNIQUE XR PROJECTS LINKED TO XR APPLICATIONS' AREAS OF FOCI

Caribbean XR Application Examples	**XR Applications' Areas of Foci**
Giving hands-on training and virtual practical exams nationally and then worldwide with free access to those who cannot afford it	Training, Education, Learning, Understanding
Develop the layout of our utilities' infrastructure and how it interacts with other physical elements	Design, Planning, Testing, Evaluation
Developing competencies to address conflict-related issues peacefully	Training, Education, Learning, Understanding
To stir tourism activity and to provide a new way for the local market to advertise	Customer engagement; Entertainment, Escapism
To support shared recreational experiences between and among remote participants	Remote collaboration; Entertainment, Escapism
To promote coral reef conservation	Training, Education, Learning, Understanding; Customer engagement
Measurement of Carry-On Baggage	Machine control, Data interface
Making biology laboratory technicians more efficient and teaching students biology laboratory skills	Training, Education, Learning, Understanding
Promotion of art created by women mostly	Customer engagement; Entertainment, Escapism
Mainly assisting tourists to locate/interact with critical services	Remote support; Entertainment, Escapism
Help students prepare for a racing competition	Training, Education, Learning, Understanding
AR for lunar exploration	Training, Education, Learning, Understanding
Use VTubing to create content that inspires, entertains and creates a community of people where we support one another through this creative outlet	Entertainment, Escapism; Design, Planning, Testing, Evaluation
Developing lost/dilapidated heritage sites	Design, Planning, Testing, Evaluation
Public information translation for deaf people	Remote support
Livestock monitoring	Machine control, Data interface
Planning the construction of Martian Habitats and its implementation on Earth	Design, Planning, Testing, Evaluation

d) Q# 10. What Are the Areas of Focus For Your AR, VR or MR Idea?

Respondents identified their preference for the areas of foci, such as education (71.4%), entertainment (46.8%), remote collaboration (39%), customer engagement (36.4%), design and testing (35.1%), remote support (31.2%), and machine control and data interface (22.1%). Although education was the most popular selection of the responses, Table I illustrates the presence of the other foci based on the specific XR application.

e) Q# 11. What Are the Core Benefits of Your AR, VR or MR Project?

The respondents selected the benefits, such as augmented human contact (53.2%), reduced time of tasks (40.3%), lower cost (36.4%), reduced errors (33.8%), a replacement for monitors or paper (33.8%), increase the focus of workers (32.5%), and free hands (23.4%). The majority preference for augmented human contact suggests a need to improve the information an individual obtains from interacting with real and virtual environments. Thus, questions about haptic feedback, user experience, and real-world interactivity become valuable.

f) Q# 12. Is Haptic Feedback an Integral Part of Your AR, VR or MR Idea?

The responses demonstrated no clearly defined preference for the inclusion of experiential feedback technology, as 50.6% selected 'No'. It suggests that haptic systems are not a standard requirement of an XR application. Therefore, other variables influence the decision to implement the technology. It becomes a focus for future research to understand its use.

g) Q# 13. How Will a User Experience the Virtual Environment of Your AR, VR or MR Project?

Most respondents chose the need to have users experience an active viewing environment (76.6%). It identified the importance of the user determining the viewing area and required the virtual environment to change based on that selection. The second most selected option was character engagement (51.9%), in which a virtual avatar can interact with virtual objects. The options chosen by less than 50% of the survey were physical engagement of sensory organs (40.3%), character and scene engagement (36.4%), and passive viewing (24.7%). The top two selections focused the UX priority on having visual freedom with interactive and dynamic virtual assets that respond to changes in the user inputs. Although only approximately 40% selected the physical engagement of sensory organs, it supports future haptic research. It will help to understand whether the degree of sensory realism only using sight (as the user views the virtual worlds) is as effective as haptics.

h) Q# 14. Identify How Will You Want the User to Interact With the Real World When Using Your AR, VR or MR Idea?

The graph in Fig. 6 illustrates the respondents' binary decision in providing the user with various methods to interact simultaneously with the real world. Approximately 68% of the respondents noted that users were not required to be stationary, 61% confirmed that users would move through the physical world while using their XR project, and 53.2% would provide the ability to interact physically with the real world. However, 59.7% of the participants did not require users to be physically active. Therefore, although a user does not need physical activity in virtual space, mobility and interactivity with the physical world should be a feature component. It raises the question of the different features of an XR application, as outlined below.

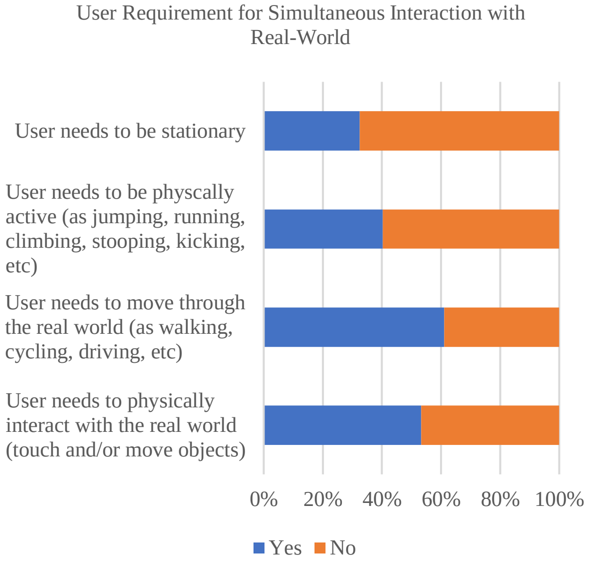

FIG. 6: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED USER REQUIREMENT FOR SIMULTANEOUS INTERACTION WITH THE REAL WORLD WITHIN THE XR PROJECT

i) Q# 15. Select the Features that Your AR, VR or MR Idea Will Have

Fig. 7 and Fig. 8 illustrate the selection of preferred XR features. The responses identified the top three as easy and fast to understand and use (72.7%), changes in the physical or digital world automatically update to alter the virtual object that informs the user (62.3%), and virtual objects' and environments' features change to suit the specific task requirements (57.1%). This minimum list identified critical criteria that should be present to facilitate an adaptive virtual experience with a short user learning curve. It supports the preference for accessing information in Q#11 and virtual adaptability identified in Q#13.

