Filmmaking of the Future: A Co-Design-Led Investigation Into the Potential of Immersive Technologies to Enhance the Small and Medium Audiovisual Production Processes

A Thesis Submitted for the Degree of Doctor of Philosophy

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Abstract

In common with many other fields, the audiovisual (AV) industry is being transformed by the use of real-time graphics engines in combination with immersive technologies such as virtual reality (VR) and augmented reality (AR). This technological mixture enables what is known as virtual production (VP) and introduces professionals to numerous new ways of creating AV content.

However, VP is still in a relatively early stage and there are various barriers to democratization that must be overcome if these technologies are to become widely used in the industry. Specifically, there is a need to promote and identify the best ways to facilitate the uptake of the technologies within the context of independent small and medium productions (SMPs).

The main aim underscoring this PhD project is to investigate how VP can enhance the process of independent SMPs; the key output is a set of recommendations for implementing VP into current production practices.

Recommendations are based upon a new VP process that focuses on immersive pre-visualization of filming locations. This process is enabled by using affordable, accessible, and easy-to-use immersive technologies to support creativity, communication, and collaboration during the pre-production phase of an AV product.

Unlike previous studies in the field, this work was performed by adopting a co-design approach whereby professionals were actively engaged in and contributed to the research by sharing their valuable knowledge, creative ideas, and feedback. The overall methodological framework adopted to develop the research was design research methodology (DRM).

The PhD project comprises five consecutive and interdependent studies:

In the first study, the working habits, challenges, and perceptions towards VP were explored through a series of semi-structured interviews with professionals who

performed different roles within SMPs. This stage contributed to the initial understanding of the SMPs' operational context and the identification of the basic user requirements for adopting VP.

The second study involved a new sample of professionals who engaged in a series of remote co-design workshops that validated the findings from the previous stage. This study also introduced into the project the method of design fiction, a process in which participants are prompted to conceptualise possible and probable ideas for the future use of VP in their work. This second study generated 14 initial scenarios on how alternative VP processes can benefit SMPs.

In the third study, ideas from the second study were merged and extended into three highly detailed design fiction scenarios that were presented in an online questionnaire. The data collected from professionals who responded to the questionnaire allowed to identify the scenario considered to be the most valuable and worthwhile of being developed in practice.

In the fourth study, a practical prototype was designed and developed based on the detailed scenario from the third study to aid professionals in the pre-production phase of an AV project. The prototype was then evaluated in person by different teams of professionals who employed it in a simulated alternative VP-enabled process. The prototype and process were seen as useful and ready to be implemented in a real-world environment.

The fifth study encompassed the final stage of the project, which involved self-reflection on the practical prototype as well as the process developed and evaluated in the fourth study. Accordingly, a set of recommendations based on the all the previous studies, was generated for the design of future VP processes for SMPs.

Overall, this exploratory research contributes to better understanding of an emerging area of investigation – VP applied to SMPs – and highlights the urgency for further research activities.

Keywords: Audiovisual Production, Co-Design, Design Fiction, Virtual Reality, Augmented Reality, Virtual Production, Location Scouting

Declaration

I declare that this thesis was written by myself, Aimone Bodini, that the work contained herein is my own except where explicitly stated otherwise in the text. I declare that this work has not been submitted for any other degree or professional qualification.

Aimone Bodini
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Publications arising from this PhD

Journal papers

Bodini, A., Colecchia, F., Manohar, A., Harrison, D. and Garaj, V., 2023. Using immersive technologies to facilitate location scouting in audiovisual media production: a user requirements study and proposed framework. *Multimedia Tools and Applications*, pp.1-22

Bodini, A., Colecchia, F., Manohar, A., Harrison, D. and Garaj, V., 2023. Envisioning the future of virtual production in filmmaking: A remote co-design study. *Multimedia Tools and Applications*

Conferences, Talks and Panel Discussions

“The Magic of Virtual Production”, Speaker, VRDays Europe, Amsterdam, Videoconference (Due to COVID-19), 4 - 6 November 2020.

“Virtual Location Scouting: A new approach enabled by Real-Time engines, Immersive technologies and Digital Twins”, ECR Speaker, BEYOND 2020, Belfast, Videoconference (Due to COVID-19), 30 November - 03 December 2020.

“AV Production inside the Metaverse - Draw me like pixels”, Panel Moderator, VRDays Europe, Amsterdam, 13 - 17 November 2021.

“The Future of AV”, Advisor, VRDays Europe, Rotterdam, 28 November - 02 December 2022.

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Definition of Terms

Term	Acronym	Definition
Artificial intelligence	**AI**	In the context of this research, AI describes algorithms capable of generating new media content, such as images or texts.
Augmented reality	**AR**	Real-time viewing of virtual elements in a real environment.
Audiovisual	**AV**	A media product resulting from the combination of visual and audio components.
Audiovisual industry	**AV industry**	The totality of all AV sectors and products (La Torre, 2014).
Audiovisual sector	**AV sector**	A specific category of the AV industry characterized by its final output, production process, and distribution dynamics (La Torre, 2014).
Audiovisual production	**AV production**	The entirety of professionals working towards the completion of all the processes necessary to create an AV product.
Audiovisual product	**AV product**	The final output generated by the AV production process.

Computer-generated imagery	**CGI**	Imagery produced using computer graphics techniques.
Design support	***/***	Blessing and Chakrabarti (2009) use this term to define the outcome of a design research process.
Digital twins	**DTs**	A digital simulation of a physical object or system that mutually exchanges data in real time.
Extended reality	**XR**	An umbrella term describing the range of technologies or approaches that are used to supplement or merge the real and virtual environments. Both in academia and industry, it is commonly used interchangeably with mixed reality (MR).
Mixed reality	**MR**	*(See XR).*
Real-time rendering	***/***	The process of rendering images at a rate rapid enough that the viewer does not see individual images, thus enabling a smooth interaction with the machine (Akenine-Moller, 2018).
Small and medium productions	**SMPs**	Includes single AV productions with medium budgets (less than $100,000), small budgets ($20,000), and micro budgets (less than $4,000).

Stakeholders	***/***	Those involved in the AV production process. The term is used broadly to include directors, cinematographers, producers, and all professional figures participating in the projects.
Visual effects	**VFX**	Visual elements (other live-action footage or CGI) added and integrated within pre-existing live-action footage.
Virtual production	**VP**	An umbrella term to define a process having at its core real-time game engines combined with several other technologies.
Virtual reality	**VR**	A simulated experience of an artificial or virtual environment that is commonly computer-generated in real time.
Workflow	***/***	In the AV industry, the term refers to the series of stages through which an AV product passes from inception to completion. In this work, it is used interchangeably with *production process* and *pipeline*.

Chapter 1

INTRODUCTION

1. Introduction

This chapter introduces the emerging field of virtual production (VP), describing its main characteristics and combination with immersive technologies. Additionally, the researcher presents the research aims, questions, and objectives at the centre of this research. Finally, the structure of this thesis is presented.

1.1 The Ever-Evolving Relationship Between Filmmaking and Technology

Since its inception, cinema has been deeply entangled with the technical mastery and technological advancements of its time. Some authors establish the birth of cinema with the Lumièrs brothers' projection of their film to a paying audience in 1895. However, many other inventors of the time were interested in capturing and projecting moving images (Nowell-Smith, 1996). Before the Lumièrs brothers, Léon Bouly developed his own version of the cinematograph in 1892. Edison patented an invention named *Kinetoscope* in 1891, and Muybridge was able, in 1878, to rapidly capture multiple images of a horse galloping. The innovations in perfecting, capturing, and projecting techniques, extra gears, and instruments has not stopped evolving. Different camera lenses to attach to the camera body have been invented, allowing filmmakers to capture close-up or wide shots of their subjects without physically moving the camera. George Eastman, the founder of Kodak, developed light-sensitive emulsions that he placed on glass plates and a cumbersome process to obtain images on flexible celluloid film, which marked a new era for photography and cinema. Mechanical contraptions to move the bulky and heavy cameras of the early days were developed, which introduced spectators to a new visual style. Then came colour, sound, light, handheld cameras, digital cameras, and computer graphics (CGs) software, to name a tiny fraction of the worldwide advancements that have been the centre of audiovisual (AV) production in the past 130 years.

Every notable technological breakthrough that has benefited AV professionals has also required them to alter their production process to integrate such innovation. Modern film directors do not make movies in the same way they did 50, 25, or even 10 years ago. Because filmmaking is a collaborative work, the same is valid for many other professional figures from different departments involved in developing an AV product. Technological innovations require them to adapt, embrace new tools, and change their working habits.

1.1.1 Virtual Production: Many Forms, Many Possibilities

Among the latest innovation in the AV field is VP, which is an alternative to the established process, whose proponents claim that it fosters creativity while saving time and money. VP is an umbrella term that includes many technologies and practices. Further details about the term are provided in Section 2.1.

Real-Time Game Engines

It is generally agreed that this new process for producing AV products has at its core real-time graphics engines, or to be more precise, real-time game engines, which are commonly used in the gaming sector. These engines can produce computer-generated images, which, in turn, can be modified through real-time interactions. Real-time game engines have improved considerably in recent years in the visual fidelity of realistic images; therefore, some filmmakers have introduced them in their production process.

Virtual and Augmented Reality

Many other technologies powered by these engines are becoming central and equally important in enabling VP. Virtual reality (VR) and augmented reality (AR) are the most common immersive technologies; VR immerses users in an artificial world when they wear a headset that occludes their sight of the real world, while AR supplements the real world with computer-generated visual elements. Filmmakers can employ VR and AR for many tasks, such as experiencing and working within an immersive digital replica of the filming location, which enables different crew members to collaborate virtually and remotely, pre-visualizing the scene without requiring travel to the physical location. This practice, in turn, reduces the carbon footprint and travel logistics, thus saving time and money.

LED Volumes

Research on semiconductor devices such as LEDs started in the late ’60s (Borden and Pighini, 1969). It gradually advanced, improving the spectrum of colours that were reproducible on LED displays and reducing the distance between pixels (technically referred to as *pixel pitch*). Later, scientists assembled many LED displays together to form an array, the so-called LED wall, which was useful for displaying large-scale images to crowds attending concerts, events, fairs, and exhibitions. A notable example of an LED wall was used during the U2 *PopMart* world tour (Thomas, 2021). In recent years, LED walls have been built inside film studios (these are called *LED volumes*), often as an extended curved stripe. LED walls replace the blue or green screen widely adopted by AV producers and offer several benefits. Shooting inside an LED volume allows producers to display the scene’s background on the LED wall and edit the background in real time by using real-time game engines. Nevertheless, this does not come without some limitations and trade-offs that filmmakers must accept. For example, the cost of building an LED volume can be several million dollars, and renting such a facility can cost tens of thousands of dollars per day for small or medium LED volumes.

Motion Capture

Motion capture is a technique widely employed to animate fictional characters in video games or movies using animation data of real people wearing suits that are equipped with sensors and markers. Real-time game engines enhance this technique since it allows filmmakers to see the humans' performance on the fictional characters' bodies in real time.

VR, AR, LED walls, and motion capture are merely a few technologies and techniques that can be part of the VP process. Many combinations are currently under experimentation by both AV industry players and academic researchers.

VP is primarily associated with *LED volumes* among AV professionals and academic researchers. However, as described, establishing a VP process using an LED volume may be expensive and out of reach for AV producers with different financial resources.

1.2 Virtual Production for All: Shifting the Focus to Small and Medium Productions

The most emblematic AV productions that have employed VP in recent years have been characterized by the vast amount of economic and human resources allocated. While exploring what may be possible through VP, one of the main challenges is the correct functioning and interoperability of hardware and software technologies. Consequently, complex workflows often result, as does the need to employ expensive gear and hire highly skilled professionals from other fields, such as engineers and computer scientists. AV producers who can afford to employ such a workforce as well as the time and technical resources are few and do not represent the whole ecosystem of the AV industry.

While the VP process is used for advancing high-end productions, little consideration has been bestowed upon small and medium productions (SMPs), which, by definition, have limited economic and human resources.

Shifting attention to explore the extent to which SMPs can employ VP is important, considering their vast presence in the AV industry. However, identifying more precisely the number of people involved in SMPs and the economic volume they represent within the AV industry is an arduous task because of its fragmented nature. Many researchers (La Torre, 2014; IDEA Consult 2013; Renée, 2015; Ibrus & Rohn, 2019) have retrieved data about specific AV sectors, especially feature films. These scholars have considered only specific countries or regions, which only partially describe the actual size of the market represented by SMPs and the number of professionals employed.

Quantifying the accurate presence of SMPs across the AV industry is beyond the scope of this study. However, this researcher discovered the lack of a systematic study that explores through a co-design approach the framework and employment of VP processes for filmmakers operating in a context with limited resources.

1.3 Research Aims

The overall aim that underscores this research is to present an exploration of VP's applications and potential in AV productions which have only limited resources. This area is a knowledge gap in the literature and industry applications. The work reports the specific VP-related needs of AV professionals who work on SMPs. Additionally, this researcher aimed to co-design, iterate, develop, and evaluate a new VP process of alternative workflows that employ immersive technologies.

1.4 Research Questions

The main research question addressed in this study is as follows:

RQ1. To what extent can VP combined with immersive technologies be employed by AV professionals in SMPs?

This main question leads to the following sub-questions:

RQ1.1. What research already exists on this topic, and to what extent is VP already developed and employed by industry players in their making process?

The intent of the first sub-question is to build an understanding of previous research and experimentation. Additionally, since the private sector has already dedicated substantial resources to advancing VP, it is crucial to include the perspective of industry players on this emerging field.

RQ1.2. What are the challenges that SMPs face due to limited resources?

The second sub-question was designed to explore the daily and practical difficulties professionals address when working with limited economic and human resources.

RQ1.3 What alternative VP process can be co-designed and developed to enable SMPs' adoption of VP?

This aim behind this third sub-question is to enable participants to contribute to the co-design, development, testing, and evaluation of an alternative VP process combined with immersive technologies.

1.5 Research Objectives

A. To review the academic literature and pre-existing processes employed by industry players regarding VP.

B. To investigate the challenges faced by AV professionals who work on SMPs.

C. To co-design with participants alternative VP processes combined with immersive technologies.

D. To translate the outcomes of Studies 1-3 into a practical prototype (study 4) to be tested and evaluated by AV professionals.

E. To discuss and self-reflect the implications of such a prototype in Study 5 and provide a set of recommendations upon which future work may advance research on the VP process applied to SMPs.

1.6 The StoryFutures Project

This PhD project is part of StoryFutures: Gateway Cluster Partnership for Audiovisual Digital Creativity (AH/S002758/1), a creative industries research and development programme funded by the Arts and Humanities Research Council (AHRC). The overall aim that underscores the programme is to define and develop the next generation of storytelling approaches by exploring the opportunities offered by the latest developments in the immersive technologies of VR, AR, and mixed reality (MR). The StoryFutures consortium includes more than 35 academic and creative industries organizations based west of London. This work is complementary to the efforts established by other academics who participate in StoryFutures project when exploring an emerging field such as VP. These academics investigate VP applied to high-budget AV projects, while this researcher examined VP applied to AV productions that have limited resources, such as SMPs.

1.7 Structure of the Thesis

This thesis is divided into nine chapters; the present chapter offers an overview of the thesis' theme, aims, and contributions.

In Chapter 2 is an overview of the definition of VP, its employment in both industry and academia, and its relation to how immersive technologies have been adopted and employed both in academia and the AV industry.

Chapter 3 describes the design methodology chosen for this research as well as the reasons for its selection. This part also presents the design methods considered most appropriate to collect qualitative and quantitative data.

Chapter 4 (exploratory study), Chapter 5 (idea co-generation), Chapter 6 (idea filtering and iteration), and Chapter 7 (prototype design and evaluation) contain consecutive studies that enabled the researcher to collect data and gather insights. These four works are interdependent. Findings that emerged from the exploratory interviews were crucial to structuring and defining the scope of the co-design workshops, which in turn were fundamental to co-design innovative ideas, which were filtered, further iterated, and finally developed into a working prototype for stakeholders' evaluation.

These progressive data collection and analysis stages guided the researcher to generate valuable output: an alternative workflow for pre-production, which participants evaluated as ready to be employed in a real-world scenario for further assessment.
Chapter 8 discusses the findings of the research, while Chapter 9 explains the main contributions of this research and establishes directions for future work.

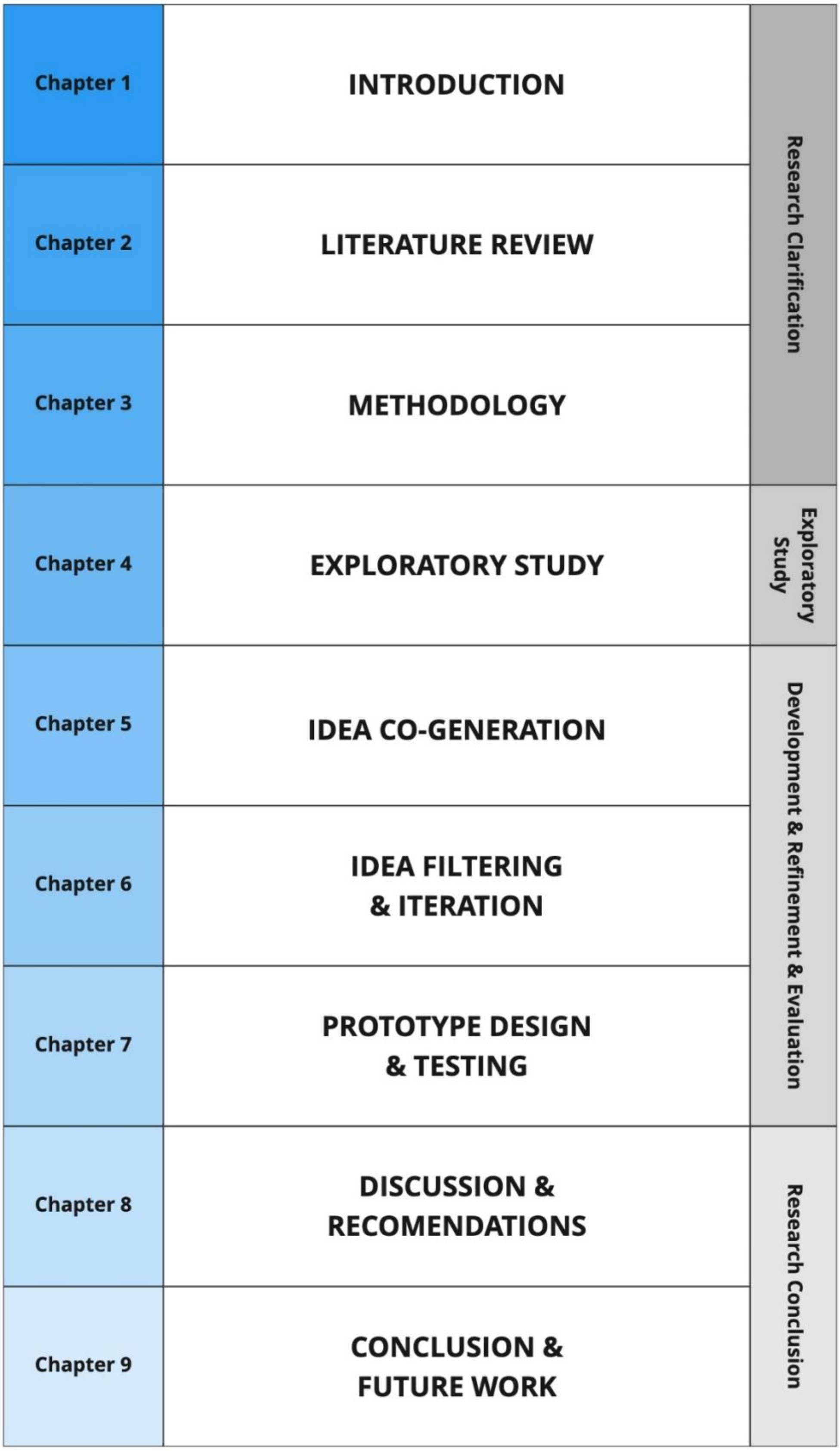

Figure 1.1 Outline of the Thesis

Chapter 2

LITERATURE REVIEW

2. Literature Review

2.1 Introduction

This section provides a clarification and analysis of both previous academic studies and pre-existing industry processes regarding VP, an emerging process in the AV field. From the review of the literature, the researcher ascertained that the VP process encompasses different applications, taking advantage of a wide range of technologies, especially the use of real-time game engines commonly employed to develop video games.

This VP process assist the pre-production, production, and post-production processes for stakeholders' AV projects. Because of the many ways in which VP can be employed, Sebastian Sylwan, former chief technology officer at Weta Digital and member of the VES founding board, states that *'there is no checklist of things you can go through and say, if you have all of these, this is virtual production'* (Thacker, 2012). He further explains that the industry is still in the process of learning and exploring VP. Consequently, the researcher considered it appropriate to present an organized explanation and review to the reader. This approach identifies and differentiates how VP has been employed in different contexts and production sizes. Discovering and reviewing the state of VP in the academic literature and existing industry applications were of primary importance to identify the current knowledge gap.

2.1.1 Definition of Virtual Production

As Dunlop states (2014, p. 304), the VP process "*is becoming the norm for any movie requiring large scale visual effects*" (VFX). The term *VP* started to be used more frequently after the production of *Avatar* (Cameron, 2009). In recent years, an increasing number of iconic high-budget films, such as *The Jungle Book* (Favreau, 2016), *Ready Player One* (Spielberg, 2018), and *The Lion King* (Favreau, 2019), as well as TV series, such as *The Mandalorian* (Favreau et al., 2019) and *Westworld (Abrams et al.,* 2016), proved the potential of the most advanced VP techniques. These productions, which are set in imaginary worlds and therefore require heavy use of VFX achieved through CGs, found in VP a useful tool.

Different industry players and academic researchers define VP differently; however, many authors agree that it is a process to pre-visualise, produce, and post-produce an AV project by taking advantage of real-time technologies and shifting the established workflow from linear to non-linear where possible to iterate creative decisions quickly.

ACADEMIA	INDUSTRY
'The virtual production process enables directors to view live footage of the actors on set integrated with placeholder versions of the CG elements of a shot'. **Dunlop (2014)**	'VP combines virtual and augmented reality with CGI and game-engine technologies to enable production crews to see their scenes unfold as they are composed and captured on set'. **MPC in Kadner (2019)**
'The concept of virtual production foresees to combine key aspects of media production in a real-time, or close to real-time, environment where creative decisions can be taken in direct consultation with other members of the team'. **Helzle, Grau, and Knop (2015)**	'Virtual production is where the physical and digital worlds meet'. **Weta Digital in Kadner (2019)**
'VP combines virtual and augmented reality with computer-generated imagery. All this is made possible by real-time game-engine technology'. **Bennett et al. (2021)**	'As VFX have grown to be a greater part of movies and television today, there is a growing divide between what the filmmakers can see through the camera on the live-action set, and what they have to imagine will be added digitally many months later. Virtual Production attempts to unite those two worlds in real-time'. **Magnopus in Rogers (2020)**

Based on these definitions, VP is not a technology itself but rather an alternative to the established production process currently employed in AV projects. VP has at its core real-time game engines to which several other software and hardware technologies can be added and combined to produce an AV result.

2.1.2 Benefits of Virtual Production

The VP process has the potential to bring economic and creative benefits for stakeholders involved in the creation of an AV production. Adopting VP for scenes with VFX allows directors and other professionals involved on set to acquire real-time feedback on VFX integration inside the scene. Hence, the director can see on the monitor a closer representation of the final appearance of the scene and quickly iterate the decision-making process, thus saving time and, therefore, money. Directors are not the only figures to benefit from VP. Actors and actresses can feel more immersed in new filming facilities designed explicitly for VP, which are characterized by an array of LED panels. This technique displays the scene background on the array, giving players a better idea of the setting than large, empty spaces surrounded by a monochromatic green screen.

Figure 2.1 Green Screen Studio (top) and Stagecraft LED Volume (bottom)

Furthermore, integrating the VP process with immersive technologies such as VR and AR allows industry players to push the boundaries even further. Wearing a VR headset, the director could be immersed and navigate freely in the virtual scene as if the crew were in a real location filming a live-action scene, a process with which shooting teams are familiar.

Consequently, the director can ask the crew to make changes in the camera position, lighting, set design, and so on to better and more quickly recreate the vision, as they can shoot multiple takes with ease.

Increasingly, productions adopting VP are aiming to complete the so-called *final pixel* on set, meaning that further post-production processes, such as the addition of VFX elements, is not needed and being able to obtain the final look of the image at the end of the shooting day (Pohl, 2019).

Professionals in many other roles can benefit from VP. Cinematographers can try different camera movements, whether those be handheld or movements that simulate cranes or dolly systems. They can change the scene lighting, simulating the hard light of the sun at noon or replicating the sunset without time constraints, which would be a factor if they were shooting during the so-called golden hour on a live-action set.

The advantage of VP for scenographers is that they can immerse themselves in the virtual world through a headset and thus perceive the 3D volume of the scene, which allows them to make creative choices on where to place props and interiors and then pitch their ideas to the director.

Even if they are accustomed to staying on the other side of the camera, actors and actresesse can also significantly benefit from the VP process; as producer Brian Binder explains:

> *'Let's say you're doing a show that takes place primarily on a bus, and instead of sitting there for day after day after day staring at the green screen through the windows, and the entire crew and all the cast being so disconnected from what's going on and what this thing is going to look like at the end of the day, we're actually able to bring that experience to everybody live on set'* (Pohl, 2019).

A further explanation of the benefits of VP for the aforementioned roles and for other people involved in AV production is explained and discussed in the following sections.

2.2 Sources

This literature review presents materials from various sources, including online audio and video materials, social media posts from film industry insiders, blogs, software-specific documentation as well as guides, and established sources such as academic papers and articles.

Academic Digital Libraries

Literature on VP was sought using the following keywords: *virtual production, virtual reality cinematography, digital twin, location, capture location, film photogrammetry scan, virtual location scouting,* and *virtual filmmaking*.

Scopus and Google Scholar search engines were used to locate books, peer-reviewed journal papers, conference articles, and PhD theses; other digital libraries, such as ‘Association for Computing Machinery’ (ACM) and ‘Institute of Electrical and Electronics Engineers’ (IEEE), were also consulted.

Online Videos

Numerous conferences focus on CG and game development, such as ‘Special Interest Group on Computer Graphics and Interactive Techniques’ (SIGGRAPH), ‘Film & Media Exchange’ (FMX), Game Developers Conference (GDC), and Digital Dragons, offering videos from industry leaders sharing their experiences on the VP processes they developed and adopted for their projects. These resources allow a deeper examination of the strengths and features of current VP processes.

Similarly, both Unreal Engine and Unity, the industry's two most popular software programs for VP, generated a large number of case study videos on specific projects to promote their real-time technologies (Unreal Engine, 2019a, 2019b) as well as articles (Blondin, 2019) and roundtables (Unreal Engine, 2018) where they interview their stakeholders and explain in detail the advantages of using their real-time engines.

Facebook Groups

There are numerous Facebook groups regarding VP and other topics relevant to this research, such as ‘Unreal Engine: Virtual Production’, ‘Virtual Production’, ‘Virtual Production Group’, ‘Remote Mocap’, ‘Virtual Reality’, ‘Volumetric Imaging’, ‘Virtual and Augmented Reality’. They are composed of people who are passionate about these topics and international professionals working in the field who often share their works and design processes, explain their approaches, and discuss further applications with other group members. Facebook groups are a valuable resource to acquire insights on general trends in VP, read feedback and opinions on current design processes, and identify potential experts to interview.

Conferences Websites

Generally, websites of renowned conferences and events for professionals in CG and VFX offer materials such as video recordings, interviews with professionals, and scientific papers.

Among the conferences which have presented VP works in the past are SIGGRAPH, IEEE, Real Time Conference (RTC), Laval Virtual, GDC, and FMX.

Podcasts

Many times, podcasts are presented by a host who invites relevant figures in a specific field to discuss a topic in depth. Some podcasts, such as *Behind the Screen*, which is hosted by Carolyn Giardina, bring multiple leading professionals to the same table. Consequently, the discussion produces not only the vision of a single person but also a broader perspective on current trends and challenges in VP. Accordingly, the podcast *Visual Disruptor*, hosted by Mike Seymour and promoted by Unreal Engine, is highly relevant, as many VP topics are discussed with experts.

Documentation and Guides

Another source of important information related to these high-end production processes is the documentation provided by real-time technology companies such as Epic Games with their *The Virtual Production Field Guide* (Kadner, 2019), which explains in detail the advantages of using *Unreal Engine* for VP.

As discussed in the following pages, Technicolor employs a similar strategy by providing an overview of its VP process, Genesis (2018), which was born in strict collaboration with another real-time technology company, Unity.

2.3 Review

Because the end goal of this research is to identify how immersive technologies can aid AV professionals in adopting the VP process, the literature review is organized to explain and discuss how VP has been impactful for stakeholders.
Therefore, the literature review emphasises use cases rather than detailing the technology and technical innovations developed to date.
However, some exceptions occur to facilitate the reader's understanding of how specific technologies work and why they can be helpful when needed.

2.3.1 Premise

The researcher located few studies while searching for relevant publications on VP and immersive technologies in media production overall. In other branches of knowledge, immersive technologies have been extensively researched in recent decades in fields including medicine (Satava, 1995), human factors (Furness, 1983), psychology (Gaggioli, 2001), manufacturing (Jayaram, Connacher, & Lyons, 1997), and education (Helsel, 1992), among others.
It is argued that the reason for this different quantity of knowledge may be due to the different scopes and requirements of the media production sector.
If functionality is favoured in some disciplines over a realistic representation of the virtual reality environment (VRE), the same cannot be said for a sector whose scope is to make AV products.
It is possible that professionals in other disciplines were more inclined to accept the visual quality trade-off offered by immersive technologies of past decades. For example, an immersive simulation created to familiarize technical operators with machinery controls may not require a faithful visual representation of the real machinery and VRE. A minimal but functional interface and representation of the virtual objects and environment is sufficient to train operators and evaluate their performances.
Therefore, a possible reason for the disproportionate number of studies that focus on the employment of immersive technologies in the AV sector can be explained by the overall visual representation of the VRE at the time, which is a trade-off that did not reach industry standards and expectations.

Based on the researcher's professional experience in the AV industry, filmmakers usually have a keen eye for images. They are attentive and capable of spotting artefacts and inconsistencies while observing an image.
Researchers conducting studies in other fields, such as those mentioned previously, do not seek to produce images through the employment of immersive technologies. The visual aspect is subordinate to other scopes. It is a tool to fulfil other tasks, so they can afford to have a simplified representation of the VRE as long as it suits their needs.

Additionally, the search was extended to the media studies discipline to better understand other outputs presented in the current literature. The stance taken by media studies authors (Aylett & Louchart, 2005; Ryan, 2009; Bodini, 2017) has been shifting towards exploring *whether* and *how* these immersive technologies could be considered new media that are capable of telling stories and conveying meaning, similar to film, theatre, and arts. As expected, these studies have explored VR and AR as new media rather than new tools to integrate into AV production processes.

Only in recent years has there been a growing interest among researchers to explore and experiment with these AV technologies to aid AV professionals (Kadner, 2019). It may be due to the technical advancements in immersive technologies, such as VR, AR, and real-time game engines (Unreal Engine, Unity), in image quality, affordability, and accessibility. Regarding VR devices, it is worth mentioning the breakthrough represented by the headset *Oculus DK1,* which was invented by Palmer Luckey in 2012 and has significantly contributed to a new approach for making VR headsets and enhancing immersive experiences (Blake, 2019).

2.3.2 Academia

An AV product is the result of activities performed by an AV production team, ranging from organizational and legal tasks to creative or technical assignments. However, among the existing academic works, most researchers have focussed their efforts on helping filmmakers in specific activities, such as pre-visualizing VFX elements for a scene (de Goussencourt, Dellac, & Bertolino, 2015).

This need to understand how the final scene will appear started with the invention of cinema and fictional AV productions. Disney produces animated movies by dedicating effort to pre-visualizing the final images and animations using storyboards. This approach is also valid in live-action movies where directors of the calibre of Alfred Hitchcock or Orson Welles rely on detailed planning before shooting begins (Okun & Zwerman, 2020). VFX elements appear in almost every modern movie production (Zimmer, Drochtert, & Geiger et al., 2017) for both creative and economic reasons; hence, the main creative challenge is real-time pre-visualization that combines both real and virtual elements in the shot.
This faithful representation shows cinematographers and directors an image as close as possible to the final image after post-production processes.
Additionally, from an economic perspective, deciding to add VFX elements can be costly, so carefully planning each shot is crucial.

Researchers at the Filmakademie Baden designed the ‘Virtual Production Editing Tool’ (*VPET)*, an AR tool developed for consumer technologies such as iPad and iPhone, to enable independent filmmakers to perform pre-visualization on set in a relatively affordable and accessible way (Spielmann et al., 2018).
One of the main features of a tool set such as VPET allows the so-called *set extension* of part of the film set. In this way, production designers can visualize an augmented version of the pre-existing scenography for the final scene on their tablet or smartphone and communicate their vision to people in other departments.
Furthermore, Zimmer, Drochter, and Geiger et al. (2017) developed an accessible and easy-to-use AR tool set to enable an independent director to plan and pre-visualize a film scene. Once in a location-specific context, this AR tool set allows the user to place and manipulate virtual elements (objects, characters, etc.) in real-world environments (streets, football fields, etc.) planned for the movie's filming location. Then, they can pre-visualise elements that are not available during pre-production but will be used during the shooting phase.

Bennet and Carter (2014) adopt a practice-led approach to explore how VP could be used by filmmakers performing motion capture for short animated films. The feedback received from the participants was positive overall and highlighted aspects to improve, such as data management for the large files generated by motion capture, the need for virtual characters designed for motion capture, and the need to work with professional performers.

Additionally, Bouvile, Gouranton, and Arnaldi (2016) investigate how VR can improve the performances of actors and actresses who must manage the impediments imposed by VFX on set.

> *'Not being able to see what is around them, they cannot perceive occlusions nor avoid obstacles. The performance becomes even more difficult when they are asked to play opposite virtual partners. First, they must avoid missing eye contact when conversing with a character who is not actually there. Second, they must give the illusion of maintaining a consistent eye-line while following a moving virtual character or a virtual object'* (Bouvilee, Gouranton, and Arnaldi, 2016).

The result of their experimental study shows how VR-trained actors and actresses perform as well as their classically trained peers during shooting; the authors foresee a future in which a lighter and more affordable technical setup may be available to improve the quality of work and acting performances.

Kuchelmeister (2020) compares the production time required to shoot a live-action short film with one generated using real-time rendering. He finds some advantages in the freedom to change the scene in the virtual environment at any point, although he recognizes the significant resources required to undertake this kind of VP and the expertise needed in various domains. In fact, before producing the short film in the real-time game engine, it was necessary for Kuchelmeister to research how to integrate the virtual set created in Unity, develop the virtual character to be animated, record the motion capture performance, and clean the same motion capture animation. He concludes by anticipating the development of more intuitive tools that will make VP more accessible.

Instead of working on a more versatile tool set, others researchers (Lin et al., 2018; Chiu, Huang, & Ouhyoung, 2017; Muender, Fröhlich, & Malaka, 2018) have studied specifically how VR filmmakers could use real-time game engines to experiment with different cinematography solutions, while virtually exploring different lighting scenarios and camera movements.
This kind of system would benefit cinematographers during the pre-visualization phase and allow aspiring cinematographers to learn more about cinematography techniques and technicalities.

The potential to remotely collaborate in VR when planning a scene has been proven successful and is perceived as useful in a real-life pre-production scenario by a participant in Ardal et al.'s (2019) experiment.
Allowing participants to collaborate in the same virtual space, having the same visual context of the environment, and acknowledging the presence of other collaborators through a virtual avatar combined with the potential to communicate verbally have been evaluated by the same participants involved by Ardal et al. as similar to real-world situations.

Among these different studies, common themes emerge from their conclusion chapters: Constant experimentation with more advanced and recent technologies is needed, and evaluating new methods, processes, frameworks, and tools must be conducted in real-world scenarios that directly involve potential stakeholders.
Although VP targets different roles (directors, cinematographers, actors &actresses, and production designers), the technology has been adopted during pre-production phases for pre-visualizing scenes.

2.3.3 Industry

Shifting the focus to relevant VP processes and techniques developed by the industry players, it is first necessary to distinguish between high-end productions that have at their disposal immense financial resources (hundreds of millions of dollars) and those with far less means and capabilities, such as SMPs.

Another important note is the wide variety of AV products that can be generated depending on the scope of an AV production.

In his book *The Economics of the Audiovisual Industry: Financing TV, Film and Web*, La Torre (2014) analyses the main economic and financial features of the AV industry, explaining that the industry is determined by the sum of all AV sectors, which differs in the nature of the product generated, production processes, and distribution dynamics.

The majority of relevant AV productions that employ VP are feature films or TV series. However, the numbers of other AV sectors are many: commercials, documentaries, music videos, and video art, among others. Explaining to the reader how each differs, sometimes slightly and sometimes significantly, would require additional effort and may distract from the main aim of this research.

Nevertheless, it is crucial to underscore, to offer a better idea of its considerable impact, that not only can VP be adopted for movie making but the core concepts of such new processes can also be employed efficaciously in many other AV sectors. This ever-evolving context is supported by La Torre's (2014) conclusion that the taxonomy presented in his book *‘should also be analyzed considering its ‘work in progress’ nature’* since the difference between AV products ‘*is less relevant than it previously was*’ (2014).

2.3.3.1 High-End Productions

One of the most expensive movies ever made, *Avatar* (Cameron, 2009), directed by James Cameron, is considered the birthplace of VP. This film sparked interest among significant industry players to further develop the VP process for their high-end productions.

Every AV production has specific challenges. In the most ambitious productions, filmmakers push the boundaries of AV production to achieve never-before-seen sequences. Hence, they develop specific film sets, technologies, or custom workflows. One of the many examples is *Gravity* (2013), wherein director Alfonso Cuaron, cinematographer Emanuel Lubezki, and VFX supervisor Tim Webber combined their efforts to achieve their notable zero-gravity shot. They built a one-of-a-kind contraption consisting of an LED-panel stage, a robotic arm, an Arri Alexa camera and '*a row of extremely talented technicians with their laptops*' (Seymour, 2013).

One can see from this example that the specific need drove most of the process creation required for each production, and this is true for the most recent VP processes.

To recreate a familiar and filmmaker-friendly setup for *Rogue One: A Star Wars Story* (2016), director Gareth Edwards and Industrial Light & Magic (ILM) R&D team developed an effective custom process.

As Jutan and Ellis (2017) state:

> '*Gareth Edwards is a hands-on filmmaker, often operating the ARRI Alexa camera on set. He does not like to be constrained to the initial sequence planning, opting instead to try alternative angles to find the most interesting shot. Our system provided this freedom within the pure digital environments of Rogue One*'.

Jutan and Ellis suggest that placing live-action directors in live-action environments can significantly enable them to shape their vision without worrying about the technology involved, provided that the way of shooting is similar to one with which they are accustomed.

Jutan and Ellis decided to employ *off-the-shelf* devices for the VP setup, including the HTC Vive, iPad Mini, Gamevice controller, and a motion capture (mocap) tracker. However, despite their affordable and accessible hardware setup, their greatest achievement is their custom ILMvCAM application which communicates in real time with their Zeno application framework, which was developed in house in 1997 and has been continually updated since then by a highly skilled team.

In making *The Mandalorian* (Favreau et al., 2019), ILM specifically built *Stagecraft*, a facility that has a curved video wall positioned behind the actors and actresses. The wall is 20 feet high, 180 feet wide, and comprises 1,326 LED panels. The images on the LED wall are generated in CG and manipulated in real time using Unreal Engine 4.

The use of real-time technology allows the director to see the CG environment change on the LED wall according to the camera movements.

One of the benefits of employing this process is the convincing lighting from the LED wall that bounces off actors and actresses and real props on set. The result is that reflections and tonalities on metallic surfaces as well as on actors and actresses skin and costumes are more coherent with the virtual environment, which is not achievable using green screen techniques. The LED panels' pixel pitch is an essential factor influencing the final picture: The shorter the pixel pitch, the clearer the image on the LED panel and the less risk of encountering a technical issue such as a *moiré* pattern, which would compromise the image by creating strange-looking wavy patterns.
According to Seymour's (2020a, 2020b) article on *fxguide*, the *Stagecraft* screens have a 2.84 mm pixel pitch. A best practice to avoid the *moiré pattern* is to use cameras and lenses capable of recreating a certain degree of field depth to defocus the background. Longer lenses and lower iris aperture (T-stops) narrow the field depth and, therefore, significantly defocus both background and foreground. ILM primarily used lenses larger than 50 mm and generally exposed the shots between 2.5 and 3.5 T-stops. Over 50% of the first season of *The Mandalorian* was filmed with the VP process.

