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Designing and evaluating Technology-Enabled Sustainable Tourism Offerings: a case study of Virtual Reality conferences

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ABSTRACT

Global sustainability transitions and the rise of emerging technologies present both threats and opportunities for tourism organisations to navigate. Yet no framework currently exists that provides guidance on how to identify the value of emerging technologies for specific tourism offerings, and how to design, implement, and evaluate the effectiveness of technology integration. This topic is explored through a case study of the integration of social virtual reality (VR) and digital twin technologies to develop an alternative to face-to-face conference offering in response to demands to reduce conference air travel and the associated CO₂ emissions. The study, which takes a participatory action approach, comprises three ground-breaking social VR conferences, evolving from a small research pilot (GRONEN2020) to a non-academic conference (Circular Fashion Summit, Paris Fashion Week 2020) to a hybrid social VR, Zoom, and in-person session (SIGGRAPH Frontiers 2020). These events evidence the first known application of the integration of a building digital twin within a social VR platform for conferences. Integrating project findings and relevant literature, we propose the Technology-Enabled Sustainable Tourism Offering Framework, a dynamic framework that builds on Kolb's Experiential Learning Theory to guide the implementation of emerging technologies for tourism offerings, and contribute timely theoretical insights.

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Introduction

Tourism, like other industries, is facing pressure to decarbonise to achieve global targets critical to limiting the catastrophic impacts of climate change. Given the

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significance of carbon emissions resulting from transport (Jaramillo et al., 2022; Wadud et al., 2024), aviation-dependent conferences and events have become a focus of efforts to reduce carbon emissions (Høyer & Naess, 2001; Hamant et al., 2019; Klöwer et al., 2020; Wenger et al., 2025). While the hard-to-abate aviation transport sector is projected to grow significantly in the coming decades (Portugal-Pereira & Müller-Casseres, 2022), researchers also argue the limited means to decarbonise aviation will require a shift in consumer behaviour to avoid flying in order to meet decarbonisation targets (Wendt et al., 2024). Such a shift poses fundamental challenges to aviation-dependent tourism organisations, particularly as many rely on holding in-person events and conferences as their primary source of income (Niner & Wassermann, 2021). At the same time, digital technologies including Virtual Reality (VR) are becoming increasingly relevant to the tourism industry and are suggested as a means of improving sustainability outcomes for the sector (Kim et al., 2020; Rauscher et al., 2020; Talwar et al., 2023; Williams & Hobson, 1995; Yuan & Hong, 2024; Yuksek et al., 2020; Yung et al., 2022).

Despite the growing research on sustainability transitions and emerging technologies, scholars argue there is currently insufficient guidance for tourism organisations on how to navigate the resulting threats and opportunities. In particular, how to identify the value of emerging technologies to improve the sustainability of tourism offerings such as conferences (Cavallin Toscani et al., 2024; Sousa et al., 2024b; Vander Schee & DeLong, 2022) and how to implement the technology innovations (Cavallin Toscani et al., 2024; Niner & Wassermann, 2021). We therefore seek to answer the research question: how can organisations integrate emerging technologies to improve the sustainability of tourism offerings?

We investigate this issue by conducting a Participatory Action Research (PAR) case study of the design and implementation of a technology-enabled sustainable tourism offering. Specifically, we develop a social VR conference offering, including its multiple iterations and commercial adoption. Guided by experiential learning theory, reflections from the research team, including researchers, conference organisers, and interdisciplinary technology experts, form the data for the study (Cassell & Johnson, 2006; Park, 1999).

Integrating project findings with relevant literature, we develop the Technology-Enabled Sustainable Tourism Offering Framework, detailing a process that includes understanding the value offered by the emerging technology, aligning the technology and business model with the offering, and evaluating its effectiveness in achieving the desired sustainability outcome. In doing so, we contribute to the tourism literature, particularly how to integrate Kolb's (1984) Experiential Learning approach to address the barrier of lack of expertise in emerging technologies faced by tourism organisations, and stages identified in the literature as critical to successful technology integration, including design, evaluation, and business model selection. The study also provides new insights to key future research topics identified in the recent systematic review of environmental sustainability in event industry research, "mitigating the mismatch between event research and practice by providing more relevant sustainability guidance to event practitioners, [...] and understanding how digital technologies can transform events and affect their environmental impacts and strategies" (Cavallin Toscani et al., 2024, p. 2684). Finally, the manuscript addresses the call for solutions-oriented research that bridges the gap between research and practice (Coghlan, 2022; Font et al., 2023) as well as further identified limitations of the extant literature (Gössling, 2021; Sousa et al., 2024a).

Literature review

Transport emissions account for 23% of global energy-related CO₂ emissions (Jaramillo et al., 2022), with demand and emissions projected to increase six-fold by 2050 and 12-fold by 2100 (Portugal-Pereira & Müller-Casseres, 2022). Sector- and transport-dependent industries are, therefore, experiencing pressure to decarbonise (Rajendran & Popfinger, 2022; Wenger et al., 2025). Transport is fundamental to many tourism offerings, particularly conferences and events, where people travel to meet in a specific location. While aviation travel is less common than other modes of travel, it is critical for international conferences and events and contributes a larger share of emissions than other transport modes (Jaramillo et al., 2022). In academia, for example, air travel was found to account for up to 30 per cent of the greenhouse gas emissions for Australian Universities (Glover et al., 2018).