This feature selection also provided insight into the applicability of the I4.0 key concepts [8, p. 88] specific to an XR project. The developers' choices highlighted a preference for decentralised and integration of value chains versus the other I4.0 key concepts of evolution, connected, and intelligent systems (Fig. 7). However, the majority of the survey did not select any of these options. It demonstrates a lack of alignment with the I4.0 strategy. Therefore, designing the XR application with a focused I4.0 strategy would improve each key concept so that the enabling technology would achieve the full benefits of I4.0

[9, p. 577]. The data also show that more developers selected more UX than I4.0 elements.

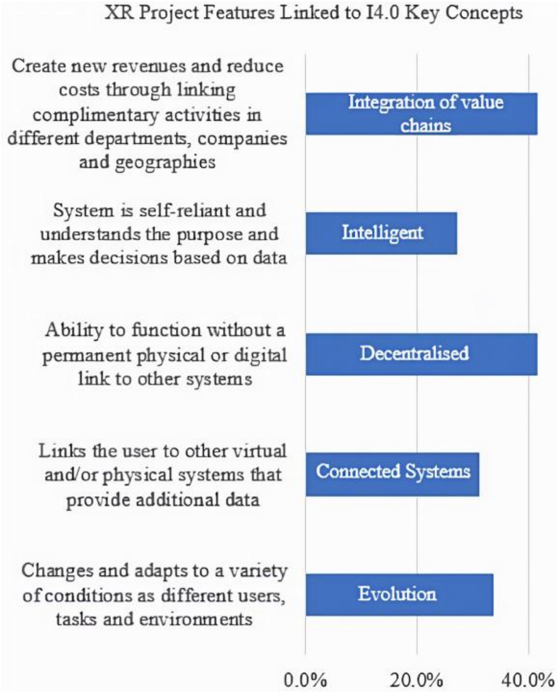

FIG. 7: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED FEATURES OF AN XR PROJECT LINKED TO I4.0 KEY CONCEPTS (IN WHITE)

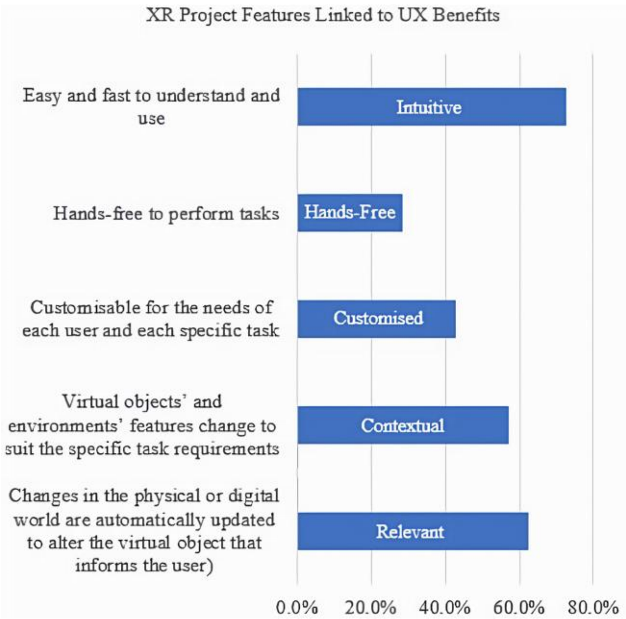

FIG. 8: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED FEATURES OF AN XR PROJECT LINKED TO USER EXPERIENCE (UX) BENEFITS (IN WHITE)

Although there is an inherent preference for UX, a focused UX strategy can adopt all the features, such as being relevant, contextual, customised, hands-free and intuitive (Fig. 8). This improved user experience will increase the value of using the XR application. However, it only focuses on the individual using the application. Therefore, UX alone will not encourage innovation within the industry or region. Whereas adopting I4.0 leads to UX benefits and innovation. It raises the question of encouraging innovation and improving the Caribbean.

j) Q# 16. How Will Your AR, VR or MR Idea Encourage Innovation?

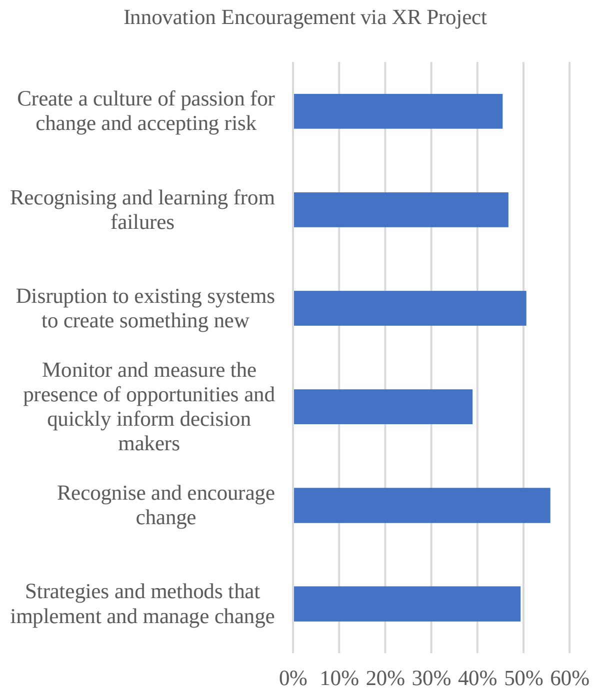

FIG. 9: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED METHODS OF INNOVATION ENCOURAGEMENT VIA AN XR PROJECT

Responses over 50% selected two approaches XR projects can encourage innovation: recognise and encourage change (55.8%) and disruption of existing systems to create something new (50.6%). Therefore, the XR system achieves innovation by deliberately disrupting the pre-existing environment to force an evolution. It identifies, develops and sustains the new value created. The methods correspond to the I4.0 key concepts as the evolution and integration of value chains (Fig. 7). This reinforces the need for adopting an I4.0 strategy which can satisfy the innovation requirements [47]. Fig. 9 identifies the other methods that XR projects use to encourage innovation. It provides future developers with a checklist their XR project can satisfy.

k) Q# 17. How Will Your AR, VR or MR Idea Improve the Caribbean Region?