Similar to ILM's *Zeno* tool, Technicolor's MPC studio developed a VP process named *Genesis* and evolved its custom VFX pipeline, as Tovell and Williams (2018) explain. The main goal with *Genesis* is 'to provide the foundations and tools to produce a higher quality result from the pre-viz stage, and therefore give the rest of the VFX process a huge head start'.
This approach is possible because of a strict collaboration with real-time engine company Unity, which enabled the substantial customization of the system's behaviour in three fundamental aspects: (a) the creation of a platform for remote collaboration with different devices; (b) the creation of a virtual camera capable of integration with a wide variety of standard filmmaking gear, such as a dolly and wheels as heads, for example; and (c) the generation of high-quality film output which can be re-used by the VFX department as a starting point for their work.
Once again, a key ingredient in this process was that Technicolor's Genesis could rely on pre-existing in-house processes, such as *Tessa*, which is a solid and mature

asset management system that organizes and stores meta-data produced on set during the VP process (such as camera position, props position, snapshots, etc.) and enables 3D artists to fine-tune a scene according to the meta-datapreviously generated using Autodesk's Maya 3D software.

Additionally fundamental was the adoption of the universal scene description (USD) format, which was developed by Pixar to create (a) a standard format for 3D data (modelling, shading, animation, lighting, effects, and rendering) that is readable by many software programs as well as (b) scalable (allowing high or low-poly representation) and (c) suitable for teamwork since it enables non-destructive collaborative editing in which previous edits made by others can be retrieved.

As with the JSON and .fbx formats, the USD format effectively transfers data back and forth from Maya and Unity, allowing a quick and continuous iteration of the virtual set.

Similar to Edwards' *Rogue One* experience, veteran cinematographer Caleb Dechanel, while shooting *The Lion King,* offered a similar opinion on adopting this process, stating:

> *'If somebody had asked me, you know, five years ago – would you be working on a film at the cutting edge of film technology? – I would say – Are you crazy? – but I actually find it much more agreeable than I thought from the point of view that is very similar to what I'm used to doing. I mean[,] I find myself making the same kind of[,] you know[,] decisions in the same way. The same eye towards telling a story'* (Movie Trailer, 2019).

Employing *Genesis* for an AV production such as *The Lion King* – the story is set in the African savannah and the entirety of the environment was recreated via CG – allowed director Jon Favreau and his collaborators to conduct *virtual scouting* to decide the shooting location, as explained by Moving Picture Company's (MPC) VFX supervisor Rob Legato:

> *'What it did (Virtual Production) was to allow us to have five or six people in VR at any one time location scouting, talking about where the animals are going to start and stop, all the blocking, the actor blocking of that and figure out what the action is and what's the best vantage point to shoot it from. And we were able to hop*

from location to location, literally miles and miles of fabricated (CG) Africa' (Giardina, 2019).

The interest in developing processes for virtual scouting has also been expressed by other players in the industry, including The Third Floor, a studio that specialises in pre-visualizing scenes for high-budget movies that contain a vast amount of VFX. Their immersive application, *Pathfinder*, was initially developed for the TV show *Game of Thrones* and further developed to create an intuitive and filmmaker-centred tool that enables virtual scouting of real-world locations (*virtual location scouting*) and is digitized with 3D capturing techniques to recreate a digital twin (DT) of that location.

The company also adopted '*virtual set scouting* when the scene was set in an imaginary city like the one [in] 'King's *Landing*' (The Third Floor Inc., 2020). They virtually explored the city, which had previously been digitally reconstructed by the virtual art department using 3D modelling software, which allowed users to visit different areas of the set, including interiors, backlots, or sets built in real-world locations. When wearing the VR headset, directors could start *blocking* actors and actresses, a phase in which they decide where players will stay or move in a scene. The blocking phase is also related to the lighting design of the scene. Using a virtual viewfinder, cinematographers can test different camera angles, positions, or lenses and take a picture to review later. Production designers can freely manipulate construction and objects, experimenting with different stylistic choices.

In addition to feature-length blockbuster movies, professionals in a number of other AV sectors are employing VP to create projects for advertising (Seymour, 2022), music videos (Katy Perry, 2020), or broadcast (Webster, 2020; Vizrt, 2022).
An excellent example of the VP process applied to the broadcast sector is the *2020 League of Legends Worlds Championship* (Webster, 2020), which was broadcast employing the VP process. This enabled the blending of the physical and digital worlds in real time, virtually extending the physical set of common broadcasting studios (Figure 2.2) and adding 2D or 3D graphics and animation.

Figure 2.2 Stage Appearance to Players (left) and Viewers (right)

This alternative approach to broadcasting produces changes both for AV professionals (by requiring them to operate a new workflow) and for the audience (who now have a new format with which engage).

2.3.3.2 Small and Medium Productions

Academics and professionals do not have a common agreement on the meaning of the term *independent productions*.

As stated by film critic and professor Emanuel Levy, ‘*Over the years the definition [of independent] has blurred*’, increasing unclarity and confusion that exist over the definition of 'independent’ (Levy, 1999). In his book *Cinema of Outsiders: The Rise of American Independent Film*, Levy reports different interpretations of the definition of *independent* offered by other authors and film directors; two criteria are common in their statements: First, freedom is provided to directors to express their vision without compromise or constraint imposed by a committee represented by major studios.

The second commonality is budget size. The Sundance Institute, a nonprofit organization born to support and promote independent filmmakers, uses the term *indie* to identify productions with budgets below $1 million (Renée, 2014). Similarly, the nonprofit organization Film Independent created the Spirit Awards to recognize notable independent productions; one award category is named after filmmaker John Cassavetes and highlights films with budgets of $1 million or less (this amount was formerly $500,000; Spirit Awards, 2022).

Nevertheless, AV productions are not limited to feature films. They can range from commercials to art installations, documentaries to music videos, and TV broadcasting to online vlogs. Each AV sector features different characteristics in business model and budget size. For instance, $1 million can label a feature film as low-budget but can also be an exorbitant budget for a music video.
This relative labelling further complicates the definition of independent AV productions.
Despite limiting their investigation to a European level only, IDEA Consult (2013) reports that the majority (51%) of AV firms that responded to their survey fall in the category of less than five employees, which further reinforces the idea that the AV industry is *'is characterized by firms with a weak organizational structure, small dimensions, small number of employees'* (La Torre, 2014).
To improve the findings in this PhD thesis, the researcher considered it appropriate to outline an arbitrary definition of the AV productions that represent the population in this research. Inspired by the European Union (European Commission, 2022) and UK government's (FCDO, 2022) categorization of small and medium enterprises (SMEs), this research uses the term s*mall and medium productions* to identify those AV productions with a maximum budget of $100,000 for medium productions and $20,000 for small productions.

For the independent science fiction movie *I Am Mother* (Last Pixel, 2019), independent Australian studio *Last Pixel* developed a VR application to storyboard the film, which is set within a futuristic space similar to a spaceship. Only 10% of the movie was set outside of the spaceship. After completing most of the storyboarding in VR, director Grant Sputore states, '*I've gotten so used to storyboarding in this way (VR) [that] I wasn't exactly about to go back to pencil sketches on the back of a napkin'.*
Similar to *Pathfinder*, Last Pixel's VR application offers a series of tool sets, such as a virtual viewfinder, and the freedom to manipulate the virtual environment.

Filmmaker and software engineer Matt Workman investigated and developed various VP processes that are autonomously accessible and usable for independent

filmmakers. In 2018, Workman developed *Cinetracer* with Epic's game engine Unreal 4*,* and he continually iterates this tool set. Cinetracer is sold on the video game platform Steam, which, through its gamer-friendly user experience (UX) and user interface (UI), the game has recently attracted significant interest from the filmmaking community, leading Workman to showcase the application at conferences such as SIGGRAPH (Unreal Engine, 2019c) and FMX (Cinematography Database, 2019).
Cinetracer is a sandbox (a game genre where there is any specific goal or linear story to follow, but which instead provides to the player a great degree of freedom and creativity) single-player experience that allows the user to photograph and light realistic environments with real-world film equipment. It enables filmmakers to virtually pre-visualize (on a 2D computer monitor) the scene they intend to shoot. Consequently, they can be more prepared and have the opportunity to explore different creative ideas. In Cinetracer, users can set the scene by placing 3D objects (set design), lights and cameras (cinematography), or even virtual characters (acting) by using elements within Cinetracer's library or importing their own assets. In one of his first experiments (Cinematography Database, 2018), Workman captured an interior environment using Leica's BLK360, a high-end *light detection and ranging* (LiDAR) scanner that combines 360 photographs and laser data to generate a point cloud (each point has unique XYZ coordinates) of the interior that has been scanned. Finally, Workman started using Cine Design (a Cinema4D plugin on which Cinetracer is based) to add virtual elements such as props, lights, and characters to pre-visualize the scene that would be shot in a specific real-world location. Later, the point cloud data are elaborated on an iPad Pro through the Autodesk ReCap Pro application, and they are converted into a 3D mesh by the 3D modelling software Cinema4D. These processes are performed in a 2D modality by interacting with the software on an iPad touchscreen or by using a mouse and a keyboard connected to a desktop PC.

2.4 Conclusion of the Literature Review

This descriptive approach to the current literature that is relevant to VP demonstrates the infancy of the field. Although new opportunities enabled by this production process have already arisen, many aspects require further investigation.

Overall, the industry is paving the way in developing and experimenting with practical VP innovations. If this new production process leads towards time and cost savings, then these high-end productions, consider a strategically good investment allocating significant resources to their internal R&D departments to advance increasingly efficient and effective VP processes,

Academics are motivated to investigate this field, and this PhD work is an example of such interest. Some are dedicating their efforts to mapping and coding industry trends among high-end productions. However, others argue that the picture they are trying to capture will miss crucial pieces. VP processes developed by these high-end production companies represent a valuable asset for their owners. They are the result of years of R&D investments, and therefore, their owners are interested in keeping their knowledge and expertise private and as one of the participants interviwed states: *‘If you are not working within Netflix’s virtual production department, you will always be late’* (PI04, leading expert).
In this chapter, some papers published by industry players were used as examples, but their work may not be explained in detail in these papers for this reason.

An alternative to rsearch VP, may be integrating researchers in these high-end production companies and working closely with industry veterans to improve VP processes. However, publishing new knowledge may generate conflicts with these private companies’ strategies to maintain the confidentiality of their breakthroughs. Additionally, it is important to remember that the aforementioned studios, such as MPC or ILM, developed custom VP processes – *Genesis* and *Zeno,* respectively – to fit and answer their specific needs. Therefore, the research efforts dedicated to improving those VP processes are not likely to be extended and generalized to other AV production companies.

Unreal and Unity are focussing their efforts on providing tools to enable more AV professionals to use VP, however, as identified by Bennett et al. (2021) and Jobin (2022), today few people have sufficient knowledge to set up a VP process.

Table 1 High-End VP Virtual Production Characteristics

ADVANTAGES	DISADVANTAGES
A custom VP process is designed to be integrated with one's current and specific pipeline. See ILM's Zeno (Jutan & Ellis, 2017) or Technicolor's *Genesis* (Tovell & Williams, 2018).	These VP processes are not generalizable to other AV productions since communication between proprietary systems is challenging (Kavakli & Cremona, 2022).
High-quality assets are integrated into the virtual scene. While shooting inside LED volumes, such detailed imagery enables the acquisition of the final pixel on set. (Pohl, 2019).	Establishing high-end VP processes requires many highly skilled and multidisciplinary professionals (Bennett et al., 2021).
Custom VP processes remain confidential and may represent an advantage against competitors.	Custom VP processes cannot be improved by those outside the company.
	Implementing high-end VP processes demands significant technical resources (Jobin, 2022)

Despite partial access to VP's internal structures, paying attention and observing the pre-existing high-end VP processes enabled the researcher to determine the need for further research in this field.

<u>1. Exploration of additional benefits brought by VP is required.</u> Existing contributions by other authors have illustrated the potential of pre-visualizing VFX in camera (ICVFX) while shooting (de Goussencourt, Dellac, & Bertolino, 2015; Zimmer et al.,

2017; Spielmann et al., 2018). This real-time visualization favours a quick assessment of the shot, which accelerates iteration and decision-making. However, many shots or entire AV productions do not require VFX to be added. Additionally, many experts refer to VP as an umbrella, but there is no clear definition of VP's beginning or end. Therefore, further exploration is required to discover what other valuable applications of VP may offer AV professionals.

1.1 Virtual is not limited to LED volumes. Many experts agree that *VP* is a broad term that includes many technologies; hence, it is limiting to think about VP as a process that occurs only inside LED volume facilities and only offers ICVFX.
This association between LED volumes and VP has likely been caused by the most emblematic VP realized in recent times: *The Mandalorian* (2019), which was shot inside ILM's LED volume *Stagecraft*. However, these facilities represent only one of the many combinations that can be achieved between real-time engines and other technologies (such as VR and AR). *The Lion King* (2019) and *The Jungle Book* (2016) were not shot using LED volumes.

This fever for LED volumes is now being reconsidered. Industry expert Nathan Bazley (2022) designed a flowchart (presented in Appendix V) that may enable those in AV production companies to think twice before deciding to adopt LED volumes. Bazley believes that, in many cases, it would be more convenient or economical to shoot in real locations or in studios. Similarly, Favreau, after several years of extensively using LED volumes, recognized the limit of LED volumes when shooting scenes with hard light, such as sunlight. Because of this aesthetic need, Favreau and his team opted for a traditional location and set-based shooting for *The Mandalorian* (Desowitz, 2023).

2. VP processes for SMPs are limited. The investigation that was presented in this chapter highlights a significant knowledge gap about the benefits that VP can bring to AV professionals working in SMPs as opposed to those in large-scale film productions. Future researchers should explore the challenges faced by AV professionals working in SMPs to better understand their resources and priorities as well as the requirements for designing and evaluating successful VP processes for SMPs. Not only is this an urgent knowledge gap to fill, but it is also speculated that such an investigation could be financially appealing. Leipzig (2014) reports that despite the SMPs' small budgets compared to blockbuster production budgets, the independent world is composed of a much larger number of projects. Anderson (2004) popularizes the long tail concept, pointing to a new business model for media consumption and explaining that niche contents (the tail), as opposed to hits (the head), represent a new and relevant market: *'Combine enough nonhits on the Long Tail and you have got a market bigger than the hits'.*

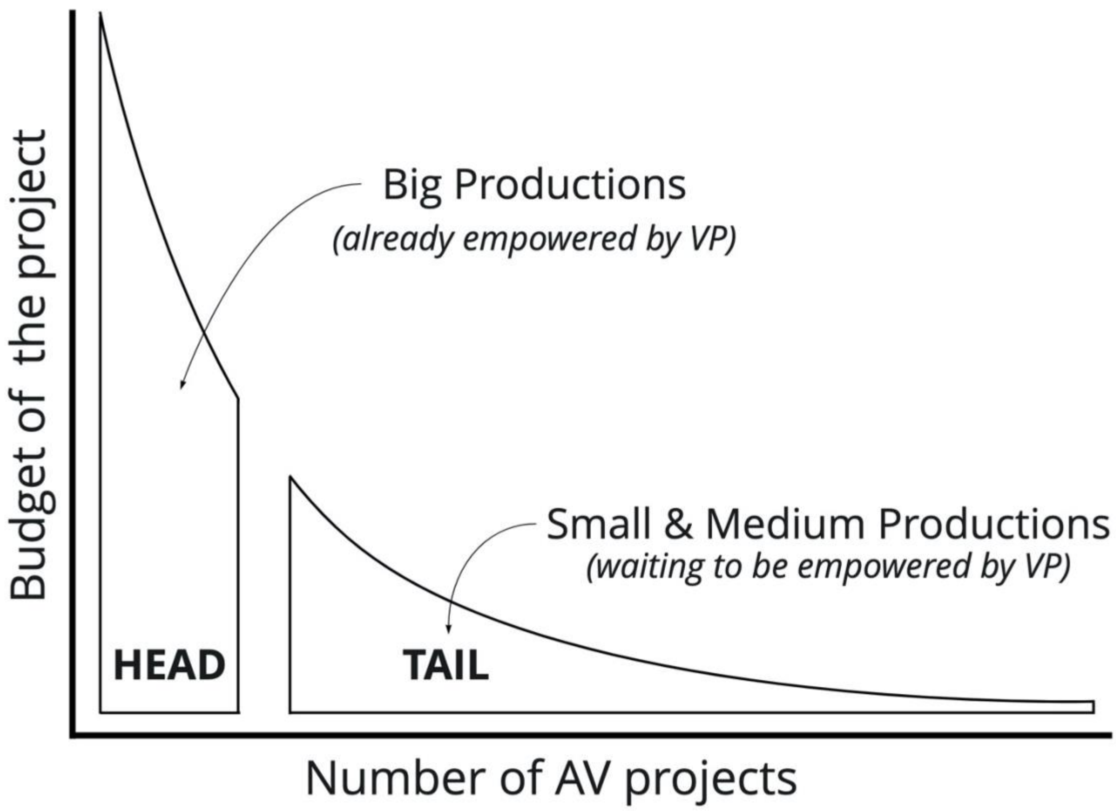

Figure 2.3 Adaptation of the Long Tail Concept (Anderson, 2004)

3. VP presents limited academic research. Few researchers outside of academia have explored opportunities enabled by VP through practical designs. Those undertaking this path have focussed on designing and prototyping alternative technical VP processes that are limited to specific tasks and, therefore, to specific AV roles. Zimmer et al. (2017), Spielmann et al. (2018), and Stamm, Teall, and Benedicto (2016) have agreed that their work only scratches the surface of what is possible for SMPs and that future scholars should consider technicalities or different AV figures. A VP process which by design extends its adaptation to several AV functions and better represents the profoundly collaborative nature of the AV production process is missing.

3.1 Stakeholder involvement in the design process is missing.

Researchers developing alternative VP processes have formally involved participants during the evaluation phase (Ardal et al., 2019; Trottnow et al., 2015) or, alternatively, have collected informal feedback at conferences and events when presenting their work (Zimmer et al., 2017; Spielmann et al., 2018). Furthermore, they have not provided much detail on the participants' profiles, the AV sectors where they operate, their specific roles, their challenges, or their needs. Previous studies have not included space for AV professionals during the design process of the alternative workflows enabled by VP. An iterative design process – starting with their current challenges, passing through idea co-generation, and concluding with evaluating the alternative VP process co-designed with SMP AV professionals – has not yet been explored.

The following chapter describes the methodology adopted in this research and how this PhD scholar intends to cover the identified gaps in the knowledge.

Chapter 3

METHODOLOGY

3. Methodology

'We are like dwarfs on the shoulders of giants, so that we can see more than they, and things at a greater distance, not by virtue of any sharpness of sight on our part, or any physical distinction, but because we are carried high and raised up by their giant size' Bernard of Chartres.

3.1 Introduction

Undertaking any kind of research requires scholars, especially novices, to fully understand how previous authors have performed this process.

According to Crotty (1998), researchers should frame the research design by taking a stance in four hierarchical elements: epistemology, theoretical perspective, methodology, and methods. Gray (2004, p. 16) supports the hierarchical nature of these elements, which better describes this interdependence: '*The choice of methods will be influenced by the research methodology chosen. This methodology, in turn, will be influenced by the theoretical perspectives adopted by the researcher, and, in turn, by [the] researcher's epistemological stance*'. Consequently, he further advises researchers to start the research process by reflecting on *what it means to know* (2004).

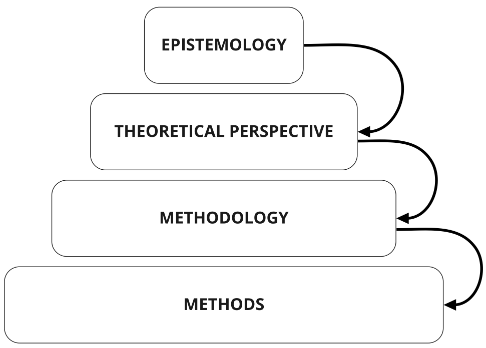

Figure 3.1 Four Elements of the Design Process (Crotty, 1998)

The epistemological stance can fall into three categories: objectivism, constructivism, and subjectivism (Crotty, 1998).

With an objectivist stance, researchers believe that there is an objective truth to discover and that they have no influence on the subject of the investigation. Researchers adopting a constructivist epistemology consider themselves to be a part of the phenomenon they are researching. They see themselves as inherently involved and responsible for affecting the outcome. This belief leads to different interpretations and opinions of the phenomenon depending on the researcher. A subjectivist stance imposes the subject over the object. The interaction with the matter of the study does not affect the meaning.

The epistemological stance a scholar chooses is deeply linked with a specific theoretical perspective. Positivism and interpretivism are among the most influential. Objectivism is linked to positivism, which states that reality is what is available to the senses. It exists separately from the researcher, and enquiries should be based on scientific observations. Consequently, positivism is directly linked to quantitative research strategies.
Conversely, constructivism is linked to interpretivism, which asserts that studying social reality requires researchers to employ qualitative strategies that are suited to investigate abstract and unique phenomena.

After reviewing these different epistemological stances and theoretical perspectives, the researcher decided to adhere to the principles of constructivism and take an interpretivist theoretical perspective. This decision was made because the filmmaking process is a hub of complex, dynamic, and diverse human activities. Many stakeholders are involved in the production process, and each has different needs, priorities, and capabilities. A successful project depends on the ability to comprehend these different viewpoints and combine them. It is challenging to examine elements from different perspectives and to understand others' reality, but this is what the filmmaking process is all about: it is a 'choral' work.

Adhering to a constructivist stance means that knowledge is considered a human construction, and the researcher and participants co-construct understanding. How can this be done in practice? Cross (1999, as cited by Feast & Melles, 2010) suggests that this is possible by *making artefacts,* meaning that new knowledge can be generated after making and reflecting upon these artefacts. This procedure to acquire new knowledge inspired the researcher to develop, test, and evaluate a design tool (artefact), which became one of the main aims and contributions of this PhD work.

Explaining the philosophical stance taken and the reasoning behind it is necessary for the reader to appropriately interpret this work (Huff, 2009). Furthermore, since *PhD* is the abbreviation of the Latin term *philosophie doctor*, which, in turn, comes from the Greek meaning ‘lover of wisdom’, the researcher felt obligated to state his philosophical stance and his belief towards knowledge.

3.2 Design Research Methodology Framework

A solid methodological framework on which to lay the foundation is crucial. In the words of Frankfort-Nachmias and Nachmias (1996), ‘*It is the methodology that makes a topic of investigation scientific*’. Therefore, searching for previous knowledge on how to structure a PhD investigation was necessary.
This chapter aims to explain the design research methodology (DRM) framework and the rationale for its adoption.

Blessing and Chakrabarti (2009) ideated and proposed the DRM framework because of the lack of scientific rigour in design research. Today, it is widely accepted among researchers (Cifter, 2011; Nickpour, 2012; Wang, 2015). This systematic approach allows design researchers to conduct their study efficiently and effectively. The framework is divided into four stages which, if executed properly, may lead to the generation of new knowledge in the design field.

Research clarification, descriptive study I (DS-I), prescriptive study I (PS-I), and descriptive study II (DS-II) are the main stages of the DRM framework ideated by Blessing and Chakrabarti.

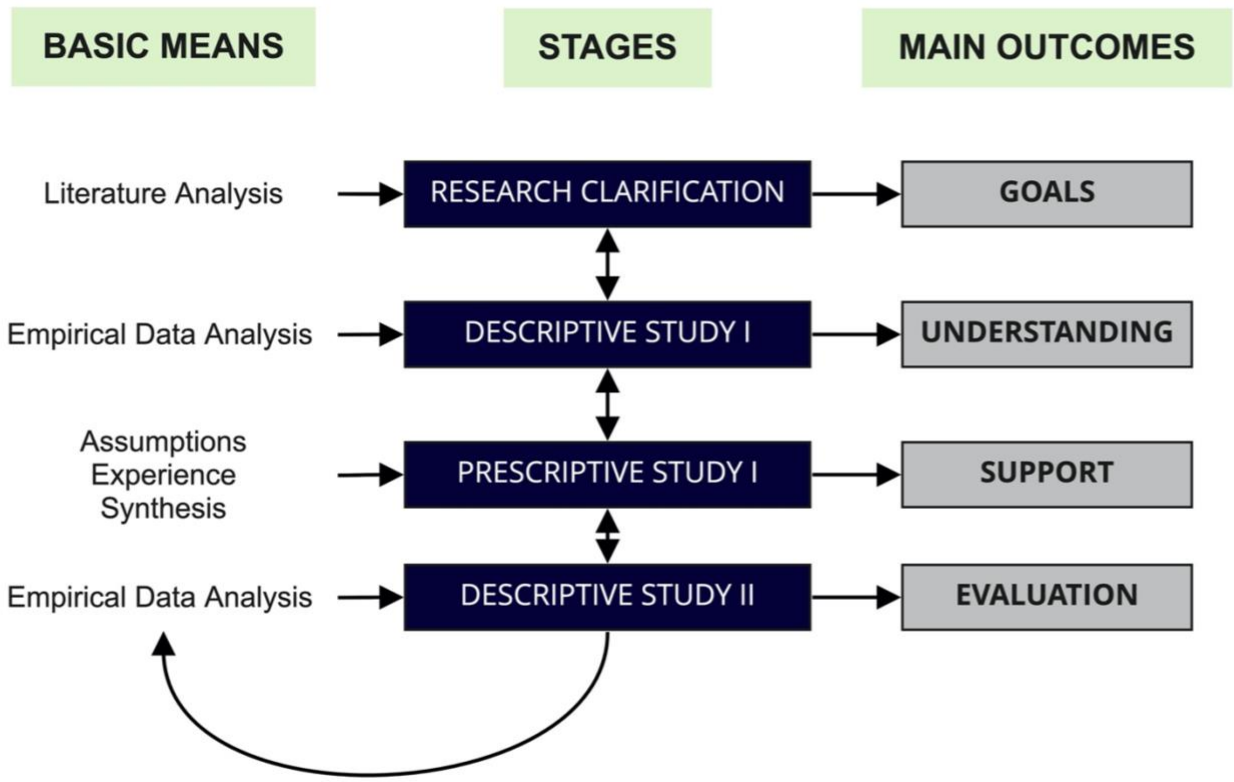

Figure 3.2 Design Research Methodology Framework (Blessing & Chakrabarti, 2009)

Research Clarification Phase

As shown in Figure 3.2, the DRM framework starts with the research clarification (RC) phase, which asks the researcher to establish the research focus and goal as well as determine why it is worthwhile to investigate that specific problem and what contribution is expected. Additionally, Blessing and Chakrabarti (2009) recommend defining a clear *initial reference model,* which will be used to evaluate the final outcome (*design support*) of the research. Developing a design support is possible after an extensive review of the work of previous researchers in the chosen field. The RC stage profoundly influences the next stages of the DRM framework, as it elucidates which approaches and methods are ideal to gather data during DS-I to better understand the context and the problems around the topic. RC also guides the development of support for the PS and its evaluation during DS-II.

Descriptive Study I

DS-I allows the researcher to understand the complexity of the problem and provides insights on how to develop (PS stage) and later (DS-II stage) evaluate the support that was established for the PS. According to Blessing and Chakrabarti (2009), this understanding can be obtained by reviewing the literature regarding empirical research or undertaking empirical research.

Prescriptive Study I

At this level, the researcher wants to create a design support system to answer a particular requirement or issue identified in RC and DS-I. It is critical to have specified at this stage the researcher’s perspective on the function of the support, how it will be assessed, and how it will affect the initial reference model. The goals of this stage are to construct an expected support based on the findings of DS-I, to define how the support is intended to be utilized, and to build a strategy for its assessment in DS-II.

Descriptive Study II

This step requires the researcher to evaluate the support developed. Blessing and Chakrabarti (2009) distinguish two types of evaluation: *application evaluation*, which is concerned with determining the usability and applicability of the design support, and *success evaluation*, which is concerned with determining whether the support has the desired impact.

After conducting the empirical studies needed, the outcome of the evaluation is compared with the initial reference model.

3.2.1 Using and Adapting the Design Research Methodology Framework

This section explains the DRM framework's ideal suitability for answering the three research questions in this study. The framework established a systematic approach that led the researcher to a specific outcome in each stage. First, through the RC stage, it was possible to answer RQ1.1. The activity related to this stage was a literature review of academic studies and a critical review of innovative processes employed by industry professionals. RQ1.2 was answered upon successful completion of the DS-I (exploratory interviews to understand the context where SMPs operate) and DS-IIA (confirmation of DS-I findings). Then, PS-I and the following iterations led to the creation of design support, which, according to Blessing and Chakrabarti, is the ultimate goal of design research (p. 33). Developing and iterating design support was necessary to answer RQ1.3.

In addition to this clear distinction between these stages, Blessing and Chakrabarti (2009) state that the DRM framework is intended to be *flexible* and *adjusted* depending on the specific researcher's needs. According to Fricke (1993), structuring a custom approach for one's research goal leads to better results compared to researchers who follow a predefined research process step by step. Reich (1995) further supports this statement. When critically reviewing a mathematical theory of design, such as the general design theory. Reich expresses that existing methodologies should be seen as a models from which to take inspiration rather than a strict *diktat* to follow. Hence, Figures 3.3; 3.4 and 3.5 illustrate which aspects of the DRM framework were adapted to better suit this investigation's purpose.

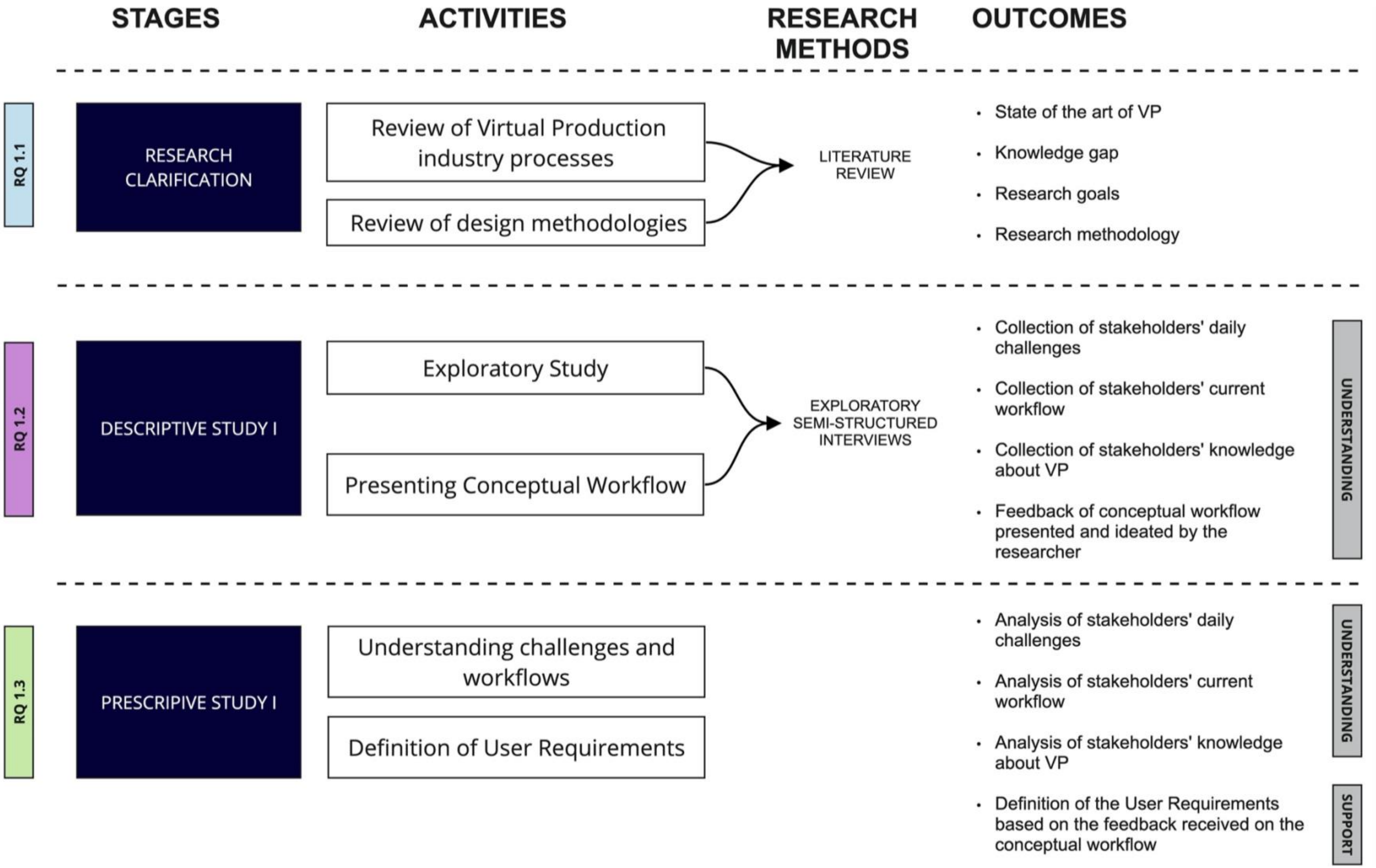

Figure 3.3 Research Methodology: Stages, Activities, Methods, and Outcomes (part one)

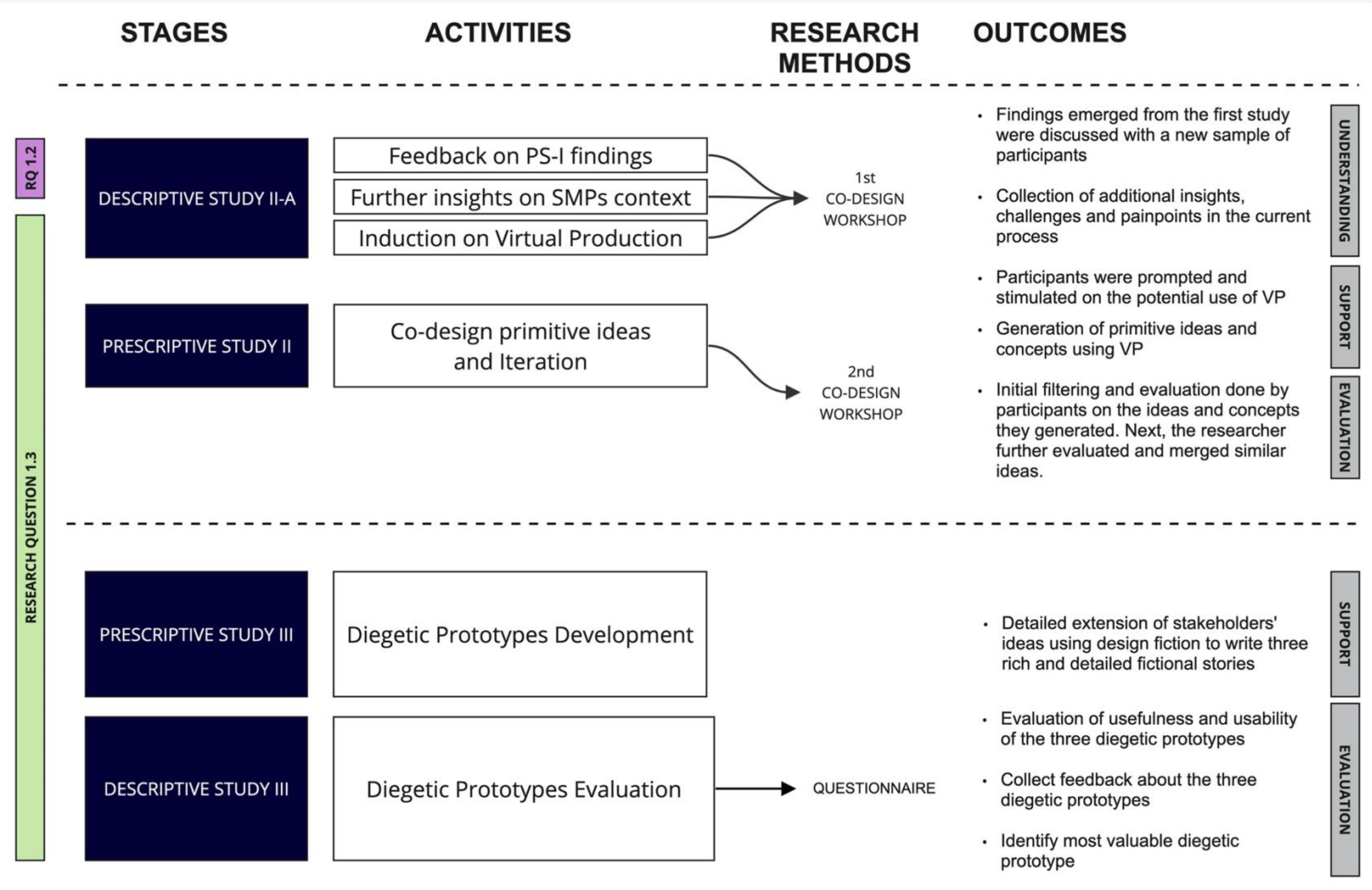

Figure 3.4 Research Methodology: Stages, Activities, Methods, and Outcomes (part two)

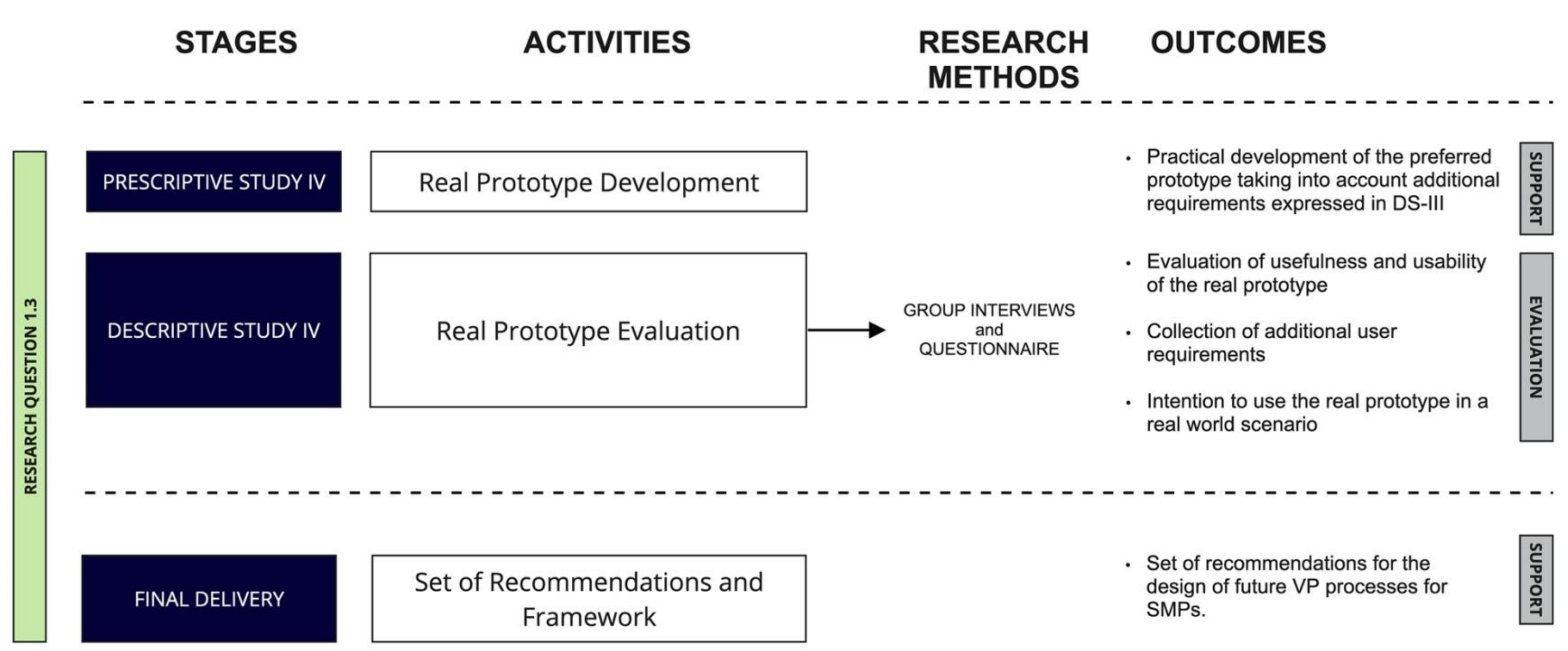

Figure 3.5 Research Methodology: Stages, Activities, Methods, and Outcomes (part three)

As new information is gathered and processed, researchers commonly re-examine previous considerations and reinterpret assumptions made in earlier stages of the process. Adding iterations, such as PS-I, in combination with iterations of DS-I allowed the researcher to continuously improve and evaluate the design support generated, leading, in DS-IV, to the development of highly detailed design support, which in turn enabled the researcher to draw reflections from it.