Strategies to reduce carbon emissions in the hard-to-abate aviation industry, such as substituting fossil-fuel-based fuel for bio-Sustainable Aviation Fuels (bio-SAFs), are limited in emissions reduction potential (maximum of 50%) (Boerboom et al., 2025) and lead to other negative sustainability impacts (e.g. on food security, water consumption and biodiversity loss) (Grewe et al., 2021; Portugal-Pereira & Müller-Casseres). As a result, scholars argue the need to reduce flying (Wendt et al., 2024), posing significant implications for conference and event organisers. In response, emerging technologies have been identified as an opportunity to maintain tourism offerings, income potential, and attendee outcomes without requiring aviation travel (Wenger et al., 2025). Indeed, research argues virtual attendance options at conferences can reduce air travel emissions by up to 60-80% (Cavallin Toscani et al., 2023), yet conference organisers and attendees have been slow to adopt virtual formats. Understanding what conferences are and do is particularly important to provide insights as to why this is the case, particularly given tourism mobilities research argues new technologies can blur traditional conceptions core to conferences “(including home/away, authentic/inauthentic, leisure/work, host/guest, extraordinary/mundane, present/absent)” (Hannam et al., 2014, p. 178). Research also identifies fundamental impacts to business models associated with technology adoption (Gössling, 2021), requiring conference and tourism organisers to consider the value of conferences to attendees and potential changes to their business model.

Conferences are a collection of both formal and informal activities facilitating interaction between participants (Anderson, 1996; Seidenberg et al., 2021), providing value to attendees through professional learning, disseminating knowledge, building networks and reputation, and initiating collaborations, many of which are important for professional promotion (Niner & Wassermann, 2021; Seidenberg, 2021; Wenger et al., 2025). Researchers argue the success of a conference is linked to their ability to deliver the value or return on investment sought by attendees (Seidenberg et al., 2021). Critically, research has found that while current technology may deliver superior value to attendees from a learning perspective, it is argued to be incapable of replicating informal interactions or relatedness, identified as some of the most essential benefits of conferences to attendees (Vander Schee & DeLong, 2022). In recent years, however, social VR has emerged as a possible alternative due to its potential to meet such interaction expectations.

Virtual Reality and tourism

Within the tourism literature a variety of definitions of VR can be found (Beck et al., 2019) yet primarily refer to a simulation of imaginary or real-world places in a virtual environment that users interact with to create authentic, realistic, and sensory experiences enabling users to feel fully immersed in the digital experience as if they were genuinely part of that environment, and requiring VR systems (software) and head-mounted displays (hardware). Research on VR tourism has evolved from work in the 1990s identifying the opportunities and impacts for tourism policy, planning, and marketing applications (Cheong, 1995; Williams & Hobson, 1995), to exploring VR use for management, entertainment and education in tourism (Guttentag, 2010; Pearlman & Gates, 2010), tourist's willingness to visit a destination (Gibson & O'Rawe, 2018; Kim et al., 2020), drivers of engagement (Tussyadiah et al., 2018; Zhang et al., 2022), destination marketing (Marasco et al., 2018; Rauscher et al., 2020; Sousa et al., 2024c), hotel marketing (Leung et al., 2020), preserving culture (Rafal et al., 2004), acceptance of VR technology among users (Guttentag, 2010; Rauscher et al., 2020), accessibility (Fennell, 2021; Guttentag, 2010), and influence on the tourism experience including post-vacation, (Aldossary & McLean, 2022; Fan et al., 2022; Sousa, Jorge, et al., 2024; Wei et al., 2019). Despite the increasing quantity and breadth of research, application in commercial settings remains limited, argued to be a result of a lack of expertise and unfamiliarity with emerging technologies such as VR (Sousa et al., 2024d; Vander Schee & DeLong, 2022).

From a sustainability perspective, VR is argued to facilitate positive sustainability outcomes in tourism including to reduce on-site impacts from foot traffic (Dewailly, 1999), encourage conservation behaviours (Hofman et al., 2022; Loureiro et al., 2022; Lv et al., 2024), act as an alternative to in-person travel for eco-conscious tourists (McLean et al., 2023; Talwar et al., 2023) and to reduce the associated carbon emissions of conferences and academic travel (Cavallin Toscani et al., 2024; Glover et al., 2018; Klöwer et al., 2020). The potential of VR to authentically replicate the real world and extend the possibilities of interaction in a virtual social environment has made it particularly attractive to investigate as a tool for conference offerings (Jiang et al., 2023; Talwar et al., 2023), though such research remains limited (Talwar et al., 2023). Indeed, research finds the use of VR can enhance the accessibility of conferences for communities whose ability to attend the conference in-person are limited due to financial constraints (Mulders & Zender, 2021; Porwol et al., 2022), geographical barriers (Moreira et al., 2023), health concerns (Fennell, 2021; Williams & Hobson, 1995) or clashing commitments (Goebel et al., 2020; Mulders & Zender, 2021), subsequently leading to better representation of marginalised groups through VR conferences (Moreira et al., 2023). However, research on previous waves of ICT adoption identifies the potential for marginalised groups to remain disadvantaged, particularly in lower-income countries where digital infrastructure may be limited (Gössling, 2017), thereby retaining or exacerbating traditional negative sustainability impacts (Niner & Wassermann, 2021). Research argues the design phase of ICT adoption or virtual conferences is critical to avoid or mitigate such adverse outcomes (Flavián et al., 2024; Sox et al., 2017). As such, we analyse the extant literature on the design of VR conferences.

Designing VR conferences

Delivering a valuable experience to conference attendees in a virtual format is argued to require a completely different approach to conference design (Bidmon et al., 2020). In the case of VR conferences, this includes careful consideration of VR hardware and software accessibility and affordability, as well as ensuring attendees are familiar with these technologies beforehand (Moreira et al., 2023; Porwol et al., 2022; Rather et al., 2024) to prevent technical issues and support the knowledge sharing and networking activities expected at conferences (Kowalski et al., 2023). In addition, the enhanced scheduling flexibility offered through asynchronous and synchronous participation can be drawn on to improve access to diverse materials and support attendees' educational and social development (Moreira et al., 2023; Mulders & Zender, 2021; Porwol et al., 2022).