The respondents' answers demonstrate that the implementation of XR projects in the Caribbean can provide various improvements, which are an outcome of adopting the I4.0 strategy [9, p. 577] and reinforces its importance in XR development. Evaluation of the combined responses identified associated sector activities and XR applications' areas of foci (Table II). They depend on the specific type of XR improvement project, as shown in Q#7 (Table I). Table II illustrates the following Caribbean sector activities and specific subsets: education, healthcare, tourism, culture, manufacturing for export, construction, entertainment, game development, agriculture, and environmental protection. These areas are part of the economic sector activities selected by the respondents (Q#8). Developers can use this list as an initial reference guide to identify target sectors for their XR applications. Any industry or sector can adopt the general improvement strategies listed below. As XR can encourage innovation and improve the Caribbean, it raises questions about how and who will develop the virtual elements that make up an XR project.

- Reduce time of tasks (including job durations), errors and overall production costs to increase response time, production, productivity and efficiency of organisations (such as in a biological laboratory) and develop growth through new revenue streams that will create a competitive advantage
- Greater efficiency when working across borders and long distances through improved remote work
- Empower users to feel more confident making decisions in the physical world by providing decision-makers with easier access to critical data
- Provide an alternative form of communicating information (such as public health or disaster management) to nationals (that would also visually benefit persons hard of hearing)
- Enhance the ability to demonstrate remotely or experience products or services
- Introduce creativity and adaptability to change to improve reliability and interaction
- Interconnect regions and industries to facilitate technology innovations and improve outcomes for stakeholders, such as increased employment, more significant interactions and enhanced problem-solving approaches
- Advance digital transformation to improve the transactions and interactions between people and their environment (such as making it easier to carry out tasks and services)
- Provide an avenue for creativity, expression and fulfilment through the use of VTubing that allows people to be more of who they are and explore themselves
- Advanced technology understanding and adoption in the region through education to develop ICT competency that will create more opportunities for innovation which will also broaden the scope of computer science within the Caribbean with the potential to make XR and Web 3.0 the standard
- Cost reductions in various sectors (such as health and security) by advocating peace

TABLE II: SUMMARY OF COMBINED SURVEY FREE RESPONSES OF XR PROJECTS IMPROVING THE REGION LINKED WITH SECTOR ACTIVITIES AND XR APPLICATIONS' AREAS OF FOCI

Potential Improvements in the Caribbean	Sector Activities	XR Applications' Areas of Foci
Connecting and engaging people (including adult learners) remotely to continue their educational progress provide a new educational modality to improve the way learners (such as early childhood students as well as persons in the manufacturing and defence industries) are taught (as learning fundamentals before the actual activity) and interact with topics (as human anatomy) as well as provide training to increase technical capabilities	Education	Training, Education, Learning, Understanding; Remote Collaboration
Increase client and public acceptance of projects by enabling them to virtually experience the completed spaces and continuation of construction sector activities (planning, improving logistics, work site safety assessments and future development) during social distancing requirements	Construction	Customer engagement; Design, Planning, Testing, Evaluation; Remote Collaboration
Support improved health, well-being, and social connectedness (including a focus on seniors in healthy ageing) to improve the quality of healthcare through remote experiences	Human health and social work activities	Remote support; Remote Collaboration
Promotion, preservation, education and cost reduction of cultural products and activities (such as Carnival) through remote virtual interactions	Tourism; Arts, entertainment and recreation	Customer engagement; Training, Education, Learning, Understanding; Remote collaboration; Entertainment, Escapism
Increase tourism promotion and revenue through virtual maps and targeted adverts highlighting attractions as well as the ability for anyone to virtually visit difficult locations (such as the ability of non-divers and non-swimmers to see the coral reefs)	Tourism; Arts, entertainment and recreation	Customer engagement; Entertainment, Escapism
Create and promote "Caribbean-made" innovations and products for the export market	Manufacturing	Customer engagement; Design, Planning, Testing, Evaluation
Enable the Caribbean diaspora to access regional entertainment remotely	Arts, entertainment and recreation	Entertainment, Escapism
Promote regional game and XR development and enable easier and faster content creation and interactive experiences to increase monetisation of new revenue streams (to reinvest into the community's growth) as well as using the medium to market countries and their culture that will also position the region as an added value technology solution provider (as leaders in innovation and not just followers of trends)	Arts, entertainment and recreation	Customer engagement; Design, Planning, Testing, Evaluation
Cultivate environmental stewardship	Agriculture, forestry and fishing	Training, Education, Learning, Understanding
Encourage persons to adopt farming by predictively viewing the potential of their crops	Agriculture, forestry and fishing	Customer engagement

E. Process and Tools to Develop Your AR, VR or MR Idea

a) Q# 18. How Will the Following Virtual Elements Be Developed For Your AR, VR or MR Idea?

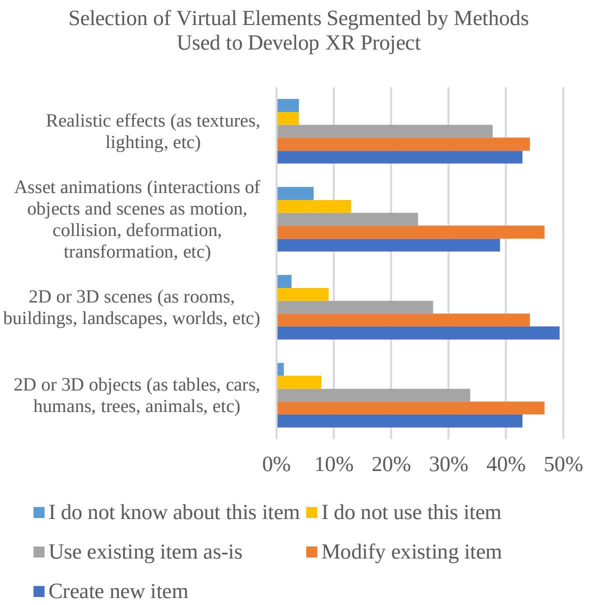

FIG. 10: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED THE SELECTION OF VIRTUAL ELEMENTS SEGMENTED BY THEIR METHODS OF USE TO DEVELOP AN XR PROJECT

Fig. 10 illustrates the presence of virtual elements in the developer's XR projects. It also segments the items into the type of use. Approximately 40% to 50% of the respondents created or modified each virtual element: objects, scenes, animations, and realistic effects. The preference for modification was slightly larger than that for the creation of most of the types. The exception category was scenes (such as rooms, buildings, landscapes, and worlds). The percentage of the survey that used an as-is item was lower than the number of people creating or modifying it. Therefore, the focus on creating or modifying highlights the need to customise elements to suit the specific requirements of an application's purpose and design. It provides an active and immersive user experience. It supports the people, location, and purpose identified in Q#9. The most significant use of an as-is item was for realistic effects (e.g., textures and lighting), at 37.7%. It suggests that developers usually find the appropriate products to implement compared to other as-is elements.