3.3 Co-Design

According to Sanders and Stappers (2008), co-design refers ‘to the creativity of designers and people not trained in design working together in the design development process’. This approach of actively involving participants is not new. It was already in use in the '70s in Norway, Sweden, and Denmark, where workers were encouraged to create new workplace systems to improve the value of industrial production. The Scandinavian participatory design (PD) movement was not isolated in this current of thought; many other researchers, such as Papanek (1972) and Cross (1972), started shifting their attention towards this design approach where users are not only passive subjects but also collaborators involved in the design process.

Figure 3.6 illustrates the distinction among different human-centred design research approaches.

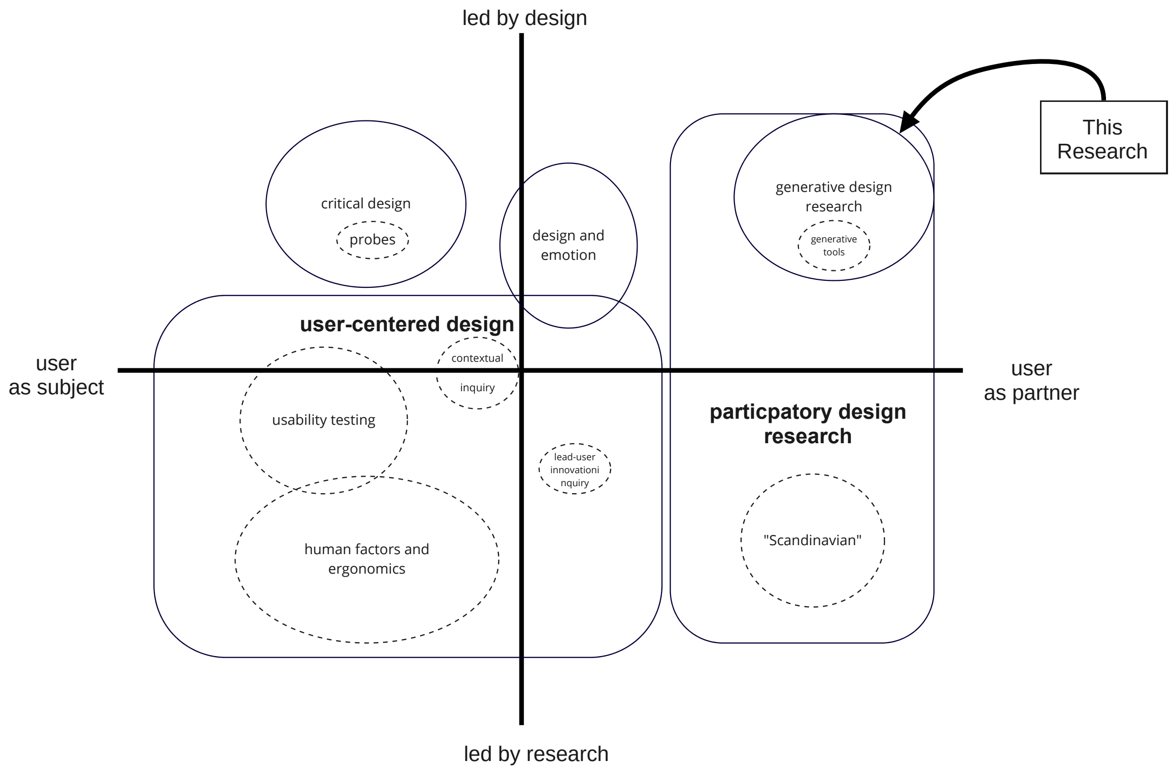

Figure 3.6 Nature of This Research Within the Design Research Landscape

This replacement of the term *PD* with *co-design, is relatively new,* which contributes to confusion among researchers (2008).

In this regard, Szebeko and Tan (2010) distinguish between the terms, explaining that co-design requires researchers to engage participants from the beginning to the end of the design process. In PD, this can be limited to a specific stage.

Aware of this distinction, this researcher refers to all collaborative activities as *co-design* because participants were crucial in developing, iterating, and evaluating different design ideas.

Nevertheless, it was considered valuable to consider the PD principles outlined by Spinuzzi (2005) because co-design is rooted in PD. Additional considerations on how to engage participants in the research process were provided by other authors: Muller et al. (1993), Bødker, Kensing, and Simonsen (2004), Schuler (1993), and Robertson and Simonsen (2012).

Co-design is a specific approach to constructing an item (a product, a service, an interface, a building, etc.). Consequently, it shares the same goal as the design itself: changing existing situations into preferred ones. How? This is where co-design differs from other design approaches, such as user-centred design. User-centred design is a common approach in which trained researchers observe and interview primarily passive users whose role is to perform prescribed activities and provide feedback on product ideas generated by others. User-centred design was the most effective product design approach in the '90s, but its current usefulness is debatable (Sanders, 1992). The modern complex world requires a more holistic, multidisciplinary approach, according to Sanders and Stappers (2008). In this scenario, it is preferable to work on the *purpose* of a specific design solution rather than on *product-specific* features.

Co-design is also recognized as appropriate when envisioning the future use of immersive technologies, and Robertson and Simonsen (2012) as well as Sanders and Stappers (2008) indicate that co-design is a mutual learning process for both designers and users. Designers keep track of existing technologies and their unique features, limits, and business contexts. They are aware of the state of the art and the latest advancements in such technologies. Therefore, they can share this knowledge with users, informing and prompting them towards the generation of innovative ideas. In turn, users inform designers and researchers of their context, process, abilities, habits, and preferred scenarios.
Actively involving users is the key to discovering the current situation and giving insights and inspiration to the researcher to envision new solutions as believed by Robertson & Simonsen (2012) when stating: ‘*If we are to design the futures we wish to live, then we need those whose futures they will be to actively participate in their design*’.

As expressed in Chapter 1, the research purpose is to investigate the opportunities that new immersive technologies present to the AV field. As explained, the human component in the AV field is dominant throughout the production process. Therefore, the researcher believed it to be crucial to consider the opinions, perspectives, and ideas generated by users and stakeholders. Furthermore, stakeholders must participate in the co-designing process since the aim behind RQ1.3 is to generate design support that might be introduced in their current workflow.

The process of generating innovative ideas together with participants is described in Chapter 5 where participants were involved in remote 1 workshops using online tools such as Mural (2023) facilitating collaboration and discussions.

3.4 Design Fiction

The term *design fiction* was created by science fiction author Bruce Sterling in *Shaping Things* (2005). Sterling describes design fiction as the act of ‘*deliberate blurring of fact and fiction*’ and later as ‘*the deliberate use of diegetic prototypes to suspend disbelief about change*’ (Sterling, 2013).

It is essential to introduce design fiction by citing Sterling because his contribution increased awareness in the scientific community that imagination can be the fuel for fiction and science. Many modern inventions have been inspired by fictional stories shown in cinema and television or told in science fiction books.

Before being fully functional real-world inventions, these ideas were presented in fictional media as *diegetic prototypes*, according to David Kirby, author of *The Future Is Now: Diegetic Prototypes and the Role of Popular Films in Generating Real-World Technological Development*. Among the many examples, Kirby offers one relevant to the nature of this thesis because it relates to the real-world impact of a story based on VR technology. He considers the science fiction movie *The Lawnmower Man* (1992) and explains that its production required the development of several diegetic prototypes to represent the virtual world exploited by the protagonist. This movie highlights ‘*the potential of virtual reality and three-dimensional (3-D) interactive technologies*’ to the public, and ‘*the diegetic prototypes developed directly resulted in funding opportunities and the ability to construct real-life prototypes*’. To extend Kirby’s observation into the present, it is possible to examine another movie: Spielberg’s *Ready Player One* (2018), based on Ernst Cline’s novel of the same name. This movie depicts not only VR technology but also the *metaverse* (a network of virtual worlds accessible via the internet) and presents many of the implications (social, cultural, economic, etc.) of such a speculative scenario.

In recent years, many researchers have been interested in exploring design research through design fiction (Auger, 2013; Bleecker, 2009; Grand & Wiedmer, 2010; Markussen & Knutz, 2013; Morrison, Tronstad, & Martinussen, 2013; Rattay, 2019).

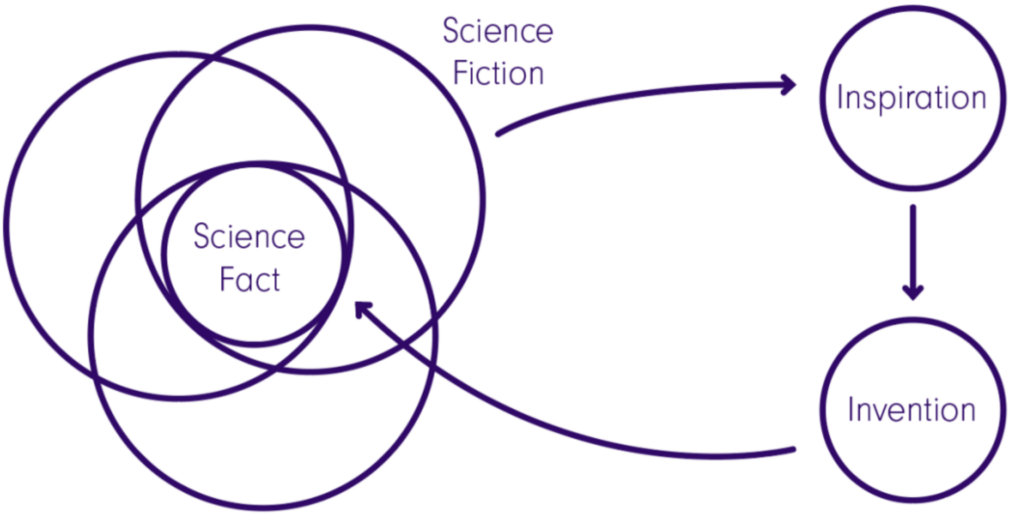

Figure 3.7 Science Fact and Science Fiction According to Rattay (2019)

After research to understand why many academics adopted design fiction for their studies, it was noted that such an approach can encourage a creative and open environment to grow and foster bold and provocative ideas (Figure 3.7).
Approaching design research using design fiction means answering what-if questions in relation to a specific future scenario where new technologies are likely. Such a question aims to initiate a critical discussion around the many implications introduced by a fictional but probable and preferable scenario.
Huusko et al. (2018) support the idea that integrating design fiction elements into the co-design strategy may be beneficial for those scholars wanting to envision the introduction and development of new technologies. Consequently, during the co-design workshops held during DS-IIA, DS-IIB, and PS-II, the two design approaches were combined with the expectation of obtaining valuable data.

3.4.1 Diegetic Prototypes

Diegetic prototypes explain future technological needs and feasibility to viewers (Kirby, 2010); in this study, they were developed and employed in DS-III. Diegetic prototypes were preferred to other techniques, such as *cards scenarios,* which describe a hypothetical scenario without giving many details (Lucero et al., 2016). Card scenarios is a technique used mainly in workshops to start the conversation around a topic but leaves participants with the duty of extending that initial scenario. Since this degree of freedom was granted while participants brainstormed ideas in PS-II, diegetic prototypes were considered ideal for facilitating an in-depth assessment and evaluation of participants' design fiction scenarios.

3.5 Study Design

The researcher adhered to the principles of constructivism and assumed an interpretivist theoretical perspective; consequently, qualitative rather than quantitative methods were employed to undertake this research.

3.5.1 Design Methods

A complex issue with people at its centre, such as the one examined in this study, is challenging to capture with existing measures that reduce participants to a statistical mean that overlooks the uniqueness of individuals (Creswell, 2013). Therefore, this researcher almost exclusively used qualitative methods to collect data.

As reported and reviewed in Chapter 2, VP is a recent AV production process, and advancements are evolving quickly. Therefore, listening to experts share their previous experiences in the field is essential when planning to investigate such a new topic. Concurrently, understanding which perspectives of stakeholders to enhance is crucial. Qualitative methods are often used to collect people's thorough perspectives, to acquire insights into problems, and to identify a phenomenon that has not been studied (Flick, Kardoff, & Steinke, 2004) or to identify when an issue should be explored (Creswell, 2013). According to Creswell, qualitative researchers want precisely this: '*to empower individuals to share their stories, hear their voices*' (Creswell, 2013, p. 48).

Qualitative methods such as interviews, workshops, observations, and questionnaires were used to collect data. Due to the COVID-19 pandemic, these methods had to be restructured, sometimes slightly and sometimes considerably. Social research had previously been conducted online (Lupton, 2020), but the pandemic forced this manner to become the norm. In this regard, Lupton created a crowdsourced document containing many techniques for fieldwork that avoid in-person interactions. Some of them, such as online interviews and video-based co-design workshops, were used for this study.

DS-IV participants tested the design support ideated and evaluated its effectiveness and usability; consequently, qualitative methods, such as observations and group discussion, were combined with quantitative methods. Participants were asked to complete a survey based on the technology acceptance model (TAM; Davis, 1989). Quantitative methods are, in fact, usually employed when testing an existing theory (Bryman, 2016). In DS-IV, the goal is to understand better the design support that might benefit the stakeholders.

According to Creswell (2013), deciding to use both qualitative and quantitative methods in the same research can enable the researcher to acquire a significantly deeper understanding of complex topics. This mixed-methods approach was adopted during DS-IIB, DS-III, and DS-IV.

3.5.1.1 Interviews

Throughout the history of social sciences, interviewing subjects to gather data has been widely used in qualitative research. Interviews are fundamental to understand how subjects experience and see the world. According to Frey and Fontana (1991), three types of interviews are commonly used: structured, unstructured, and semi-structured. During structured interviews, each participant receives an identical set of questions. Conversely, those conducting unstructured interviews use a more conversational and casual approach. This type of interview is used when the objective is to have a more profound, complete, and authentic reply from the participants. In semi-structured interviews, the researcher asks participants several specific questions but also allows participants to take the initiative and discuss related topics with flexibility.

For this study, in-depth semi-structured online interviews with professionals working in the AV field were planned for the DS-I stage. During this phase, the goal was to collect data regarding current pre-production, production, and post-production practices. Starting with exploratory interviews, the researcher investigated the current challenges and issues in many different roles (director, cinematographer, set designer, producer, etc.). Understanding the context and the current pain points in each role was necessary to understand the context where SMPs operate.

3.5.1.2 Workshops

The word *workshop* initially identified a *‘room or building where things are made or repaired using machines and/or tools*’ (Cambridge University Press, 2022). However, this term is now part of everyday language and can be applied in different contexts. In design research, a workshop can be identified as ‘*an arrangement whereby a group of people learn, acquire new knowledge, perform creative problem-solving, or innovate to a domain-specific issue*’ (Ørngreen & Levinsen, 2017). These arrangements can be held in person or remotely, and the researcher or facilitator plans numerous tasks to gather data for the study. For example, a workshop may begin with an introduction to a specific topic and continue with group discussions and creative activities, such as brainstorming, mapping, creating collages, or drawing. Typically, simple tools are provided to participants to generate ideas, drawings, and mock-ups. Organizing a workshop is challenging, but it can lead to acquiring a substantial volume of precious data to further analyze and discuss. The design workshop approach is often used in generative research, in which individual participants or groups generate and validate design direction in response to a design challenge or brief. Workshops may also be utilized as an evaluative tool, in which participants are asked to assess ideas, provide input, and offer insights into the design iteration and improvement process (Hanington & Martin, 2019).

After gathering initial data through exploratory interviews during DS-I, the researcher determined the most appropriate structure for the workshops. It was possible to unite different stakeholders and create an environment where they could freely exchange thoughts and be inspired by each other's inputs. However, it is essential to mention that there were many difficulties in engaging with professionals, as they have little time to dedicate to academic and non-paid activities.
An additional challenge was posed by the COVID-19 restrictions, which did not allow arrangement of physical workshops. Therefore, it was necessary to consider alternative solutions. In this regard, the online service MURAL was identified as functional for the workshops. This service was specifically designed for virtual workshops; all participants and the facilitator were provided with a series of digital tools similar to those commonly used during in-person workshops, including interactive sticky notes, boards, stopwatches, tables, images, and much more. Brainstorming was one of the most useful activities that led to the generation of many ideas to further discuss and evaluate. The basic concepts and initial ideas resulting from this activity were refined in PS-II and used as a starting point for DS-III.

3.5.1.3 Questionnaire

In DS-III, the researcher considered it useful to adopt a questionnaire to collect quantitative and qualitative data on three design fiction scenarios that were generated during PS-III; these were presented in the questionnaire as written stories. Quantitative data were meant to be captured by adapting Davis' (1989) TAM and other closed-ended questions.
For collecting qualitative data, some open-ended questions asked respondents to explain the reasoning behind their answers to closed-ended questions.
After analyzing the questionnaire data, the researcher filtered from the three scenarios that which would be most valuable for AV professionals and could be further developed into a prototype in PS-IV.

The questions that asked participants to evaluate the *perceived usefulness* and *ease of use* of elements that were presented in the DS-III design fiction scenarios were also asked of participants who experienced the prototype firsthand in DS-IV. This is because the researcher considered it significant to collect participants' feedback on the concrete implementation of the design fiction scenario.

3.5.1.4 User Testing

As a result of findings from DS-III, an actual prototype was designed, developed, and tested. During PS-II, the researcher planned to identify and extend one of the concepts generated during the workshops. The choice of which concept to develop was determined by (a) the degree of innovation a specific concept represented and (b) the degree of technical feasibility that participants believed would offer real benefits according to considerations they made throughout the study.

To evolve the chosen idea into a basic prototype, it was crucial to identify and test pre-existing hardware devices and software applications considered appropriate to achieve such a result.
Different groups of AV professionals tested the prototype, which had been ideated during an in-person user testing session in which the researcher was a facilitator. Both quantitative (through a post-experience questionnaire) and qualitative data (through a group discussion) were collected.
The same TAM adaptation employed in DS-III for the online questionnaire was used to evaluate the questionnaire. Evaluating the qualitative data was inspired by the framework proposed by Horvat et al. (2022), and the prototype testing is further explained in Section 7.5.1.

3.5.2 Data Analysis Methods

One of the key challenges in using qualitative methods is that they generate substantial data (Bryman, 2016). To analyze participants' responses to interviews, workshops, open-ended questions, transcripts, and discussions among participants during workshops, thematic analysis was considered appropriate for this study due to its flexibility (Braun & Clarke, 2006). In fact, during this phase, thematic analysis is instrumental in identifying common themes across participants' interviews. The vast amount of data generated by using qualitative methods means that keeping track of all the materials can be an issue (Bryman, 2016).

The computer-assisted qualitative data analysis software NVivo12 was used to organize, analyze, and find insights into qualitative data sources, such as interviews (Lewins, 2001). After transcribing each interview, data were coded and later grouped into general themes. The qualitative data analysis process has three phases: transcribing, coding, and grouping (Cho & Lee, 2014). The original qualitative data were first filtered and transcribed to be analyzed and detailed for further analysis (Bailey, 2008). Participants' social talking that was irrelevant to the study topic was not reported in the transcription.

Quantitative data analysis derived from the questionnaire in DS-III and DS-IV were manually imported in Excel, and the frequency with which each option was selected for the closed-ended questions was calculated.

3.5.3 Sampling

Many sampling techniques can be employed to conduct social science research, depending on the nature and type of the research (Etikan et al., 2016). Because of the exploratory nature of this study, the researcher decided to adopt non-random sampling techniques, such as purposeful and snowball sampling.

Such techniques are employed when researchers have limited time and resources as well as when the goal is not to make population-wide generalizations (Etikan et al., 2016). One of this technique's limitations is that participants are selected based on subjective criteria established by researchers.

However, one of the advantages of purposeful sampling is that participants receive in-depth and detailed information about the topic under investigation.

The criteria were determined based on the knowledge gap identified in the literature review, which indicated that the exploration of the VP process for AV professionals with limited resources has yet to be investigated. Therefore, among the population of AV professionals, participant selection was based on the budget and team size of the productions in which they were usually involved.

After having identified a number of participants through purposeful sampling, the researcher also adopted snowball sampling, a technique where participants suggest additional people who may want to be involved in the study. To do so, the researcher provided instructions about the kind of participants to involve in the study.

Snowball sampling (Parker, Scott, & Geddes, 2019) proved crucial in increasing the sample size and tackling the critical challenge of involving AV professionals as participants. These people are immersed in a highly stressful environment (Alony, Whymark, & Jones 2007) and work long hours (Hesmondhalgh & Baker 2010), having little time left to dedicate to other activities. In fact, due to the insular nature of the AV industry, the researcher found it difficult to engage people in the film and TV industry as participants.

As with the critiques of purposeful sampling, snowball sampling is criticized for the biases associated with participants suggesting additional participants. However, as this is exploratory research, external validity is not sought (Parker, Scott, & Geddes, 2019). This researcher aimed to lay the groundwork in this new field, and future works will strengthen the generalization of the findings.

Additionally, it is essential to mention a characteristic of the current AV industry. In *Local Hollywood*, Goldsmith (2010) explains that major studios and SMP enterprises (p. 87) commonly split some of the AV production processes across the globe. Goldsmith describes this phenomenon as a cross-pollination of places, people, and service providers that pushes the development of common approaches so that everyone is on the same page and both people and places become interchangeable and interoperable (p. 20). An additional analysis on the AV players' current strategy is offered by Lotz (2021), who reports the case of the streaming service and production company Netflix: *‘Examining the locations in which Netflix has established production facilities shows a multinational presence’.* He continues, *‘Netflix largely relies on contracting other production companies to make its series and films’.* Relying on existing companies in a specific country means involving professionals

from that country who are compliant with international standard processes (Goldsmith, 2010, p. 153).
Therefore, potential biases that are introduced by recruiting professionals from one cultural context rather than another have relative importance since the workflows for AV productions are rather homogeneous.

Additional and more specific details about the participants are provided in each chapter where fieldwork is presented and discussed. Table 2 presents an overview of the participants involved.

Table 2 Participant Sampling Strategy

Phase of DRM	Research methods	Sampling technique	Sampling size	Participants involved in previous phases	Code name
DS-I	Semi-structured interview	Purposive sampling Snowball sampling	20 participants	/	PI (participant interview)
DS-IIA PS-II DS-IIB	Co-design online workshop	Purposive sampling Snowball sampling	15 participants	1	PW (participant workshop)
DS-III	Questionnaire	Purposive sampling Snowball sampling	30 participants	12	PQ (participant questionnaire)
DS-IV	User testing	Purposive sampling Snowball sampling	29 participants	5	PT (participant testing)

Some participants were involved in multiple phases of the research because they were considered gatekeepers who were able to add new participants.

The research involved 94 participants, 76 of whom were involved in one research phase only. Consequently, the vast majority of participants were new to the research and could objectively evaluate what was discussed and generated in previous phases by other participants. Such a strategy further strengthened the studies.

Furthermore, the AV industry includes a variety of professionals with diverse responsibilities and needs; therefore, throughout the research, people in different roles were involved, such as directors, assistant directors, executive producers, producers, assistant producers, cinematographers, camera operators, set designers, editors, sound designers, 3D artists, VFX artists, and VP experts.

3.5.4 Limitations Due to COVID-19

The ethnographic approach was initially born in the late 19th century to research cultures, human behaviour, and social relations in the Western colonies. Design ethnography was initially considered an appropriate design method to create empathy with stakeholders involved in the design process. Adopting such an approach requires researchers to examine issues from the perspective of the subjects under study (Stickdorn et al., 2011).

To do so, typically, an ethnographic approach begins with the researcher identifying and interacting with the so-called *gatekeeper*, an individual who is a member of a cultural group. This gatekeeper is the initial contact for the researcher and leads the researcher to other participants (Hammersley & Atkinson, 1995). According to Creswell (2013), the researcher is then required to spend extensive time in the field to collect data on the field issue and form an insider perspective.

However, due to the state of emergency caused by the COVID-19 pandemic, this approach was challenging or, in many cases, not possible. Consequently, the researcher’s previous work experience in the AV field was helpful since he could act as a gatekeeper himself. Additionally, this researcher’s background simplified the decoding of tacit knowledge rooted in participants’ stories and anecdotes throughout the research process.

3.6 Chapter Summary

This chapter described the systematic procedure developed and implemented to investigate to what extent the VP process can be adopted by SMPs. It explained the novel methodology employed to fill the current gap of knowledge which sees filmmakers out of the ideation and development process discourse when designing new VP processes. For this reason, it was thought as optimal to adopt a co-design approach and therefore involve filmmakers from the beginning to the end of the research process. Adopting such research process to investigate a field such as VP is currently missing in the literature and considered optimal to build and validate new knowledge. A detailed description of each step of the research process undertook is explained in Figure 3.3. when introducing the DRM framework by Blessing and Chakrabarti and how it was adapted to better suit the goal of this PhD thesis.

Qualitative and quantitative methods were used, including interviews, workshops, questionnaires, and user testing. After acknowledging the impact of an external factor in the COVID-19 pandemic, the researcher employed and adapted a mix of remote and in-person data collection methods to meet the research goal.

In the following chapters, the research questions are answered through different studies (DS-I, DS-II, DS-III, PS-I, and PS-II), and the objectives, design, samplings, data collection, and data analysis of the study are explained with more details.

Chapter 4

EXPLORATORY STUDY

4. Exploratory Study (DS-I, PS-I)

4.1 Introduction

Conducting interviews was considered by the researcher to be the most appropriate technique because of the novelty of VP, as detailed insights were required from participants who adopted this process in the past or might benefit from its use in the future.

According to O'Leary's (2010) study process, there are four stages in an interview: (a) planning the interview, (b) developing the interview questions, (c) conducting the interview, and (d) analyzing the data. In the preparation stage, the researcher identified the participants, the time and location for the interviews, and how the interview would be conducted.

4.2 Aim

The researcher expected that data gathered from the interviews would enable a better understanding of the current workflow, challenges, and issues that AV professionals encounter daily. The researcher also expected that people in different roles would provide different answers because of their different perspectives regarding a production.

An additional goal of this study phase was to identify the user requirements for a potential immersive application capable of assisting stakeholders in their work. In this regard, at the end of each interview, a simple conceptual workflow ideated and proposed by the researcher was presented to prompt participants to evaluate and eventually further develop the workflow proposed with new insights and feedback.

4.3 Method

The study involved 20 AV professionals in semi-structured, one-on-one online interviews. Establishing the appropriate number of participants for in-depth interviews is not a trivial decision, and Hennik et al. (2016) offer an answer this question. In their study, they interviewed 25 participants and find that, after interviewing nine participants, the range of thematic issues was identified. Nonetheless, only after 16-24 interviews did they develop a rich understanding of the issue. Additionally, O'Reilly and Parker (2013) agree that the interview process should continue until no new insights are added and no new patterns emerge from the data. Within the context of this study, the saturation of the analysis *codes* was reached after interviewing two thirds of the participants. The final one third of interviews reinforced and added detail to the themes, thereby offering slightly different perspectives on the various topics identified. This addition was helpful not only for noting all the issues raised by the stakeholders but also for gaining a deeper understanding of the problem and its context.

4.4 Participants

The 20 study participants were all active in the AV industry at the time of the study and worked in a variety of AV sectors (feature films, short films, documentaries, commercials, music videos, and video art). The participants were based in the US (9), Canada (1), UK (3), and Italy (7). The majority (85%) were 25-40 years of age, which is the generation referred to as *millennials* (Strauss, 1991). Millennials have grown up experiencing digital technology and represent the next generation of filmmakers. Three participants were over 40 years of age, two of whom were leading VP experts.

The sample of participants comprised relevant stakeholders (18) and leading experts (2). The first group included those involved in the pre-production phase of a project, such as directors and cinematographers, who operated in SMPs. As the potential users of the final workflow resulting from this study, they were well suited to share their current approach to location scouting, to comment on pre-production challenges, and to offer a reliable evaluation of the conceptual workflow in the form of a diagram in Figures 4.2 and 4.3) ideated and proposed by the researcher based on the critical analysis of the literature review. The participants in the second group were leading VP experts whom the researcher chose to involve to gather more information on the state-of-the-art technology and to listen to their experiences adopting the technology in major blockbuster productions. In addition to providing expert input, the second group commented on specific stakeholder needs for participation in high-end structured productions. This clarification differentiated the needs of stakeholders in high-end productions as opposed to those in SMPs. Seven of 18 participants worked on projects involving real-time technologies, VR, and AR, while the remaining 11 understood the macro concepts surrounding immersive technologies and how they can be adopted.

Table 3 Summary of the Total Participant Pool (Interviews)

PARTICIPANT	ROLE	DESCRIPTION
PI01	First assistant director	Assisting directors and producers on daily tasks
PI02	Producer	Overseeing the entire process and actively seeking funding
PI03	Cinematographer	Operating cameras and lighting on set, working closely with director
PI04	Leading expert	Designing and overseeing the VP process on blockbuster movie production
PI05	Leading expert	Designing and overseeing the VP process on blockbuster movie production
PI06	Producer	Overseeing the entire process and actively seeking funding
PI07	Producer	Overseeing the entire process of commercials
PI08	Director	Directing short films and commercials
PI09	Director	Directing short films and commercials
PI10	Cinematographer	Operating cameras and lighting on set, working closely with director
PI11	Director	Directing short films and commercials
PI12	Cinematographer	Operating cameras and lighting on set, working closely with director
PI13	Director	Directing short films
PI14	Director	Directing short films
PI15	Producer	Overseeing the entire process and actively seeking funding
PI16	Director and producer	Overseeing the production of corporate videos and social media content
PI17	Producer	Involved during the development phase of a project
PI18	R&D video technician	Designing systems for remote and low-latency live streaming services
PI19	Set designer	Involved during the preparation of independent film and TV sets

PI20	Video consultant	Involved by companies to design video strategies and oversee production

4.5 Procedure

Semi-structured interviews were conducted using videoconferencing software. Each of the interviews were approximately 60 minutes in length. The data generated by each interview were recorded through interview scripts. Interviews were performed in either English or Italian. Responses from non-English speaking participants were transcribed and translated into English.

The interviews were split into two parts. The first part was conducted to acquire a broad view of the participants' perspectives on their challenges during the pre-production phase of an AV project, especially when they are required to shoot in a real-world location. In the first part of the interview, four standard ethnographically oriented questions were used to learn more about participants and their background. Participants were asked about their job titles, years of experience, previous projects, and challenges faced in the making of their projects:

1) *Could you briefly tell me more about your background and your role today?*
2) *What is your experience and knowledge about immersive technology?*
3) *What are your challenges when doing pre-production for a project?*
4) *What are your challenges when dealing with location scouting?*

The fifth question presented the core of the interview and allowed participants to freely envision ways of taking advantage of immersive technologies:
5) *How can immersive technology, such as VR and AR, solve some of these challenges?*

The second part of the interview was dedicated to presenting the conceptual workflow ideated by the researcher to each participant for empowering stakeholders during the pre-production phase. After presenting the proposed workflow, participants provided their feedback, offered new ideas, and asked questions to gain a deeper understanding.

4.6 Findings

After completing the interview process, data were analyzed, following the six steps in the analysis phase presented by Braun and Clarke (2006). The main goals of this phase were to (a) identify the most relevant and common themes emerging from the data gathered, and (b) express feedback on the conceptual workflow presented in the second part of the interview. To facilitate the thematic analysis, Nvivo12 (QSR International, 2021) was employed to process the data (interviews' transcripts). Initially, the process involved a phase of data familiarization, followed by the systematic coding of transcripts to identify relevant insights. Subsequently, main themes emerged from the coded data were named and reported in detail in the following chapter.

4.7 Discussion (PS-I)

The data collected from the participants allowed the researcher to identify daily challenges that were common to all participants involved in SMPs and those that were role-specific.

4.7.1 Common Challenges

Making a professional AV production requires coordination of contributions from people with different skill sets, from pre-production to post-production.

Consequently, efficient *communication* across the different departments throughout the process was identified as key by most participants. The way that needs, issues, tasks, and ideas are communicated is crucial regardless of whether the information shared regards technical details on where to park the truck outside the location or creative ideas, such as the effects that need to be achieved through lighting.

Preparation is crucial to avoid unexpected problems during shooting, which is generally the most expensive phase of the entire process, and to enable the exploration of different creative solutions.

A combination of *communication* and *preparation* is *pre-visualization*. Participants noted that *pre-visualization* is useful in the pre-production phase. Even a rough visual representation of how the creative people, generally the director, envision the scene can significantly facilitate communication across the whole team. This visual information is beneficial not only for the director's creative collaborators, such as the cinematographer and costume designer, but also for those in more organizational roles, such as the producer or assistant director, who are required to plan and manage the production.

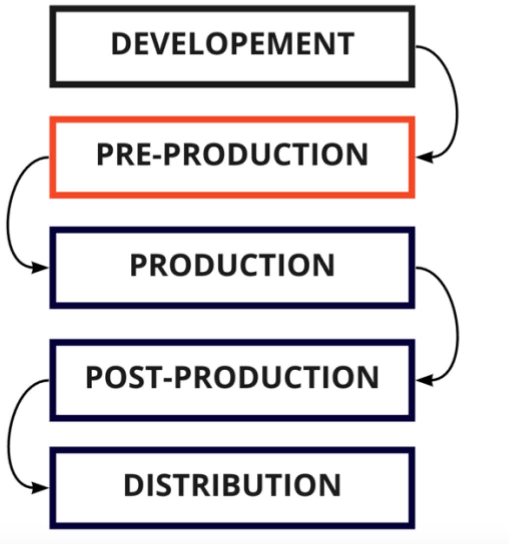

Figure 4.1 Established Linear AV Workflow

4.7.2 Role-Specific Challenges

a) Directors

When approaching an AV production, directors are responsible for identifying the optimal way of visually translating what is written on the script. This involves coordination of different people's roles to enable directors to achieve their vision. However, as PI10 (cinematographer) stated, '*not everybody speaks the same language*'. The same words of a script can be interpreted differently by different readers. Consequently, aligning all crew members to the same vision is one of the main challenges for directors throughout the production process, particularly during pre-production. Different visual materials, such as mood boards, are currently used to address this challenge. This can be combined with detailed storyboards to share proposed solutions. These approaches can also be useful when directors are seeking funding and need to pitch their project to potential funders.

b) Cinematographers

Crucial in recreating the optimal visual appearance of the project, cinematographers propose the most appropriate creative and technical solutions to directors. They have a keen eye for images and deep knowledge of required technical gear (e.g., cameras, movements, lenses, filters, and lights) to fulfil the director's vision. Nevertheless, sometimes it is not possible for them to anticipate which filming and lighting equipment are ideal. This is additionally relevant to aspiring and new cinematographers with limited experience. This conservative attitude may lead them to recreate lighting setups or camera movements used in previous projects to reduce the risk of mistakes and delays in the production; however, it may limit their creative potential. Cinematographers are involved in the location scouting phase and during the subsequent *technical scouting* phase, during which they become aware of technical information, such as ceiling height, availability of electrical power sources, and the presence of reflective surfaces, just to name a few elements.

c) Producers

Producers organise and oversee the whole process, including budgeting the script and securing funding, arranging logistics during production, identifying a facility for post-production, and ensuring the final delivery. Throughout the entire workflow, a quality producer addresses in advance those problems that may arise in later phases of the production process. This includes obtaining permission for shooting on public streets, ensuring catering has considered food allergies or specific requests, and writing the daily call sheet to estimate the budget needed to complete the project. Producers have several tasks to complete before the beginning of the shooting phase, and careful planning can make the difference between failure and success.

> '*Any problem that gets brought up on set is infinitely more expensive than a problem that was brought up beforehand, because beforehand it's just a problem that doesn't have a value to it...You can't foresee all problems, but it kills you if there's a problem you could have foreseen'* PI06, producer.

Study participants in this role reported that they need to communicate with all crew members for logistical reasons, understanding their specific needs and evaluating potential solutions. As explained by PI07 (producer), their duty and need are to keep everyone on the same page because *‘streamlining communication tends to kind of always be an issue, and something gets lost in translation sometimes’*. Before and during the production phase, producers share a variety of documents and ensure that everyone has a clear idea of what is expected of them. Similar to directors and cinematographers, producers are deeply influenced by the nature of the chosen location. Depending on the findings from location and technical scouting, they will organize the production phase differently.

4.7.3 Participants’ Vision of Immersive Technologies in the AV Pre-Production Process

Participants were asked to express their vision of how immersive technologies such as VR and AR might allow them to solve their challenges; they explained that these tools could enable them to save time, improve the use of financial resources, and enhance their creativity. The main benefits they expected are listed below.

1) Avoid travelling and save time during location auditioning

The workflow that is proposed in this chapter will enable users to experience locations remotely within immersive environments, which could be useful to support the decision-making process during a preliminary phase called *location auditioning*. In this phase, many options are considered. The proposed conceptual workflow avoids physical travel from location to location, thereby saving time, optimizing use of financial resources, and reducing the overall environmental footprint. Having the opportunity to immerse oneself in the virtual location and explore it remotely could overcome several limitations of 2D photos, which are currently used to preselect the possible locations.

> ‘*If I could wear the headset and be back in the room, where I took the photographs...go home and instead of having only my memory or photo in two dimensions being able to see the space in three dimensions, I think it would make*

me think much more clearly about where and how I want to place the equipment.' PI12, cinematographer.

The participants felt that physically scouting the chosen location at least once after the virtual screening is still vital, which suggests that the proposed conceptual workflow could be integrated within existing workflows without necessarily replacing established processes in their entirety.

2) Remote collaboration

Several participants speculated that virtualising the location scouting process would also favour collaboration among team members based in different geographical locations.

3) Lack of constraints

During the interview, a participant noted the following: '*There are a lot of independent productions that don't allow time for location scouts, which I really don't like, and then I just get thrown into it on the day, and I'm not sure*' PI10, cinematographer.

The new workflow that is proposed in this chapter allows professionals to access a digital capture of the selected location at any time, which enables them to spend more time exploring the virtual space, thereby facilitating the generation of creative output.

4) Virtually audition props and costumes

PI06 (producer) commented on the benefits of virtual exploration ahead of physical location scouting in terms of saving time and using financial resources more efficiently in relation to, for example, improved choice of dresses and furniture to be rented: '*The director hopefully could sit there and look at [it] and go – I don't like it. I don't like it. Okay, this is the one that we should run because I like the way it looks in the actual scene'* PI06, producer.

5) Facilitate logistics

Having the ability to perform location and technical scouting virtually may allow different department heads to address many logistical and technical questions that are usually answered by producers. Some of the most common questions that need to be answered before shooting to enable the production to run smoothly are the following: *'Where to park the truck? Where to store the equipment? Where are the power sources? Where to create a holding area? Where to create the production office?'* (PI06, producer).

6) Pre-visualise the lighting setup

When planning the lighting setup, the proposed conceptual workflow may be useful to pre-visualise how a particular light model or disposition will affect the look of the picture (e.g., how a hard light or soft light would illuminate actors' and actresses faces). Similarly, pre-visualizing the impact of sunlight coming directly or bouncing from a window is crucial and can affect the director and cinematographer's decisions.

Being able to simulate how sunlight will influence the scene lighting on a specific day and time would be useful because *'sometimes during location scouting, you're not necessarily there at the exact right time of when you intend to shoot'* (PI10, cinematographer). Some cinematographers currently rely on non-immersive mobile applications, such as Helios Pro (Chemical Wedding, 2021).

7) Pre-visualise camera movements

By taking advantage of VR, it may be possible to pre-visualize complex camera movements that are achievable with expensive gear, such as lights, cranes, or dollies, and then evaluate their use in production if they are considered appropriate to fulfil the cinematographer and director's vision. Having such an opportunity is useful for professionals when renting or purchasing the required equipment for production because they have tested it virtually in advance.

8) Pitching and fundraising

This workflow has the potential to facilitate the creation of a storyboard and a teaser to pitch to potential funders and investors. In this regard, PI12 provided the following example:

> *'Yes, let's take in example the idea of using a crane...Guys, this is how it would look like if we take the cherry-picker and do the shot from top to bottom. To do so, we have to spend £1,200 or more because we need the crane and three operators. That's it. What do we do? Do we spend it or not?*' PI12, cinematographer.

Furthermore, as explained by PI08, this application can have the following benefit:

> *'Empower beginning or mid-career directors who want to be ambitious and are trying to push the limits and are very creative, very innovative, and are looking at creating something that doesn't exist and they might not have the resources for. I think it's for visionaries'* PI08, director.

9) Communication among crew members

PI12 (cinematographer) offered an example of his relationship with the key grip, who is responsible for positioning and setting lights to illuminate the scene as desired by the cinematographer:

> *'Sometimes you explain all the work to the key grip and he doesn't remember everything you explained to him. At the end of each scene, you have to explain it all over again, and sometimes you have to talk to the director, to the client, you are busy with other things*' PI12, cinematographer.

This process is usually implemented verbally or with a roughly drawn scheme. However, it is not rare for one of the people involved in the conversation to forget some details and information about the setup. The participant speculated that providing key grips with a VR device on set so that they can immerse themselves in the pre-visualisation of the lighting setup would lead to better and more effective communication and would reduce delays and risk of mistakes. A similar principle can also be applied in other contexts. One example is the collaboration between the cinematographer and director, where moving virtual cameras, cranes, lights, and props can be completed more efficiently and transparently.