To date, gamification has been a key feature of VR experience design such as the use of avatars (Gunkel et al., 2018; Porwol et al., 2022), whiteboards (Kowalski et al., 2023; Predescu et al., 2023), beaches and dancing (Moreira et al., 2023), and sports (Mulders & Zender, 2021). Such gamification has been found to lead to feelings of excitement which can help meet tourists' expectations (Griffin & Muldoon, 2022; Jiang et al., 2023) and foster memory creation (Hung et al., 2024), however, it is also argued important to provide immersive experiences by replicating the physical reality of a place (Griffin & Muldoon, 2022; Predescu et al., 2023). Despite this finding, a review of the literature finds the majority of empirical papers consist of cartoonish VR environments, particularly when replicating university campuses (Alhilal et al., 2023; Moreira et al., 2023; Predescu et al., 2023), conference spaces (Kumari et al., 2023; Speidel et al., 2023), and other learning environments (Mulders & Zender, 2021). It is argued these cartoonish representations can affect feelings of immersion, socialisation, place, and presence, undermining the purpose and benefits of VR use (Jiang et al., 2023).

One tool proposed to overcome these limitations is Building Information Modelling (BIM), which uses scanning data to digitally replicate buildings, spaces, or objects, creating a digital twin (Inzerillo et al., 2023; Nguyen et al., 2022). While large scale applications of BIM have been used to enhance access to cultural heritage of sensitive tourism destinations like tombs (Banfi et al., 2022), temples (Nguyen et al., 2022) and mausoleums (Inzerillo et al., 2023), its use in conference settings consist of individual objects at a small scale (e.g., desks, soda cans) (Moreira et al., 2023). In VR tourism, BIM is argued to enhance vividness and interactivity while also delivering tangible and intangible value to VR participants, creating a more effective VR tourism experience (Banfi et al., 2022; Zhu et al., 2023). As such, the use of BIM in tourism warrants further investigation to uncover further applications and benefits.

Despite at times conflicting insights into the design of VR conferences, determining the success of integrating emerging technologies into sustainable tourism offerings requires analysis of the tourism offering's outcomes from both commercial and sustainability perspectives. The current state of knowledge regarding methods for evaluating VR use in tourism is therefore investigated.

Evaluating VR use in tourism

Within the tourism literature, identification of the purpose of VR integration varies, with some authors missing it entirely (Alhilal et al., 2023; Goebel et al., 2020; Tussyadiah

et al., 2018), some implicitly or partially considering it (Kumari et al., 2023; Mulders & Zender, 2021; Nguyen et al., 2022; Rather et al., 2024; Speidel et al., 2023), and only a small number explicitly stating the purpose and reflecting upon how this was or was not fulfilled. Among the small collection of articles that did consider the purpose and evaluate the outcomes of VR use (Griffin et al., 2017; Griffin & Muldoon, 2022; Hung et al., 2024; Predescu et al., 2023), none featured a model or process to explain how this purpose came to be achieved. While insights relevant to the integration of VR are evident in the research, particularly focusing on evaluating user experience (Griffin & Muldoon, 2022; Hung et al., 2024; Kowalski et al., 2023; Kumari et al., 2023), VR design (Leung et al., 2022; Zhu et al., 2023), implications for tourism (Griffin et al., 2017; Rather et al., 2024) conference organisation (Moreira et al., 2023), or the learning experience of participants (Mulders & Zender, 2021; Predescu et al., 2023; Speidel et al., 2023), the literature does not integrate these findings. The research, therefore, provides limited guidance on how tourism organisations should use VR to improve the sustainability of their events or offerings, for example how to identify an intended aim, select and implement the technology, and evaluate whether the aim is achieved. In addition, two groups critical to VR conference outcomes are conspicuously absent from these articles: 1) the VR tourism offering developers (e.g. conference organisers) and 2) business conference attendees, with much research focusing on academic conferences despite the significance of business communities to the conference industry.

Given the critical barrier of lack of expertise with emerging technologies and their rapidly evolving nature, we draw on Kolb's seminal work and subsequent research to guide our exploration and learning of social virtual reality and digital twin technologies to enable the development of a more sustainable tourism offering.

Experiential learning theory

The role of experience in knowing and doing has been fundamental to many cultures throughout history, with some arguing the inability to truly know or do without experience (Baggini, 2018). Kolb's (1984) seminal book, *Experiential Learning Theory: Experience as the source of learning and development*, provides a theoretical framework and empirical evidence for applying the concept of experience to learning across different contexts. ELT is defined as "the process whereby knowledge is created through the transformation of experience" (Kolb, 1984, p. 41), and its influence is evident in the theory's presence in a variety of literatures (Kayes, 2002), as well as more than 86,000 citations (GoogleScholar, 2024). In recent decades, the theory has been extended through insights from poststructural analysis (Kayes, 2002), developmental action inquiry (Meyer, 2003) and more, seeking to address criticisms of the theory. It is argued holistic, integrative learning requires four interdependent processes, including action, cognition, reflection and experience, all of which are features of the ELT approach. Cycling through the four core components of the framework extended by Saunders (1997) and Meyer (2003), concrete experience, abstract conceptualisation, reflective observation and active experimentation, delivers the greatest learning potential (Meyer, 2003; Saunders, 1997). In addition, ELT relies on six assumptions of learning, that "learning a) is a process, not an outcome; b) derives from experience; c) requires an individual to resolve

dialectically opposed demands; d) is holistic and integrative; e) requires interplay between a person and environment; and f) results in knowledge creation" (Kolb, 1984, pp. 25–38). ELT not only informs the theoretical contribution of this study, it also forms an integral component of the method outlined in the next section.