At least 50% of the respondents did not choose any selection. Between 3.9% and 13% did not use any elements. A small percentage (1.3% to 6.5%) noted they did not know about the specific virtual item. These data did not provide a clear majority selection. However, they demonstrated objects, scenes, animations and effects used in XR projects. The respondents' answers highlighted the need for a content development environment (for creation or modification) and a marketplace (for pre-built elements) [8, pp. 90–91].

b) Q# 19. Who Will Develop Various Elements of Your AR, VR or MR Idea?

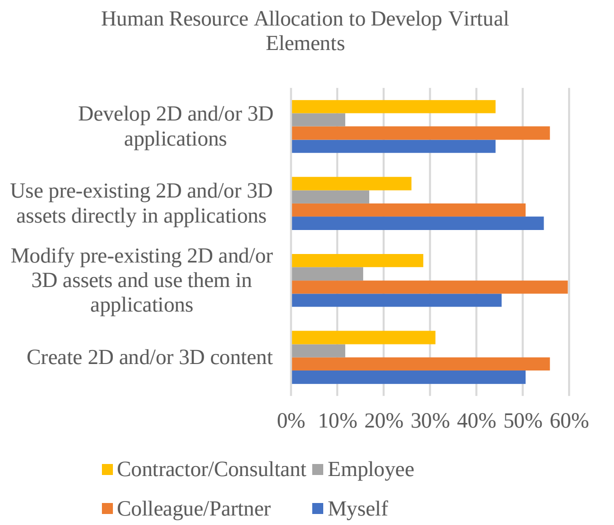

FIG. 11: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED HUMAN RESOURCE ALLOCATION TO DEVELOP VIRTUAL ELEMENTS OF AN XR PROJECT

This question focused on different developmental categories of 2D or 3D, or both elements as creating content, modifying existing assets, using pre-existing assets, or developing applications. Fig. 11 provides an additional level of detail to the answer. Approximately 44% to 55% of the survey noted they could complete any categories alone. Between 50% and 60% of respondents identified the assistance of a colleague or partner in developing any of the items. An average response of 14% in each employee segment category indicated that it was not an essential requirement. However, survey participants had an unequal preference for the items provided by contractors or consultants. Approximately 44% of developers selected a contractor or consultant for the application development category. In contrast, an average of 29% allocated external assistance to each one of the other categories.

The responses show the importance of having a colleague or partner develop any elements. However, a higher portion of the survey identified the ability to use pre-built assets alone. This category also has the lowest percentages of using contractors. The capability to do it unaided suggests a less complicated process, a lower technical requirement, easier use, or faster use. In contrast, the developing application category has the lowest percentage for doing it alone and the highest percentage for a contractor. It demonstrates the increased difficulty in this segment and the increased reliance on a contractor, which supports the human resource preferences in Q#5. Therefore, developers would benefit from a democratised process to facilitate the development alone through a platform that is easy to use, fast, has a low technical requirement and is used on various platforms [8, pp. 90–91]. As such, an important question is the skills needed to develop components of an XR project. At least 50% of the sample identified the following options:

- Modify pre-existing 2D or 3D, or both assets with a colleague/partner (59.7%)
- Create 2D or 3D, or both content by myself (50.6%) or with a colleague/partner (55.8%)
- Develop 2D or 3D, or both applications with a colleague/partner (55.8%)
- Use pre-existing 2D or 3D, or both assets by myself (54.5%) or with a colleague/partner (50.6%)

F. Skills Needed to Develop Your AR, VR or MR Idea

a) Q# 20. Which of the Following Areas Will You Want Training to Develop Your AR, VR or MR Idea?

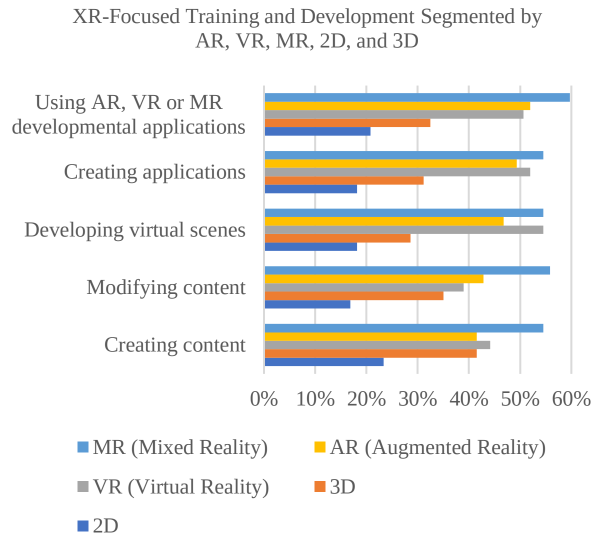

FIG. 12: PERCENTAGE OF COMBINED CARIBBEAN RESPONSES THAT IDENTIFIED XR-FOCUSED AREAS OF TRAINING AND DEVELOPMENT SEGMENTED BY AR, VR, MR, 2D, AND 3D

This question addresses the training and development required in creating content, modifying content, developing virtual scenes, creating applications, and using XR developmental applications. Fig. 12 illustrates the segmentation of each category into 2D, 3D, AR, VR, and MR to identify the specific training focus. The respondents identified MR as the most popular requirement in each category, ranging from 54.5% to 59.7%. Approximately 50% of the survey identified a need to develop skills in using AR developmental applications and creating AR applications, whereas 41.6% to 46.8% noted other areas. The lowest area of need was for any 2D training, averaging 19.5% across all categories. Within this segment, the greatest need was to create content (23.4%). It was also the highest requirement for 3D training (41.6%). The highest percentage within the VR segment was for training in developing virtual scenes (54.5%). The smallest was for modifying content (39%).