4.7.4 Description of the conceptual workflow

In the second part of the interviews, participants were verbally presented with the concept of using *VP* to facilitate collaboration among all crew members within the same virtual environment during the pre-production phase. The discussions with participants helped to expand and refine this concept into a more *articulated* conceptual workflow for *SMPs* that involve shooting in real-world locations. This workflow consists of three main steps, illustrated in Figures 4.2 and 4.3.

The initial step in the conceptual workflow involves capturing data of the real location to create a virtual replica where all crew members can collaborate. This can be achieved through techniques such as photogrammetry or LiDAR technologies. The second step requires users to set up and prepare the virtual location by importing all the assets required for the project, which were not included in the digital capture conducted in step one (e.g. pieces of furniture not present in the real location). Special attention was given to ensuring flawless compatibility among different formats of the 2D/3D assets for import, eliminating the need for additional format conversion or extra steps to make them work. To enhance accessibility and usability, both the digital replica of the location capture and all other assets should be available on the cloud, allowing retrieval from any device with access to the project. The third step is the actual collaborative phase, enabling crew members to start pre-production activities within an immersive environment (the digital replica of the shooting location). This can be done remotely, granting them the ability to rapidly iterate through various creative and technical decisions. It was mentioned also how different roles within the crew would require different toolsets to execute their tasks and activities. For instance, Cinematographers would appreciate access to various lighting options to set up their preferred light design.

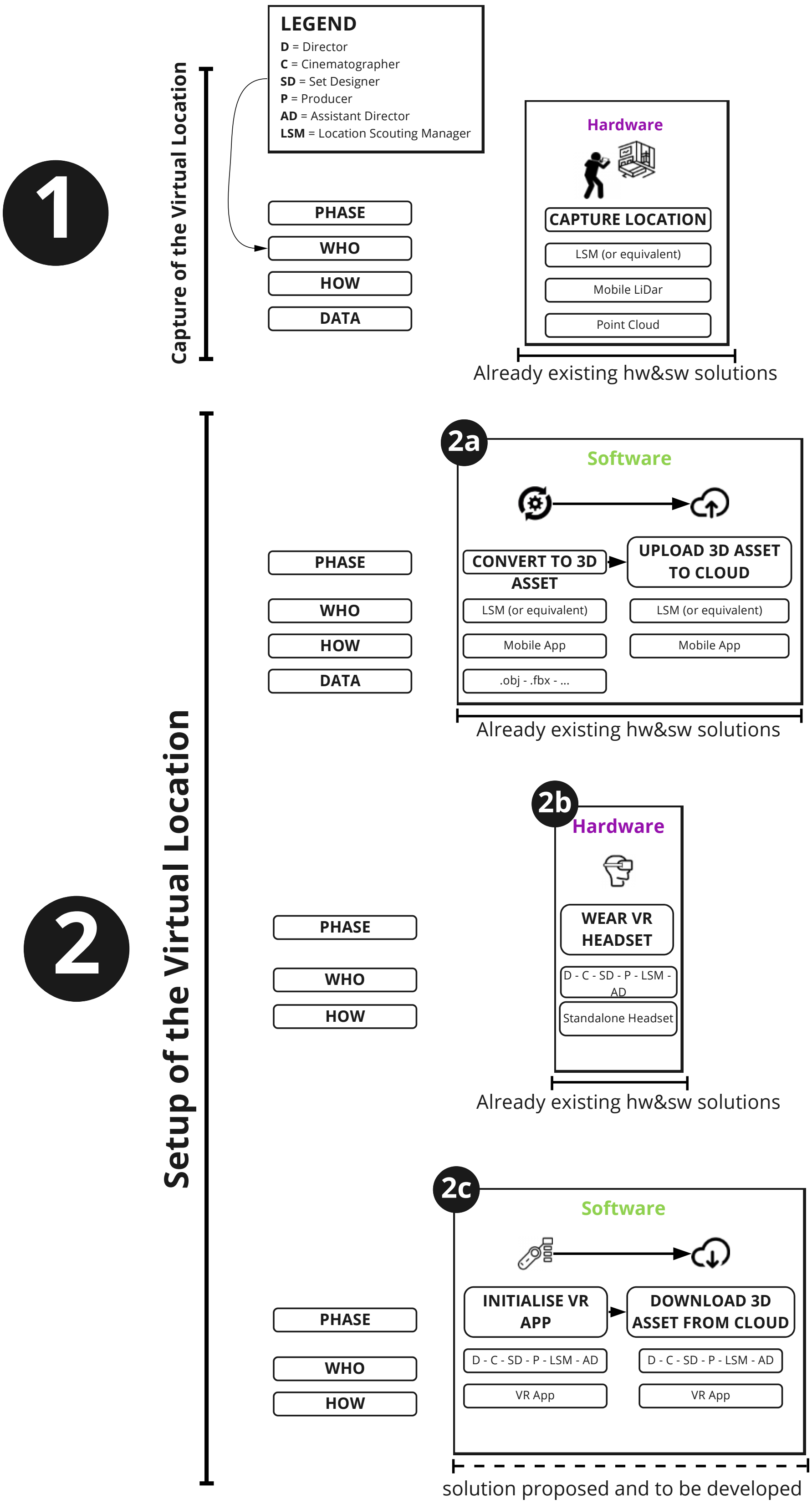

Figure 4.2 Conceptual Workflow Incorporating Ideas and Feedback (Phases 1-2)

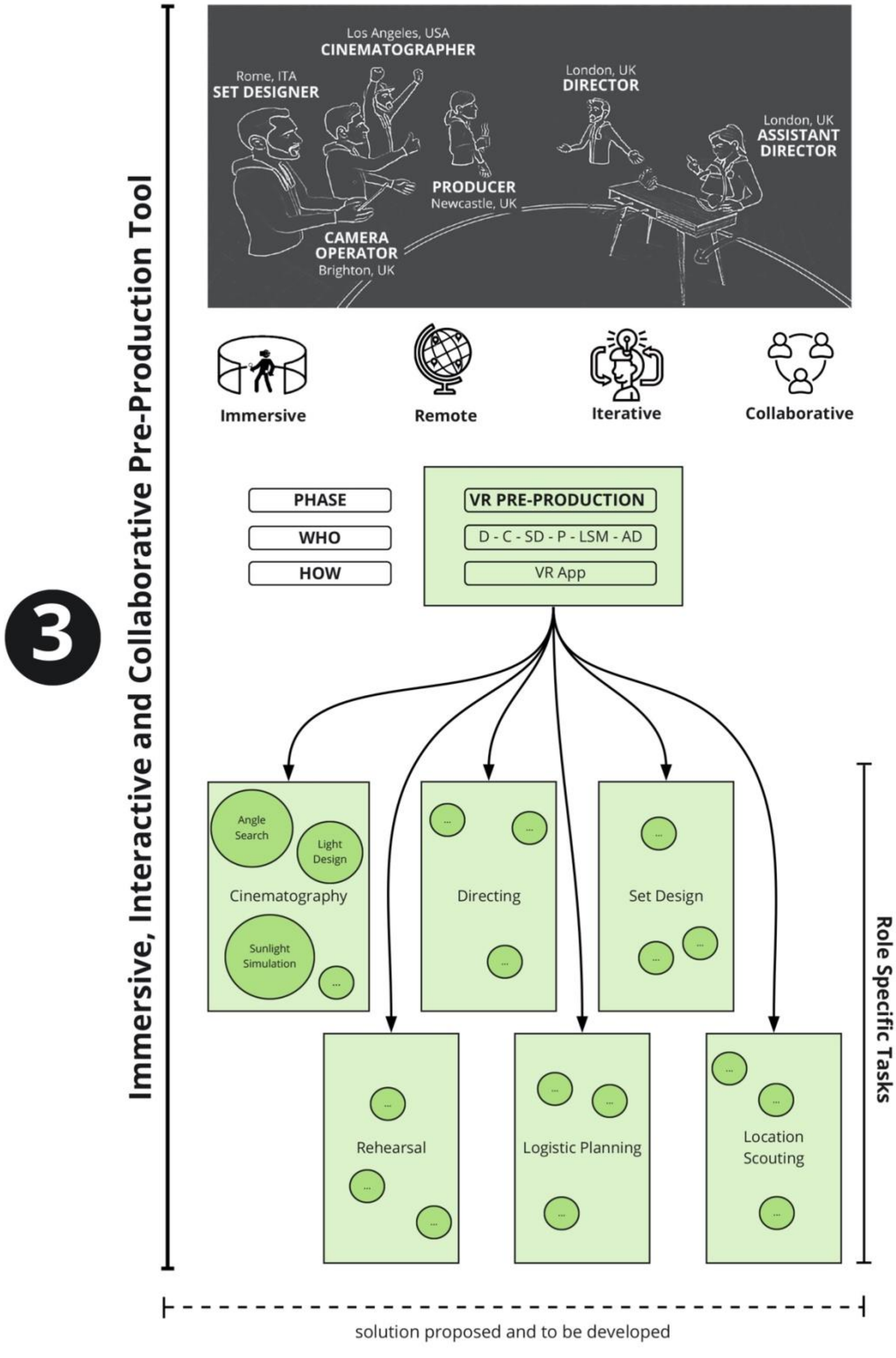

Figure 4.3 Conceptual Workflow Incorporating Ideas and Feedback (Phase 3)

4.7.5 Feedback on the Proposed Conceptual Workflow and Additional Insights

The positive feedback and comments received from all participants on the initial proposed conceptual workflow were used to add elements to what initially ideated by the researcher and to strengthen the concept. The result of the integration is illustrated in Figures 4.2 and 4.3, which are conceptually part of the same diagram.

The visual quality of the digital location captures, which were obtained via either LiDAR scan (Alban, 2021) or photogrammetry (Figure 4.4), when showed to participants, were highlighted as critical by participants during the interviews. Similar remarks were offered about the integration of all other relevant virtual elements in the scene at later stages of the production process.

Figure 4.4 LiDAR Textured Mesh (left) and Wireframe (right)

The trade-off between affordability and output quality of the available digital capture mobile hardware and software meant that it was necessary to evaluate whether this conceptual workflow could be beneficial for film professionals. Most participants thought that having the ability to move freely in a 3D space (through the six-degrees-of-freedom movements allowed by many standalone VR headsets) is a greater benefit than having a high-fidelity representation of the location without the freedom to explore the surrounding space.

Cinematographers also remarked about the quality of the virtual lighting simulation. Simulating reflections and proper lighting has long been a challenge in real-time

CGs. Participants noted the potential detrimental effect of inconsistency between pre-visualisation and the real production scenario, particularly in receiving misleading information. Nevertheless, having the opportunity to place lighting equipment in a virtual location was considered useful to gain a better understanding of the space required for lights and other lighting-related equipment, such as stands, booms, flags, and jibs.

'*Even without realism, if I place a light from above, representing roughly the lighting effect, the director can fill the gap of the lack of representation with his imagination to visualize how it would look on set in reality'* PI12, cinematographer.

The proposed workflow is intended to allow AV professionals to pre-visualize locations and prepare for production. Consequently, access to high-fidelity representations is not a priority, as the pre-visualization output is not the final output from the project.

The potential to collaborate remotely, seamlessly, and in real time within a digital representation of the location was also considered useful by participants. To better explain this feature, they referred to *Google Docs* (Google, 2021), a web application which allows different people to work in and edit the same document in real time. This further suggests the importance of potential security and privacy issues for a future platform implementing the proposed workflow and the need to establish a permissions system for edits and revision history.

The Importance of Ease of Use

An important aspect that was emphasised by the majority of participants was the ease of use of such a workflow. As they expressed, poor usability can be a dealbreaker for the proposed conceptual workflow. Learning a new workflow and related software is a tedious and time-consuming process with which potential users are not necessarily willing to engage.

'*I foresee there might be a gap between an independent filmmaker wanting to use this technology and himself actually being able to manage it…Many independent filmmakers are in a way…they simplify greatly, they greatly simplify things and the workflow because of the condition of the productions or budget or maybe even people. Moreover, they are okay to do so to get the movie done'* PI03, cinematographer.

'*How long would it take? How complicated is it? What the learning process would be for someone who isn't necessarily experienced in visual effects or 3D modelling?'* PI08, director.

Therefore, participants suggested that they should be actively involved in designing intuitive UIs when the workflow is implemented to reduce the slope of the learning curve and facilitate rapid progress for all users.

The Importance of Pre-Existing Tools

An aspect that surprised participants was the current availability of key components of the proposed conceptual workflow through existing competitive hardware and software that is affordably priced for SMPs with limited resources. Making participants aware of such tools increased their interest, and they were involved as beta testers of the first version of the prototype.

The Importance of Uniqueness

Another aspect highlighted by PI03 (cinematographer) is that the most thrilling and exciting part of filmmaking is often the unexpected. PI03 explained that observational documentaries are rich in unique and fortuitous moments, such as the genuine reaction of the people interviewed or spontaneous events happening in the area while shooting. However, he also stated how: '*even if it's a documentary, there could be sequences that are more constructed and even slightly rehearsed. Furthermore, this tool can help that too. So it can be used on documentaries as well. I wouldn't rule it out*' PI03, cinematographer.

The Difference Between Location Scouting and Location Recce

Participants mentioned the confusion among professionals about the terminology used to describe pre-production phases, including location scouting, which refers to that phase where potential locations are considered and proposed; this initial phase is oriented towards meeting the director's creative vision. *Location recce* (derived from the military term *reconnaissance*), which is sometimes used interchangeably with *tech scout* (abbreviation of *technical scouting*), consists of visiting the chosen location in person. This phase allows personnel to collect important information that cannot be determined in the previous phase, such as logistics, natural lighting, power sources, hazards, space for make-up or wardrobe rooms, and noise that may affect the audio recording quality, among others.

4.8 Chapter Summary

This chapter described the exploratory study (DS-I) required to identify the key daily challenges faced by directors, cinematographers, and producers during pre-production by qualitatively analysing remote in-depth interviews with AV professionals (PS-I).

Potential uses and benefits of using immersive technologies in the current pre-production workflow were discussed by participants and based on that a conceptual workflow was co-designed and represented visually in the form of a diagram.

The following chapter describes a new study (DS-II) that confirms the conclusions that emerged from the analysis described in DS-I and PS-I and presents initial co-design ideas regarding integrating immersive technologies into the participants' current workflow.

Chapter 5

IDEA CO-GENERATION

(DS-II, PS-IIA, PS-IIB, PS-III)

5. Idea Co-Generation (DS-II, PS-IIA, PS-IIB, PS-III)

5.1 Introduction

The exploratory study paved the way for structuring a more interactive and productive phase: co-design workshops.
Two workshops were conducted remotely, thereby providing an example of successful strategies for online implementation of co-design workshops during the COVID-19 pandemic. The workshops united a diverse group of AV professionals who work on small and medium-budget projects not involved in the previous study, except for one participant that helped recruit additional participants.

In this second study it was decided to re-open the conversation on how VP could impact not only the pre-production phase but also production and post-production. Despite the literature indicated how pre-production is the phase benefitting the most from novel VP processes, because of the co-design workshop are still a conceptual phase of the research process, it was considered as appropriate to do not limit participants imagination and creativity.

The first workshop led to identifying pain points in existing filmmaking workflows (DS-II), and the second generated several innovative concepts (PS-IIA and PS-IIB) with a potential for further development and testing in operational settings (PS-III).

5.2 Aim

The study prompted participants to generate collaborative ideas that build on immersive technologies and offer the potential to improve existing AV production workflows. Identifying an effective research approach and design method was central to fostering this creative process.
Co-design was deemed appropriate to facilitate the generation of innovative and useful designs that respond to stakeholders' needs (Steen, Manschot, & De Koning, 2011) and to instil a sense of ownership and empowerment in the participants (van Rijn & Stappers, 2008). Concurrently, the role of the facilitator is not to be

underestimated. The facilitator is responsible for providing the correct tools and methods to enable non-designers involved in the design thinking process to generate and express their ideas (Sanders & Stappers, 2008). In relation to this study, the facilitator organized a series of design thinking workshops to motivate participants to explore innovative uses of immersive technologies in VP processes.

Design workshops are well suited for idea generation (Broadley, Cara, & Smith, 2018; Avital, 2011) in that they allow the participants to more effectively express the often tacit and implicit aspects of their working habits (Sleeswijk-Visser, 2009) and to share anecdotal experiences with others. The co-design workshops were carefully designed and operated via online collaborative software boards (Mural.com). The boards were implemented to encourage participants to freely yet consistently express their opinions and ideas through a predetermined sequence that maintained focus in the discussions. In particular, a set of sequential activities was designed and implemented to guide participants in transitioning from one activity to the next (Figure 5.1). According to Sanders, Brandt, and Binder (2010), this sequential aspect is critical to the successful execution of co-design workshops.

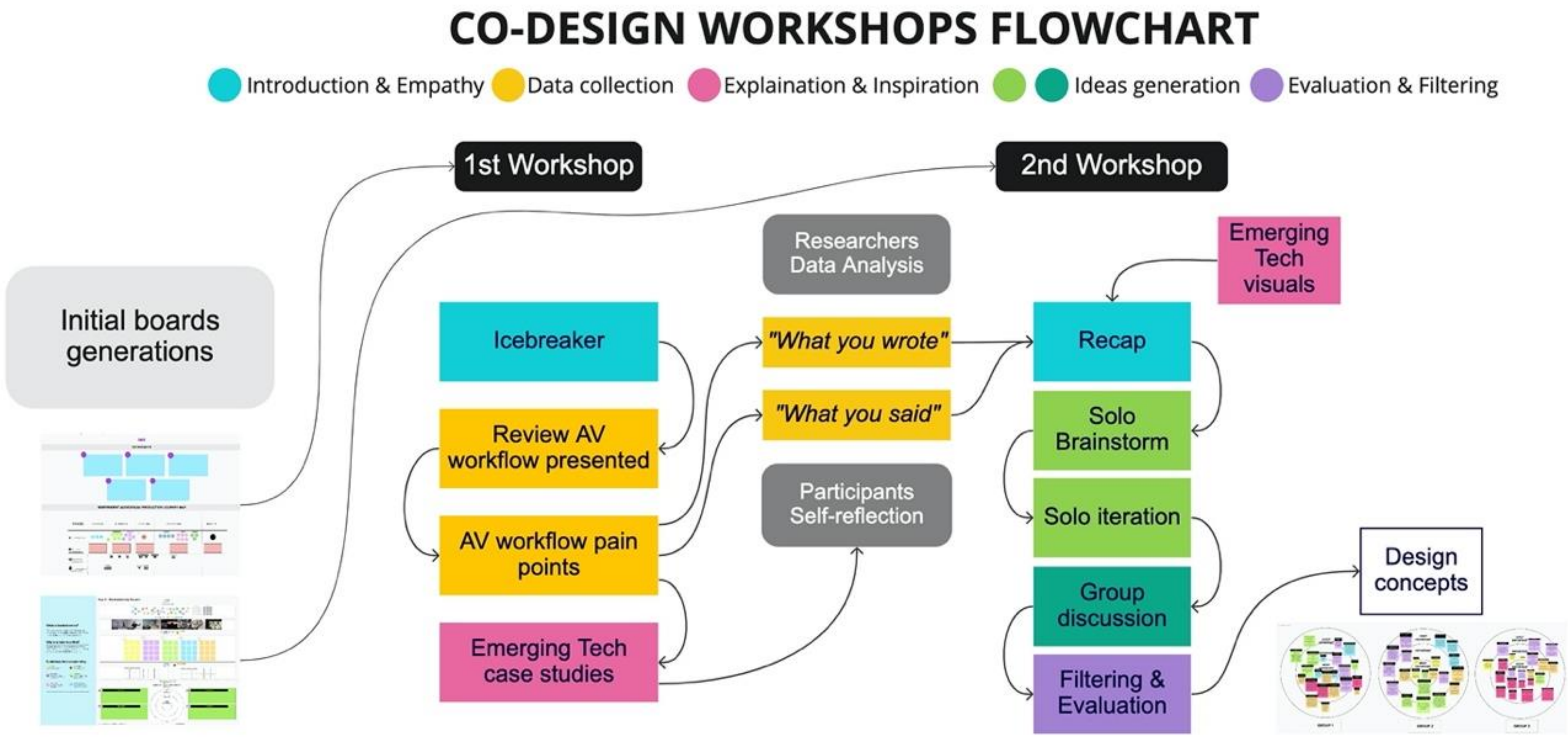

Figure 5.1 Flowchart of the Co-Design Remote Workshops

5.3 Participants

To co-design effective and innovative concepts, the involvement of professionals working in the AV industry, including directors, cinematographers, producers, and editors, was essential (Table 4). The participants were based in the US (2), UK (3), and Italy (10).

Table 4 Summary of the Participant Pool (Workshops)

PARTICIPANT	GROUP	ROLE	DESCRIPTION
PW01	GROUP 1	Cinematographer	Operating cameras and lighting on set, working closely with directors
PW02		Cinematographer	Operating cameras and lighting on set, working closely with directors
PW03		Editor	Working mainly on documentaries
PW04		Producer	Overseeing the entire production process of fiction and documentaries
PW05		Sound designer	Working closely with directors in producing the audio component for documentaries
PW06	GROUP 2	Producer	Overseeing the entire production process of fashion commercials
PW07		Producer	Overseeing the entire production process of fashion commercials
PW08		Producer	Overseeing the entire production process of fashion commercials
PW09		Director	Directing commercials, music videos, and fiction
PW10		Editor	Working mainly on commercials and TV series
PW11	GROUP 3	Archive producer	Overseeing the production and post-production of documentaries
PW12		Producer	Involved during the development phase of a project and actively seeking funding
PW13		Animator	Working as animator on fiction and independent games
PW14		Director	Directing short-films and art installations and actively seeking funding
PW15		Producer	Working on the business side of film or TV projects

Through the involvement of a range of professionals across AV roles, diverse knowledge, perspectives, and skills were combined, which created favourable conditions for identifying solutions to complex problems (Meroni, Selloni, & Rossi 2018).

Three groups, each composed of five participants, were recruited for the workshops. This choice of group size is in line with recommendations in the literature concerning remote collaborative workshops and reduces the risk of technical issues interfering with the creative processes (Flynn, Albrecht, & Scott, 2018; Daniels et al., 2019).

Two groups included participants who had already collaborated with each other on previous projects. This strategy was meant to facilitate more effective and honest communication compared to groups whose participants were unfamiliar with each other, as this reduced the risk of individuals feeling embarrassed or judged by others during the activities. There was also an expectation that the group dynamic could be favourably impacted by participants' ability to recall common experiences on previous projects, which could encourage them to share different viewpoints. This is in line with observations during the implementation of the workshops. As documented in Muller and Druin (2003), stories can be effective in opening conversations, as they often encode details about user habits, needs, pain points, expectations, desires, and additional contextual information that can be particularly meaningful when addressing a design problem.

5.4 Procedure

Conducting in-person (as opposed to remote and online) co-design workshops has advantages in the depth of the input generally received from participants through the enhanced sense of cohesion within each participant group and through the availability of a richer set of communication channels, including non-verbal cues. In-person workshop discussions often result in more spontaneous reactions and more genuine answers to questions (Brüggen & Willems, 2009).

However, the COVID-19 pandemic placed unprecedented constraints on fieldwork activities, which prompted researchers to identify new ways of collecting data from participants (Slingerland et al., 2022; Bakırlıoğlu et al., 2020; Ali et al., 2021). A useful online document, which was crowdsourced and manually curated, details remote fieldwork methods employed by social researchers worldwide during the COVID-19 pandemic (Lupton, 2020). The document covers a range of communication channels, including online discussion platforms, and has proven useful during the design of this study.

Similar to other researchers' findings, this thesis argue that the execution of remote online co-design workshops can increase participant access to in-person activities by lowering potential barriers associated with travel time and cost (Zhang et al., 2022) and therefore may allow researchers to engage with participants around the world (Bertran et al., 2022) or with hard-to-reach populations (Blomkamp, 2018). Such a degree of accessibility was particularly relevant to professionals who were willing to engage in this study in the absence of financial compensation.

The implementation of remote online co-design workshops in this research presented challenges that, if not uniquely associated with reliance on an online medium, were compounded by it. In particular, keeping participants continuously engaged online despite potential distractions in their domestic settings was a priority for the facilitator that proved critical to the successful implementation of the co-design activities. Attention was paid to whether prior professional relationships were in place among participants to achieve a balance between groups in which participants were not familiar with each other and those consisting of participants with prior shared professional experience. Two of the three groups consisted of participants who had previously worked together.

As part of this effort, digital tools, platforms, and services suitable for the implementation of online workshops were identified.

The Zoom platform proved useful for video-based participant activities because of its intuitive interface and the availability of recording functionalities. Importantly, participants were already familiar with Zoom, which reduced friction and enabled a smooth execution of the online activities. Audio recordings were processed using the Trint software, and transcriptions were proofread and edited.

In addition to the Zoom video-call service, other collaborative online platforms (Miro,Mural, & Klaxoon) were tested by the researcher in preparation for the workshops to identify the most suitable program for replicating the whiteboards that are commonly used for in-person activities. All three platforms enabled effective interaction among participants during the online workshops by replicating common actions, such as placement of post-it notes, writing, and drawing. The browser version of Mural was selected for its ease of use.

5.4.1 First Workshop: Board Framework

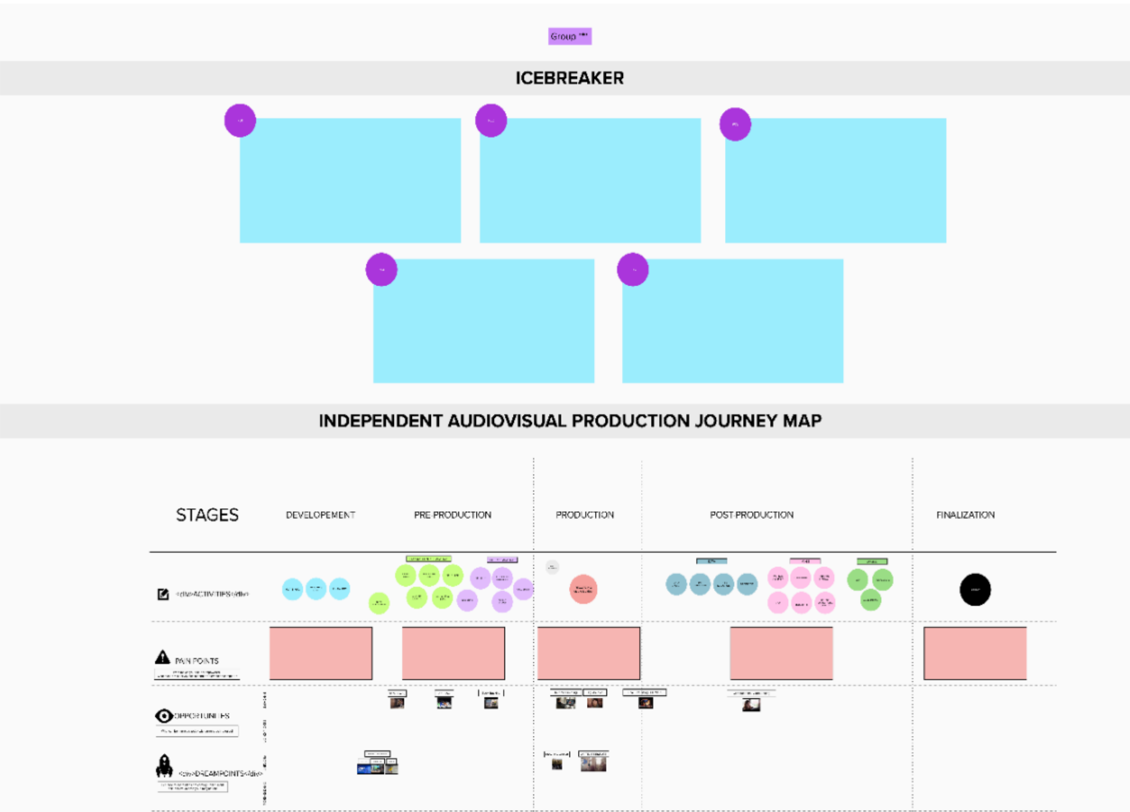

Figure 5.2 Mural Board Designed for the First Workshop

The first workshop, for which the Mural board displayed in Figure 5.2 was adopted, was implemented to achieve the following objectives: (a) introduce participants to each other, thereby facilitating the creation of an open and friendly environment; (b) discuss pain points across their AV productions; and (c) introduce participants to emerging technologies (VR, AR, AI, DTs), using existing case studies to illustrate the potential of these technologies for augmenting AV production workflows.

The first objective – creating an environment where every participant could be empowered to express themselves without feeling judged – an icebreaker activity was introduced (Figure 5.3). Icebreaker activities are commonly used for overcoming initial participant reticence and insecurity. Participants were asked to consider a science fiction object emblematic of a movie or TV series and sketch it in the box assigned on the Mural board (Tactivos Inc., 2022). In addition to building a feeling of mutual empathy, this activity familiarised participants with the functionalities provided by the platform, including navigation, selection, and drawing tools. Asking participants to focus on an emblematic science fiction object further required them to enter a futuristic mindset, distance themselves from limitations associated with existing technologies, and consider innovative ideas. The positive impact of playful tasks on creative workshop activities has been documented in Ehn (1993) and Muller (1993).

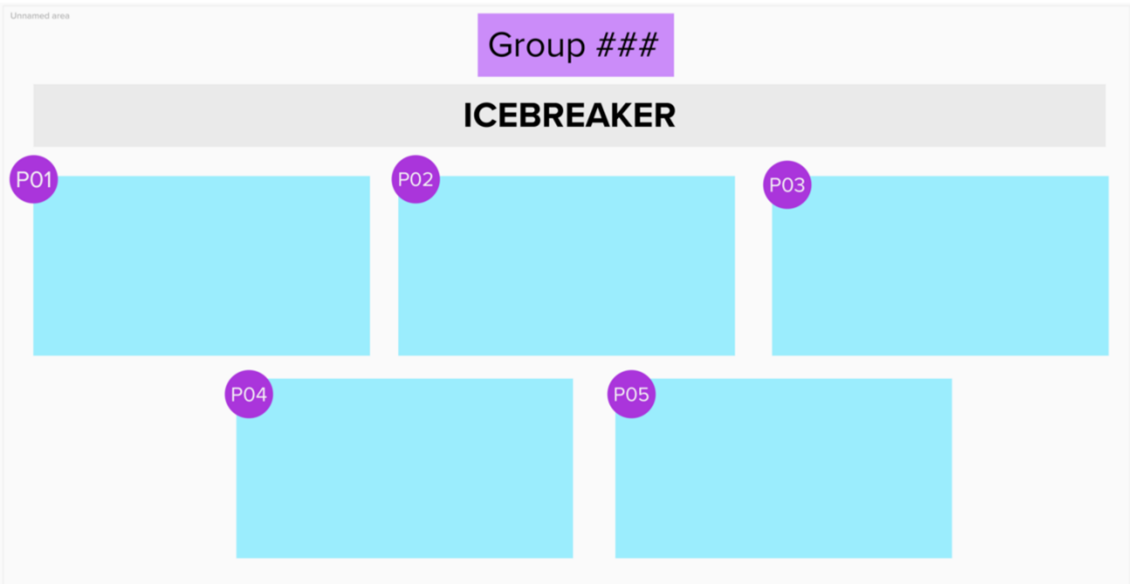

Figure 5.3 Board Used for the Icebreaker Activity

Following the icebreaker, participants were asked to express their opinions regarding the next section of the Mural board by focussing on the existing linear AV production process, which is common in the AV industry and consists of sequential stages including development, pre-production, production, post-production, and finalization (Figure 5.4). Participants were shown the results of a study on immersive technologies for VP based on one-to-one exploratory interviews with AV professionals (Bodini et al., 2023), which allowed them to evaluate the outcomes from the study and allowed the researcher to gather additional opinions and thoughts in relation to potential applications of immersive technologies for AV production.

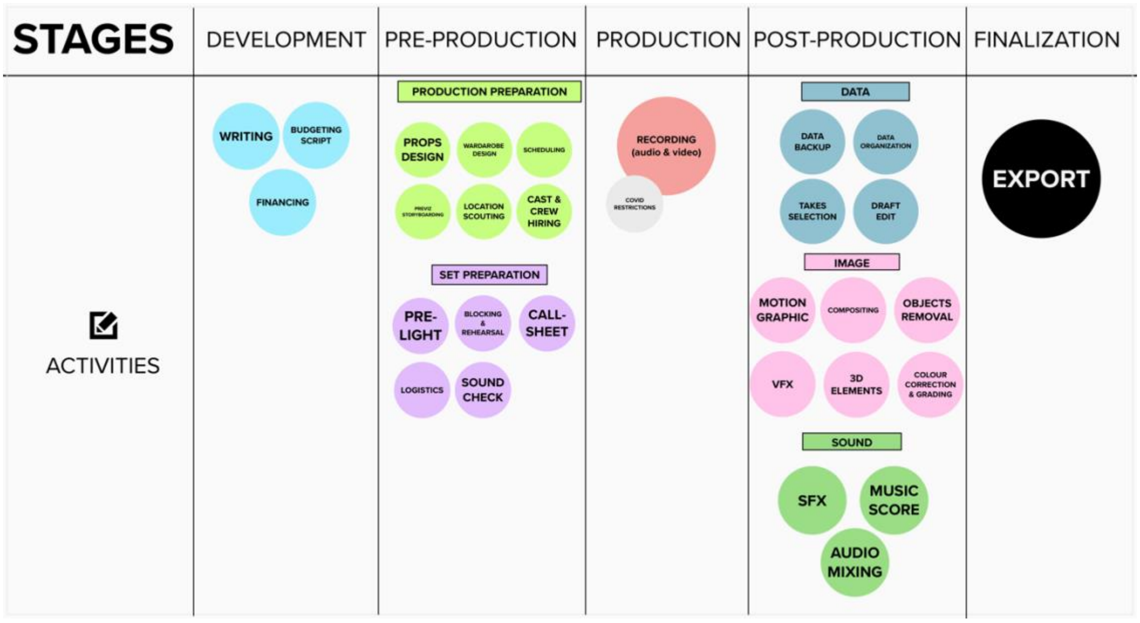

Figure 5.4 Stages of the AV Filmmaking Process Identified in DS-I

Afterwards, participants were asked to reflect on the obstacles they encounter throughout the AV production process (Figure 5.5). This resulted in an open discussion where participants elaborated on their current pain points and shared relevant anecdotes from previous projects.

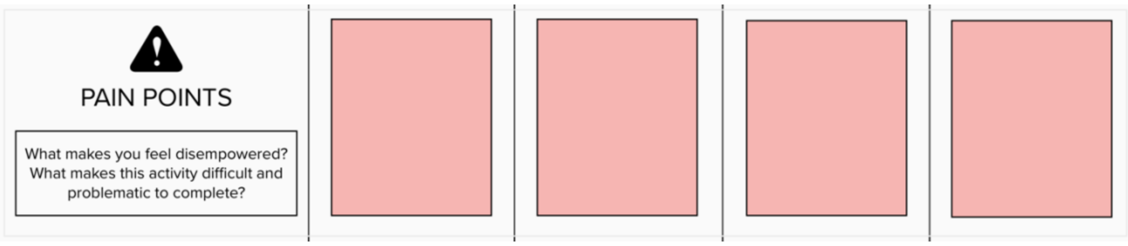

Figure 5.5 Boxes to Record Challenges Faced in Existing AV Production Workflows

The final activity of the first workshop focussed on presentation and discussion of case studies in relation to high-end VPs, such as *The Lion King* (Giardina, 2019) and *The Mandalorian* (2019; Seymour, 2020). The emphasis was on the role played by immersive technologies (VR, AR, XR), real-time game engines, and a broader range of emerging technologies, such as those enabling automated image generation based on descriptive text. Artificial intelligence (AI) algorithms such as DALL-E (Ramesh et al., 2021), its iteration DALL-E 2 (Ramesh et al., 2022), and Imagen (Saharia et al., 2022) are considered potentially disruptive to the media industry and have attracted attention in recent years (Newton, 2022).

To further inspire participants, recent developments in DTs applied to humans were mentioned and explored with the participants. This included a discussion of MetaHuman (Epic Games, 2022), a freely available cloud-based application from Unreal Engine that facilitates the creation of realistic virtual human agents for use in media productions. This phase of the workshop prompted participants and allowed them to envision design fiction scenarios (Figure 5.6).

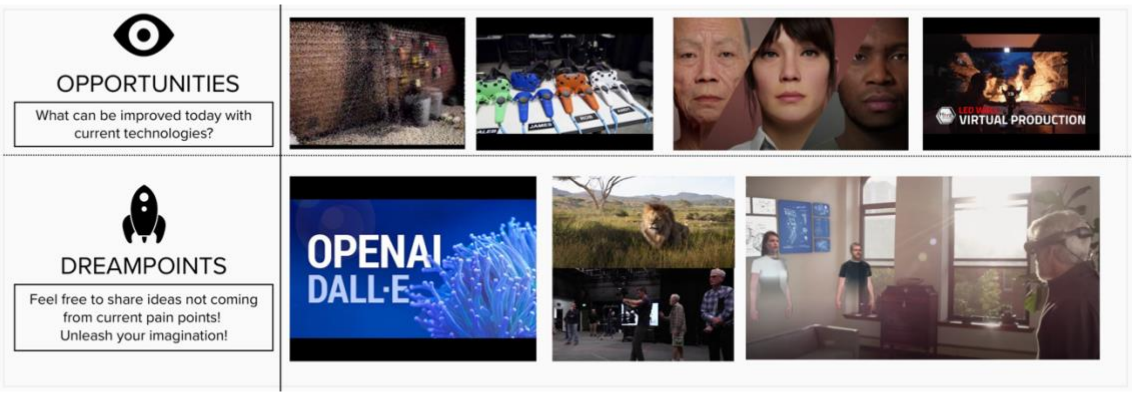

Figure 5.6 Pictures and Videos Shown to Prompt Participants

Keeping participants focussed throughout the workshops was not straightforward. Unveiling parts of the Mural board in a stepwise fashion instead of presenting the board in its entirety required participants to focus on one aspect at a time, which proved to be particularly useful. In a follow-up discussion after the workshops, one participant noted that the stepwise unveiling of the Mural board was beneficial because it allowed participants to better understand the board and reduced the risk of cognitive overload.

5.4.2 Self-Reflection Task Between the Two Workshops

A break of few days was introduced between the first and second workshops, following the recommendation from Di Stefano, Pisano, and Staats (2015), who demonstrate that self-reflection following a learning activity can improve learning outcomes. Participants were invited to reflect on previous discussions, further explore the materials that were made available to them (videos and articles on the emerging technologies that were presented during the first workshop), and return to the Mural board for refinement in their own time over the following days.

5.4.3 Second Workshop: Board Framework

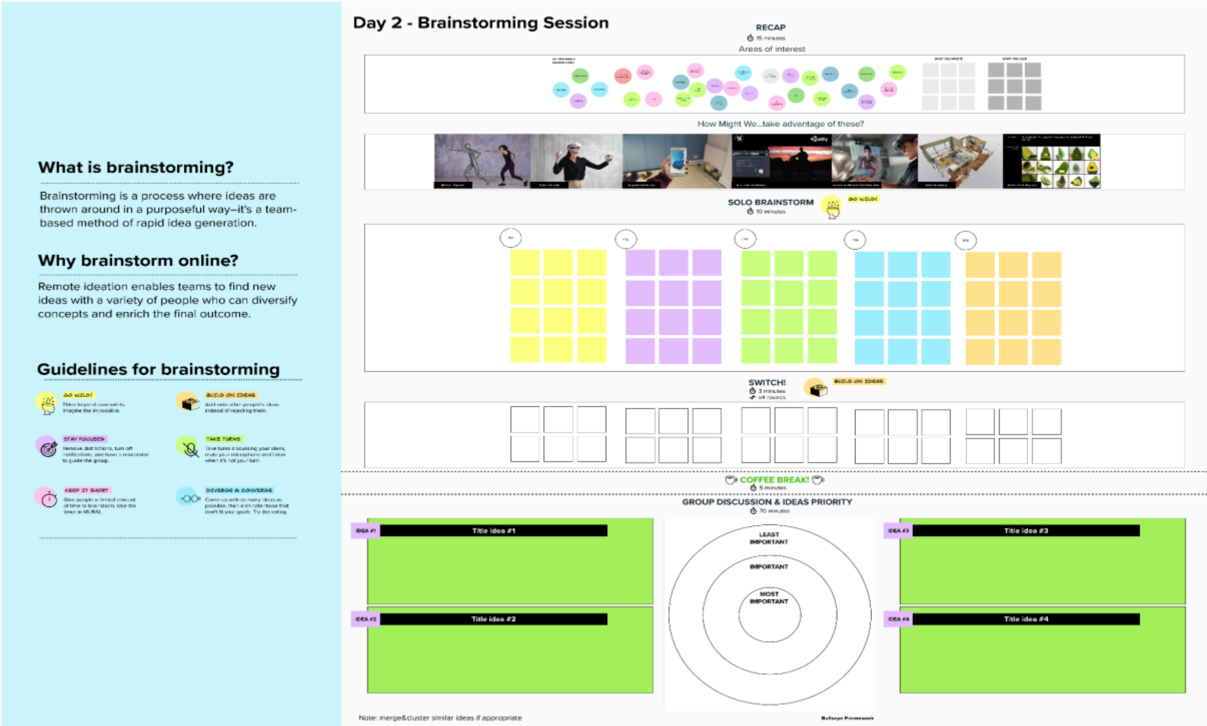

Figure 5.7 Mural Board Designed for the Second Workshop

The objective of the second workshop was to generate innovative ideas that rely on emerging technologies discussed during the first workshop. A range of activities was implemented: (a) recapitulation, (b) visual prompting, (c) independent brainstorming, (d) building on others' ideas, (e) group discussion, and (f) filtering and evaluation.

i) First, the output from the first workshop was summarized to refresh the participants' memories about the pain points previously identified (right-hand side of Figure 5.8: '*What you wrote*' and '*What you said*'). Additionally, the main phases of the filmmaking process were reported in the 'Areas of interest' box (left-hand side of Figure 5.8) to prompt participants to consider relevant works from which they could take inspiration during the following brainstorming activity.