Method

It is argued the only way to understand social systems is through 'deliberate intervention and diagnosis of responses to the intervention' (Van de Ven, 2007, p28). In addition, while case studies provide less generalisable results, they offer greater depth of detail and insights which are critical for the study of nascent research topics (Bryman, 2012; Eisenhardt & Graebner, 2007). We therefore undertake a case study of the selection and integration of an emerging technology to improve the sustainability of a tourism offering. To do so, we take a Participatory Action Research (PAR) approach, that is, academics working with other members of society to co-create solutions to societal challenges (Reason and Bradbury, 2008). Performing PAR requires researchers to overcome several challenges, including gaining in-depth access to stakeholders and acceptance of the intervention and evaluation process within a social or commercial setting (Van de Ven, 2007). We overcame such challenges by using our role as academic conference organisers, drawing on existing relationships with industry and global networks of academics. Other important aspects of the research study design include incorporating a process perspective (Edelheim et al., 2018) and opportunities to experience the technologies (Vander Schee & DeLong, 2022). As such, ELT was used as a method to guide the process of exploring emerging technologies to reduce aviation travel for the conferences. The diverse range of stakeholders forming the research team also resulted in diverse interests, which reflects another challenge of PAR (Van de Ven, 2007). The project lead mapped team members, their roles, and interests to understand potential influence on the project. A focus on delivering the conference offerings and maximising potential value and positive experience for attendees allowed the research team to prioritise efforts during the case study, with differing academic interests (e.g., publishing in different disciplines) managed collaboratively following the delivery of the conferences.

Case study

Prior to the emergence of the COVID-19 pandemic, we responded to the challenge of finding more sustainable conference offerings, working with the organisers of the *GRONEN2020* conference to run a pilot study of a social VR conference offering as part of their virtual conference stream pilot. Once the conference became a virtual-only event due to travel bans associated with the global COVID-19 pandemic, the VR offering took on a new value proposition, providing a superior experience compared to the continual stream of webinar conferences and meetings. The success of the social VR pilot led to commercial adoption of the model by the Circular Fashion Summit (a VR-only, commercial (non-IT) conference application) and, finally, to an evolution of the model at the SIGGRAPH Conference, running as a hybrid physical, VR, and Zoom panel event, all held in 2020. The Case study comprises all three events, reflecting the process of development, evolution, and extension of technology-enabled sustainable tourism offering (Figure 1).



Figure 1. Case Study consists of three applications of Virtual Reality Conferencing.

Data collection and analysis

Data consists of materials recorded through the development and implementation process as well as regular individual and team reflections guided by the ELT framework, including meeting notes, materials prepared as part of the exploration research, presentations to gain approval for hosting the technology enabled tourism offerings, recordings of conference events, and reflections of experiences in the various VR worlds during project development, refinement and implementation. Due to the iterative nature of hosting three consecutive events, each with tailored strategy and implementation, the reflections of experiences were analysed both throughout the project as well as at the conclusion of the three events (Table 1).

Table 1. Data collection phases and timeline.

Timeline	Phase of the project	Data
End 2019 – early 2020	Project ideation	Team and sub-team meeting notes Project grant proposals Presentation to GRONEN Conference Executive Committee
Early – mid 2020	GRONEN Conference design and world builds	Team and sub-team meeting notes Individual and team reflections Final business model
June 2020	GRONEN Conference	Individual and team reflections on experience
September 2020	Circular Fashion Summit event	Individual and team reflections on experience Final business model Social media associated with the event
September – November 2020	SIGGRAPH Frontiers event design and build	Team and sub-team meeting notes Individual and team reflections Final business model
November 2020	SIGGRAPH Frontiers event	Individual and team reflections on experience
December 2020	Project finalisation	Individual and team reflections on experience Team and sub-team meeting notes Reporting to the project funder [University] Presentation and explanation of the project and the GRONEN Conference world as part of the [University] online Alumni event

Data were analysed both inductively for themes and through the four stages of ELT: concrete experience, abstract conceptualisation, reflective observation, and active experimentation (Meyer, 2003; Saunders, 1997). Reflections on team dynamics, incentives, roles, and potential biases were also considered during the data analysis stage, as suggested by Van de Ven (2007).

Findings – Social VR conference development process

GRONEN 2020 conference

The conference experience

A small conference (up to 100 attendees) of business sustainability academics to be held in Lisbon, Portugal. The social VR offering pilot was a Professional Development Workshop (PDW) that consisted of open discussions among up to 20 conference attendees, sharing information and recording ideas discussed in the session. The research team challenged themselves and each other to identify what would convince them not to travel and to reflect more deeply on the value of academic conference attendance and how it differs among the various cohorts of attendees (PhD candidates and early career academics compared to senior faculty, those with caring responsibilities, less access to travel funds, or geographically distant).

The sustainability challenge

provide a social VR alternative to remove the need for academics to fly to the conference, reducing aviation emissions. Success would be measured by interviews with

virtual and VR session attendees to identify reductions in travel, estimated travel distance, and associated emissions.

Experiential learning of the technology

The members of the team with experience with VR guided other team members through existing publicly available VR applications to understand what VR actually is and to get used to the feel of the hardware and software, the weight of the headset, how long you can wear it, how absorbed you are when using a headset compared to other digital technologies to name a few. This extended to using the social VR application AltspaceVR, where we talked to each other and to strangers who were also using the application. We even shook hands with our colleagues, understood how the technology allowed us to communicate not only through speaking but through non-verbal communication such as waving, turning your head or body and more.

Evolving from gamified to a digital twin based VR world

We initially replicated the conference room setting in Lisbon using a gamified style reflective of existing social VR worlds (Figure 2(a)), yet through the experiential learning process, specifically considering the experience of the conference attendees who were business sustainability academics (as opposed to the tech industry staff who until that point were the main users of VR technology in a work setting) we became concerned that the VR conference world may not look professional enough for people paying to attend to discuss their work. One team member, a Civil Engineer who used digital twins for road and rail tunnel infrastructure projects, suggested using a digital twin of a building to provide a more sophisticated representation of a real building (Figures 2(b) and 3). Replicating a building in another country became an additional feature of the project, as attendees could 'visit' multiple destinations in one conference.