There was no consistency among the lowest or highest selections of segments within a specific category. It demonstrates that training depends on the developer's needs. The mixed reality was the only segment selected by over 50% of the sample across all categories. It shows that MR is more complex and requires a greater focus on training. Therefore, the developer's competency level and the XR project complexity should determine the type of training. The selections identified by at least 50% of the respondents were as follows:

- Modifying content for MR (55.8%)
- Creating content for MR (54.5%)
- Developing virtual scenes for VR (54.5%) and MR (54.5%)
- Creating applications for VR (51.9%) and MR (54.5%)
- Using XR developmental applications for VR (50.6%), AR (51.9%) and MR (59.7%)

G. Summary of Survey Analysis and Results

The following table summarises the criteria selected by at least 50% of the respondents and the most popular selection within this grouping. It highlights the critical areas of foci. For clarity, since the latter is a subset of the former, there is no duplication in the column "At least 50%". The table also lists the least popular option(s). These could be expendable based on the requirements of any limitation. The table does not include summaries for the free responses in questions #9 and #17.

TABLE III: SUMMARY OF COMBINED SURVEY RESULTS FOCUSED ON CRITERIA WITH POPULAR AND LEAST POPULAR OPTIONS IDENTIFIED BY RESPONDENTS

Criteria	Most Popular (>50%)	At Least 50%	Least Popular
XR project status (Q#1)			Completed and ready to present the final working product
Fund allocation priorities (Q#2)	Funding required to develop the final working product	No funding is needed to develop the details of the product concept idea	No funding is required to develop the final working product
Software licence type (Q#3)	Free software (an amalgamation of all free types)		Free trial period with full features; I did not/will not use any software
Required software features (Q#4)	Easy to use	Integrated into various hardware and software platforms; Low cost or free	Low-technical requirement
Human resource requirements (Q#5)	Development of the product concept idea by oneself	Development of a visual representation with a team or a partner	Hire developers from outside CARICOM to develop the details of the product concept idea
Proof-of-Concept development time (Q#6)			Less than 8hrs
XR project focus type (Q#7)			Combined VR + MR
Economic areas of XR-focused development (Q#8)	Education		Electricity, gas, steam and air conditioning supply
XR areas of focus (Q#10)	Training, education, learning, understanding		Machine control and data interface

Criteria	Most Popular (>50%)	At Least 50%	Least Popular
XR project core benefits (Q#11)	Augment human contact		Free hands
Haptic feedback preference (Q#12)	No		Yes
XR project UX (Q#13)	Active viewing enables the virtual environment to change based on the user's input	Character engagement which allows the user to interact with virtual objects	Passive viewing, in which users have no control over the changes in their virtual environment
User simultaneous real-world interaction (Q#14)	Users do not need to be stationary	Users need to move through the physical world; Users do not need to be physically active; Users need to interact with the physical world	Users need to be stationary
XR project features (Q#15)	Easy and fast to understand and use	Changes in the physical or digital world are automatically updated to alter the virtual object that informs the user; Virtual objects' and environments' features change to suit the specific task requirements	The system is self-reliant and understands its purpose, and makes decisions based on data
Innovation encouragement via the XR project (Q#16)	Recognise and encourage change	Disruption of existing systems to create something new	Monitor and measure the presence of opportunities and quickly inform decision-makers
Development of virtual elements (Q#18)			I do not know about 2D or 3D objects
Human resource allocation (Q#19)	Modify pre-existing 2D or 3D, or both assets with a colleague or partner	Create 2D or 3D, or both content by myself or with a colleague or partner; Develop 2D or 3D, or both applications with a colleague or partner; Use pre-existing 2D or 3D, or both assets by myself or with a colleague or partner	Using an employee for either creating 2D or 3D, or both content and developing 2D or 3D, or both applications
XR-focused training and development (Q#20)	Using XR developmental applications for MR	Modifying content for MR; Creating content for MR; Developing virtual scenes for VR and MR; Creating applications for VR and MR; Using XR developmental applications for VR and AR	Modifying 2D content

IV. Discussion

The combined CARIRI AR/VR and Caribbean XR Development questionnaires captured 77 respondents from 13 Caribbean countries. It provided anecdotal evidence of the requirements for XR developers to create applications. These data add value to the XR body of knowledge. It captures information from individual experiences and points to the areas needed to advance the region's XR and metaverse development [8].

Two countries (Trinidad & Tobago and Jamaica) produced the most responses. It may mean that some of the inferences drawn do not accurately reflect the entire Caribbean region. Nevertheless, the analysis of the summary of results (Table III) produced the following learnings: support mechanisms, project requirements, applications' thematic elements, and an XR development strategy. The first section of the support mechanism focuses on finance, as the authors' previous work identified the availability of global funding to develop XR applications [8, pp. 91–92].

A. Support Mechanisms Needed to Develop XR Ideas

a) Financial

The data show that the final phase of most XR projects requires funding. However, the priority is not software procurement or payment to developers. The preference for free-to-use software supports this point (Q#3). Similarly, a few respondents required assistance in developing 2D or 3D, or both dimensions for content or applications, which would also achieve financial savings (Q#19). However, a project's increased complexity in the final stage requires dedicated time and focus by the developers to complete it. The increased difficulty level and time demand also determine the use of external assistance through contractors or consultants (Q#5). Therefore, project complexity creates a need for a financial support mechanism. It also dictates the developer's competency level to execute complex projects satisfactorily within an acceptable timeframe. Training and development are essential factors in support mechanisms. The following section discusses this area.

The data indicated that it was rare for any project's completion to be within 8 hours and that almost half of the respondents identified a time longer than 160 hours (Q#6). This demand on time becomes a limiting factor for those involved in creating their initial concept idea. As such, a factor not considered in the research was whether the core team (either an individual or a group of colleagues or partners) spent time on other sources of income. Could this be why an average of 51% did not require funding during the first two phases (Q#2)? Although this would alleviate the need for funding in the early phase, it would impact their time allotment to the project. Therefore, one hypothesis is that many respondents engage in XR development during their spare time (away from substantive employment). As such, it hinders accelerated activity in the XR development space. Hence, there is a need for more investments in Caribbean XR development to contribute to the region's economic growth.

Therefore, the following two criteria should determine the funding recommendation. The project's complexity affects each option.