Figure 5.8 Recapitulation of the Topics Discussed During the First Workshop

ii) *Visual Recapitulation*

Similarly, a set of images providing examples of emerging technologies were displayed in this initial phase of the workshop to further stimulate participants' imaginations and inspire them during the execution of the core activity of the workshop (Figure 5.9). During this phase, participants were also encouraged to ask for any clarifications and enquire about the technologies considered during the self-reflection task.

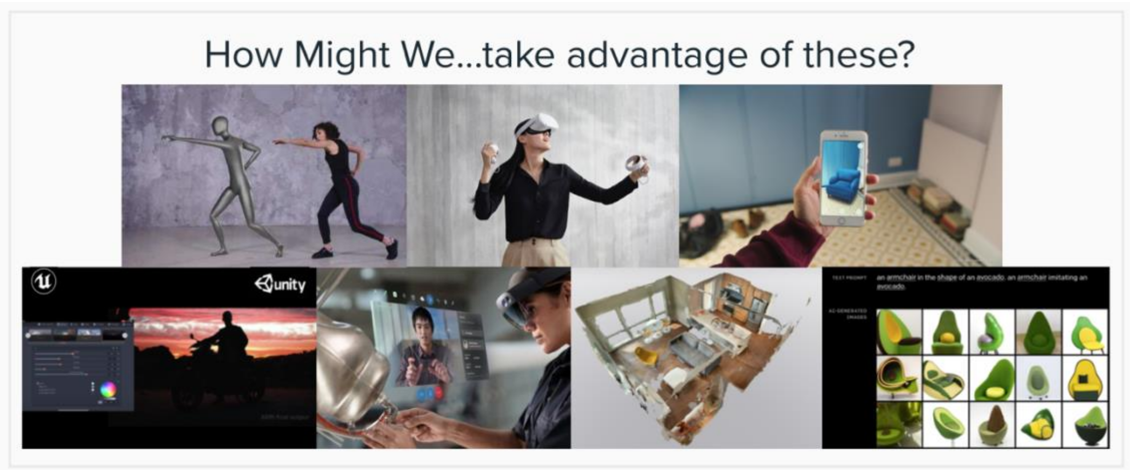

Figure 5.9 Visual Recapitulation of the Technologies Introduced During the First Workshop

iii) *Solo Brainstorming*

After the facilitator introduced the workshop, participants were given 10 minutes to independently brainstorm ideas (Figure 5.10). The Zoom breakout room feature was used to isolate individual participants for the duration of the activity. The facilitator was able to join each participant's breakout room to ensure correct understanding of the task. Additionally, the facilitator was provided with a real-time view of the ideas generated by the participants on the Mural board, and he monitored the time by using the stopwatch feature.

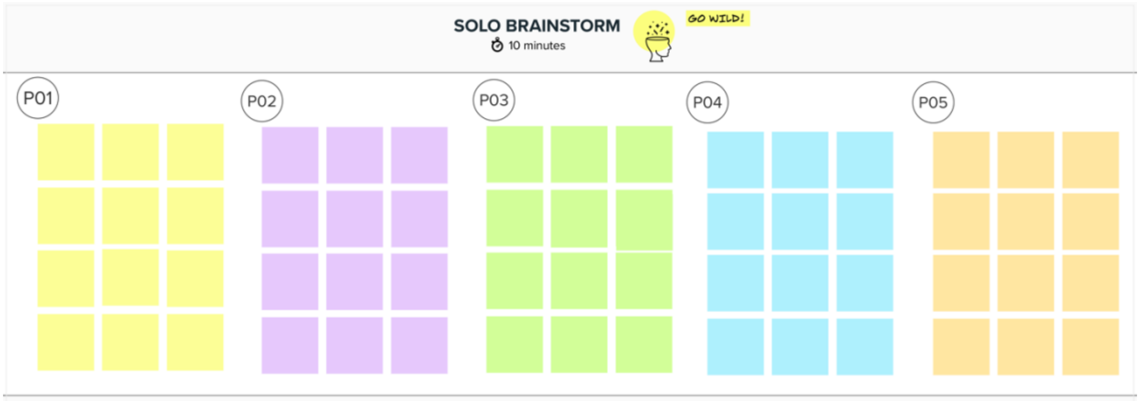

Figure 5.10 Boxes to Record Ideas During the Solo Brainstorming Activity

iv) *Idea Iteration*

At the end of the activity, all participants rejoined the Zoom group call and received instructions about the follow-up activity. They were asked to consider others' ideas and add any thoughts, comments, and critiques to others' notes on the board to expand the concepts (Figure 5.11). Each participant was allocated up to 3 minutes for the execution of this activity, which comprised a total of 12 minutes.

Figure 5.11 Boxes to Record Ideas During the Idea Iteration activity

v) *Group Discussion*

Following a short break, a group discussion occupied the remainder of the workshop. Each participant was asked to elaborate verbally on the most relevant ideas they produced.

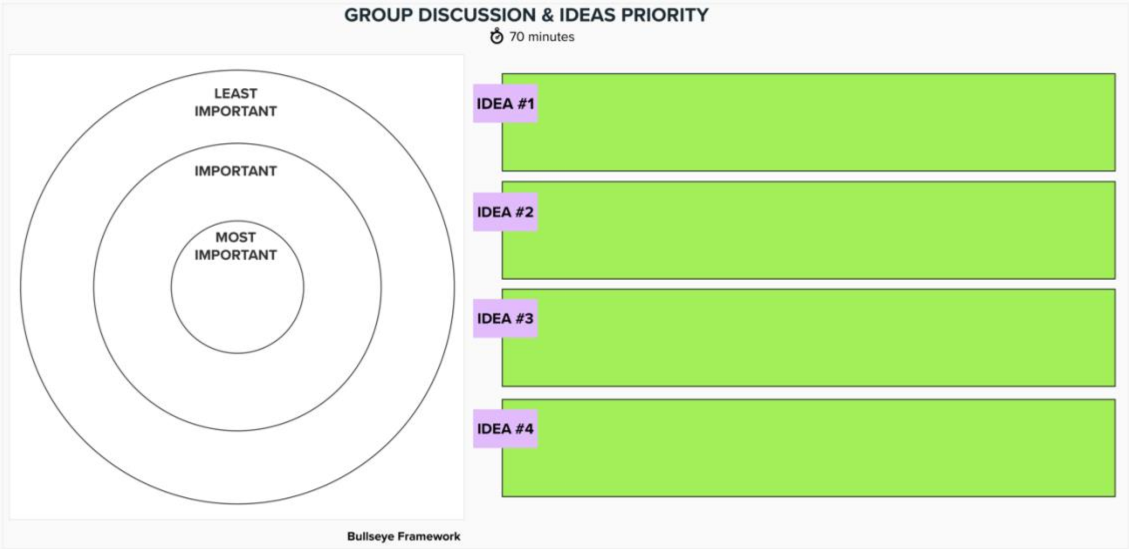

Figure 5.12 Bullseye Framework (left) and Participants' Input Summaries (right)

vi) Filtering and Evaluation (DS-IIB)

Finally, participants were asked to position individual ideas within a bullseye framework, which comprised three concentric circles labelled 'most important', 'important', and 'least important' on the Mural board (Figure 5.12). The more central the positioning, the higher the perceived relevance and value of the idea. Previous researchers have documented the usefulness of the bullseye framework for organising and prioritizing ideas (Weinberg & Mares 2015; Rayo et al., 2018). The bullseye framework was originally introduced by Mares and Weinberg (2014) to support commercial organizations in identifying the most promising marketing channels for business development. In this study, the framework was a visual representation reflecting an underlying scoring system, as detailed in the following sections.

5.5 Findings

After completing the workshops, the data generated (audio recordings and Mural boards) were analysed.

5.5.1 First Workshop (DS-IIA)

During the icebreaker activity, participants had a chance to understand the nature of the study and familiarize themselves with the workshop agenda. The icebreaker activity also provided time for participants to become comfortable with the Mural tools and allowed the Group 3 members to introduce themselves to the facilitator and to each other.

During the first workshop, participants were receptive to concepts presented by the facilitator and contributed little content to the Mural board while the focus was on the established AV production process. Participants added the following to the board:

- A note about l*egal paperwork* (e.g., permission to shoot in a specific location and film individuals);

- Clarifications about the difference between o*ffline editing* (transcoding the original high-quality footage to lower resolutions to reduce the computational resources required for editing) and *online editin*g (the concluding stage where low-resolution files are re-linked to the original high-quality footage and the final edit is made available for exporting);

- Clarifications about the so-called *treatment*, that is, a document used by directors to express their ideas about the visual style they want to achieve and how they intend to make the project happen from a production standpoint. If an AV product is requested by a client, which is often the case in the advertising sector, then directors are asked to compete with each other by proposing and presenting a prospective *treatment*.

- If directors are developing a project independently, then they normally rely on their *treatment* to sell their project and secure funding. This is often the case for feature films, shorts films, and documentaries.

Participants noted that different sectors of the industry may adopt workflows consisting of slightly different stages that may be arranged in a different order but agreed that the established AV production workflow illustrated was an accurate description of their professional experience. Therefore, the findings from this study are consistent with the outcomes from a previous investigation by Bodini et al. (2023).

Regarding pain points, a range of opinions was expressed. One participant (PW04, producer) highlighted a need to '*fulfil and combine all the requests coming from different departments'*, which can be complicated by unforeseen problems during production, thereby resulting in a need to '*micro reschedule based on daily micro issues'.*

A theme that emerged in relation to pain points with established AV production workflows is the need for effective communication across departments when addressing unexpected issues, both before and during the production stage. Those participants working in post-production roles, such as editors (PW03 and PW10) and archive producers (PW11) mentioned the challenges arising from processing and managing large volumes of data.

Participants also noted challenges associated with shooting in real-world locations. Examples were provided regarding the important role of accurate weather forecasts, which can make the difference between progressing, postponing, or even wasting an entire shooting day. In particular, the ability to gain prior understanding of how different weather conditions can influence the shooting outcome was considered critical for the decision-making process.

Part of the first workshop was devoted to presenting relevant VP case studies to the participants. Consequently, the facilitator was the only speaker, which left little space for participants to intervene except to ask questions or provide clarifications.

As anticipated, groups in which participants already knew each other featured more open discussion that often built on shared anecdotes from previous projects to highlight pain points and issues encountered.

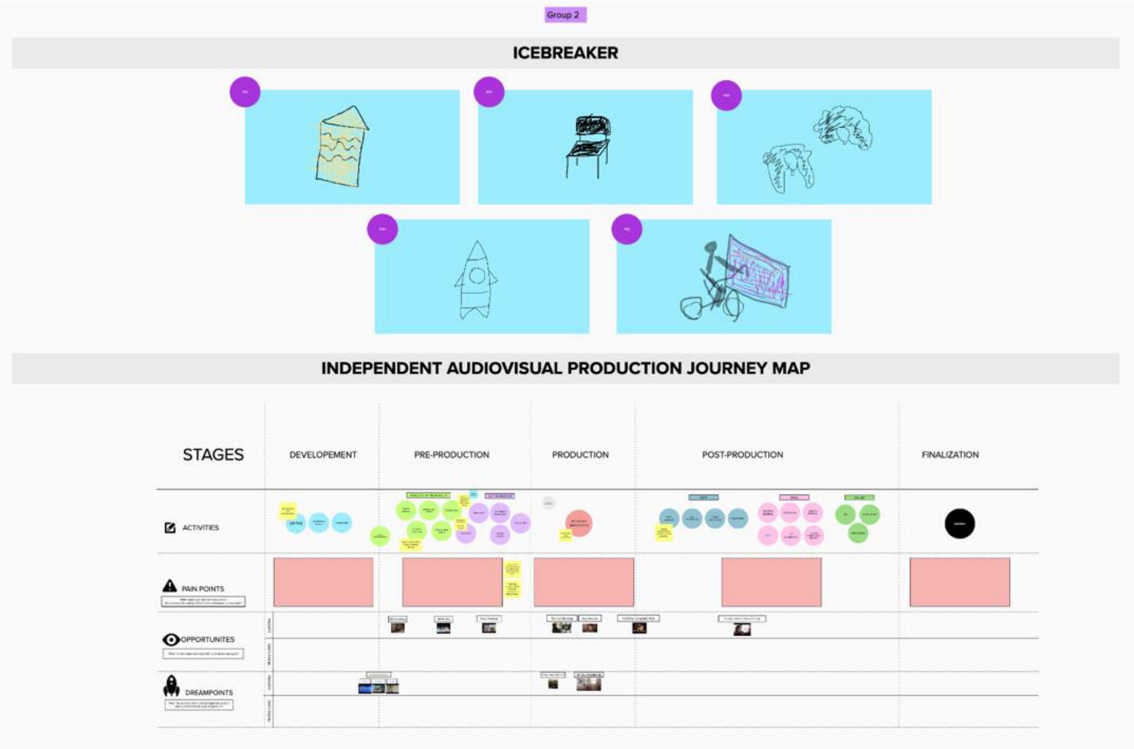

Figure 5.13 Mural Board After the First Workshop With Group 2

5.5.2 Second Workshop (PS-II, DS-IIB)

The second workshop started with a recapitulation activity to refresh the participants' memory and prompt their imagination. The facilitator reviewed participant notes that were previously placed on the Mural board ('*What you wrote'* section) and outlined the key points that emerged from the first workshop after the researcher listened to and transcribed the conversation ('*What you said'* section).

As expected, prompting participants with the recapitulation activity led to the generation of a richer dataset during the second workshop compared to the first. The independent brainstorming exercise (PS-II) was appropriately executed by all participants.

Interaction with the Mural board was frictionless, which may have been facilitated by participants' prior familiarization with the online tools during the first workshop. Moreover, the ability for the facilitator to enter and exit individual Zoom breakout rooms to check whether participants needed assistance to execute the task proved particularly useful. Similarly, monitoring time using the Mural stopwatch function was useful throughout all activities.

At the end of the 10-minute solo brainstorming activity, the number of ideas generated by individual participants ranged from three (PW05, sound designer) to nine (PW14, director).

The follow-up activity in which each participant was asked to expand on others' ideas was particularly useful for strengthening and extending the concepts initially proposed. Inviting participants to read about ideas proposed by others, which were either new or similar to theirs but expressed with different words and reflecting a different perspective, provided participants with additional sources of inspiration and enhanced the creative process. This ultimately resulted in fresh input to the original ideas generated during the workshops.

In fact, after this activity, the majority of ideas attracted additional notes from others. This included expressions of appreciation ('*Agree!*', '*Cool'*, '*Very useful!*'), questions ('*Does it exist already?', 'What do you mean?')*, and in most cases, additional input to the initial ideas ('*Not only from the point of view of a creative such as the director but also for those involved in the production department')*. In some instances, comments were meant to initiate a more structured debate (*'Some of these aspects of production need real-life evaluation…Don't you think some parts of the process will always need non-virtual dynamics?').*

During the group discussion, participants often joined the conversation and provided additional constructive input to the concept being discussed, thereby promoting the expression of different viewpoints. This dynamic facilitated the exchange of ideas, enhanced the collective thinking process, and led to a richer understanding of the anticipated benefit of future adoption of the design for the VP process. If few participants were involved in a conversation, then the facilitator invited others to join to broaden the scope of the discussion. Some concepts were presented and received few comments, while others were reviewed by several participants and underwent a more intense exchange.

Finally, participants were asked to identify a subset of ideas worthy of further development by positioning iterated ideas within the bullseye framework (DS-IIB).

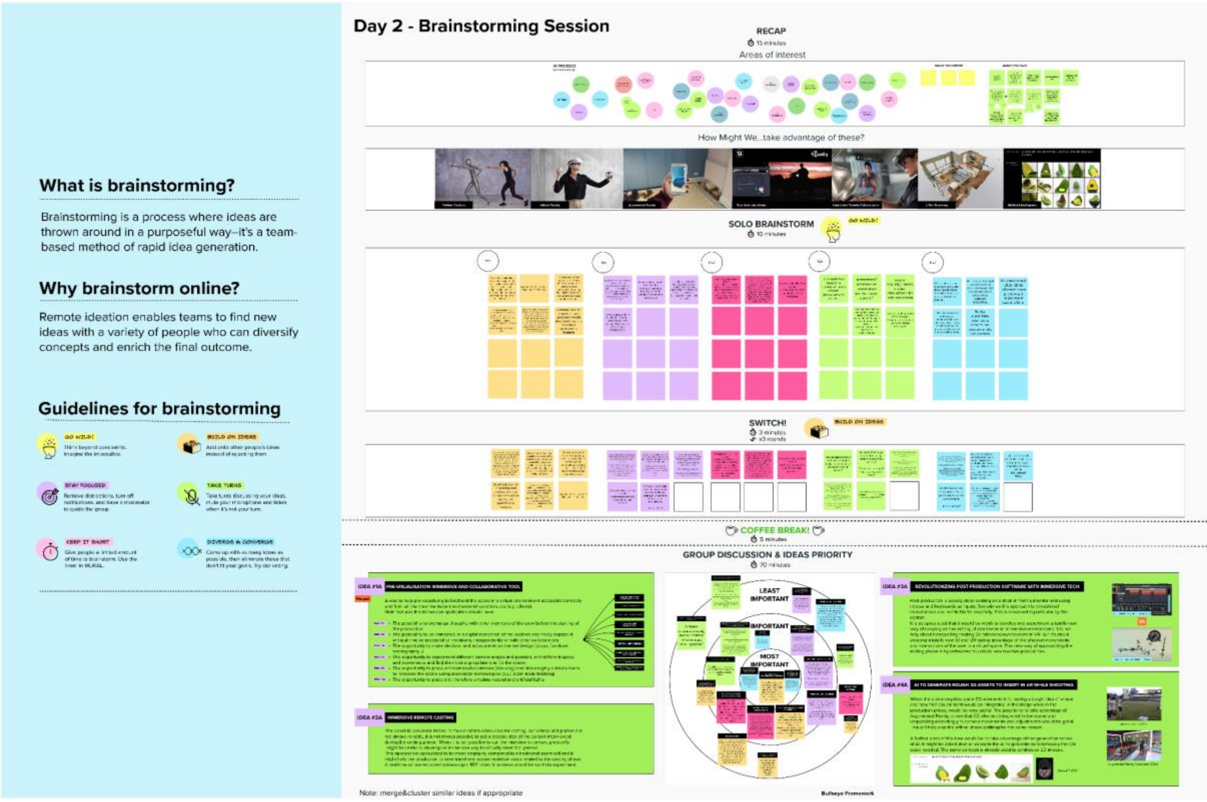

Figure 5.14 Overview of the Mural Board After the Second Workshop With Group 1

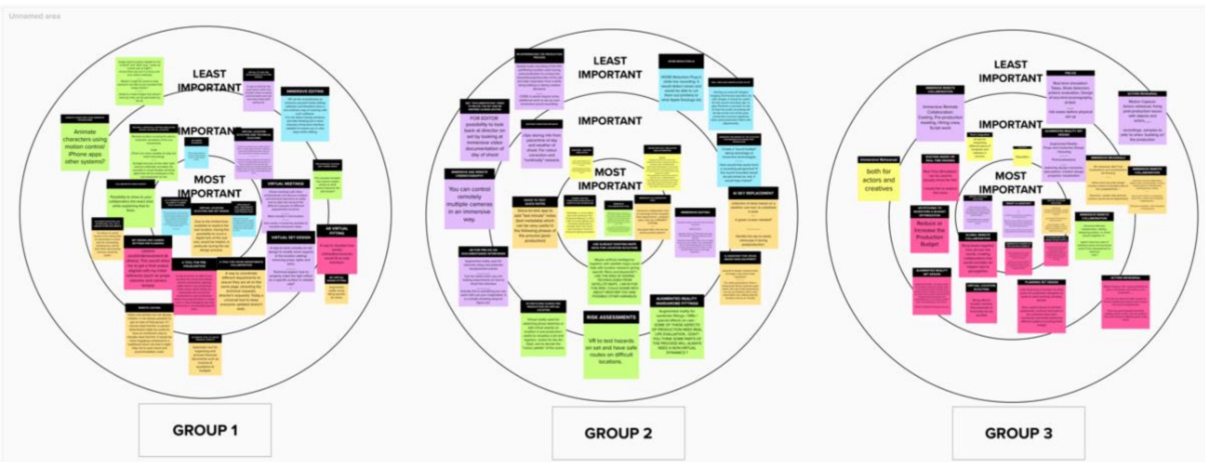

Figure 5.15 Ideas Placed Within the Bullseye Framework by Participants

A few concepts were merged or excluded from this list because they were deemed irrelevant to the aim of the study.

Each idea was assigned a score reflecting its potential usefulness as perceived by the participants. Ideas placed within the ‘Most Important’ circle of the bullseye framework were assigned a score of 3, those within the ‘Important’ circle, a score of 2, and those in the ‘Least Important’ circle, a score of 1. If an idea was generated by more than one participant within a group, then the corresponding scores were averaged (AVG_Group). If multiple groups generated the same idea, then the corresponding group-level averages were averaged to produce a total score (AVG_Tot). A final metric reflecting the perceived usefulness of each idea was obtained by multiplying the total score (AVG_Tot) by the number of participant groups in which each idea was generated (number of occurrences).
The results of the analysis of the board from the second workshop are summarized in Table 5 and illustrated visually in Figure 5.16.

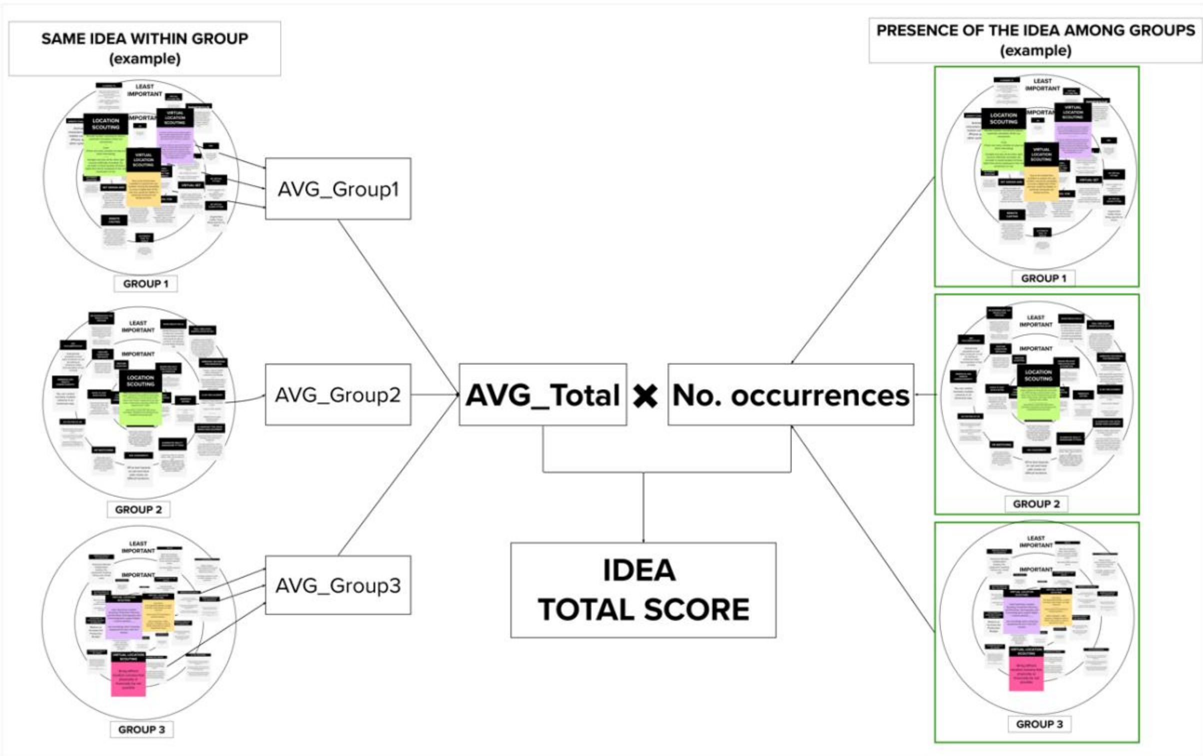

Figure 5.16 Visual Representation of the Idea Scoring System

5. Idea Co-Generation (DS-II, PS-IIA, PS-IIB, PS-III)

Table 5 Concepts Generated, Filtered, and Prioritized During the Second Workshop

#	Concept	Brief description	Bullseye's priority (avg.)	Number of occurrences among	Idea Total Score
#1	Virtual pre-production meeting	Exchange thoughts with other crew members before the start of the production.	2.33	3 of 3	6.99
#2	Virtual location scouting and location recce	Be immersed in a digital re-creation of the location and freely explore it without time or accessibility limitations, either independently or with other collaborators.	2.33	3 of 3	6.99
#3	Virtual set design	Experiment quickly with different set design layouts and facilitate decision-making.	1.5	3 of 3	4.5
#4	Virtual drone flight path simulation	Pre-plan and simulate the flight path of a flying drone.	2	1 of 3	2

#5	Virtual cinematography	Experiment with different camera angles, positions, optics, and movements.	2	3 of 3	6
#6	Actor blocking and rehearsing	Place and animate virtual actors and actresses to rehearse the scene.	1.25	2 of 3	2.5
#7	Virtual pitching	Simulate a scene virtually and pitch ideas to investors.	2	1 of 3	2
#8	Immersive remote casting	Immersive stereoscopic videos run casting remotely.	1	1 of 3	1
#9	New interactions with post-production software	Interact with the software used in post-production in an immersive way.	1	1 of 3	1

#10	AI to generate rough 3D assets and AR integration when shooting	Implement in real time, while on set, a low poly version of the objects that will be added in post-production.	3	1 of 3	3
#11	Immersive editing	Use gestures and visualize footage clips in an immersive environment.	2	1 of 3	2
#12	Re-experiencing the production process	Re-experience the filming set through a pre-recorded 360° video.	1	1 of 3	1
#13	AR for set design	Visualize beforehand how a specific object would look in the scene through AR.	2	1 of 3	2
#14	Generative AI scenarios	Use AI to predict the economic performance at the box office when casting specific actors and actresses.	3	1 of 3	3

5.6 Discussion

Conducting fieldwork research despite practical constraints arising from the COVID-19 pandemic was a complex endeavour, and identifying effective strategies to work around such limitations was a worthwhile effort that holds significant potential for future design research.

A useful review of the strengths and limitations of videoconferencing tools to facilitate qualitative research is documented in Boland et al. (2021). This study confirms some of their findings. Specifically, remote online workshops are a cost-effective method of collecting data if additional hardware and software equipment requirements are lacking. Moreover, the implementation of remote workshops using existing digital tools and services as opposed to in-person events in physical venues has the advantage of potentially lowering barriers to participation associated with travel time and cost (Forrestal, D'Angelo, & Vogel, 2017).

The adoption of a remote online approach also holds the potential to increase the speed of data collection (Kite & Phongsavan, 2017), with the only obstacle being participants' availability. A significant challenge in this study was selecting a date and time suitable for everyone, as all participants were AV professionals who opted to join this research without financial compensation and despite concurrent demands arising from their professional duties. This proved particularly difficult, as the AV industry was returning to operational levels that were closer to a pre-pandemic regime. To address this issue, workshops were sometimes rescheduled. Other researchers wishing to engage professionals in similar future research should identify suitable incentives to increase participation and facilitate workshop planning. One participant, approached again following the workshops, commented favourably on the idea of organizing future in-person workshops on this theme and stated that the opportunity to experience immersive technologies firsthand was a beneficial investment of their time.

The remote workshops conducted as part of this study were valuable in generating initial design concepts with the potential to enhance future filmmaking workflows and address some of the pain points currently faced by professionals. The adoption of a co-design approach empowered participants and generated a sense of ownership within the design process; without this approach, it would not have been possible to decode and take advantage of AV professionals' tacit knowledge to produce, iterate, and evaluate ideas as effectively as in this study.

The collaborative nature of the activities and the broad range of AV skill sets involved proved to be key enablers of a shared process of ideation and critical assessment of innovative ideas regarding the potential of immersive VP technologies.

Reliance on data collection methods that are potentially less participatory, such as focus groups, would most likely have resulted in the facilitator having to play a more prominent role in the activities, thereby potentially reducing the scope of the group discussions and limiting the creative output from the workshops. Instead, through the co-design process implemented, the discussions were primarily participant led, which created ideal conditions for generating a range of innovative design concepts.

In the first workshop, additional time could have been allocated by the facilitator to illustrate how immersive technologies can augment existing AV production workflows for smaller-scale organizations. This could have increased participant understanding and positively impacted the follow-up discussions; this will be considered for further research. Accordingly, including additional in-person activities between the first and second workshops could have been beneficial. As mentioned by Ssozi-Mugarura, Blake, and Rivett (2017), co-design '*is challenging when users have little understanding of technology*'. Therefore the main drawback of running remote (as opposed to in-person) co-design workshops is the lack of a familiarization phase during which participants – guided by a facilitator – can gain a hands-on appreciation of the potential of emerging technologies.

In the absence of restrictions to in-person interaction, studies with in-person co-design workshops would enable participants to gain hands-on experience with immersive technologies, thereby enriching exchanges of opinions and discussions. Additionally, the combination of remote online and in-person co-design activities has the potential to result in better participant understanding of immersive technologies, which can in turn facilitate the generation of innovative ideas while concurrently improving access to the co-design activities.

The next stage of the research (DS-III) focusses on assessment of the design concepts generated as part of this study with a different group of AV professionals.

5.7 Diegetic Prototypes (PS-III)

The initial concepts generated by participants during the co-design workshops, as shown in Table 5, were filtered and coded by the researcher according to the results from the bullseye framework, which was used during the workshops to evaluate and prioritize these initial concepts (PS-IIB). Furthermore, each relevant idea was assigned a score, which is also shown in Table 5. Finally, the researcher merged some of these ideas to create broader and more structured scenarios (Figures 5.17 and 5.18).

This process led the researcher to create three design fiction scenarios in the form of written stories; each one focusses on a different phase of the AV workflow:

- Scenario 1 – Pre-production
- Scenario 2 – Production
- Scenario 3 – Post-Production

As explained at the beginning of this chapter, it was considered useful to explore conceptually how VP can be employed to other phases such as production and post-production. Due to limited resources, the researcher made a decision to develop a practical prototype based on the outcomes presented in Chapter 6. In this chapter, participants were engaged through an online questionnaire to collect their preferences towards the scenario perceived as the most advantageous for filmmakers and to further develop into a practical prototype.

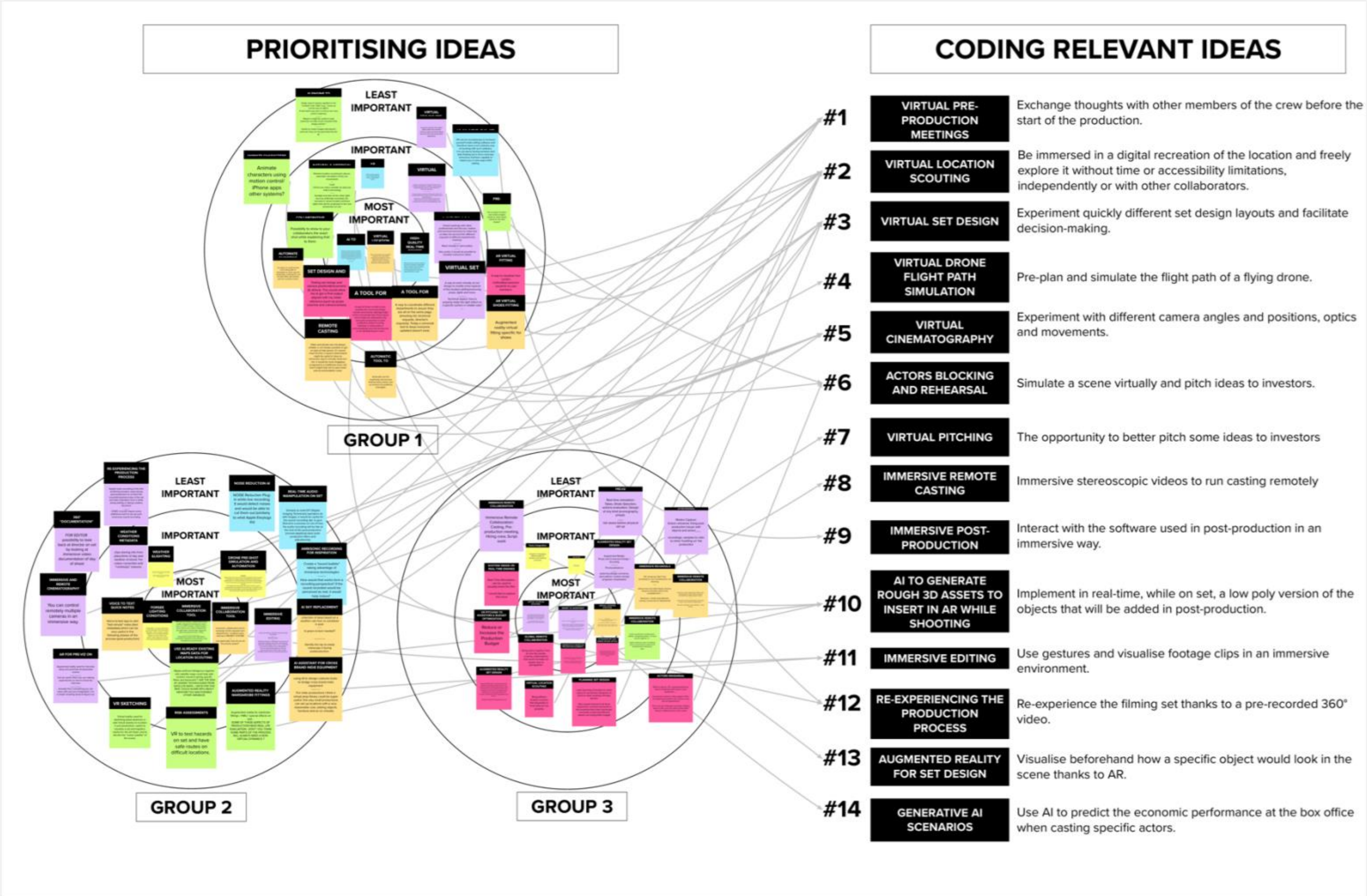

Figure 5.17 Visual Representation of the PS-III Phase (part one)

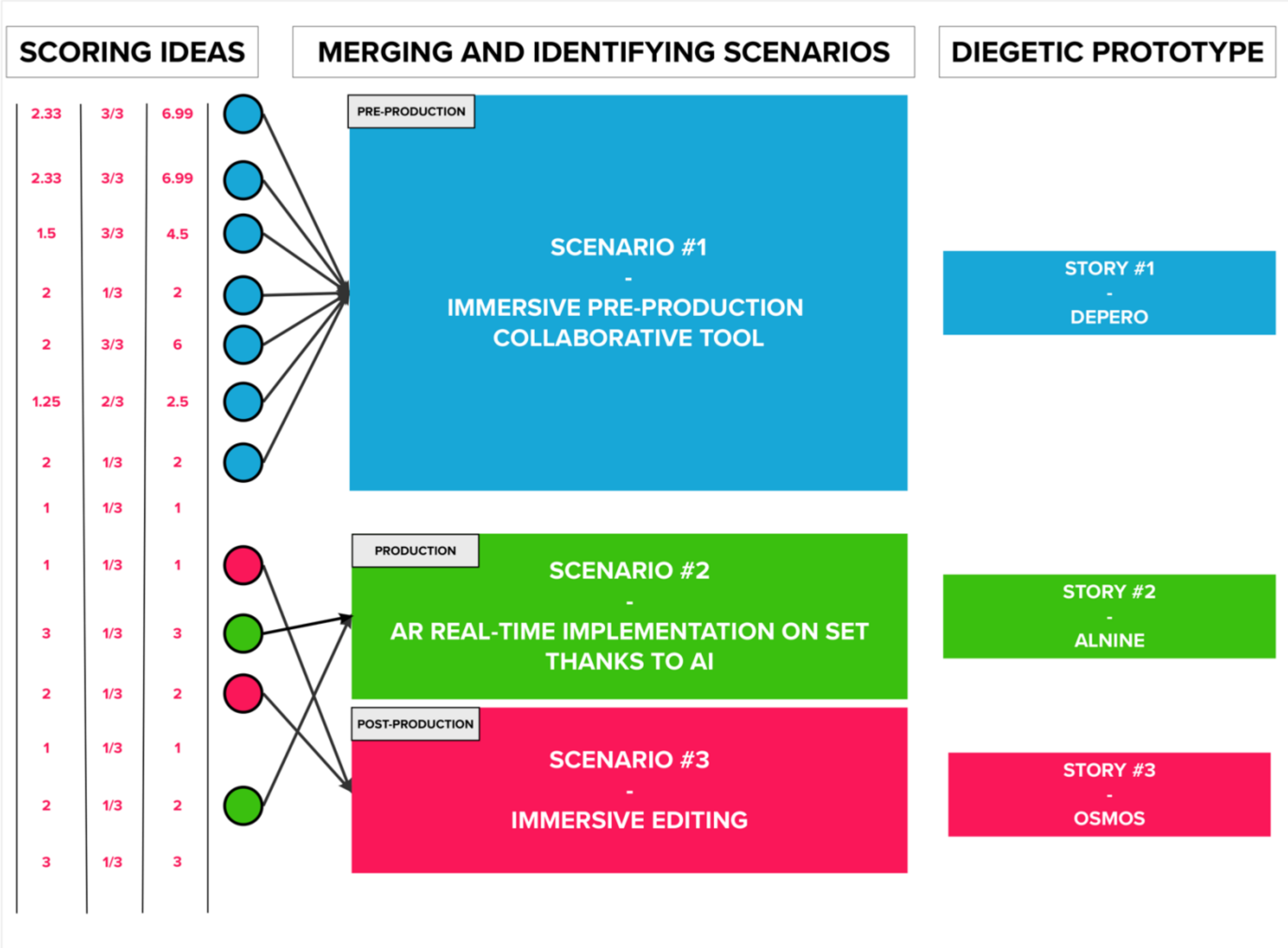

Figure 5.18 Visual Representation of the PS-III Phase (part two)

Design Fiction Scenario 1: Immersive Pre-Production Collaborative Platform

This scenario is the result of several specific ideas that were merged and included in a broader concept. The role of a digital replica of the filming location was seen as central because it enables several pre-production tasks.
Participants ideated a scenario where VR allows them to pre-visualize the scene they are planning to shoot in the production phase. They envisioned the filming location being accessible remotely and all crew members being outfitted with the required equipment (VR headset). In this scenario, it is possible to perform several activities in a group or independently in a synchronous or asynchronous way.
The potentialities of this scenario include the following:

- The possibility to exchange thoughts with other members of the crew before the start of the production
- The possibility to be immersed in a digital recreation of the location and freely explore it without time or accessibility limitations, independently or with other collaborators
- The possibility to make decisions and adjustments on the set design (props, furniture, scenography, etc.)
- The possibility to experiment with different camera angles and positions as well as different optics and movements to find the one most appropriate for the scene
- The possibility to plan the flight path of a drone and simulate other camera movements using specific gear, such as dollies, cranes, and jibs, among others
- The possibility to place actors and actresses, models, or dummies (blocking) or animate them to rehearse the scene
- The possibility to place and simulate natural and artificial lights
- The possibility to better pitch ideas to investors

This scenario is aligned with the findings reported in PS-I, in which interest was expressed from a different sample of participants about a similar concept.