Selecting the technology and business model

We discovered digital twins had not been used (to our knowledge) in social VR, reminding the team of the still-emerging nature of the technology, as well as the value in multi-disciplinary teams working together. Challenges and decisions related to user experience, particularly aesthetics versus functionality, had a direct impact on technology selection and business models.

AltspaceVR (Microsoft Corporation) was chosen as a platform to build the interactive conference environment due to its support for a large number of concurrent users, compatibility with a variety of tethered and mobile Head Mounted Devices (HMDs), a range of supported file formats, and the absence of fees for world building and invited users. Following reflections on the process the research team went through using the technology, we realised new users would also need to experience the technology to maximise the value of the experience. Not only would they need detailed instructions and guidance when using the technology the first time, they would also need the opportunity to get used to the software and hardware and time to understand the nature of the technology, prior to participating in what was to be the actual tourism offering, the PDW session. We therefore held a social event in the VR workshop space



Figure 2. Evolution of GRONEN 2020 Conference Virtual Reality Worlds (a) Pilot VR world replicating Lisbon, Portugal conference venue, b) Evolution from gamified to professional VR world through integration of digital twin and drawing on ability for attendees to be ‘anywhere’ while in VR.

the evening before the main PDW session. The importance of the unfamiliarity of the software and hardware for attendees could not be overstated, nor the time and support required within the VR world and through separate means, such as a concurrent Zoom call to ensure participants could communicate with the research team before and after the experience in a more familiar setting, or if they had technical challenges in VR.

Evaluating success

As the conference ultimately became an online-only event (due to the COVID-19 pandemic travel restrictions), we were unable to assess the reduction in travel; however, the sessions provided evidence of success in running a social VR PDW event and networking, including one-on-one discussions and networking. Interestingly, during the PDW session, interactions of attendees were quite formal, even between

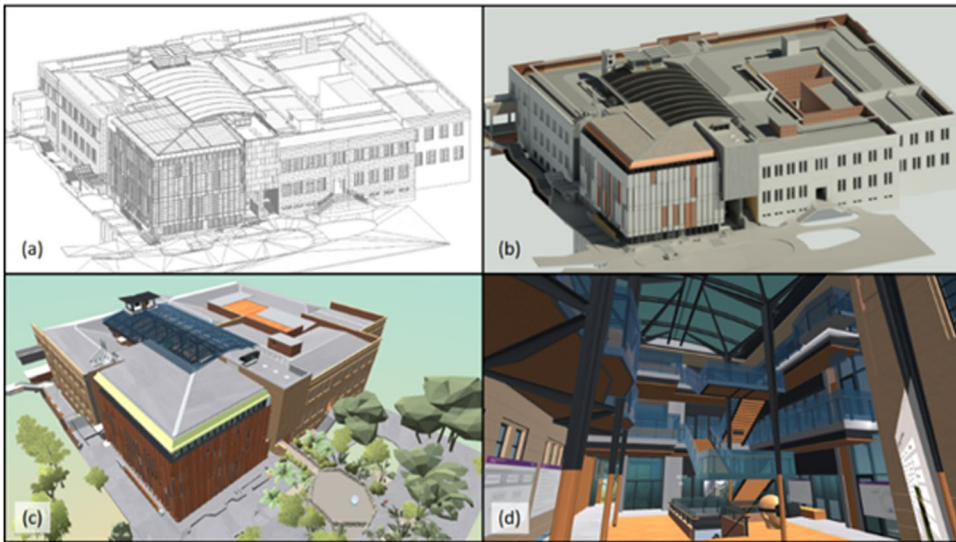


Figure 3. Digital Twin Development for the Global Change Institute (GCI) Building Atrium. This figure illustrates the evolution of the architectural Revit model for the GCI Building Atrium (a) GCI Revit Model – showcasing the digital architecture of the Atrium, (b) GCI Render – a realistic visualization of the building design, (c) GCI AltSpace Model – the digital twin integrated into the AltSpace VR platform for virtual conferencing, (d) GCI Atrium AltSpace – the immersive atrium environment in VR.

people who had existing relationships and who were having one-on-one conversations. Following the close of the formal PDW session, attendees teleported to a publicly available rooftop bar (world) in the Altspace VR app, significantly changing the nature of interactions as everyone began informal one-on-one or small-group conversations in multiple languages, reflecting the in-person interactions at traditional GRONEN conferences. This highlighted the unique ability of social VR to enable such interactions, deemed critical to choosing VR over in-person attendance.

Circular Fashion Summit, Paris Fashion Week

The conference experience

Commercial adoption of our VR conferencing model occurred within just a few months of the original GRONEN2020 Conference. The Circular Fashion Summit, part of Paris Fashion Week, was unable to go ahead as planned, again due to COVID-19 travel restrictions. In 2020, the first Circular Fashion Summit to be held in social VR was run and built by the same consultant VR world builder from the GRONEN project, using the learnings developed throughout the pilot project.

The sustainability challenge

In addition to providing a superior experience for attendees unable to attend in person due to COVID-19 restrictions, the Circular Fashion Summit sought to reduce CO₂ emissions and increase the sustainability of events in future years (through the continued use of VR conferencing technology) reducing aviation travel.

Evolving from a university building to a Paris public landmark

Consideration of the tourism offering and attendees led the VR world to replicate the Paris landmark, the Grand Palais, through digital twins of the building, bringing a sense of Paris and a venue familiar to attendees to their conference experience. However, a superior feature of VR compared to the real world was the ability to include other features such as large trees and moving elephant, giraffe and even alligator.

Selecting the technology and business model

The summit attendees, large fashion houses, and consultants were largely unfamiliar with VR technology, so the model used reflected the GRONEN2020 Conference learnings. However, this was to be a VR-only summit with multiple events and needed to be run in a commercially viable manner. Given the need to justify the registration fee, the event needed to provide the functionality expected by large companies and also to reflect as much as possible the experience of attending Paris Fashion Week in person. Similar features of the technology and business model were adopted including the use of a digital twin of a building to create a sense of presence, enhancing the sense of fun through the inclusion of specific artefacts in the VR world, the use of the Altspace app as the hosting platform, inclusion of VR headsets in the conference registration fee that would work with the Altspace app, detailed guidance for users and more.