- Need to accelerate a project's timeline
- Time dedication to work on the project

One solution is investment funding from various international sources for Caribbean XR project development [8, pp. 91–92]. However, not all of these opportunities are available to Caribbean developers. They may also require the application to be developed on a specific platform and have an area of focus outside the original scope of the initial project. In addition, regional developers face increased competition from experienced non-Caribbean entrants. Thus, the developer must have a clear application strategy that aligns with international opportunities. Alternatively, self-financing can become an option by selling elements of the virtual project as an NFT (as illustrated by the existing Caribbean NFTs [8, p. 91]).

Therefore, to support this regional development, there is a clear need for a focused Caribbean XR funding system agnostic to the development platform and the application foci.

b) Training and Development

The results showed that most respondents did not require training and development to modify 2D content, such as in simple XR projects (Q#20). However, developers need additional time to acquire the necessary skills for developing projects that require creating or modifying content, scenes, or applications for MR (Q#20). It highlights the increased complexity of MR-based projects. Thus, any team focusing on this area would be disadvantaged and potentially require more focused training. Therefore, it is essential to determine the user demand for MR applications or whether VR or AR systems can satisfy project requirements. Hence, project complexity is a critical factor. It influences the type of software development platform required to build the XR project.

B. XR Project requirements

a) Software

A critical need was access to free software. Although the specific type varied, the free full version to use forever received the highest selection within this category (Q#3). However, time-limited access to the development software would not be adequate for most XR projects, given that the estimated proof-of-concept development time would be longer than 8 hours and may extend to over 480 hours (Q#6). The least popular selection was the free trial period with full features. It indicates that most respondents preferred a more extended period of access to all free software features. It also supports the selection of the free full version to use forever. It also affects the financial support received. The Financial section noted this point. This assessment raises the question of whether developers in the Caribbean know the availability of free software platforms (such as Unity, Unreal Engine, Blender, and Roblox) that can offset the monetary requirements of XR applications [8, p. 90].

The need for easy-to-use software and its ability to integrate into various hardware and software platforms (Q#4) reinforced the demands on time. Thus, time is another factor in project requirements. It is the focus of the next section.

b) Development Time

The ability to demonstrate the potential of a proof-of-concept depends on the time taken to develop various virtual elements (objects, scenes, animations, and realistic effects). This period influences the funding recommendations of the project, as discussed in the Financial section. The preferred software feature options, which are easy to use with the added ability to integrate into various hardware and software platforms (Q#4), reflect the ability to save time in creating, reusing, or modifying elements and using them in other systems. It suggests that development time is a limiting factor in a developer's ability to bring projects quickly to this stage. As such, choosing appropriate developers with the required competency level affects the timely and successful completion of the project. The following section outlines this human resource need. The last selected software option, a low-technical requirement (Q#4), indicates that most respondents were competent in using developmental systems. Hence, there was no need to spend time learning the system.

A project's duration can be affected by its complexity. Such as the type and number of virtual elements and their required interactions and effects. It involves the following areas:

- Number of iterations involved in creating a new item or modifying an existing one
- Difficulty in finding suitable pre-existing elements to reuse or modify
- Cyclical nature of the proof-of-concept testing phases
- Inexperienced developers (which relates to the human resource needs of the project)

c) Human Resource Capacity

It is possible to advance through various project phases as an individual developer. Despite this, the data clearly illustrated that the preferred option is to form a viable team with a colleague or partner rather than employing assistance (Q#5 and Q#19), which would require financial support. However, as noted in the previous sections (Financial, Training and Development, and Development Time), an increase in project complexity can extend the development time and the need for specially skilled developers. Therefore, complex project deliverables with specific user features and completion deadlines need outside assistance to achieve them.

Identifying specific project components to subdivide and share among additional workers can help manage the time and skill requirements to complete virtual elements in parallel. Adequate assignment of the separated tasks depends upon mapping each individual's competency against the project outcomes. This ability requires the application to be modular. This decentralised ability would effectively split the workload and then facilitate the integration of the finished sections to produce the completed application on time. As such, a project team's composition and size may vary depending upon the application's thematic elements, completion timelines, and range of capabilities the lead developer possesses.

C. XR Applications' Thematic Elements

a) Learning Theme

Many developers identified education as an economic activity area (Q#8) and a core area of focus for their XR projects (Q#10). Previous research identified education as the preferred area of focus for XR applications [8, pp. 89–90]. Thus, every XR project should incorporate an educational component. It can be any item that will enable the user to learn, understand, or train on a specific objective. Therefore, users should not be discouraged from using these educational components. Hence, the application is intuitive.

It should not have barriers to entry and should encourage users with all levels of experience and knowledge of XR systems. Approximately 73% of the respondents reinforced this point, believing that potential customers would benefit from an easy and fast project to understand and use (Q#15). Hand gestures and speech recognition to operate the application [98] satisfies this requirement. A secondary benefit of these nonverbal elements is the improvement in the social engagement between users in a virtual environment. The following section outlines this as the second thematic element.

An extension of the learning theme includes the ability to recognise and encourage change, thereby encouraging innovation within a system. Disrupting an existing system to create something new requires users to understand the effects of change and identify its benefits. Thus, there is a relationship between innovation and learning [99], [100]. The focus on learning to develop innovation is based on change, and not precisely, an opportunity. The survey results support this point (Q# 16) because the ability to "monitor and measure the presence of opportunities and quickly inform decision makers" was the least popular option to encourage innovation.

b) Social Engagement Theme

Another popular requirement is to augment human contact (Q#11). It enables more significant interaction among users in the virtual space. In addition, it would facilitate the social requirement of the application using various forms of verbal and nonverbal communication, with the latter requiring the identification of facial cues and body language. Any social platform must be inclusive and consider an individual's communication difficulties. For example, a respondent's project outlined this need, as it focused on enabling the translation of audio input for deaf people (Q#9). Emerging technologies in XR speech recognition research [101], [102] and the conversion of sign language into text [103] support this need. Therefore, the subsequent section will focus on physical movement because it is integral to social engagement.

c) Physical Movement Theme

The respondents noted that freedom of movement within a real-world space is an application feature. Although this was not a mandatory requirement, at least half of the survey respondents highlighted the ability to provide that choice to the user (Q#14). Therefore, although users did not need to be physically active (e.g., jumping, running, climbing, stooping, or kicking), facilitating their movement (e.g., walking, cycling, or driving) was necessary. It suggests that the application aligns with how the average person typically traverses daily.