Design Fiction Scenario 2: Real-Time Implementation of Augmented Reality on Set Through AI

This scenario was envisioned with the specific goal of enabling those involved in the production phase to visualise VFX elements that are planned for addition in post-production.
The opportunity participants perceived in this scenario is having a faithful representation of VFX when shooting, thus providing them with a better idea of the final output through in-camera AR. The VFX, which can be 2D or 3D, are generated by an AI algorithm that is capable of synthesizing images and animations according to verbal instruction from the director or other crew members.
Participants believed that this technological aid could reduce the risks of capturing footage that is not usable in post-production due to false assumptions about the VFX that were intended for implementation.

Design Fiction Scenario 3: Immersive Editing

Post-production activities are executed by a crew member sitting in front of a monitor and using a mouse and keyboard for inputs. Sometimes this approach is considered monotonous and not fertile for creativity as well as deleterious for one's physical health.
Compared to Scenario 2, where a post-production activity such as VFX integration is included in the production phase, for Scenario 3, participants re-imagined a post-production activity not related to VFX. They conceptualized a scenario in which the editing phase is performed in an immersive environment. This extends beyond a simple integration of floating 2D tabs, windows, and screens in VR. Such a scenario offers different UXs and UIs by taking advantage of the physical movements and gestures of the user in a virtual space. This new way of approaching the editing phase could unlock new creative possibilities; one participant noted that '*editing,*

sometimes, is like dancing, and so it would be interesting to give it a try. It might let you see new solutions, new combinations' (PW03, editor). Additionally, these interactions require editors to be more involved physically.

Many participants recognised how working many hours a day in such a way can be physically exhausting. It could be beneficial to mix and alternate both the established and proposed way of editing.

5.8 Chapter Summary

This chapter described the structure of the remote co-design workshops through which the researcher aimed to confirm the pain points and challenges faced by AV professionals who operated in SMPs; these pain points and challenges were identified in PS-I with a different sample of participants. Through a design fiction approach, participants were later introduced to the notable uses of immersive and emerging technologies, which inspired the innovative ideation applied to their production process. Concepts ideated by participants within a group were iterated and evaluated by other members of the same group. Finally, during PS-III, three design fiction scenarios were created based on the findings of the remote co-design workshop.

Chapter 6

IDEA FILTERING AND ITERATION (DS-III)

6. Idea Filtering and Iteration (DS-III)

6.1 Introduction

This chapter describes the process of identifying the most preferred design fiction scenario among those generated in PS-II by participants. This research activity is part of identifying the answer for RQ1.3, and it describes the employment of an online questionnaire as a design method.

Initially, the rationale behind the questionnaire's structure is explained. Subsequently, the results obtained from respondents are presented and discussed. Finally, this chapter explains how this study (DS-III) is directly related to the next through the design and development of the preferred scenario into a concrete prototype (PS-III).

6.2 Aim

Overall, the aim that underscored the questionnaire was to identify which of the three design fiction scenarios was considered most valuable by stakeholders.

However, the goal was broader than simply collecting responses by asking closed-ended questions. The more ambitious intent behind the questionnaire was to receive more detailed feedback on the three scenarios by asking open-ended questions to capture further input. Collecting opinions on why participants preferred one scenario over another, the eventual pain points, and additional useful features to integrate into the scenarios were precious information to obtain in preparation for the next phase of the research. The scenario that received the most consensus indicated to the researcher which prototype to develop in the next phase of the research (PS-III).

6.3 Participants

When recruiting, the researcher contacted AV professionals who participated in previous phases of the research. These people were asked to circulate the questionnaire among their collaborators according to the snowball sampling method (Parker, Scott, & Geddes, 2019).
Additionally, AV professionals were scouted using Vimeo, a video hosting and sharing platform that independent filmmakers employ to disseminate their works. Those whose profiles were relevant to the study were contacted via email or private message on Vimeo and invited to complete the questionnaire.
The total number of responses the researcher aimed to receive was 30, which was thought to be appropriate due to (a) the challenges of engaging with AV professionals, (b) the effort required by participants to complete the survey, and (c) the vast amount of quantitative and qualitative data generated by the questionnaire. Moreover, Rowley (2014) expresses that certain circumstances, such as the difficulty in reaching specific populations, means that 20-30 is a realistic number of responses to expect.

This design method was employed because it could be performed independently and remotely by participants. With a specific limit of 3 weeks to submit their responses, AV professionals could participate in the study whenever they had time to spare according to their work commitments. Respondents were based in Italy (22), UK (3), US (2), Ireland (1), Mexico (1), and Malaysia (1).

6.4 Structure of the Questionnaire

A crucial aspect of designing the questionnaire was deciding what questions to ask and which number of questions was appropriate. This determined the length of the questionnaire as well as the time required by participants to complete the survey. Macer and Wilson (2014) posit that approximately 15 minutes is an acceptable limit. This aligns with Cape's (2015, as cited in Brace, 2018) suggestion: the attention span of online survey participants is 20 minutes, on average.

Other researchers, such as Rowley (2014), recognize the difficulty of defining the correct length of a questionnaire or the number of responses to collect, explaining that there are many factors researchers have to consider to better define these two aspects.

One of the factors for the questionnaire was the presence of the three embedded stories that required time for reading. The researcher thought answers may be better if respondents first read Story 1 and completed all the related questions. After that, they could proceed to read Story 2 and so on.

The overall structure of the questionnaire is divided into eight sections:

- <u>Section 1 – Consent</u>
  - Inform participants about the research and receive their ethical approval

- <u>Section 2 – Introduction</u>
  - Thank participants in advance and inform them of what they will be asked

- <u>Section 3 – Generalities</u>
  - Collect information about participants' age, roles, years of experience, AV sector, average team size, and average project budget

- Section 4 – Story 1
  Describe this design fiction scenario and collect feedback

- Section 5 – Story 2
  Describe this design fiction scenario and collect feedback

- Section 6 – Story 3
  Describe this design fiction scenario and collect feedback

- Section 7 – Final overall questions
  Ask participants to express preference towards one of the scenarios

- Section 8 – Conclusion
  Thank participants again and ask whether they are interested in being contacted for future studies

The integral Microsoft Forms version of the questionnaire used in this research to collect data can be found in Appendix II.

6.4.1 Diegetic Prototypes

The three diegetic prototypes ideated in PS-II were presented at the beginning of the dedicated session and were supported by visual suggestions (mood boards), including three abstract logos and fictional names.

- DEPERO: A tribute to a famous futurist designer of the early XX century.

- ALNINE: A tribute to HAL9000, the fictional AI presented in Stanley Kubrick's *2001: A Space Odyssey* (Kubrick, 1968)

- OSMOS 3: A tribute to designer Alex McDowell, who is responsible for the production design of the feature film *Minority Report* (Spielberg, 2002)

Figure 6.1 Fictional Logos

The length of each story was approximately 600 words, which required approximately 2-3 minutes for reading.
Each story was told from the perspective of the main character, an AV professional who performs a specific role (Story 1 – set designer, Story 2 – director, Story 3 – editor).
The underlying structure of the stories was composed of different elements with different objectives.

I. Persona bio: Describes the main characters of the story

II. Tech description: Describes the features and functionalities of fictional technologies

III. Fictional workflow: Describes how fictional technologies are employed by AV professionals in their roles and production processes

IV. Storytelling: Uses sentences and words to glue together all the elements and to facilitate the readers' immersion in the stories

The full stories and complete mood boards are reported in Appendix I.

6.4.2 Adapting the Technology Acceptance Model to This Study

The TAM is a framework introduced by Davis (1989) to predict people's behaviour towards new technology. In DS-III, it was necessary to identify which of the three diegetic prototypes AV professionals perceived as most valuable to develop into a practical prototype in PS-IV.

Davis argues that users' perception of a new technology's usefulness and ease of use affects the actual use of the technology system (Figure 6.2).

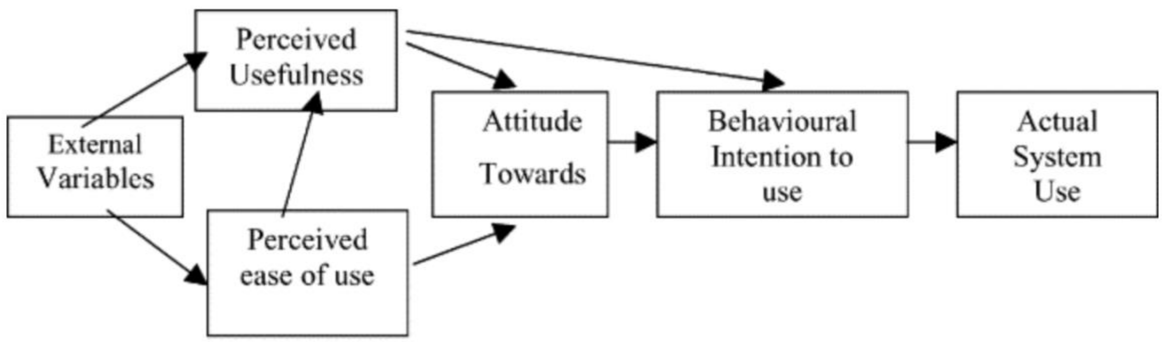

Figure 6.2 Davis' (1989) Technology Acceptance Model

Throughout the years, the framework has evolved and has become increasingly structured and complex (Venkatesh & Davis, 2000; Venkatesh & Bala, 2008). Furthermore, many researchers have adapted the framework to their needs, as reported by Marangunić and Granić (2015), who provide a comprehensive literature review about the topic. According to Al-Emran and Granić (2021), the TAM is a solid framework for conducting empirical research in various applications and fields.

Bertrand and Bouchard (2008) adapted the TAM framework specifically for VR. However, they kept the framework relatively simple and considered the original variables of perceived usefulness and perceived ease of use.

They conclude that '*the TAM can predict well the intention of a favourable population to use virtual reality as a tool for treating mental health problems*' (Bertrand & Bouchard, 2008).

Considering their conclusion, the researcher believed it to be opportune to adapt the TAM framework for this study. Similar to Bertrand and Bouchard (2008), the researcher in this phase of the study proposed to participants the employment of new technologies as tools via three design fiction scenarios ideated in PS-II. The difference is using the TAM framework in the AV field, as opposed to the medical one.

The questionnaire structure includes some queries (Q12, Q13, Q17, Q18, Q22, Q23) adapted for the AV field and based on the TAM framework, as listed in Table 6. The questions were designed following findings from DS-I and DS-II and, more specifically, around the key points of AV professionals' workflow (communication, creativity, pitching, logistic, and well-being). An additional adaptation is the measurement scale. Instead of using a 7-point Likert scale as proposed in the TAM framework, the researcher chose, after the pilot, to use a 5-point scale. This is further explained in the next chapter. What is reported in Table 6 is related to Story 1 – DEPERO, but the same list of questions was asked for Story 2 – ALNINE (Q17, Q18) and Story 3 – OSMOS (Q22, Q23). Further details are provided in Appendix II.

Table 6 Questions Adapted From the Technology Acceptance Framework

Compared with the current pre-production workflow in the AV sector in which you most frequently work...	
Q12: Perceived usefulness	5-point Likert scale
...Using DEPERO may facilitate communication with other collaborators.	Strongly Disagree = 1 Disagree = 2 Neutral = 3 Agree = 4 Strongly Agree = 5
...Using DEPERO may lead to exploring more creative opportunities.	
...Using DEPERO may be more helpful in the decision-making process.	
...Using DEPERO may be more helpful when pitching ideas and asking for funding.	
...Using DEPERO may reduce filmmakers' ecological footprint (travelling, energy consumption, etc.).	
...Using DEPERO may improve filmmakers' well-being (mental health, safety, inclusivity, equity, etc.).	
Q13: Perceived ease of use	
Learning to use DEPERO may be easy for me.	

6.4.3 Open-Ended Questions

In addition to closed-ended questions adapted from the TAM model, the researcher considered it opportune to collect more qualitative data by asking participants open-ended questions. This strategy, especially with Q27, provided a deeper understanding of the previous and crucial Q26, which allowed the researcher to discern which practical prototype to develop.

Answers collected from responses to Q14, Q19, and Q24 informed the researcher of potential pain points and criticalities in the scenarios presented. Additionally, Q15, Q20, and Q25 were introduced as feature requests for participants to offer direction on how these scenarios can be further developed.

These open-ended questions were designed to collect precious insights that would contribute to iterating the same scenarios before starting prototype development.

6.4.4 Self-Evaluation Questions

In Q7 and Q8, respondents were asked to provide more information regarding the usual team size and the average budget of the projects in which they are usually involved. These questions were inserted to verify that professionals responding to the questionnaire were working in small and medium AV productions with limited resources and to allow the researcher to identify eventual sampling biases.

Similarly, considering findings from Macer and Wilson (2014), Cape (2015), and Rowley (2014), the researcher wanted to recognize possible procedural bias; therefore, the final questions (Q28, Q29, Q30) were included to investigate whether participants encountered some difficulty while completing the questionnaire due to its length. Through self-evaluation, they could express whether they maintained a consistent focus and whether the materials provided (written and visual) were sufficient to answer the previous questions with confidence.

6.4.5 Online Platform

Microsoft Forms was chosen as an online tool because it was considered to be opportune for determining the structure of the questionnaire as intended by the researcher, allowing the inclusion of both closed- and open-ended questions and the clear, immediate visualization of the data collected.
Additionally, the program offered the possibility to split the questionnaire into different *sections*, a helpful feature that is similar to turning the page of a book. This strategy was thought to provide some breaks to the respondents and enable them to better distinguish the various sections of the questionnaire (consent, introduction, generalities, Story 1, Story 2, Story 3, final questions, and conclusion).

6.4.5.1 Pilot

As Brace suggests (2018), '*It is always advisable to pilot the questionnaire before the survey goes live*'. Consequently, seven people (master design students, PhD design students, and lecturers) were asked to participate in the pilot and review the structure of the online questionnaire. The length of the questionnaire and clarity of the design fiction scenarios were most in need of testing.

This activity further strengthened the questionnaire's structure and required slight adjustments. For instance, after the pilot, the researcher adopted a 5-point Likert scale instead of a 7-point scale because the 5-point scale was considered more straightforward, which would better allow participants to correctly interpret the scale.

6.5 Results

Initially, the researcher planned to employ the statistical software SPSS (IBM, 2022) to analyze the results, but Microsoft Forms' data visualization and analysis was already considered satisfying and valuable.

Quantitative data from the closed-ended questions Q12, Q13, Q17, Q18, Q22, and Q23 were evaluated according to the TAM framework and the 5-point Likert scale. Qualitative data collected in the open-ended questions were classified following thematic analysis.

6.5.1 Profiling

The first 10 questions collected the generalities of the respondents and are reported in Figures 6.3 and 6.4.

To preserve the initial goal of the research, it was essential to ensure that respondents were representative of and understood the participants at the centre of this exploratory research. Hence, they were asked Q7, *'What is the average team size of the projects you are involved in?'* and Q8, *'What is the average budget of those projects you are involved in?'*

In Q7, most respondents worked in teams of 21-50 (11) or 6-10 (8). Only two respondents were involved in AV productions of 50+ people, a team size that does not fall within this study's definition of SMPs. Nevertheless, their responses were considered.

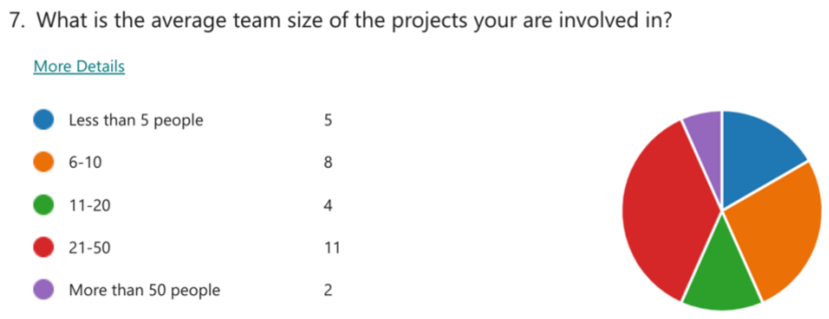

Figure 6.3 Q7 Results: Average Team Size

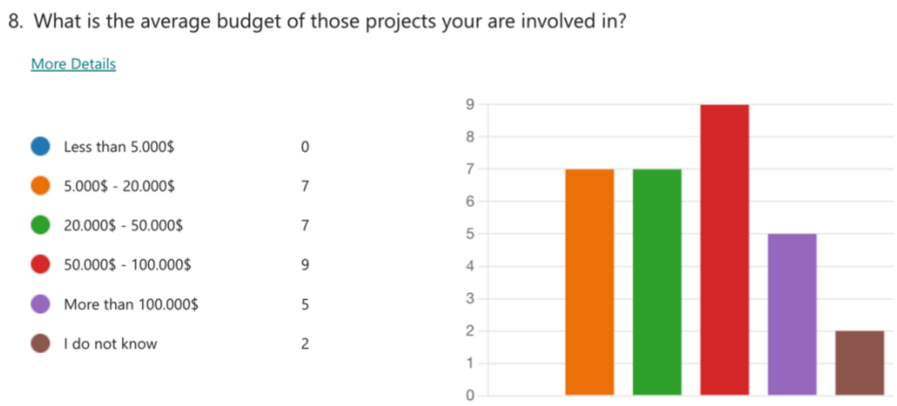

Figure 6.4 Q8 Results: Average Budget Size

6.5.2 Main Outcomes

Q12, Q17, and Q22 asked participants how a specific scenario, in terms of usefulness, compared to the current AV production process they employed. Analyzing the data collected revealed that all three design fiction scenarios were valued as preferable compared to their current workflow. According to Davis (1989), the results, derived from the average score received by each question, must be interpreted as follows:

- **Strongly Disagree** = 1.00-1.89
- **Disagree** = 1.90-2.69
- **Neutral** = 2.70-3.49
- **Agree** = 3.50-4.49

- **Strongly Agree** = 4.50-5.00

Furthermore, by analyzing and comparing the data generated by Q12, Q17, and Q22, it is possible to observe that Story 1 and Story 2 obtained similar scores in most sub-questions. However, the feedback received for Story 3 is positive but notably less positive than Story 1 and Story 2.

Table 7 Perceived Usefulness

Q12 Q17 Q22	Compared with the current pre-production, production, and post-production workflow in the AV sector in which you most frequently work...	Scenario 1: DEPERO	Scenario 2: ALNINE	Scenario 3: OSMOS
		Average score	Average score	Average score
Q##.1	...may facilitate communication with other collaborators.	4.16	4.06	3.26
Q##.2	...may lead to exploration of more creative opportunities.	4	4.46	3.7
Q##.3	...may be more helpful in the decision-making process.	4.13	4.26	3.56
Q##.4	...may be more helpful when pitching ideas and asking for funding.	3.93	4.1	3.2
Q##.5	...may reduce filmmakers' ecological footprint (travelling, energy consumption, etc.).	4.33	4.03	3.6
Q##.6	...may improve filmmakers' well-being (mental health, safety, inclusivity, equity, etc.).	3.36	3.86	3.46

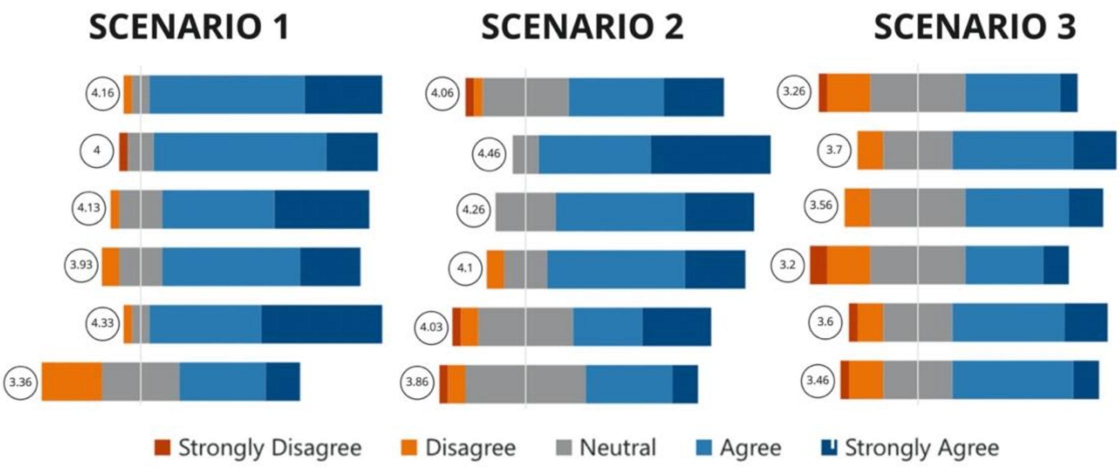

Figure 6.5 Visual Representation of Data Related to Perceived Usefulness

Therefore, to better understand what design fiction scenario was judged most promising between Story 1 and Story 2, it was crucial to examine the data from Q26.

Figure 6.6 shows that of the 30 responses received, most respondents preferred Story 1 (*n* = 22). This result means that respondents agreed that the design fiction scenario described could potentially bring the most benefits to the AV production process compared to the other two design fiction scenarios.

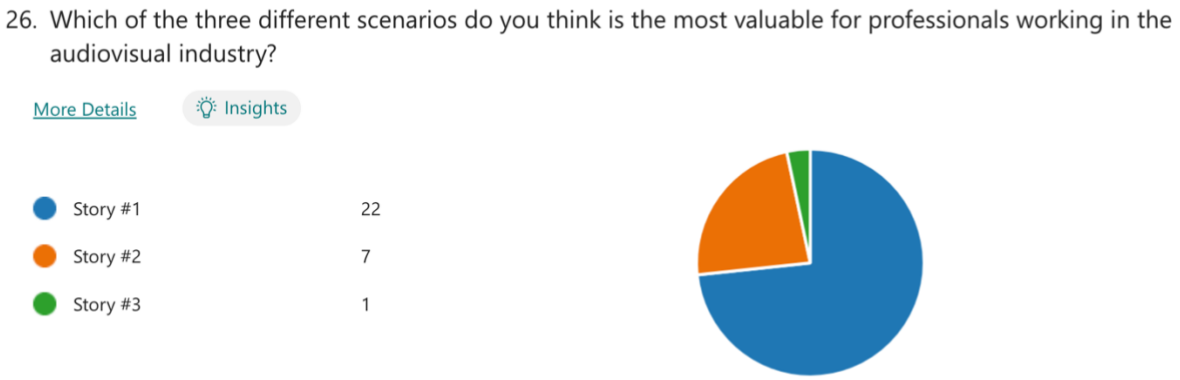

Figure 6.6 Q26: Most Valuable Scenario

Those who answered Story 1 and also better explained their reasoning for Q27 recognized the following potential benefits:

a) Cost and Time Savings

Most of the participants explained that this scenario could save time and money, thus reinforcing the opinion that also emerged from the one-on-one exploratory interviews.

> *'More opportunities for a director, time savings, lower costs, greater creativity during the shooting'* PQ13, directing department.

> *'Making a good pre-production reduces the costs and optimizes the budget (or reduces it)'* PQ15, directing department.

> *'It is more practical and the most effective in reducing production costs'* PQ17, art department.

> *'Is the most useful, as the tools described cut considerable time and expenses for pre-production'* PQ18, production department.

I believe it would be incredibly helpful to speed up a lot of pre-production processes, and it would save a lot of money for location scouting, pre-lighting, set design prepping, etc. It would save an incredible amount of time and make pre-production more efficient. The team would arrive to principal photography much more prepared' PQ23, production department.

b) Extended Workflow Impact

Some participants justified their response by expressing that it would impact many more figures and phases of the workflow compared to the other two design fiction scenarios.

> *'The first one is the most complete. It can help everybody on the crew and level up the pre-production work'* PQ06, art department.

> *'It has to do with the whole workflow for creating a movie – [whereas] the other two refer only to one step of the process. So the first scenario could potentially benefit a bigger slice of indie filmmakers'* PQ11, camera department.

c) Better Output Quality and Quality of Life

Some believed that such a scenario would improve their current quality of life and output.

> *'It will be the better way to work'* PQ09, directing department.

> *'It can help to increase the quality of the pre-production'* PQ12, directing department.

d) Carbon Footprint

A different perspective was offered by PQ25:

> *'Lowering the carbon footprint of your pre-production, especially in our current times where we are almost at the point of no return as it relates to our environment'* PQ25, development department.

e) Technical Feasibility

Some expressed a preference towards Story 1 because they considered such a design fiction scenario to be feasible in the near future.

> *'I think it is concretely the one closest to the reality of use. Story 2 and Story 3 are still very theoretical'* PQ16, camera department.

> *'I think it is the easiest to make. All the technology around it is almost already here. I also think it is something we do not have now. While we can create VFX and edit videos, there is nothing to pre-visualize a scene with photogenic precision. It is the easiest to introduce, make, and use but still the most useful. This technology could really change the behaviour of the pre-production crew'* PQ28, art department.

Additional Comments on Story 1

PQ02 (directing department) recognized the value brought by such a design fiction scenario but was hesitant in deciding whether it could replace in-person scouting:

> *'I think it could be a useful tool to add to a normal in-person location scouting. You usually have a few hours for doing the scouting, and this is a tool that allows you to work and rework on it. However, I am not sure if it could replace in-person scouting. Scouting is a time to meet heads of department in person, have a human connection, and share an idea together' PQ02, directing department.*

PQ30 expressed a less exclusive opinion about this matter:

> *'It's not trying to replace or compete with existing infrastructure but bringing something new that could be added to upcoming productions'* PQ30, camera department.

Interest in More Than One Scenario

Additionally, some participants wanted to express their interest in those design fiction scenarios for which they did not vote.

> *'I think both Stories 1 and 3 represent very useful scenarios for the industry. […] Story 3 describes tools that seem [like they] would make [the] life of editors much easier and probably healthier'* PQ18, production department.

> *'I think the first and the third are really useful. I prefer the third one just because it's for my role'* PQ01, post-production department.

> *'If I could choose two, also the first one could be really interesting, for the chance to have more tools to see alternative scenarios. But I think the second one, it is really a game changer in the industry. Also, as a director, sometimes [it] is hard to communicate with the post-production or understand how the output would be'* PQ02, directing department.

What PQ02 expressed may be due to the quality of the output from the co-design workshop and the balanced presentation of the stories in clarity and detail.

In this regard, Q30 was designed to investigate other potential procedural biases in narrating the stories. However, the results were precise and showed that none of the participants had issues understanding the design fiction scenarios.

Despite the unusual length of the questionnaire and the effort required to complete it, the outcome from Q28 was satisfying. Only five of 30 respondents answered *No*, and in Q29, one (PQ25) of these five explained that, despite their length, reading the stories was enjoyable; another (PQ11) remarked that he felt the urge to explore more aspects of what was narrated by searching online.

6.5.3 DEPERO Pain Points

After they listed the potential benefits introduced by Story 1, respondents were asked in Q14 to indicate the most significant pain point that may stop them from adopting the presented workflow; this allowed them to further assess and evaluate the design fiction scenario and increase comprehensive understanding.

> *'As a set designer, I think it can be hard to create the structures or the details that you want to design in the set's space. It can be easy to import furniture from libraries, but less easy and less fast to create brand new 3D objects or textures. You should be quite specialized in this to do it'* PQ06, art department.

One of the reasons some people pursued such professional career paths is because they enjoy spending time in close contact with other people and physically travelling to the chosen filming location. Consequently, some of them were concerned about missing the in-person visit and human exchange with other people.

> *'I think it could be a useful tool to add to a normal in-person location scouting. You usually have a few hours for doing the scouting, and this is a tool that allows you to work and rework on it. However, I am not sure if it could replace in-person scouting. Scouting is a time to meet heads of department in person, have a human connection and share ideas together. The digital filter keeps being quite a different feeling. Also, if you do narrative with dialogue, you also need to check the sound of the ambience, and in general, exploring in person a location, it is really important to me'* PQ02, directing department.

> *'A 3D set may look better than reality. Unexpected changes – such as weather – are not easy to be calculated. Even depth of field will not be considered in lenses, and location scouting is also useful to know the surrounding area. By the way, to have a better ecological footprint, do not choose crew from abroad'* PQ07, directing department.

a) Budget

A significant number of respondents indicated that the affordability of such a design fiction scenario could stop them from using DEPERO. Of 30 respondents for Q14, 10 mentioned that the cost of the software and related expenses, such as the hardware and internet connection, might represent the primary *dealbreaker* for adopting DEPERO.

This result was expected and showed the importance given by these stakeholders to their productions' budget. When they were presented with alternative and potentially more affordable scenarios such as DEPERO, before even thinking about learning how to introduce it in their workflow, they felt the urge to first investigate more about its affordability.

Therefore, these data strongly support what was discovered during the literature review and first exploratory study. VP processes employed by other industry players such as ILM, Netflix, or WETA Digital were seen as expensive and out of reach by these stakeholders.

b) Perceived Ease of Use

The average score from the 5-point Likert scale for Q13.1, *'Learning to use DEPERO may be easy for me',* was 3.56, meaning that overall, participants agreed with such a statement. As shown in Figure 6.7, 16 of 30 participants agreed or strongly agreed that it would be easy for them to learn how to use DEPERO, while 12 of 30 preferred to remain neutral.

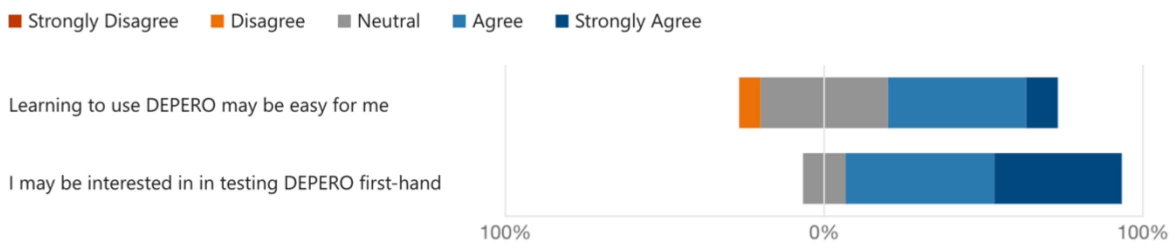

Figure 6.7 Q13 Results – Perceived Ease of Use of DEPERO

Seven of these 12 expressed in Q14 how poor usability may stop them from employing DEPERO.

> *'The difficulty in learning to use it'* PQ13, directing department.

> *'Having already many online platforms/software/systems that sometimes are not as easy to use. Learning how to use the software properly can take time and, for some people, might not be very easy (for example, older generations still in the industry)'* PQ23, production department.

> *'The challenge of getting less tech-savvy crew, directors, or producers to use VR tech, particularly older ones'* PQ30, camera department.

Introducing a new tool in the workflow of professionals remains a delicate matter, and it is one of the reasons why Davis' TAM (1989) asks several questions to investigate the perceived usability of proposed innovations.
Because AV productions are generally composed of heterogeneous age groups, PQ23 and PQ30 further mentioned that older collaborators might encounter additional friction in learning how to use new tools.

c) Network Effect, Accessibility, and Proficiency

Other participants underscored that such a collaborative scenario depends on the number of collaborators having access to DEPERO (software, hardware, and reliable internet connection) and their ability to use it.

> *'People I work with not having access'* PQ24, directing department.

> *'If the people I collaborate with on the project didn't use or didn't know how to use DEPERO'* PQ26, production department.

> *'Having an international team used to having DEPERO'* PQ28, art department.

This important aspect on which participants remarked can be traced to the so-called *network effect* first investigated in the field of telecommunications and economics

(Rohlfs, 1974) that has since been extended to software services (Gallaugher & Wang, 2002). This phenomenon describes how the benefit or value a user receives from a product or service depends on the number of customers who use similar goods. As new customers adopt the product or service, its value and utility increase.

d) AV Sector Dependent

Some participants believed that it was logical to employ DEPERO only in specific AV sectors.

> *'A software like this would not be a fit depending on the genre of film I am making. Genres like documentaries would not benefit from this workflow'* PQ11, camera department.

PQ11's perspective may have been motivated by the discussion in Section 4.7.5 in which a participant who worked on documentaries explained the value behind unforeseen events and aspects of a documentary. PQ18 offered a similar opinion regarding the unsuitability:

> *'The size and scope of the projects I work on, as they are particularly low-key…with a lot of the scouting to be done directly on location after arrival'* PQ18, production department.

e) Visual Fidelity

Some participants were critical of the image quality represented in the immersive environment. They noted that a mismatch between the simulation and the actual location could lead to false expectations and bring more disadvantages than advantages.

> *'A 3D set may look better than reality. [A] casual change – such as weather – is not easy to be calculated. Even depth of field will not be considered in lenses, and location scouting is useful also to assess the surrounding area'* PQ07, directing department.

‘Not giving a real and authentic [imaging] of the elements [such as locations or lights] can lead to creative errors or misunderstandings that can damage the production’ PQ19, production department.

‘I would stop using DEPERO if the graphic rendering and image quality were poor’ PQ26, production department.

6.5.4 Additional Features to Implement Within DEPERO

Q15 asked what additional features participants would desire to be implemented in DEPERO. Some of these features were initially included in the first draft of the design fiction scenario described in Story 1. For instance, the ability to take screenshots of the virtual scene or the need to be aware of the area's facilities, roads, and shops emerged since the first exploratory in-depth interviews. Nevertheless, it was crucial to reduce the length of the stories as much as possible; hence, the scenario presented was not comprehensive of all the features planned to integrate into the final prototype.

Features request #	Name	Brief description	Suggested by
01	Virtual actors and actresses	Being able to place, in scene, mannequins or real actors and actresses who have been scanned. Being able to animate them.	PQ2, PQ28
02	Sun keeper	Sunlight simulation based on location and date of shooting (similar to existing application *Helios Pro*).	PQ7, PQ18, PQ28
03	Budget control	An automatic feature that would inform users of the estimated cost of the scene they are planning	PQ9, PQ10, PQ19

		based on the virtual objects or equipment added.	
04	Photo and video export	Being able to take screenshots of planned references or storyboards or even record videos of the scene.	PQ12, PQ15
05	Surrounding location	Being able to assess the surrounding of the location for car parking, power sources, load-in, actors' and actresses' wardrobe, etc.).	PQ25; PQ28
06	Lighting	Being able to add artificial lights and simulate their effect on the location, objects, and actors and actresses.	PQ16
07	Day and night	Being able to simulate how the location will look like during daytime and nighttime.	PQ28
08	Digest summary	A way to keep track of the decisions made after the collaborative session.	PQ11
09	Interoperability with different media formats and telecommunications means	Being able to import, export, and share other media, such as photos, videos, or documents. Being able to start and receive phone and video calls.	PQ16, PQ30
10	Write script	Being able to write a script.	PQ17
11	Basic editing	Being able to edit different screenshots or videos.	PQ1
12	Space measurement	Being able to take the measurements between two points.	PQ18

13	Import props from library	Being able to access a library to obtain props to add to the scene.	PQ20
14	Tutorial	An introduction to the software and how to use it.	PQ21

Table 8 Features Suggested by Participants in Q15

It was deliberately decided to report the outcomes, pain points, and requested features of only the most preferred scenario (Story 1).
Further presentation and analysis of the results derived from the other stories would lengthen this chapter unnecessarily, as the overall plan of this work is to further develop into a prototype only one scenario due to time and resource constraints.

However, the results of the questionnaire and comprehensive responses to Stories 2 and 3 are reported in Appendix II. The data collected for these scenarios can provide valuable insights to those researchers seeking inspiration and interested in exploring these scenarios.

6.6 Discussion

This study not only highlighted the direction for the progression of the overall research but also offered the researcher useful feedback on the strengths and weaknesses of the prototype to be developed.
Overall the engagement in the open-ended questions was high. Many of the answers provided clear reasoning and were rich in detail.
According to participants responding to this questionnaire, the design fiction scenario presented in Story 1 was considered the most promising to develop further in a practical prototype.
This may be because, in such a scenario, more roles are involved compared to Stories 2 and 3, which present a workflow that is more role-specific.

The results also revealed that, when expressing feedback on Story 1, a significant portion of participants stated that the cost of the equipment required to adopt the workflow presented can be an obstacle to its actual use. This confirms the critical concern among SMPs around the economic implications of each choice they made: from casting specific actors and actresses to purchasing the rights for a specific soundtrack or even, as in this case, introducing new tools and technologies, every cost must be considered.

It is essential to acknowledge the potential bias in favour of Scenario 1, considering that a majority of respondents to the questionnaire were involved in pre-production and production roles. The only preference expressed for Scenario 3, related to post-production, came from an individual working as an editor. Therefore, it is reasonable to question how the results might have differed if more responses had been collected from AV professionals specializing in post-production, such as VFX Artists, Motion Graphic Designers, and 3D Artists.

In retrospect, it could be more appropriate to add a variable in Q8 that includes a budget range of $100,000-$250,000. Such a range could have provided better data granularity. Overall, the fact that 25 of 30 respondents worked on projects with budgets below $100,000 confirms that the stakeholders recruited were those intended.

Additionally, the usability of the future practical prototype intended for development was considered a potential *dealbreaker*, especially for less technologically skilled collaborators. Therefore, key aspects such as affordability and usability were considered when designing the prototype in PS-III. These considerations can be attributed to AV professionals' practical nature.

6.7 Chapter Summary

This chapter described the design of three diegetic prototypes in the form of written stories based on the three design fiction scenarios identified in PS-III. It also explained the goal of this stage, which was to identify, via an online questionnaire, the scenario considered most valuable by AV professionals. The questionnaire included closed-ended questions, many of which were adapted from the TAM framework, and open-ended queries that collected qualitative data.

After analyzing the results, the researcher concluded that the most valued scenario related to an immersive and remote pre-production workflow. This chapter's discussion of these key findings provided comprehensive insights that enabled the development of a practical prototype that was tested and evaluated in DS-IV.

Chapter 7

PROTOTYPE DESIGN (PS-IV) AND TESTING (DS-IV)

7. Prototype Design (PS-IV) and Testing (DS-IV)

7.1 Introduction

This chapter is divided into two main parts. The first explains the rationale behind the prototype designed and developed based on the findings from DS-III. Next, it describes the outcome of the prototype evaluation as expressed by participants during 11 user testing sessions.

In the second part, Section 7.6, the researcher further explores the technical feasibility of a specific feature of the practical prototype designed in PS-IV. Consequently, the researcher explains the process of designing and testing the immersive planning and automation of a drone shot, which is referred to as a sub-prototype.

7.2 Aim

In this phase, the researcher collected feedback on the prototype's usefulness and ease of use to address RQ1.3: *What alternative VP process can be co-designed and developed to enable SMPs' adoption of VP?* The outcome of this study led to the definition of design recommendations for applying VP to SMPs, which is explained in detail in Chapter 8.

7.3 Participants

COVID-19 restrictions gradually eased, which allowed this study to be the first in this research to be conducted in person, enabling participants to interact physically with the prototype and experience immersive technologies in practice.

The prototype's development was characterized by a collaborative element, so the researcher thought that testing participants should come from AV companies to enable the involvement of multiple participants accustomed to working together who could form groups.

Because of the limited time at the disposal of AV professionals, the researcher thought it worthwhile to conduct the user testing sessions at their workplace. The geographic locations where the researcher could physically travel were the London area (United Kingdom) and the Milan area (Italy). Considering this, an online search was performed to identify the most suitable AV companies in these areas.

The researcher also decided to recruit some of the participants involved in previous phases of the research. Once again, snowball sampling was employed, and previous participants were asked to involve other participants corresponding to the criteria provided by the researcher.

Since it was decided to contact production companies, most professional figures involved in this study were producers. This outcome was expected since SMP companies can be seen as empty boxes that usually fully employ only those in production roles. Once a project is confirmed and the budget defined, producers start involving the other professionals needed (camera operators, set designers, cinematographers, directors, etc.) who usually work as freelancers.

As explained in the previous chapters, producers participate in AV productions from inception to final delivery. They oversee the whole project and are aware of the different needs and working habits of all involved personnel. This scholar aimed to test and evaluate an alternative workflow; therefore, producers' presence in this research phase was considered precious.

Participants were based in Italy (23) and UK (six) for a total of 29 professionals who formed 11 groups of two or three participants each, depending on participants' availability and last-minute defections, plus the facilitator. Creating groups of three or four people was considered optimal for performing collaborative tasks and incentivizing participants to communicate with each other. It was also the maximum number the facilitator could concurrently manage. Before the beginning of the session, VR and AR devices as well as recording devices needed to be set up. During the session, the facilitator quickly fixed eventual technical issues encountered by participants and guided them through the procedure. Furthermore, four people in the same virtual space was the maximum allowed by Gravity Sketch, the VR software used for operating part of the user testing activities; this is better explained later.