Evaluating success

Following the Circular Fashion Summit in 2020, the organiser, Lablaco, continued to run multiple smaller events in the social VR world, with panel members and attendees all attending through VR. While data is not available on the number of attendees of each event, where they would have travelled from, and the specific emissions associated with their travel, there is a clear reduction in aviation travel as a result of hosting these events purely in social VR.

SIGGRAPH Frontiers event

The conference experience

Following the success of the other events, members of the research team, who were also part of the SIGGRAPH Frontiers Conference organising team, invited us to host a session in the [the university] VR world. As we defined the particular conference experience for this event, we identified clear differences that provided additional opportunities for the event's design, including having panel members in VR only. In addition, COVID-19 pandemic restrictions had eased in Australia, allowing small in-person events to be held. The event itself, a SIGGRAPH Frontiers session, was designed to discuss the frontiers of technology in the industry, and, as such, the team's ability to design a tourism offering that also pushed the frontiers of technology-enabled conferencing seemed apt.

The sustainability challenge

Provide as much interaction as possible and demonstrate the technology's ability to support conferencing in a post-COVID-19 world to reduce conference aviation emissions in future years.

Understanding VR technology

Reflecting on the original conference delivery at the GRONEN2020 event, the team considered how to evolve the delivery, visioning ideas, strategising how ideas could be implemented, trialling the ideas followed by further rounds of experience and reflection. Feasibility testing aimed to identify potential technology problems, requirements, or implications for users or conference organisers that we had not anticipated during visioning and strategising stages.

Evolving from a VR to a hybrid conference delivery

The event was held in a hybrid in-person-social VR-zoom avatar-linked style. People attended the event in one of three ways: 1) in-person in the real Global Change Building at [the university], 2) as avatars in the VR (digital twin) version of the same building, or 3) on a Zoom call, of which the host was linked to an avatar in the VR version of the building. To maximise the interactions, a large screen was installed in the real-world building, streaming what was happening in the VR building in real time. The same occurred in the VR building, with a large screen streaming a real-time video of the participants and the panel in the real-world building. This allowed every attendee to see every other attendee regardless of attendance type. Finally, several VR headsets were available in the real-world building, enabling attendees to join the VR world and have one-on-one interactions with other attendees and panel members. Another unique feature of this event was the ability to have the panel split across countries, with some in VR only and others including the conference host (project lead) in the real-world building at the same time as controlling their avatar in the VR version.

Selecting the technology and business model

Once again, the publicly available Altspace VR, which was selected due to the ease of delivery, familiarity of attendees at this conference with the technology, ability to have a private room, and integration of the [the university] digital building which had been modified to suit the Altspace VR app technologies. This groundbreaking event was technically complex. The expertise required to not only design but also deliver the event was substantial, requiring people to manually ensure the sound between the real-world and VR world was managed for each panel member. This also slowed the speed at which conversations could take place, which would not be suitable for all conferences, yet in the SIGGRAPH Frontiers event, given the attendees and the aim of the session, it was acceptable. Similar to the GRONEN2020 Conference, attendees paid to access the SIGGRAPH Conference and could attend the VR event.

Evaluating success

The success of the event was evidenced by the large number of attendees in each mode of attendance, and the reflections of each of the research team and panel members identified the achievement of a novel integration of technology for conference delivery, and superior one-on-one interaction and networking compared to other virtual attendance tools (Zoom, Teams, etc.).

Discussion

Our study contributes to both research and practice by providing evidence of the successful integration of emerging technology to enable sustainability improvements for a tourism offering, specifically, carbon emissions reductions for international conferences through social VR and digital twin technologies. While the study highlights what is possible for commercial tourism offerings, it also examines the process by which the project was ideated and delivered, as reflected in the Technology-Enabled Sustainable Tourism Offering Framework (Figure 5). This framework represents a practical guide and theoretical contribution to support tourism organisations seeking to navigate the challenges and opportunities of pressure to decarbonise (Hamant et al., 2019; Klöwer et al., 2020; Wenger et al., 2025), and rapid changes in technology (Talwar et al., 2023). The framework integrates findings from the case study and insights from the extant literature, including ICT adoption in tourism, sustainable

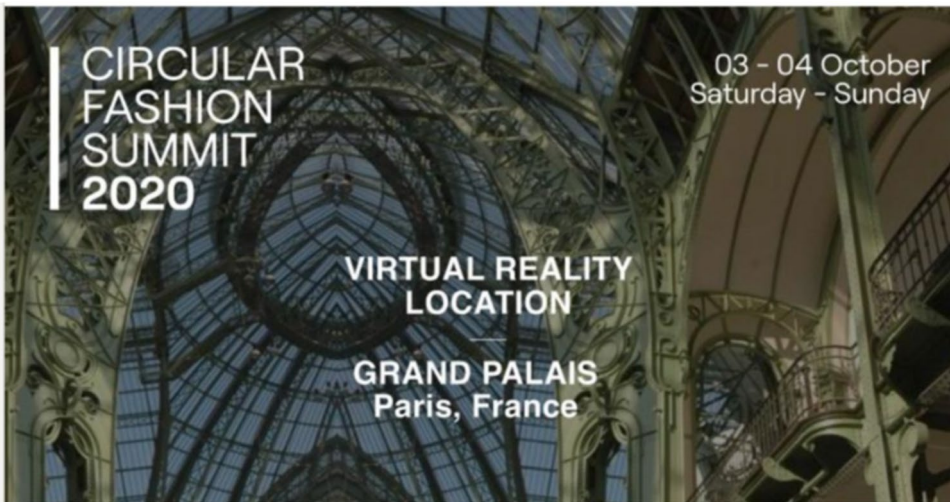


Figure 4. Circular Fashion Summit 2020, Paris Fashion Week: The first fully virtual summit held in a social VR environment, leveraging a digital twin of the iconic Grand Palais to create an immersive and business-like conference experience.