The survey results showed that the hands-free use of an XR application is not a primary benefit (Q#11). It indicates that developers expected users to hold (or manipulate or operate) a device while engaging in the immersive experience. For example, the device triggers changes in the virtual environment or allows users to interact with virtual objects. As the last selected item in Q#13, passive viewing supported this idea. This need highlights the applications' ability to adapt to various types of inputs. The subsequent section outlines this area.

However, advancements in haptic gloves [38], [104], hand-tracking systems [105]–[107], eye-tracking systems [108]–[110] and voice-controlled instructions (via speech-to-text features) [111] used in XR applications would alleviate the need for the user to hold a controller physically. It allows users to naturally interface with the virtual environment as they would in the real world and to remove barriers to physically challenged people [112]. As noted in the previous section, these technologies improve social engagement among users. The ease, cost, time, and training required to implement these features demand further research.

d) Adaptability Theme

Developers identified the need for their application's virtual elements to be responsive to changes in the user's physical or digital worlds and customised to the specific task performed (Q#15). This real-time feature provides a relevant and contextual immersive experience. It depends on the availability of data to implement the changes. However, it does not require an intelligent system (because it is data-driven). Furthermore, it does not need to be self-reliant and to understand the purpose of making decisions (which was the least selected option of the XR project features of Q#15).

Adaptability is also a benefit of adopting the I4.0 strategy since one of its key concepts is evolution [8, p. 88]. This ability to change based on different conditions highlights the importance of identifying the factors that influence the development of XR projects. The following section highlights these factors.

D. XR Development Strategy

a) Factors of Influence

The following factors (Table IV) would influence the development of an XR project.

TABLE IV: FACTORS OF INFLUENCE AND THEIR MINIMUM CRITERIA REQUIRED TO DEVELOP XR PROJECTS

Factors of Influence	Minimum Criteria
Financial	Funding focused on the final phase can support project complexity and reduce completion time
Training and development	Required for projects with increased complexity
Software	Free and easy to use
Development time	Create projects faster
Human resource	Colleague or a partner to form a viable team
Learning theme	XR application should be intuitive to use and encourage innovation
Social engagement theme	XR application should be inclusive and enable human interaction for all types of users
Physical movement theme	XR application should allow the user freedom of movement
Adaptability theme	XR application should provide relevant and contextual experiences

A summary of the support mechanisms, project requirements and XR application's thematic elements make up the factors. The minimum criteria outline the baseline level for an XR application during the development process. The next phase is to identify critical items of the application, which become the design foci.

b) Design Foci

An XR application has three key design foci: the user, purpose, and location (Q#9 and Q#18). A user refers to people who use the system. The purpose comprises users' functional activities and how they experience them. Location is a virtual representation of any imagined space and the users' physical positions. Each category is essential to provide a unique, customisable, and immersive experience that forms the UX. A successful project is specific to the characteristics of the design foci, as shown in the following examples:

- A tourist can virtually walk through and explore an island's historic buildings
- A medical student trained to perform open heart surgery on a virtual patient in an operating theatre

This level of specialisation could make it challenging to have one XR project with interchangeable foci. However, XR is a member of the I4.0 enabling technologies. Thus, a design strategy can satisfy the I4.0 key concepts of evolution, decentralisation, connected systems, intelligence, and integration of value chains. Therefore, the XR project can achieve the I4.0 benefits in the business, process and customer segments [9, p. 577]. Thus, the same user with the same hardware systems would be able to experience a different purpose and location through software upgrades or project application modifications. A modification of the previous examples enables the tourist to visit the island's embassy to apply for a visa and the medical student to practise appendectomy to remove the appendix. It demonstrates that variations in XR applications with similar purposes and locations can be accomplished by reusing pre-existing virtual elements, such as objects, scenes, asset animations, and realistic effects.

The ability to separate specific elements of the project (by decentralising the purpose and location of virtual assets) enables the evolution of the application to suit different tasks of the same user. Furthermore, it allows the new conditions to be adaptive to the change by being intelligently connected to the other assets, including the user. It ensures the seamless provision of pre-existing and new values that will facilitate the integration of value chains. It reinforces the importance of incorporating the I4.0 strategy into the design process.

In addition, each of the design foci can become interchangeable to create multiple unique immersive user experiences, such as:

- Interchanging the tourist with the engineer will enable a different user in the first example who will be able to virtually inspect and evaluate a construction site to verify the structural integrity of the building in real-time
- Replacing the patient with open heart surgery in the operating theatre with an unresponsive drowning victim on a beach will enable lifeguards to practise CPR (Cardiopulmonary resuscitation) techniques on a variety of people and conditions in a safe location
- The project's financial and temporal limitations affect t

he ability to create new virtual elements, reuse or modify existing ones, and produce variants of an XR application. Financial factors include payments to software, assets, and developers. The imposed time limitations depend upon the need to satisfy customer demand for new projects or the ability to launch an application before a competitor or submit it before a funding offer deadline.

Each design focus depends on the adoption and satisfaction of three independent strategies, I4.0, UX, and financial, including their specific options and limitations. The following section outlines the application's economic sector as it affects each design focus that shapes the final XR project.

c) Economic Sector Selection

The survey responses provided a reference guide that developers can use to select an initial area of focus on one or more of the following: education (identified as the most popular choice), healthcare, tourism, culture, manufacturing for export, construction, entertainment, game development, agriculture, and environmental protection (Q#17).

The XR application's user, purpose, and location design criteria influence the suitability of the economic sector. Thus, multiple sectors can use one application with minimal modifications, as illustrated by the following three examples. University students can use a virtual surgical training application to learn surgical techniques (the educational sector). Medical staff in a hospital can use an altered version to collaboratively plan a surgical procedure (human health and social work activities sector). Further changes to the application enable it to be part of a game environment where players accumulate rewards to save lives (arts, entertainment, and recreation sector). These adaptations make the XR application scalable across horizontal industries.

Alternatively, demand from a specific sector will create a pull effect to drive the focus of XR development in a particular direction. However, it is worth noting that developing an XR application to serve a specific industry sector does not guarantee that target users will adopt it. Again, this indicates the need for XR developers to be adaptable and flexible.