PARTICIPANT	GROUP	ROLE	DESCRIPTION
PT01	GROUP 1	Video consultant	Involved by clients to design video strategies and oversee production
PT02		Motion graphic designer	Working mainly on commercials
PT03		Camera operator	Working mainly on commercials
PT04	GROUP 2	Producer	Overseeing the entire production process of commercials and documentaries
PT05		2D animator	Working as 2D animator and motion graphic artist for commercials and documentaries
PT06	GROUP 3	Producer	Planning and organizing the production of commercials
PT07		Producer	Planning and organizing the production of commercials
PT08	GROUP 4	Executive producer	Overseeing the entire production process of commercials, documentaries, and fictional projects
PT09		Post-production supervisor	Overseeing the post-production process of commercials
PT10	GROUP 5	Executive producer	Overseeing the entire production process of commercials, documentaries, and fictional projects
PT11		Executive producer	Overseeing the entire production process of commercials, documentaries, and fictional projects
PT12		Director	Directing commercials and other fictional AV genres
PT13	GROUP 6	Executive producer	Working on the business side of commercials, film, and TV projects
PT14		Post-production supervisor	Directing short films and art installations and actively seeking funding

PT15		Producer	Working on the business side of film or TV projects
PT16	GROUP 7	Producer	Planning and organizing the production of commercials
PT17		Producer	Planning and organizing the production of commercials
PT18	GROUP 8	Producer	Overseeing the entire production process of fashion commercials
PT19		Producer	Overseeing the entire production process of fashion commercials
PT20		Editor	Editing of fashion commercials and fictional TV series
PT21	GROUP 9	Producer	Overseeing the entire production process of commercials, documentaries, and fictional projects
PT22		Assistant producer	Assisting producers in planning and organizing productions
PT23		Assistant producer	Assisting producers in planning and organizing productions
PT24	GROUP 10	Producer	Overseeing the entire production process of commercials, documentaries, and fictional projects
PT25		Producer	Working on the business side of commercials, film, and TV projects
PT26		Post-production supervisor	Overseeing the entire post-production process of commercials, documentaries, and fictional projects
PT27	GROUP 11	Cinematographer	Working mainly on commercials
PT28		Cinematographer	Working mainly on commercials
PT29		Editor	Editing commercials

Table 9 Summary of the Total Participant Pool (User Testing)

7.4 Prototype Design (PS-IV)

This section describes the rationale employed while designing the practical prototype and its functionality.

7.4.1 Convenience of Pre-Existing Technologies

Developing immersive hardware devices and software applications from scratch is out of the scope of this exploratory study and exceeds the researcher's resources in time and expertise.
Addressing RQ1.3 required the identification of accessible and affordable immersive hardware and software products that were available on the market before the storyline of Story 1 could be realized. This approach was also supported by the findings in the previous phases of the research (DS-I and DS-II), which revealed that easy access to affordable hardware products and software services was considered crucial for participants.

7.4.1.1 Overview of VR Headsets

The current landscape of suitable VR headsets does not present as much variety as other consumer electronic devices, such as smartphones or laptops. This fact significantly reduced the possible choices of VR headsets that might meet the need for this phase of the research.
The Meta Quest 2, the headset employed for this study, is a wireless, *all-in-one* VR device, meaning that both the head-mounted display and computing power (CPU) are integrated in the device and do not require any external equipment, such as a desktop computer. Meta designed this headset to be *plug and play* and aimed to reduce user friction. According to data provided by Steam (Steam, 2022), the Oculus Quest 2 has the highest market share in headsets (49.25%) at the time of writing. Other headsets, such as Valve Index, HTC Vive Pro, and Windows Mixed Reality, were initially considered. However, these are designed to be connected via cable to a personal computer to use the computational power to operate VR software. Having three or four headsets wired to their corresponding PC would limit participants' movements within the physical space.

7.4.1.2 Overview of Mobile Capturing Software

SiteScape (2022) was initially thought to be valid for capturing spatial data of the real-world location where an AV product may be set. The documentation made available by its creators was informative to move the first steps and generate high-quality scans. However, the only file formats SiteScape uses for export are .ply, .rcp, and .e57, which all represent point cloud data (a collection of individual points captured by the LiDAR scanner through a set of XYZ coordinates). Such formats would have required some additional and burdensome steps to convert files to a format representing 3D geometry, such as .obj.

Therefore, the researcher preferred to use a software capable of capturing these individual points and processing them to a 3D mesh that would allow a direct import into the VR software for the next phase of the workflow (Gravity Sketch, 2022). Additional research and testing indicated that Polycam (2022) was better than SiteScape because of the smoother workflow in processing and exporting the data captured. Polycam generates a similar visual result and allows export of the capture in more than 10 formats, including .obj, which is compatible with Gravity Sketch. In contrast to SiteScape, which supports only iOs, Polycam has also been developed for Android and offers a web application, thus allowing more users to employ Polycam.

7.4.1.3 Overview of Immersive Sketching Software

Regarding VR software that specialises in sketching, many applications have already been developed and receive continual updates to implement more features and compatibility.

Oculus Medium is a VR application focussed on creating 3D objects and characters that are compatible with Oculus Rift, Oculus Rift S, and Oculus Quest. The application was initially released in 2016 by Facebook (Meta), acquired by Adobe in 2019, and rebranded as *Medium* by Adobe. It has some advanced features specific to 3D sculpting and is well integrated with other texturing and rendering software in the Adobe ecosystem. It is a free, single-user application.

Tilt Brush is another VR painting cross-platform application released by Google in 2016. Its source code was made available in 2021. It is designed to be artistically oriented, offering a wide variety of brushes to be used freehand. Computer-aided geometric features for drawing and its compatibility with different formats and media are limited. Furthermore, Tilt Brush was originally a single-user application, but after the source code became available, Rendever developed a multi-user paid version called *MultiBrush* (2022).

Gravity Sketch is a free cross-platform VR application released in 2017 that enables sketching freehand or using a tool set to recreate symmetry, manipulate surfaces, and collaborate from anywhere through their cloud-based solution, Landing Pad. What differentiates Gravity Sketch from the previously mentioned applications is the wide variety of tools that can be employed for different purposes. It is used by designers to quickly sketch, iterate, and evaluate ideas, independently or with other collaborators. Up to four people can be present in the same virtual environment and exchange thoughts through the microphones integrated with most of today’s consumer VR headsets. Additionally, different users can work on different layers, which can be locked by the owner of the room. This basic permissions system for edits is aligned with the user requirements that emerged during PS-I.
Equally important is Gravity Sketch’s compatibility with widely used geometry definition file formats, such as .obj and .usdz, or graphic formats, such as .png and .jpeg, thus allowing users to smoothly import and export files.
Gravity Sketch was considered the most suitable to recreate Scenario 1 among the three programs because of the sketching tools provided, the multi-user support, and its economical accessibility, an aspect that was often mentioned by participants throughout the phases of the research.

To better understand ideal practices to acquire optimal performances from these programs, the researcher directly contacted these programs' online customer service and asked specific questions to obtain further insights and guidance.

7.4.2 Prototype Description

Prototypes are commonly associated with initial models of physical objects to test a design. However, the term *prototype* can also be extended to the design of workflows or processes. The scenario portrayed in Story 1 describes an alternative process related to the pre-production phase; therefore, the prototype designed in PS-III and tested in DS-IV was a *workflow* composed of different stages that employed various technologies.

This alternative pre-production process can be divided into two stages:

1) Capturing and retrieving a digital replica of the filming location
2) Immersive pre-production in the digital replica of the filming location

7.4.2.1 Capturing and Retrieving a Digital Replica of the Filming Location

Findings from previous studies (DS-I and DS-II) indicated that location is crucial in defining an AV production. The location dictates several creative and technical decisions that professionals must make in the pre-production phase. Consequently, accessing the digital replica of the location was identified as the starting point for the proposed alternative pre-production workflow.

To do so, the prototype workflow was integrated into two possible options:

i) Generate a digital replica of the intended location using capturing technologies, such as photogrammetry or the LiDAR sensor, integrated into the iPadPro in combination with the Polycam application,

or

ii) Retrieve pre-existing 3D models or scans of the locations sought on platforms and marketplaces, such as Sketchfab, Thingiverse, TurboSquid, and CGTrader.

In the prototype testing phase (DS-IV), participants tested both options to collect different feedback, as explained in Section 7.4.3.

7.4.2.2 Immersive Pre-Production in the Digital Replica of the Filming Location

Once the 3D model of the location was generated or retrieved, it was imported into the VR application Gravity Sketch. Although Gravity Sketch is meant to be used by product designers as the end users, with some imagination, it is possible to re-interpret some of its features and functionalities to align with AV professionals' needs.

Importing into Gravity Sketch the 3D model of the location enabled AV professionals to virtually execute some of the tasks commonly performed during the pre-production phase, such as location scouting, location recce, rehearsing, compiling a shot list, and designing the set. Some of these activities are represented in Appendix V in Figure V.1.7.

It is also important to mention that the significant amount of qualitative data collected in DS-III contributed to iterations of the prototype design before its development in PS-IV.

Participants were asked in Q15 which additional features should be integrated into DEPERO, and they listed several functionalities that are not present in Gravity Sketch.

To overcome this limitation, some of the desired additional features were integrated by adapting the Wizard of Oz technique, which was first proposed by Kelley (1983) and then widely adopted in the Human Computer Interaction (HCI) research community (Weiss et al., 2009). The concept behind the Wizard of Oz technique is having a human (the wizard) simulate the missing functionalities of a system. This allows users to have the perception of a flawless experience and enables researchers to collect their feedback and opinions as they experience the final system.

In this study, the facilitator was the wizard during the user testing sessions and demonstrated some of the functionalities requested by participants but not integrated into Gravity Sketch. Users were informed about the adoption of the Wizard of Oz technique.

Creative use of tools provided by Gravity Sketch combined with the facilitator's storytelling (Wizard of Oz technique) offered users the impression that the following functionalities were integrated into Gravity Sketch:

- A day and night mode to simulate these lighting looks (PQ28)
- A budgeting chart updated in real time depending on what object or filming gear (lights, cameras, dollies, etc.) is added to the scene (PQ9, PQ10, PQ19)

Some of the functionalities derived from the responses to Q15 could be integrated into the prototype since they were already present in Gravity Sketch.

- Import props for set design (PQ20)
- Import 3D scans of people (PQ2, PQ28)
- Export photo and video (PQ12, PQ15)
- Take measurements through the *tape* tool (PQ18)

The complete list of activities and tasks executed in this immersive pre-production phase is reported in Appendix III.

7.4.3 Virtual Locations

Filming locations are at the centre of many creative and technical decisions. Three virtual locations with different characteristics, aesthetics, and purposes, were retrieved from 3D asset libraries (Location 01 and Location 03) or captured manually by the researcher (Location 02).

7.4.3.1 Location 01: La Casa Gassia (Demonstration)

Figure 7.1 3D Capture of La Casa Gassia

The first location presented to participants was a historical and remote house named *La Casa Gassia*, a domestic location in the Pyrenees that is not convenient in the preliminary phase as a location recce.
Participants were also offered some context and reasoning regarding why they would shoot here: they were involved in a short film set in the 19th century, and their director considered this location to be a suitable place to shoot the project.
One participant responding to the questionnaire (PQ06, set designer) expressed interest in importing a 3D asset in the scene from pre-existing 3D libraries. Therefore, while designing the practical prototype, the 3D model of *La Casa Gassia* was retrieved from Sketchfab (Giravolt, 2021). On this platform, creators share their 3D creations under different licences (Creative Commons included).

7.4.3.2 Location 02: Tower D (Practice)

Figure 7.2 3D Capture of Tower D Entrance at Brunel University

The second location, Tower D, presents a peculiar backstory that is worth explaining. While designing this user testing study, the researcher discovered that Brunel University was one of the main filming locations for Kubrick's famous feature film, *A Clockwork Orange* (Kubrick, 1971). The university was designed by Richard Sheppard, who opted for brutalist architecture, a style that since the '50s has become increasingly popular in the UK. The use of bare materials, such as concrete, and angular, minimalistic geometric shapes characterize brutalist architecture. Kubrick thought that establishing the fictional Ludovico Medical Facility in such a context was appropriate to convey the sense of oppression and domination that the main character, Alex, would face in that part of the story.
Some other interiors of the university, such as the entrance of Tower D, were used

for other scenes of the movie, including where Alex encounters his gang waiting for him (Figure 7.3).

This scene was a source of inspiration while designing the study, as it allowed the researcher to experiment with and practice the first part of the proposed process. The entrance of Tower D was captured using Polycam and the LiDAR scanner, which were integrated into the iPadPro 2020. Once the capture was elaborated by the Polycam cloud, the resulting .obj file was imported into Gravity Sketch and ready to be experienced by participants in the collaborative room of Landing Pad (Figure 7.2).

Figure 7.3 Scene From A Clockwork Orange *Set at the Entrance of Tower D*

When participants reached this point in the user testing sessions, they were instructed to recreate a scene without being informed that it was based on the screenplay of *A Clockwork Orange*. When the allotted time ended or when they completed the tasks, they were asked to remove the headset and take a break. During this pause, they were shown the original scene shot by Kubrick more than 50 years before in the location they had just virtually experienced. This surprised them and created a link between the proposed prototype and a real-world scenario.

In conclusion, choosing Tower D as the backdrop of the second location was useful for the scope of the study and represented an unexpected tribute to Kubrick.

7.4.3.3 Location 03: Mont-Saint-Michel (Practice)

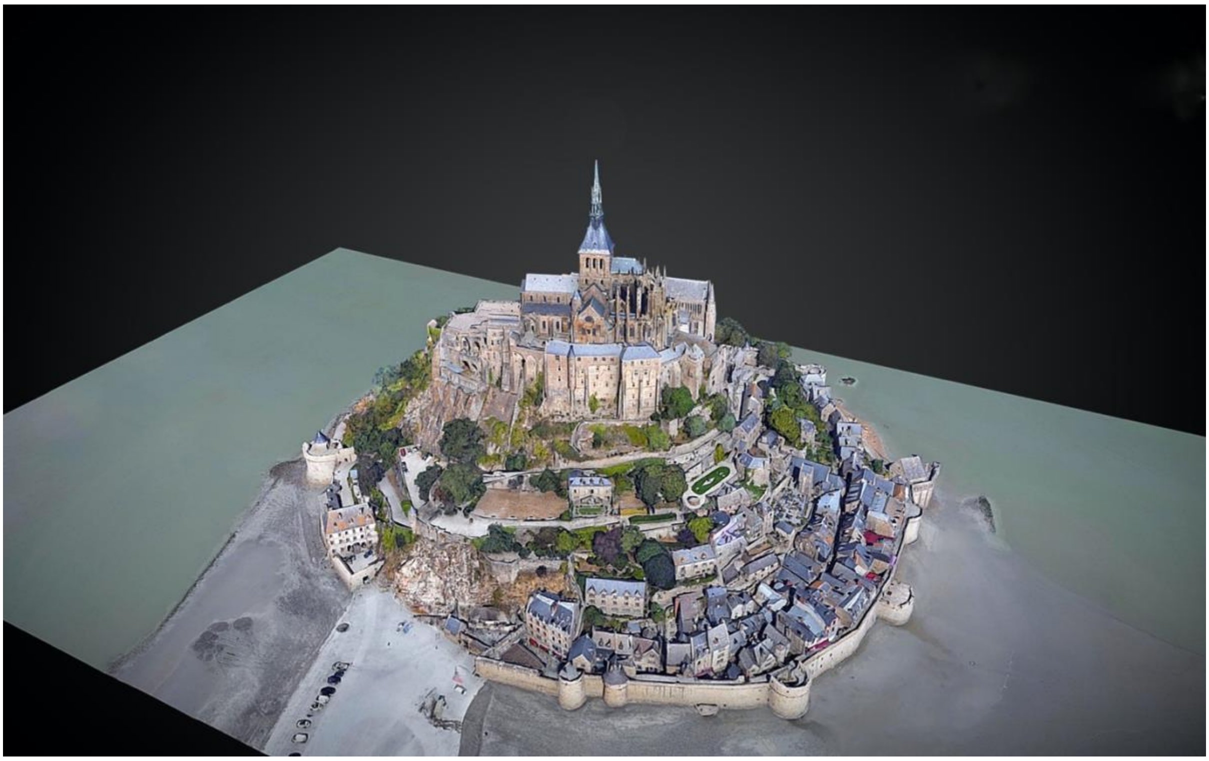

Figure 7.4 3D Capture of Mont-Saint-Michel

Many filming locations are set in interiors, but many other AV productions are set in exteriors. Consequently, the third location was a capture of Mont-Saint-Michel, the famous tidal island in Normandy, France. The 3D model was retrieved from Sketchfab (3dcreation_lyon, 2021).

The first two locations were shown at a 1:1 scale to participants; however, this 3D location was presented on a smaller scale, as if it were a physical 3D model used by architects when presenting a project.

The scale and perspective from above provided participants with a more comprehensive understanding of the entire location and its surroundings.

A quick overview of the 3D model was considered optimal for the fictional script ideated by the researcher to prompt participants in executing some tasks.

In this phase, participants were informed that the client, Normandy's ministry of tourism, wanted them to recreate a complex camera shot using a drone flying around Mont-Saint-Michel. Once again, this idea was inspired by one of the participants during the co-design workshops (PW02, cinematographer), who imagined a workflow where one could use the controllers to draw the drone's flight path in the 3D space to simulate in an immersive environment.

In this phase of the user testing session, participants were also presented with a different experience of visualizing the virtual elements through the *Passthrough* experimental feature offered by Gravity Sketch (Figure 7.5).

Passthrough allows one to see the real surroundings (e.g., the room where the user testing session is occurring) through the front cameras that are integrated into a VR headset, such as the Meta Quest 2. Using this hybrid view mode, it is possible to view in the real space virtual objects that are tracked in real time. There is no common agreement on the terminology to use to define this viewing mode. Pioneering researchers Milgram and Kishino (1994) developed a taxonomy encompassing the various forms of immersive technologies, the so-called *Virtuality Continuum,* which *'connects completely real environments to completely virtual ones*'. Industry players such as Meta (Oculus VR, 2021) refer to this as MR, and others, such as Varjo, as XR (Konttori, 2020). In this research, the umbrella term *MR* was adopted. The reason for switching from VR to MR was purely exploratory and aimed at collecting participants' opinions and feedback.

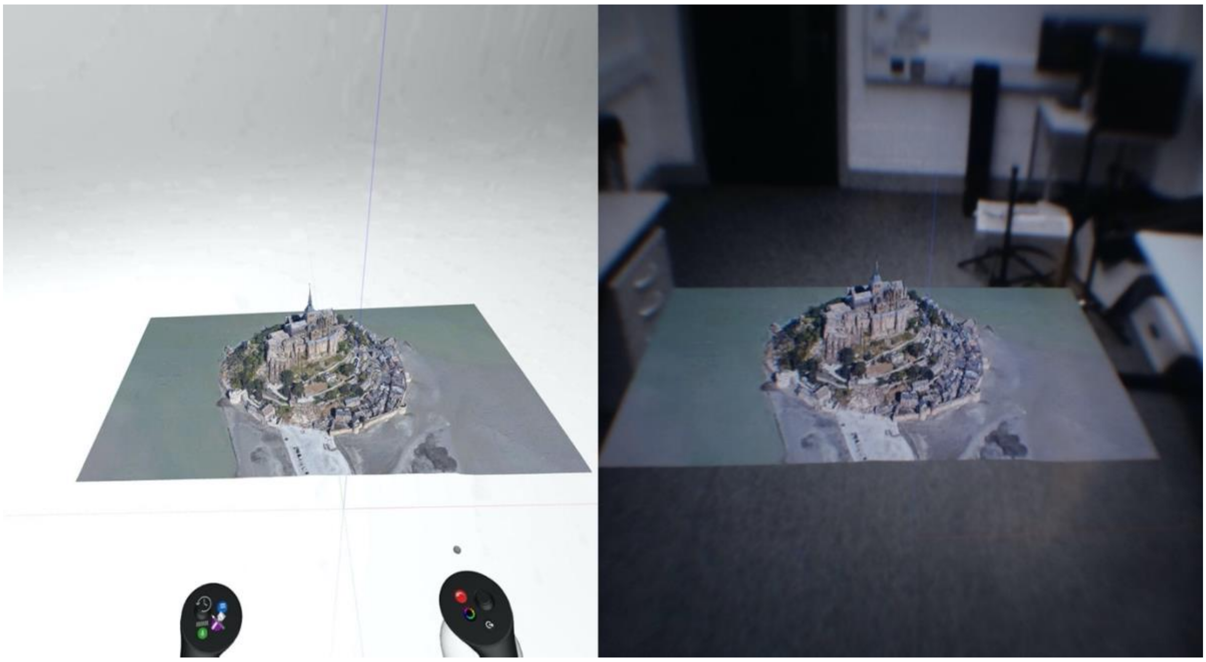

Figure 7.5 VR Viewing Mode (left) and Mixed Reality Viewing Mode (right)

7.5 Prototype Testing (PS-IV)

Pilot

To test the overall procedure, a pilot study session was held involving doctoral design researchers and film production students at Brunel University London.
After the pilot, it emerged that preparing the equipment and the virtual environment was crucial to avoid delays during the testing session. Additionally, it was important to prevent participants from taking extra steps that were not relevant to the scope of the study.

Once in Gravity Sketch and assessing the location's digital capture, participants taking part in the pilot study, were confused by the incorrect scale of the location showed while immersed in VR. To overcome this issue, while preparing the virtual environment, the researcher ensured that the location was scaled correctly and then locked it using the permission system already present in Gravity Sketch, as shown in Figure 7.6.

Figure 7.6 Layers' Functionality Inside Gravity Sketch

Locking some elements, such as the location's 3D capture, prevented participants from accidentally moving or deleting elements with which they were not supposed to interact.

Additionally, the researcher desired to reduce the time spent explaining how to use all the functionalities of the controllers, which could result in information overload. For the scope of the study, it was more important to push participants' attention to the verbal assessment and discussion of pre-production tasks needed in a specific location.

Accordingly, the initial number of tasks to be executed by participants was reduced in favour of providing the facilitator with more time to demonstrate the different features of the potential prototype workflow.

Finally, during the several planned breaks, participants exchanged thoughts on what they had just experienced, so it was important to consider these breaks as an important time frame to collect participants' spontaneous feedback.

7.5.1 Procedure

The following sections describe the procedure designed by the researcher according to the scope of the specific study.

7.5.1.1 Preparation

After agreeing to join the user testing session, participants were informed via email or phone about the requirements needed to successfully operate the designed procedure. More specifically, they needed to have an empty, walkable 12 foot by 12 foot room and a Wi-Fi connection.

The researcher created four Gravity Sketch accounts, one for each VR headset. This allowed four people to access the same virtual space, which Gravity Sketch calls a *Landing Pad Collab* room. Moreover, to quickly identify each headset, each was assigned a code name inspired by the famous movie *Reservoir Dogs* (1992), where the main characters were named after colours, such as Mr Orange, Mr White, and Mr Pink. As with the tribute to Kubrick, this choice of referencing a famous movie was both functional and helpful to engage with participants in a playful way.

Figure 7.7 Naming and Setup of VR Headsets

All the 2D (photos, screenshots, textures) and 3D assets (set design props, characters, 3D scanned locations) had previously been organized in a cloud folder on Landing Pad. An internet connection made it possible to retrieve the assets needed anytime and anywhere and place them in the virtual environment. Additionally, for highly detailed assets, such as the 3D location and character scans, the open-source 3D modelling software Blender was used to reduce the polygons of these assets. As reported in the documentation provided by Gravity Sketch (Kujovic, 2022), when using the Oculus Quest 2 wirelessly, participants should not introduce a scene with more than 500,000 polygons (or faces). Exceeding this would negatively impact the performance of Gravity Sketch.

Data were collected using an omnidirectional microphone to capture what was expressed by participants regardless of their position in the room and a video camera to capture participants' behaviours as well as interactions and to have an additional audio backup.

Furthermore, the VR collaborative sessions on Gravity Sketch and their sketches were saved. The same was done for the 3D captures created using Polycam. This decision allowed the researcher to retrieve what was generated by participants and extract visual materials to include in this writing for illustrative purposes. Testing session participants were rewarded with a £50 voucher.

7.5.1.2 Execution

Figure 7.8 Collage of the 11 Sessions With a Total of 29 Participants

Before starting, participants provided their informed consent, and a brief introduction to the study was offered. Using the Polycam application installed on the iPad Pro, the facilitator demonstrated how to capture the surrounding space digitally. Participants tried to replicate the process, and they were asked to think aloud while performing the task to provide direct data on their ongoing thinking processes (Van Someren, Barnard, & Sandberg, 1994).

After the end of this phase, they were shown how to wear the Oculus Quest 2 devices, and then the facilitator provided a VR headset to each participant. When wearing the headset, each participant was already in Gravity Sketch and logged in to the collaborative room.

They could see each other as minimalistic avatars where only their head and hands were represented in the virtual world (Figure 7.9).

Figure 7.9 Gravity Sketch Avatars

The facilitator then briefly explained the controllers' main buttons with an illustration prepared beforehand and already present inside the virtual environment (Figure 7.10).

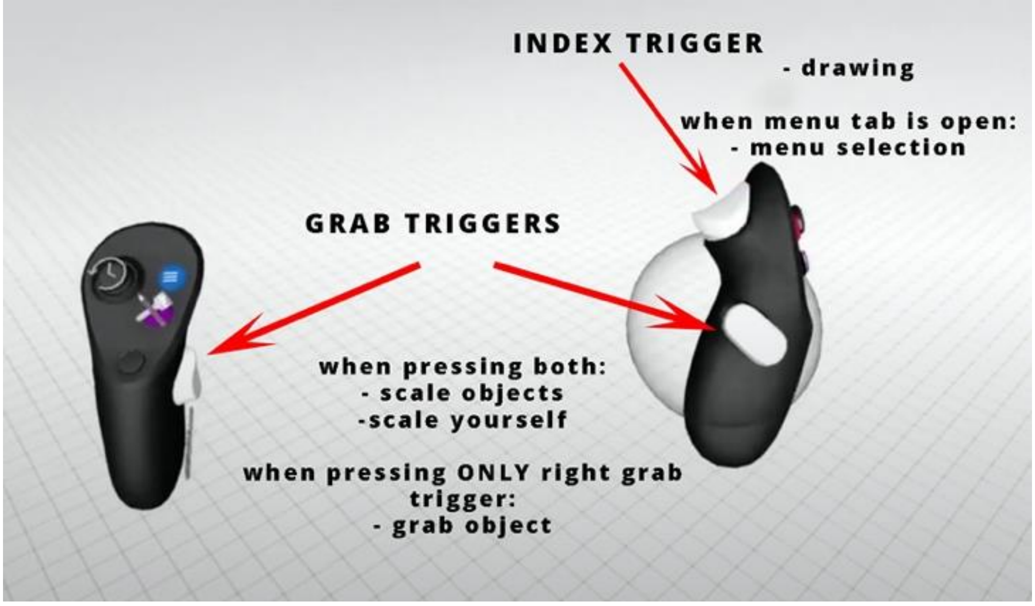

Figure 7.10 Controllers' Instructions for Participants

The considerable amount of effort required of the facilitator to oversee multiple aspects for the correct execution of the testing session prompted him to create and import part of the procedure into the virtual environment. This eased the process for the facilitator and allowed him to remember the planned activities (Figure 7.11).

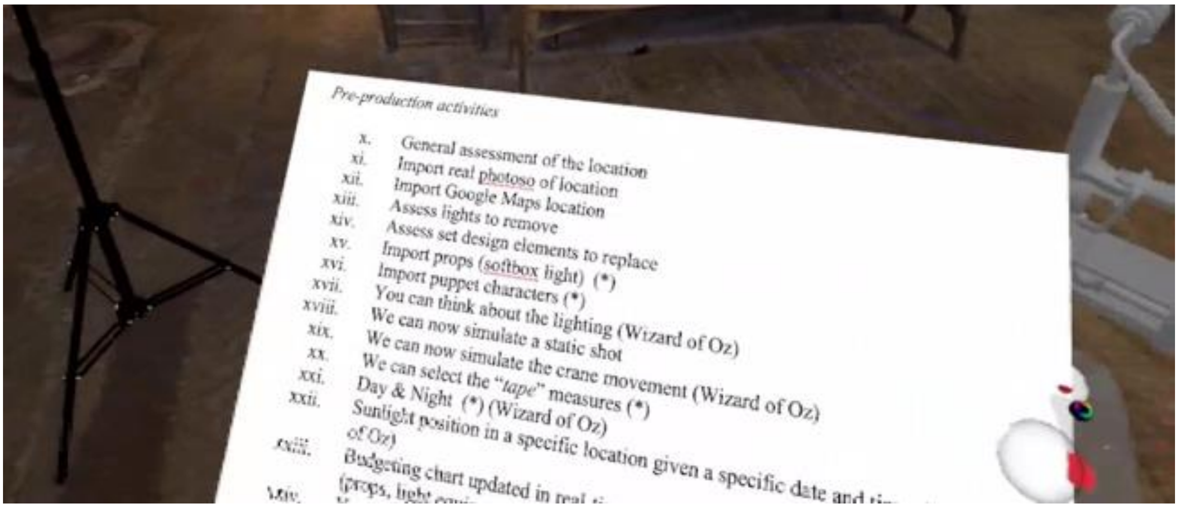

Figure 7.11 User Testing Procedure Document Imported Within Gravity Sketch

After assessing, discussing, and collaborating in the three locations (01: La Casa Gassia; 02: Tower D; 03: Mont-Saint-Michel), participants were informed that this activity in Gravity Sketch was over and a semi-structured group discussion would ensue.

To collect qualitative data from the group discussion, the questions asked of participants required them to assess the main aspects and functionalities of the prototype they had experienced.
The group discussion questions were designed to acquire additional feedback on the following:

a) The virtual location scouting and recce activity (*navigation*)
b) The overall visual representation of the location and other objects (*representation*)
c) Communication and collaboration with other people (*collaboration*)
d) Interface and interactions (manipulation, edit, creation, output)
e) Intention to use the proposed workflow in a real-world scenario
f) Economical aspects

The questions presented some similarities to Horvat et al.'s (2022) classification scheme. In their work, the authors identify eight classes to analyze when exploring the potential of immersive VR. applications developed for Design Reviews: *input, representation, navigation, manipulation, collaboration, edit, creation, and output*.

Table 10 Class Category Description According to Horvat et al. (2022)

Class category	Description
Input	Importing the content and information to be reviewed
Representation	Designing content that is available to users within the virtual environment
Navigation	Changing the viewpoint within the virtual environment
Manipulation	Temporary editing of the environment for better view or analysis purposes

Collaboration	Conducting Design Reviews collaboratively, either synchronously or asynchronously
Edit	Creating or changing the digital content under review
Creation	Creating a review content
Output	Exporting the review content and reviewed design

Horvat et al. (2022) propose a systematic and rigid classification to code categories (a total of eight), class subcategories (a total of 22), and classes (a total of 55); however, the set of questions designed for this study were more general and flexible. The questions prompted participants to begin an open discussion. Nevertheless, the questions asked during the post-study group were aligned to those eight main *categories* from Horvat et al. (2022) and are crucial when evaluating immersive VR Design Reviews software, such as Gravity Sketch.

Table 11 Questionnaire Questions in relation to Horvat et al.

#	Question (Post-study group discussion)	Category (according to Horvat et al., 2022)
1	How was your overall experience of the workflow?	/
2	How was the experience of being immersed in the location where you are going to shoot?	Navigation, representation
3	How did you find communicating your ideas with the other participants in the virtual environment?	Collaboration
4	How did you find collaborating at the same time with other participants in the same virtual environment?	Collaboration
5	How did you find interacting with the interface proposed?	Input, manipulation, edit, creation, output

6	What did you find most difficult when interacting with the interface?	Input, manipulation, edit, creation, output
7	Would you use this exact workflow presented in a real-world scenario? Why or why not?	/
8	What would stop you from using this workflow?	/
9	Do you think this workflow may be helpful in saving time and therefore money? How?	/
10	Was there anything you wanted to do while planning your production that you were unable to do?	Input, manipulation, edit, creation, output
11	How did the proposed virtual pre-production workflow compare to traditional pre-production?	/

In addition to the questions in Table 11, participants expressed their thoughts and feedback on relevant aspects.

At the end of the group discussion, participants were provided with a brief questionnaire; this reviewed Q12 and Q13 of DS-III's online questionnaire and asked whether the results obtained from judging the design fiction scenario were different from those obtained after testing a real prototype such as the one proposed in this DS-IV phase. Finally, participants were thanked for their contribution.

Table 12 Questionnaire From the End of the User Testing Session

Perceived Usefulness Compared with the current pre-production workflow you are experiencing in the AV industry, the proposed pre-production workflow...					
	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

...may facilitate communication with other collaborators.					
...may lead to explore more creative opportunities.					
...may be more helpful in the decision-making process.					
...may be more helpful when pitching ideas and seeking funding.					
...may reduce filmmakers' ecological footprint (travelling, energy consumption, etc.).					
...may improve filmmakers' well-being (mental health, safety, inclusivity, equity, etc.).					
Perceived Ease of Use					
…may be easy for me to learn.					
…would be easy for me to become skilful at adopting.					
would be clear and understandable for me to use.					

The complete study procedure can be viewed in Appendix III.

7.5.2 Results and Discussion (DS-IV)

Only two of the 29 participants felt discomfort while experiencing VR. Nevertheless, they were able to complete the whole procedure.

None of the participants expressed a total lack of knowledge towards VR and AR, and their degree of familiarity with these technologies varied.

Audio files recorded were transcribed using Trint, and video files were watched to observe participants' behaviours. Quantitative data were evaluated by adopting the adaptation of the TAM framework previously used in DS-III. Qualitative data were evaluated using an adaptation of the evaluation framework proposed by Horvat et al. (2022).

7.5.2.1 Questionnaire Results

Q12.2, Q12.3, and Q12.4 all received positive feedback, meaning that participants agreed with the proposed statements after experiencing the real prototype.

Q12	Compared with the current pre-production workflow in the AV sector in which you most frequently work...	Design fiction scenario – DEPERO (questionnaire)	Real prototype Polycam + Gravity Sketch (user testing)
		Average score	Average score
Q12.1	...may facilitate communication with other collaborators.	4.16	3.38
Q12.2	...may lead to explore more creative opportunities.	4	3.93
Q12.3	...may be more helpful in the decision-making process.	4.13	3.93
Q12.4	...may be more helpful when pitching ideas and seeking funding.	3.93	3.76
Q12.5	...may reduce filmmakers' ecological footprint (travelling, energy consumption, etc.).	4.33	3.9

Q12.6	...may improve filmmakers' well-being (mental health, safety, inclusivity, equity, etc.).	3.36	2.85

Table 13 Results Comparison: Usefulness

The scores are not as positive as those obtained in the online questionnaire and when judging the design fiction scenario. However, the degree of consistency seen in the results of these three questions indicates that the responses still show agreement.

The outcome of Q12.6 was the lowest score (2.85 = neutral) among all the questions. This result may have two explanations. First, filmmakers fear the replacement of phases where people meet and interact in person, and location scouting or recce is one of those moments. As PT10 stated:

> *'It would be opportune that the workflow proposed would be an addition and not a total replacement of the current one we have today…even if I think that in the future this totally virtual workflow will be the new norm'* PT10, executive producer.

The second reason could be that participants were returning to former work patterns after 2 years of confinement, where they had been forced to interact virtually with others both personally and professionally. This feeling was expressed by PW09 when noting how, when possible, scouting locations physicallyis preferred *'especially after this period [COVID-19 pandemic]'.*

The score obtained for Q12.6 may therefore represent participants' caution towards spending additional and extensive time in VR in this historic period.

Q13	Compared with the current pre-production workflow in the AV sector in which you most frequently work...	Design fiction scenario – DEPERO (questionnaire)	Real prototype Polycam + Gravity Sketch (user testing)
		Average score	Average score
Q13.1	…learning to use DEPERO may be easy for me.	3.56	3.58
Q13.2	…I may be interested in testing DEPERO firsthand.	4.26	/

Q13.4	…it would be easy for me to become skilful at adopting the proposed workflow.	/	3.83
Q13.5	…my interaction with the proposed workflow would be clear and understandable.	/	3.58

Table 14 Results Comparison: Ease of Use

For perceived ease of use (Q13), it is possible to observe that the results obtained after the user testing session are slightly more positive than those obtained in the online questionnaire. When participants were asked to judge the perceived ease of use of the description of the diegetic prototype, they answered with prudence, not knowing how that workflow would actually be experienced in practice (*'I'd have to try before expressing myself'* PQ10, post-production department). However, when participants completed the user testing session, they may have felt more secure about expressing positive feedback. Overall, they seemed confident about ultimately improving their skill and proficiency in using the proposed workflow.

This consideration is further supported by the facilitator's observations during the user testing session. Several participants initially encountered trouble in interacting with the design support. However, most eventually understood the functionalities and features when they were explained; a few achieved this independently.

7.5.2.2 Think-Aloud and Group Discussions

As expected, the strategy of involving professionals accustomed to working together and designing a procedure where multiple participants were asked to simultaneously experience and evaluate the prototype called for an open and transparent discussion without embarrassment or shyness. The activities designed for the procedure and the questions asked by the facilitator prompted participants to start discussions with one another, exchanging ideas and perspectives. Sometimes they agreed on a specific matter. Other times their opinions diverged, but in doing so, the study was enriched with valuable data that lent the researcher a more comprehensive and in-depth understanding of the subject.

Usefulness

After receiving this brief training, some participants recognised that this process would allow them to send other collaborators on location (‘*A very simple process, very doable that allows me to say to my assistant producer, I cannot go on location [to perform the capturing], you go’* PT18, producer). They also believed that taking a digital capture of the location would be useful to *‘show other heads of departments’* who could not attend the recce, especially in international productions, as stated by PT24 and PT25 (producers). They further described that their trusted cinematographer occasionally was not able to visit and assess the location in advance, forcing them to ‘always *rent and employ the same lighting equipment*’, therefore limiting their creativity in illuminating the scene.

During the demonstration phase of Location 01, participants were presented with the outdoor area near La Casa Gassia through a capture extracted from Google Maps (2022) and imported into Gravity Sketch (Figure 7.12). On that occasion, PT10 reiterated the importance of the space surrounding the filming location (adjacent rooms and spaces, both interiors and exteriors). This opinion was further supported by PT16, PT17, and PT18, who stated that ‘*if we think that this is our filming location, I would definitely go and capture every space that is accessible to get a comprehensive idea*’.

Figure 7.12 Capture Extracted From Google Maps

PT24 and PT25 explained that set designers usually work and plan the scenography on rough sketches of the space. They believed that '*having the actual spaces, having this* [digital replica of the space] *and sending it to set designers would show them very easily* [the space, thus] *facilitating working on the scenography, [as] sometimes there are spaces that are quite specific*'. PT04 (producer) and PT12 (director) also recognized the benefits for a set designer.

Figure 7.13 Set Design Notes Drawn by Sketching Red Circles Around Props

PT04, PT10, and PT24 claimed that capturing existing locations (both interiors and exteriors) should be a natural step for any location agency (that may be called different names, such as *regional film office*, *film commission,* or *film institution*) that assists AV production companies in seeking appropriate locations for their projects. The researcher explained to Group 8 that Polycam was also capable of capturing objects and creating a 3D digital asset, which caused them to recall a past client's request to transport heavy and bulky furniture to a remote location. They wondered if this technology and process could have solved that problem and so secured that project and budget.

Figure 7.14 User-Generated Capture of a Sofa using Polycam

Ease of Use

While using Polycam, most participants found the room scanning process to be simple and intuitive; they also liked the opportunity to learn the dimensions of that space. The speed at which they could generate a 3D image was unexpected and received positive feedback, and some claimed that this factor contributed to accepting some trade-offs in visual output. Participants were told that Polycam provides best practices (Polycam Learn, 2022) for scanning the space, and they recognized that dedicating time and effort to learning these best practices could improve the quality of their captures.

Similarly, at the end of the VR activities with Gravity Sketch, there was a consensus that participants could become more proficient after spending time in the application. Finally, it is important to mention that participants were informed that the researcher imported the 3D assets they experienced in Gravity Sketch before the user testing session because of the researcher's limited time and because the researcher thought the procedure was overly complicated. However, participants' feedback on the prototype's ease of use could have been different if they had personally executed the necessary steps to set up the virtual environment. Facilitation by the researcher represent a limitation of the study and in future iterations of the prototype, it is imperative to assess its ease of use more objectively.

Representation

While assessing the 3D capture that they generated, PT04, PT05, and PT08 agreed that the visual output was sufficient if the purpose was to have an overall understanding of the location. In few cases, the captures that users generated were not aligned with their expectations of visual output.

PT10 expressed that to better assess the location scanned, it would have been necessary to examine 2D pictures of the location. This feedback was expected, and in the following VR activity, participants were also provided with some real photos of the location, as shown in Figure 7.15.