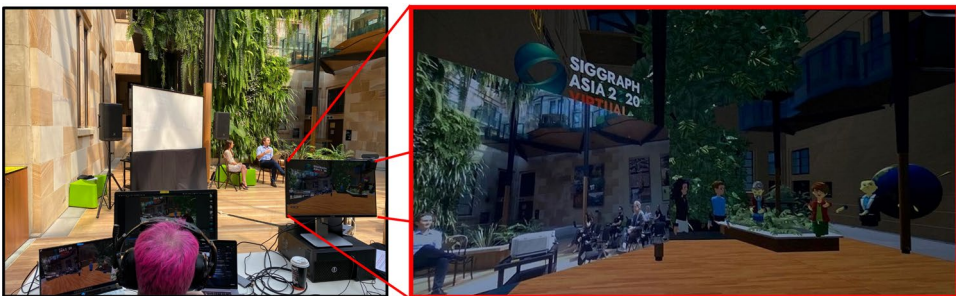


Figure 5. SIGGRAPH Frontiers Event – Conference attendance in-person in the GCI building, in the GCI Virtual Reality World and via a Zoom call linked to an avatar in the GCI VR World.

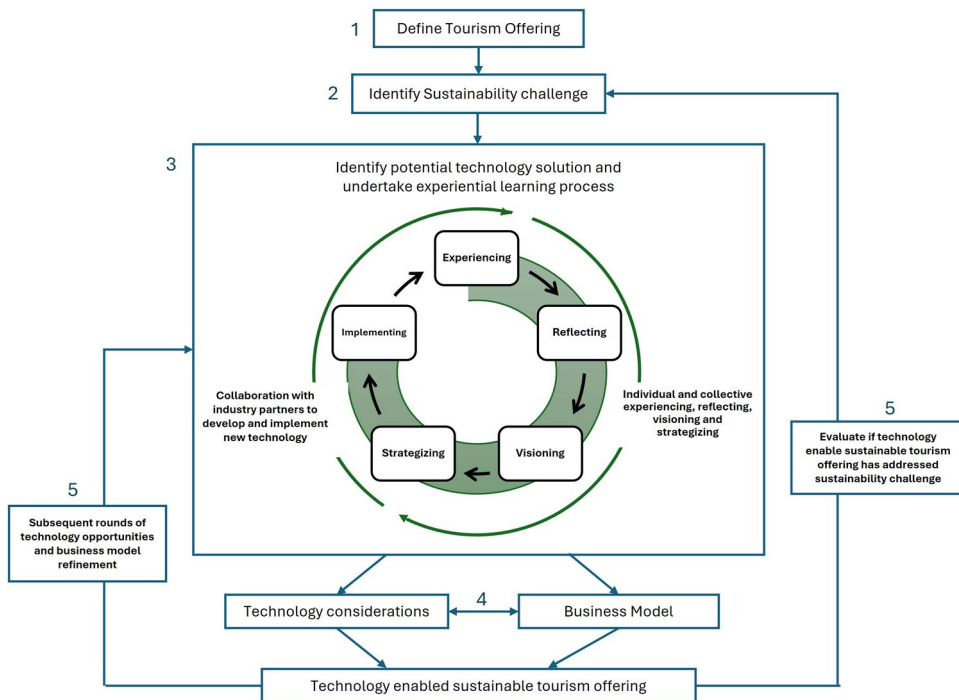


Figure 6. Technology-Enabled Sustainable Tourism Offering Framework.

tourism transport (mobility), VR conferences and events, and experiential learning. In doing so, it contributes to identified deficiencies in the literature, including the need for theoretical frameworks (Jiang et al., 2023), guidance on value identification and business models (Cavallin Toscani et al., 2024; Niner & Wassermann, 2021; Sousa et al., 2024b; Vander Schee & DeLong, 2022), diversity of VR research across a variety of applications (Gössling, 2017), and research that bridges the research-practice gap (Coghlan, 2022) (Figures 4 and 5).

Technology-Enabled Sustainable Tourism Offering Framework (Figure 6)

Define the tourism offering

The first stage requires understanding the tourism offering, i.e. what is the underlying purpose or meaning of the experience? In the case of a conference or seminar, the experience includes presenting research or information, speaking to a group of people, having one-on-one conversations.

This stage is critical as emerging technologies can enable a reimagined experience (Edelheim et al., 2018; Kim et al., 2020; Seidenberg et al., 2021), even ‘blurring’ concepts of place, separation, and other aspects related to tourism travel (Hannam et al., 2014).

Identify the sustainability challenge

The second stage requires defining the sustainability challenge to be solved or addressed. Being specific about the challenge and how you will measure success will

assist in the final stage of evaluating the technology integration process and ensure you are solving the right problem. For example, reducing air travel to reduce Co2 emissions measured by the number of individuals choosing to attend in VR and the Co2 emissions saved by their no-fly attendance.

Identify the potential technology solution through experiential learning

In the third stage, multiple rounds of *experiencing* an emerging technology, *reflecting* on the experience, *strategising* potential applications and value to users, and *implementing* ideas will allow for the evolution and selection of appropriate technology solutions. These steps should be undertaken both individually and collectively by members of the team, who each provide unique and crucial perspectives on the process as detailed in Table 2. The inclusion of multi-disciplinary team members may also allow for greater potential to identify unique opportunities and potential negative impacts.

This stage is particularly important given research identifies lack of experience and expertise with technology as key barriers for tourism (Sousa et al., 2024b, 2024d) and the importance of the design phase to avoid or mitigate the negative impacts of technology integration for conferences (Flavián et al., 2024; Sox et al., 2017).