Demand in different economic sectors can be accelerated through financial benefits directly from entities within the industry group (such as revenue generation from purchased XR projects or NFTs of virtual elements) or through a funding agency, which directly affects the financial strategy component. Compete Caribbean is an example of a funding agency which allocates finances to the region to improve sectors such as tourism, agriculture, financial services, information and communication and the blue economy [113].

d) XR Development Strategy Summary

The development of an XR project depends on the design foci of its application. The specific parameters of the user, purpose, and location depend on the interaction of three independent strategies: I4.0, UX, and financial. The developer should design the application to meet a minimum set of criteria identified in the factors of influence to satisfy the needs of a specific economic activity area (or industry sector), which can outline the conditions of the financial strategy. An alternative approach to the industry sector determining the design foci is to match the application's final parameters with potential sectors to identify the best fit or sectors that only require minor changes to the final project. Fig. 13 summarises this process.

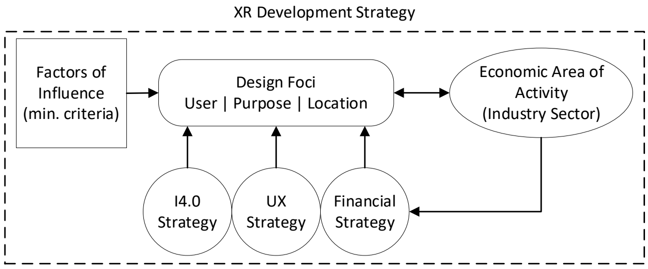

FIG. 13: SUMMARY PROCESS DIAGRAM OF AN XR DEVELOPMENT STRATEGY

V. CONCLUSION

The Caribbean's metaverse evolution began before the pandemic with the development of regional XR projects and NFTs of creatives' art, music, fashion, and collectables that enable unlimited engagement with customers throughout the global marketplace [8]. The Caribbean’s interest in the metaverse and XR accelerated during the Covid-19 pandemic due to the effects of physical isolation. Therefore, encouraging and accelerating the development of XR projects is essential to the growth of the regional metaverse. XR also strengthens the region's innovation, competitiveness, and sustainability to offset the effects of disruptions on physical reality. In 2020, CARIRI launched an AR/VR challenge to encourage XR development in Trinidad and Tobago. The competition attracted 83 participants. Thus, this study's purpose is to answer the question: What factors of influence will encourage the development of XR projects in the Caribbean to advance their development? An online survey distributed from July 2021 to December 2021 throughout the Caribbean obtained responses from 77 people across 13 regional countries. The survey's analysis provided answers that enabled the creation of an XR development strategy. It can encourage and accelerate the metaverse evolution in the region.

Content creators can benefit from this strategy. It is a framework for designing an XR application to meet the consumer's needs. Creators can use the approach to select the specific design foci (of the user, the location, and the purpose). It affects the level of immersion to create experiences for each type of user performing a unique task in a specific area. The parameters of each design foci depend upon the adoption and satisfaction of three independent strategies: I4.0, UX, and financial. The factors of influence and the selected economic area sector(s) (or industry sector(s)) form the boundary of the design foci.

The factors of influence define the minimum criteria needed for the project. They comprise the support mechanisms (financial as well as training and development), project requirements (software, development time, and human resources) and XR application thematic elements (learning, social engagement, physical movement, and adaptability).

The economic area sectors are those that will apply the application. It can also affect the financial strategy. A reference guide for selecting suitable sectors includes the areas of education (identified as the preferred option), healthcare, tourism, culture, manufacturing for export, construction, entertainment, game development, agriculture, and environmental protection. These sectors can narrow down the potential areas of XR application research and funding activities. The strategy also facilitates using an existing XR application's design foci to determine other suitable industry sectors that could benefit. It increases the horizontal scalability of the application with minimal modifications.

As such, there are two possible directions for a developer to follow. One is to create an XR project that will satisfy the most extensive user base, and the other is a niche application focused on specific user demands. The use of data would improve the outcome of each choice. Therefore, there is a need for continuous research into the Caribbean's demand side of XR applications to determine user-based variables that affect the development strategy. For example, research done in the United States of America focused on questions that identified the "overall penetration and adoption" [114] and the “critical mass to attract content developers en masse" is dependent upon a minimum of 10 Million users on a specific platform [115].

The acceleration of the developmental process to reduce the completion time and encourage more creators depends on financial strategy. It should incorporate financial mechanisms, such as generating revenue directly via the sale of virtual elements in the form of NFTs or attracting investments from various entities. The investors should focus on assisting Caribbean developers to get to market faster, such as the Compete Caribbean funding agency.

However, it raises the question. Does the Caribbean region have the potential to engage in the XR space in a meaningful way? Therefore, factors that can support the development of the sector policy-wise can answer the question. This policy connection would require future research involving the evaluation of the proposed XR development strategy with Caribbean stakeholders.

The survey had a response rate that highlighted the need for a more inclusive data-gathering approach to obtain feedback from non-respondent countries. It skewed the regional exercise due to an unbalanced representation. Thus, it is essential to know this limitation. As such, it will be valuable to identify the population size of persons involved in XR development in the Caribbean in future work. Respondents highlighted this problem in their responses to questions #21 and #23. It demonstrated a missed opportunity in participants entering the CARIRI AR/VR challenge competition and the lack of other specific XR events in the region. The only other Caribbean-specific XR event identified by respondents was via EON Reality through their partnership with the UWI. However, respondents identified other competitions in which they could enter an XR project, such as OECS Green Entrepreneurs, IET Caribbean PATW, Idea to Innovation (i2i) and Digital Jam. An update to this work is the addition of the IDB Lab Metaverse Community Challenge launched on the 25th of October 2022 [116]. Hence, there were two XR development events open to the entire Caribbean.

This paper presents an XR development strategy to encourage and accelerate XR projects. The value of this strategy is that it enables content creators to design an XR application to meet the needs of the consumer, increase the regional adoption of the I4.0-enabling technologies (AR, VR, or MR), and achieve the I4.0 benefits of innovation, competitiveness, and sustainability. The impact of the research on the Caribbean is to facilitate a path to the regional metaverse evolution.

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