Select technology and business model

Technology (hardware and software) and business model selection are intrinsically linked and must be considered concurrently. The selection of technology needs to deliver the specific desired experience and functionality, suit the needs of the user

Table 2. Stakeholders’ key perspectives/roles.

Stakeholder	Key perspectives/roles
<i>Conference Organisers</i>	Sustainability challenge identification and definition Approvals / Funding (e.g. Minimum Viable Product) Consumer preferences Potential value to the organisation Business model considerations, including pricing Integration with existing offerings Final decisions on technology selection and the new business model
<i>Sustainability Experts</i>	Sustainability challenge definition Current evidence and projections (e.g. will aviation be decarbonised in the near future or not) Methods of measuring baseline and change in the sustainability issue Identification of unintended/negative sustainability impacts
<i>Offering Delivery (e.g. conference session host)</i>	Functionality requirements for offering/technology Consumer preferences
<i>Consumers</i>	Consumer experience of new technology Potential value to the consumer
<i>Technology Experts (generalists and technical specialists)</i>	Initial solution ideation based on technology knowledge Technology upskilling of team members Alternative ideas and problem-solving based on team visioning and strategising Current state and future trends of hardware and software Building technology or technology integration Technical support for tourism offering delivery where required

and be delivered through a business model that also supports the commercial requirements of the organisations involved. For example, which headset is affordable, easily accessible and provides the interpersonal experience demanded by the end user, or which social VR platform allows for the required number of participants concurrently, is private or public, and can be used on a desktop if required. The value of the experience will determine the business model, i.e. the price tourism end users are willing to pay for such technology and tourism offering. For example, the original GRONEN business model, and that implemented in the Circular Fashion Summit, was to offer tickets to participating end-users (fashion houses in the case of the Circular Fashion Summit) that included a suitable VR headset as well as the instructions required for those new to the technology to enable them to participate in the summit. It is also critical to ensure details from Stage 1 remain in the considerations, as the original tourism offering can be fundamental to these decisions. For example, the SIGGRAPH Frontiers Summit audience and panel members were more familiar with VR technology; as such, many already owned VR headsets and were familiar with using social VR.

While the tourism literature identifies fundamental impacts to tourism business models, there remains a lack of specific guidance on what and how digital technologies can be implemented to improve sustainability (Cavallin Toscani et al., 2022; Gössling, 2021). The guided process of experiential learning in Stage 3 supports tourism organisers to develop their own insights with which to select an appropriate technology and business model in Stage 4.

Evaluate outcomes and refine tourism offering

The final stage of the process is to evaluate if the project has achieved its aim of addressing the sustainability challenge identified in Stage 2. In this case study, questions included: Are fewer people flying to the conference to attend in person, reducing CO2 emissions associated with the conference? Are the CO2 emissions associated with the technology lower than those of the traditional in-person attendance option? These points can be calculated through detailed Life Cycle Assessment, surveys and other data, if desired, or more rudimentary calculations can be made depending on resource constraints and required accuracy. Returning to the experiential learning phase (i.e. Stage 3) will also enable individual and collective reflection on opportunities for the technology to maintain or enhance specific tourism offerings.

This stage can be tailored for specific and accurate evaluations such as LCA (Cavallin Toscani et al., 2022), or broader sustainability evaluation for example how the initiative contributes to the Sustainable Development Goals (SDGs) (Gössling, 2021).

Limitations

While the case study comprises three separate conference events, representing a variety of contexts, the process of exploring technology-enabled tourism offerings is a single case, limiting potential generalisability. However, the foundations of the proposed framework, ELT, have been rigorously tested across a broad range of industries and contexts, providing proven transferability of the core learning process of

the framework. The study also considers the integration of only two emerging technologies, digital twins and social virtual reality. Future research investigating the applicability of the framework within a diversity of tourism offerings and emerging technologies would provide valuable insights about the entire framework's relevance to the broader tourism industry. Other research could include investigating business models for integrating emerging technologies, the type of tourism offering, and the resulting commercial and sustainability outcomes.

Conclusion

We provide a framework to guide tourism organisations as they seek to integrate emerging technologies or combinations of technologies to improve the sustainability of their tourism offerings. The framework allows for learning about the new technologies, visioning possible applications, identifying value derived through the technologies, and the selection of an appropriate business model. An initial step to identify the sustainability challenge to be addressed and a final step to evaluate the success of the technology adoption are also included. Given the critical nature of expertise and stakeholders to the process, we also provide a typology of actors and their respective roles in the application of the framework.

The COVID-19 pandemic travel and gathering restrictions removed the option of in-person attendance for two of the conference events. This made it impossible to achieve our initial plan to measure how many people chose a virtual reality conference option rather than in-person attendance, and the potential reduction in CO2 emissions associated with aviation travel. However, while the academic conferences did not run the VR conference event in the immediate years following the COVID-19 pandemic, as people sought in-person experiences, the Circular Fashion Summit has continued to run a series of events solely in social VR, resulting in a successful process of reducing CO2 emissions from flying to their conference event.

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Author contributions

CRedit: **Cristyn Meath**: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing; **Alex Smith**: Conceptualization, Data curation, Funding acquisition, Investigation, Project administration, Resources, Software; **Jurij Karlovsek**: Conceptualization, Data curation, Formal analysis, Investigation, Project administration, Resources, Validation, Writing – review & editing; **Luke Bubb**: Conceptualization, Data curation, Investigation, Methodology, Project administration, Resources, Writing – original draft; **René Bohnsack**: Conceptualization, Data curation, Investigation, Project administration, Writing – original draft; **Mashhuda Glencross**: Conceptualization, Data curation, Investigation, Project administration, Resources, Supervision; **Stephen Viller**: Conceptualization, Data curation, Investigation, Resources; **Jason Weigel**: Data curation, Investigation, Project administration,

Resources; **Paul Schlosser**: Data curation, Investigation, Project administration, Resources; **Syannah Wilson**: Writing – original draft; **Christina Bidmon**: Data curation, Project administration.

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