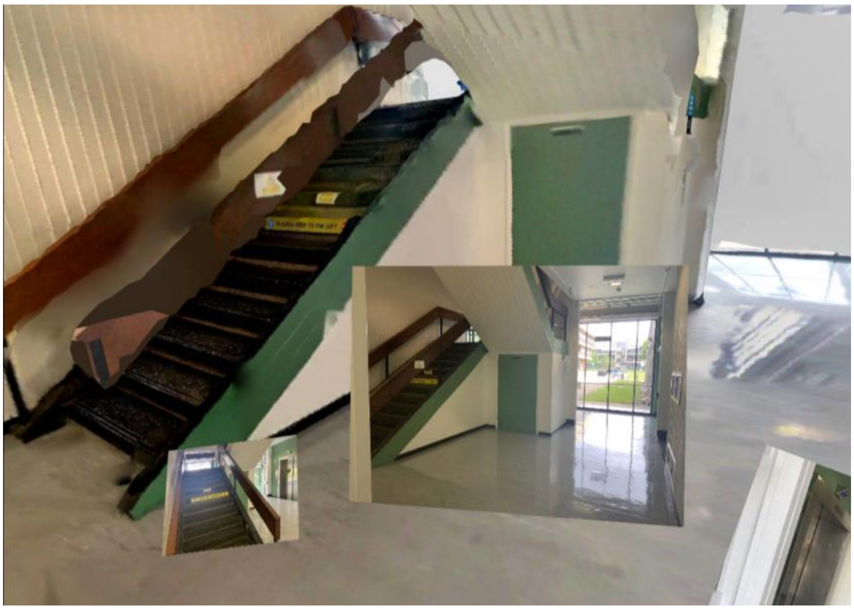

Figure 7.15 Real Photos of Location 02 Imported Into the Virtual Scene

A concern was expressed about the file size of captures generated using Polycam. The facilitator informed the participant that the average size of the .obj file was a few megabytes, and he felt reassured.

When assessing the result of the capture, PT01 and PT20 expressed that it could be useful if Polycam would also provide some information on the degree of accuracy of specific areas while capturing (such as, '*Wait! You didn't accurately scan this area'*). These users ideated that after processing, a heat map could highlight parts of the scanned object or environment that had some imprecisions.

During the session, Group 5 shared an anecdote regarding how they had already employed Polycam in a previous project. They used Polycam to generate a 3D capture of a location that was later inserted in a 2D scene, creating contents that were functional for their 2D production rather than using the tool to facilitate their production process.

Gravity Sketch allows users to experience a 3D replica of a scaled model (e.g., 1:50), which is similar to architects' physical architectural models that are made of cardboard. Experiencing a scaled model in VR or MR may cause artefacts and imperfections in the captures to be less evident, although users can easily perceive the overall location as more credible and accurate in its representation. As PT12 (director) stated, '*It seems [to be] a super accurate mode'*.

Figure 7.16 Location 01: La Casa Gassia at 1:1 (left) and 1:50 (right) Scales

Navigation

When participants wanted to explore remote areas of the virtual environment, they could not physically reach the spot because the real environment in which the user testing session was held was smaller than the virtual environment. This constraint is common for most VR applications. To overcome such limitations, VR designers usually propose alternative ways to enable this navigation, such as teleportation, joystick-based navigation, or redirected walking (Langbehn, Lubos, & Steinicke, 2018). Participants were instructed on using the teleportation tool in Gravity Sketch. Some participants could not easily teleport themselves around the virtual environment but managed to move within the virtual space after trial and error. The common tendency was to walk physically within the spatial limits of the room where the user testing session was occurring.

When experiencing Location 03 and activating the Passthrough feature, participants were surprised, and those who felt some degree of motion sickness now felt more comfortable than when they experienced VR. Since they could see each other's bodies and their respective avatar simultaneously, they noticed a discrepancy in their positions. To improve this viewing mode, defined by PT10 as 'familiar', the virtual avatar visualization should be removed when MR mode is activated. Moreover, some participants noticed that the Passthrough visualization was black and white and expressed that a fully coloured viewing was preferred. A few months after this user testing study occurred, Meta released a new headset named Meta Quest Pro, which provides a full-colour Passthrough function.

Collaboration

Many times participants put themselves in the shoes of other professional figures, expressing their opinions on how other personnel would feel when using such tools. It seemed to be a natural behaviour that may be due to the profound interconnections between these professionals. In some cases, the facilitator had to repeat questions and specify that the study purpose was to collect participants' feedback on what they experienced.

As a result of this strict collaboration among AV professionals, some participants, such as PT11 (executive producer), were hesitant to complete the questionnaire because of a conflict between their intention to use the proposed workflow and their expectation that collaborators may experience difficulty in using it. PT22 also made this remark, which can be traced to the DS-III findings, where the usefulness of the proposed workflow depends on the number of collaborators adopting the same workflow ('network effect'). PT07 (producer) noted that if the proposed workflow were to be adopted and bring value to the AV production, then:

> '*it has to be used by as many collaborators as possible…and to facilitate other people in using it, it has to be simple, very intuitive. The moment I open it* [Gravity Sketch]*, I should know how to use it. When this will happen, [it] will be a game changer'* PT07, producer.

Figure 7.17 Three Participants in the Virtual Environment Simultaneously

PT10 explained that it would be useful to see other collaborators' perspectives when they are trying to communicate. This feature was not available at the time of testing. However, after further research into this matter, it was discovered that Gravity Sketch later implemented this function as a beta feature, calling it *VR perspective*: '*You can follow any VR users in the room by clicking the Pin icon under the people menu; this will pin their view to your screen and you will see exactly what they are seeing'* (Humphreys, 2022).

Interface and Interactions

After wearing the VR headset and holding the controllers, participants – perhaps prompted by curiosity – tended to freely explore the different interactions possible within Gravity Sketch, although they were not instructed to do so. Sometimes it was necessary to redirect participants' attention. In a few cases, the facilitator needed to correct participants' mistakes, such as recovering objects they accidentally deleted or settings they unintentionally changed.

Unexpectedly, some participants preferred a scenario in which they could work on the same production in an immersive and 2D manner. PT01 suggested that because filmmakers may find it more intuitive to work on 2D screens, they might also prefer to edit the scene and manipulate objects within the virtual environment using established inputs, such as a mouse and keyboard.

Similarly, other groups suggested that one of their collaborators who was proficient with such a workflow could mirror the reviewing process on a 2D screen. Therefore, it is important to clarify that some participants preferred a 2D viewing and experience of the virtual environment but wanted to take advantage of the possibilities in the real-time rendering aspect of the workflow.

Economical Aspect

PT05 was surprised that such hardware and software technologies are already on the market and ready to be used. PT16 was surprised by the current price of a VR headset such as Meta Quest 2, which was perceived as much more expensive. While evaluating the capture output of the room generated using the iPadPro and Polycam, PT26 (post-production supervisor) said, *'I think you would end up with something that you could definitely use, especially for free'* (PT26, VFX artist). Overall, the price required to adopt the proposed workflow, which can increase depending on the number of collaborators whom a production team wants to enable (equipping more people would require more VR headsets), was considered affordable and did not represent a 'dealbreaker' for its adoption. Participants agreed that deciding to spend money on the equipment needed to enable such a VP process would require further discussion within the team.

Intention to Use

When discussing the intention to use the proposed alternative workflow, it was clear that those in different roles may be more interested than others in integrating the workflow. Many participants believed that creative figures, such as set designers, directors, and cinematographers, would benefit from spending time learning how to use this immersive VP process, which would therefore enhance their work. Others, such as producers, were uncertain whether introducing this workflow would simplify their daily tasks and bring some benefits or whether it would complicate the whole process. Nevertheless, other figures involved in the post-production phase, such as editors or VFX supervisors, expressed a neutral opinion since they are usually not involved in the pre-production process.

AV professionals working in the advertising sector agreed that the workflow should be used internally by the team and not extended to their clients while presenting their creative ideas or plans on the production's organization. This consideration was made because of the constraints and limitations regarding representation and ease of use. The risk foreseen by participants was that it could create more misunderstandings than explanations in the eyes of their clients, who, in their opinion, already struggle to comprehend even the basic principles of the established AV process.
Overall, participants expressed interest in experimenting with the alternative workflow in a real-world scenario to enable a more thorough evaluation.

7.6 Sub-Prototype: Drone Digital Twin

During the remote co-design workshops, PW02 (cinematographer) first conceived the idea of planning the drone's flight path. This concept could support directors, cinematographers, and drone operators involved in capturing complex drone movements. Since the rest of the group positively evaluated such an idea, it was considered worthy of further exploration of its technical feasibility.

Recently, drone cinematography has become increasingly affordable for AV productions (Mademlis et al., 2018), and some researchers have explored how drone cinematography can be pre-planned (Angelopoulos et. al., 2022) and automated (Liu & Shen, 2020) using immersive technologies.
Zhang et al. (2020) previously investigated drone cinematography in a virtual environment. To do so, they captured the area where they wanted to simulate the drone's flight path, or they used pre-existing 3D environments (similar to the description in Section 7.4.2.3) based on Google Earth's source data. They imported such 3D environments in Unreal Engine 4 and then virtually simulated the drone's flight path. They conclude that future work should be focussed on experimenting with (a) *how the workflow can integrate and employ VR devices* and (b) how *the data generated in the simulation can be added to autopilot software for autonomous drone operation*. If data generated in the immersive environment could be transferred successfully into autopiloting software, then this workflow could generate

a DT of the drone's flight path, thus opening new possibilities for cinematographers, as suggested by PW02.

7.6.1 Definition of Digital Twins

DTs were first formally introduced by Michael Grieves in 2003 at the University of Michigan (Grieves, 2014) and, more specifically, for the manufacturing process. However, the concept of DTs had been familiar to NASA since the 1970s (Barricelli, Casiraghi, & Fogli, 2019). At its Space Center in Houston, Texas, NASA had 'mirrored systems' of spacecraft that had been sent to space. The most famous example is Apollo 13: through this mirrored system, engineers on earth instructed astronauts on board the spacecraft to solve a critical issue they encountered.

The scientific definition of DTs has not yet been determined (Negri, Fumagalli, & Macchi, 2017); therefore, it is still a topic of debate. In this regard, Barricelli, Casiraghi, and Fogli's (2019) survey is helpful in outlining the current definition, characteristics, and applications of DTs. After analyzing 75 papers, they state, '*DTs can be defined as (physical and/or virtual) machines or computer-based models that are simulating, emulating, mirroring, or 'twinning' the life of a physical entity, which may be an object, a process, a human, or a human-related feature'.* This comprehensive definition encompasses the various definitions from the current literature. Notably, they mention the word *process*, which is the same term used in Section 2.1.1 to describe VP. Therefore, it is necessary to further investigate the relationship between the two.

Based on their review, a crucial requirement for all DTs is having a *seamless connection* and *continuous data exchange* between the physical and virtual twins. Through this exchange, the virtual twin is constantly aware of what is occurring in the actual world to its physical counterpart. This *awareness* is possible through sensors, which can be many and specific, installed on the physical object, system, or human and are capable of collecting data. Therefore, DTs are related to another emerging technology: the Internet of Things (IoT). DTs can also be combined with AI to predict future failures of the physical twin, leading to so-called 'predictive maintenance'. According to Barricelli, Casiraghi, and Fogli (2019), DTs have been employed mainly in manufacturing, medicine, aviation, and hospital management. However, in the last chapter of their study, they explain that many other applications of DTs may be viable in other sectors. Hence, the reason and opportunity for applying the DT concept to the AV field with this additional experiment is to expand the current literature on this emerging field.

Considering the user testing session, specifically Location 03 (planning a drone shot of Mont-Saint-Michel), the first direction from Zhang et al. (2020) was completed successfully. Zhang et al.'s (2020) next step is testing the feasibility of translating the data generated in VR (the hand-drawn drone flight path) to instructions that would be entered into drone autopilot software. Figure 7.18 compares the contribution that the researcher aimed to generate as the output of this work to Zhang et al.'s goal.

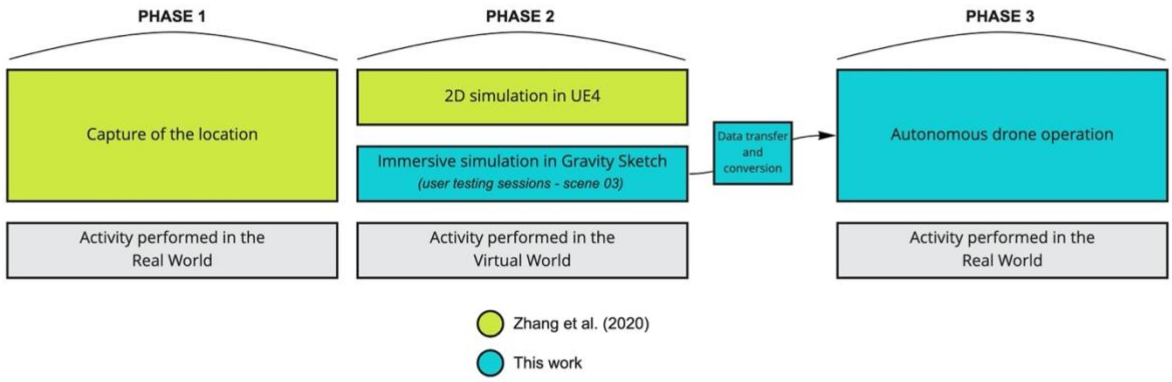

Figure 7.18 Relationship Between Zhang et al. (2020) and This Work

It was necessary to clearly understand which file formats could be exported from Gravity Sketch and would be compatible with autopilot software.

7.6.2 Experiment Design

Landing Pad (2022), the cloud-based solution to access, upload, and download Gravity Sketch projects (version 5.5.55) allows users to export the following formats: .fbx, .iges, .obj, .gltf, .usdz, and .mp4.

Among these, the .obj format is thought to be the most promising when opening the file with a generic text editor. Reading how the data were stored and organized, the researcher noticed that this format preserved the absolute values of the vertexes of the flight path drawn in VR, as shown in Figure 7.19.

```
v -0.164776 0.009674544 0.1441538
v -0.1647589 0.00986948 0.1432138
v -0.1647455 0.01050841 0.1424971
v -0.1647393 0.01142014 0.1421959
```

Figure 7.19 Gravity Sketch .obj File, Opened With a Text Editor

It became conceptually clear that the absolute values of the XY axis needed to be converted into GPS coordinates (latitude, longitude), and the absolute values of the Z axis needed to be converted to altitude.

Even if the conversion can be done automatically, it is still necessary to manually set a reference point or value that could be interpreted identically in both the starting format (.obj) and ending format (.klm).

The .klm format (keyhole markup language) was chosen as the ending format because it is supported by Litchi (2022), the autopilot software that was employed in the study. Additionally, this software is compatible with the DJI Mini 2 drone that was used for the test and is widely used by filmmakers when trying to accomplish drone shots.

```
                <LineString>
                        <tessellate>1</
tessellate>
<altitudeMode>absolute</altitudeMode>
                        <coordinates>
                                -0.4650379039650
554,51.53134397876618,45
-0.4650284634613466,51.53110960842304,65
-0.4650298077373272,51.53097237110476,45
-0.4650299859186668,51.53085184228244,80
                        </coordinates>
                </LineString>
        </Placemark>
</Document>
</kml>
```

Figure 7.20 File in .kml Format to Import in Litchi, Opened With a Text Editor

The researcher initially planned to employ a DJI Mavic 3 (DJI, 2022a) from the start to the end of the process, but while testing, it was discovered that compatibility between this drone and Litchi was not possible. Therefore, the new strategy consisted of using the DJI Mavic 3 to capture the initial dataset of images because it was capable of capturing higher quality images than the DJI Mini 2 (DJI, 2022b). Then, the DJI Mini 2 was employed during the shooting phase because of its compatibility with Litchi.

7.6.3 Results

The drone was flown around the Brunel University campus, and its subject was the iconic lecture centre, a location chosen by Kubrick more than 50 years ago for *A Clockwork Orange* (Kubrick, 1971).

Figure 7.21 Scene From A Clockwork Orange *(1971) Set Outside the Lecture Centre*

It took approximately 10 minutes to fly around the chosen building and 15 minutes to upload and process the images on Polycam (89 images in the .jpg format taken from different perspectives).

Figure 7.22 Images From the Dataset Collected Using the DJI Mavic 3

Polycam allows users to process the dataset on a different *level of detail* (LOD), which is a common term in CGs, especially video games, to describe the different levels of complexity attributed to 3D geometric figures. Setting the output detail to ‘raw’ created a 3D mesh of 921,599 polygons (or faces), which needed to be reduced to be experienced smoothly in Gravity Sketch.

The same was valid for the two textures generated (8192 x 8192 pixels) each, which were merged into one with image manipulation software, such as Adobe Photoshop (2022). Setting the output detail to ‘full’ on Polycam created a 3D mesh of 184,450 polygons and one texture of 8192 x 8192 pixels. This export setting from Polycam was considered the best option since it did not require extra time for post-processing and could be directly imported into Gravity Sketch.

Figure 7.23 Movie Scene (top) and 3D Model Generated (bottom)

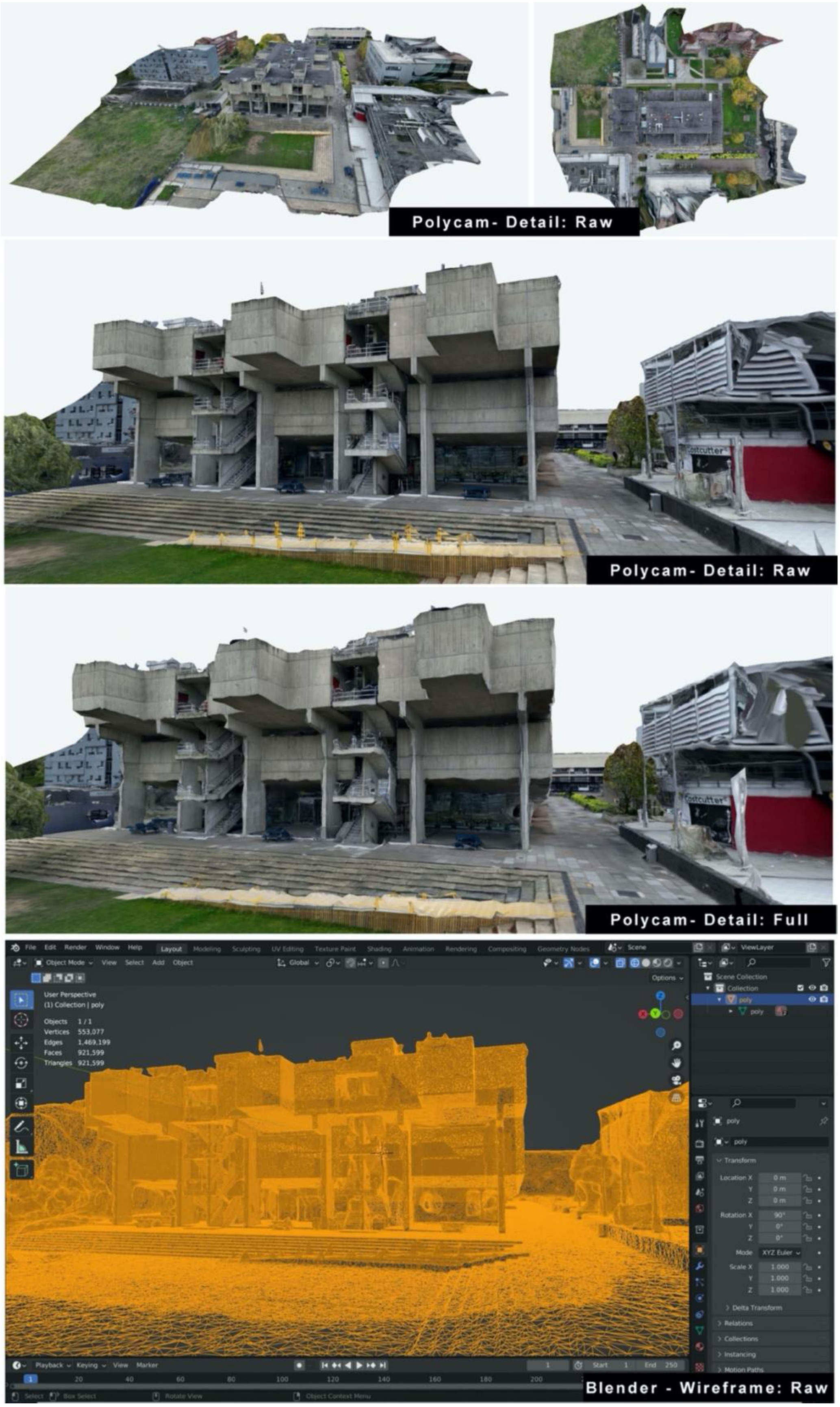

Figure 7.24 Different Levels of Detail Using Polycam and Blender

Once the .obj file that was exported from Polycam was imported in Gravity Sketch, it was possible to plan the drone's flight path and draw the preferred itinerary.
First, a reference object was created to place inside the scene. The shape of a cube was considered the most appropriate since it could be framed in front of the lecture centre, which presents a 90° angle.
Next, a freehand red stroke representing the drone's flight path was drawn.
Figure 7.25 portrays how the level related to the 3D model of the lecture centre is made invisible so that only the cube and the red stroke are exported.

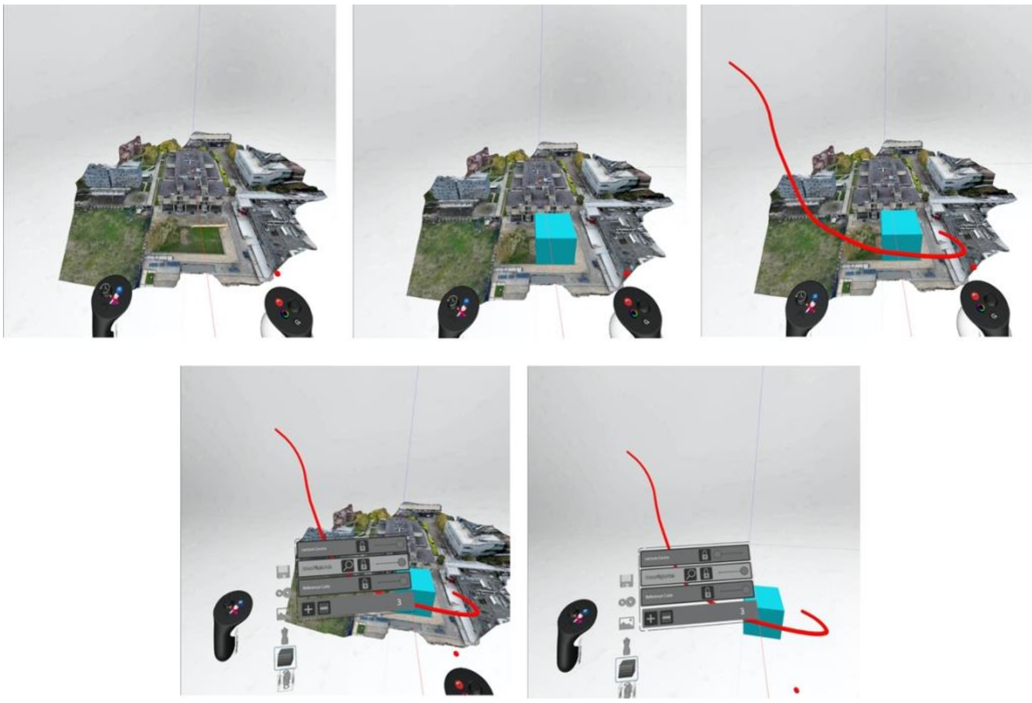

Figure 7.25 Steps Performed Using Gravity Sketch

After saving the sketch on the cloud (Landing Pad), the same sketch that was exported as a .obj file was converted into a .3ds format using a free online format converter platform, such as ASPOSE, so that it could be imported into SketchUp.
From here, the 3D mesh of the stroke and cube were assigned geospatial metadata information through one of SketchUp's features, Add Location.
Then the cube was appropriately scaled and positioned to frame in front of the building once again, as shown in Figure 7.26. This step introduced approximation due to the manual intervention of positioning the cube in the reference position.

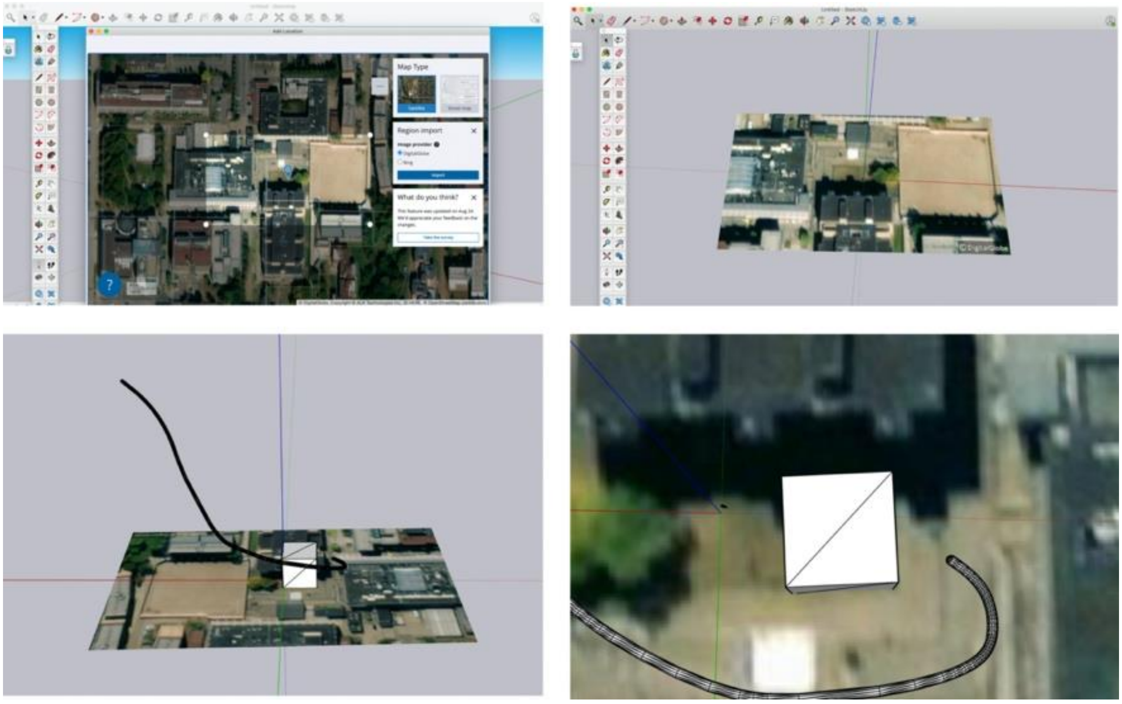

Figure 7.26 Steps Performed in SketchUp

A .kmz file was exported from SketchUp and imported into Google Earth. Because of the metadata associated with the 3D model while using SketchUp, the model, once imported into Google Earth, was placed directly in the correct position, as shown in Figure 7.27.

From here, it was possible to use the Add Path feature in Google Earth to manually draw key point after key point over the stroke that was initially made in Gravity Sketch. This process of manually replicating the stroke introduced a degree of approximation, which made it impossible to set the elevation (Z axis) of the single key point, so this 3D aspect of the flight was lost.

Figure 7.27 Steps Performed in Google Earth

After that, it was possible to export the flight path as a .kml file, which can be imported into the Litchi cloud platform.

Using the Litchi application on the iPad (Figure 7.28), it was possible to synchronize the cloud with the application and set additional commands, such as drone altitude (Z axis) for each key point and camera orientation. Once the preferred settings were chosen, it was possible to let the drone fly autonomously through the flight path that was initially planned in VR.

Figure 7.28 Steps Performed in Litchi (Cloud and Mobile Application)

7.6.4 Discussion

Overall, the initial process of capturing the exterior location (photogrammetry) and planning the flight path using an immersive device (Meta Quest 2) and software (Gravity Sketch) was smooth and feasible.

The location capture generated a highly detailed and overall satisfactory 3D asset of the location. Nevertheless, some areas of the building presented some artefacts and inaccuracies. Thin objects were not correctly captured, as can be seen in Figure 7.29, where the handrail of the external stairs is poorly represented. In this regard, it is crucial to note the risk of flying a route where there are light poles or other thin objects that were not previously detected by the capture.
Similarly, if the intended flight path is in a building or area that is subject to changes over time (e.g., tree branches, new structures and buildings, etc.), it is recommended to pre-plan the flight from a recent capture. An additional risk may occur if the drone is flying autonomously through the pre-planned route and encounters wild animals (birds) flying in the same area. If the drone is not instructed by proximity sensors to avoid crashing into unexpected obstacles, then this could represent a danger.

Figure 7.29 Capture Artefacts: Tree Branches and Leaves (left), Handrails (right)

Testing also proved that weather conditions might affect the quality of the capture. It is not recommended to capture when sunlight is casting a strong shadow on the ground since it creates an abrupt transition between highlights and shadows in the picture (known in photography as *hard light*). These sudden lighting changes between different faces of the building were not well elaborated by Polycam when processing the uploaded pictures. Consequently, it is advised to capture data during overcast weather when sunlight is filtered and softened by clouds (known in photography as *soft light*).

The immersive planning of the drone's flight path was technically feasible; however, translating data that originated in Gravity Sketch was not. As shown in Figure 7.30, two steps of the proposed workflow required manual intervention: altering original data due to approximation while (a) repositioning the reference object in SketchUp and (b) redrawing the flight path in Google Earth.

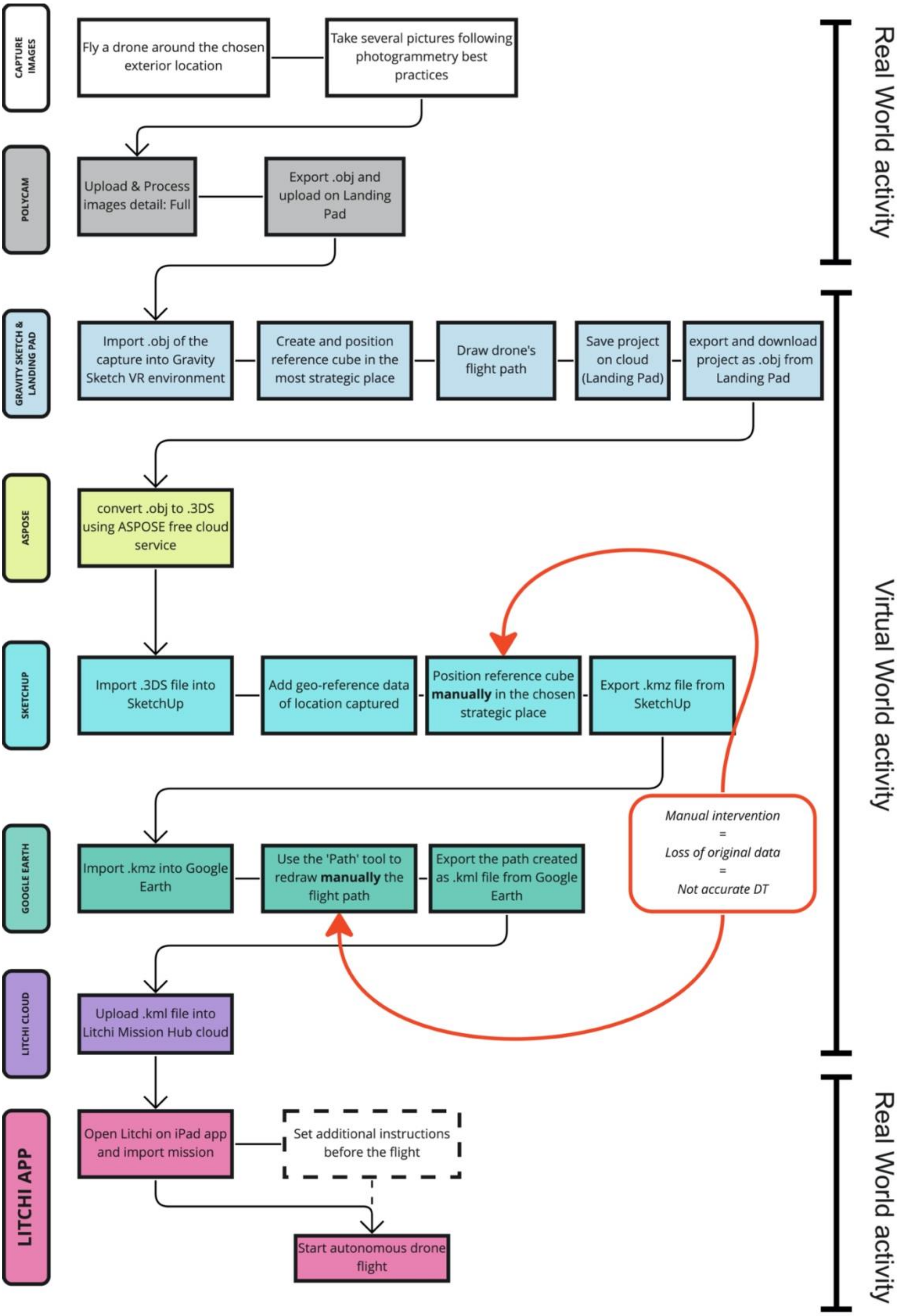

Figure 7.30 Proposed Workflow for Immersive Planning and Drone Automation

A limitation of Google Earth’s *Path* feature is that it only allows users to set points that are linked, thus creating a polygonal chain that cannot be curvy. Recreating the curved trajectory drawn in Gravity Sketch is not possible inside Google Earth, but it can be redrawn manually inside the Litchi application. Similarly, to set the altitude of each point, it is necessary to insert values inside the .klm file or from within the Litchi application.

Manually repositioning the reference cube in SketchUp and redrawing the flight path in Google Earth introduced a degree of inaccuracy. A conservative estimation of this error in the 3D space is between 50 and 150 centimetres on all axes. This inaccuracy is directly related to the time and effort spent by the user while executing these manual tasks.

These discoveries reinforce Zhang et al.'s (2020) conclusions: finding a way to convert formats generated in immersive environments that are compatible with autonomous drone piloting software is still needed. Nonetheless, the proposed workflow may be an alternative aid to cinematographers and drone operators when planning a drone's flight path. While experiencing Location 03 during the user testing sessions in DS-IV, participants expressed positive feedback about the usefulness of such an approach when planning a drone shot.
What has yet to be investigated by future scholars is the proposed alternative workflow that is summarized in Figure 7.30, as evaluated in practice by drone operators and cinematographers.

In this work, the researcher attempted to accurately convert a .obj file to a .kml file. However, it is essential to be aware of how the starting and ending formats can be replaced. The steps explained herein might be subject to change if software is discontinued or updates no longer support specific formats. What is most important in the context of this study – the core goal – is discovering how to link geometrical information located in the Euclidean space to GPS.

Nevertheless, describing and visually illustrating the workflow ideated and followed to achieve the result shown was considered helpful for a better understanding of the original concept.

7.7 Chapter Summary

This chapter described the outcome of collaborative in-person testing and evaluation of the practical prototype, which was developed in PS-IV, by 11 groups with a total of 29 AV professionals. The prototype consists in a workflow made possible by the combination of already existing hardware and software solutions (Meta Quest 2, iPad, Polycam, Gravity Sketch). The main benefit brought by this workflow is to immerse filmmakers into a virtual replica of the shooting location and facilitate several pre-production activities. Details on the prototype and its functionalities are reported in Appendix III. The rich amount of qualitative data collected during the testing session, and later analyzed, contributed to the answer for RQ1.3 and to recommendations for implementing the prototype within SMPs and, ergo, its evaluation in real-world scenarios. These recommendations are described in Chapter 8.

Furthermore, the specific concept ideated by one of the PS-II participants regarding the immersive pre-planning of a drone's flight path was empirically tested and further extended the work of previous researchers on the topic. In this regard, an alternative workflow is proposed when planning a drone camera shot.

Chapter 8

DISCUSSION

8. Discussion and Recommendations

This chapter presents the outcome of the research process and the output generated from each study. Additionally, recommendations are provided for investigating emerging areas and designing other VP processes that can be applied to SMPs.

8.1 Research Output

8.1.1 General Discussion

<u>The Importance of Virtual Production Among Small and Medium Productions</u>

Many VP processes have been developed by industry players and described in detail in the literature. However, few were developed while considering the significant number of SMPs that are also part of the AV industry. However, the designs described in these studies were ideated autonomously by the same researchers without systematically involving the AV professionals from the beginning of the design process.

The in-depth interviews conducted during the exploratory study (Chapter 4) provided additional supporting evidence that an alternative VP process was desired by SMP practitioners while also revealing initial user requirements. The curiosity and interest in alternative, affordable, and easy-to-adopt VP processes were present among participants. The possibility of experiencing the VP process, similar to their counterparts working in high-end productions, was welcomed with enthusiasm.

<u>Filling the Gap</u>

The alternative VP process with its emphasis on pre-production was presented in PS-IV (Section 7.4) and tested by professionals in DS-IV (Section 7.5); the design fiction scenarios were developed in PS-III (Section 5.7), and the initial concepts were collected from DS-IIB. Each represents practical contributions to the VP field, as shown in Figure 8.2 and briefly described in Figure 8.3.

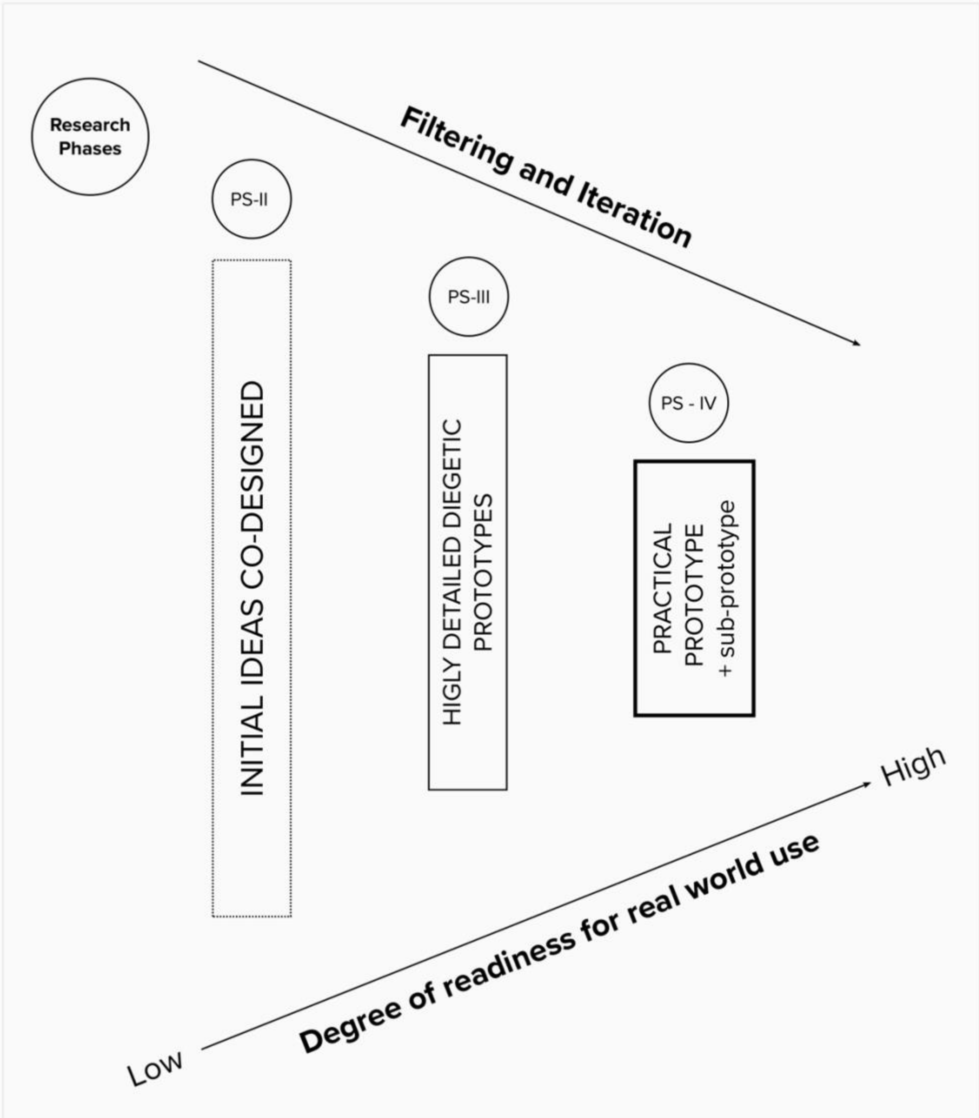

Figure 8.1 Illustration of the Practical Output Generated Throughout the Research

Additionally, this chapter explains that the insights collected throughout the research contributed to generating a new conceptual framework for developing VP processes for AV professionals throughout SMPs, as explained in the next section.

While filling the gap in the literature, the findings in this PhD work also led to further considerations of how the research output produced from this investigation may be adapted to other fields and uses.

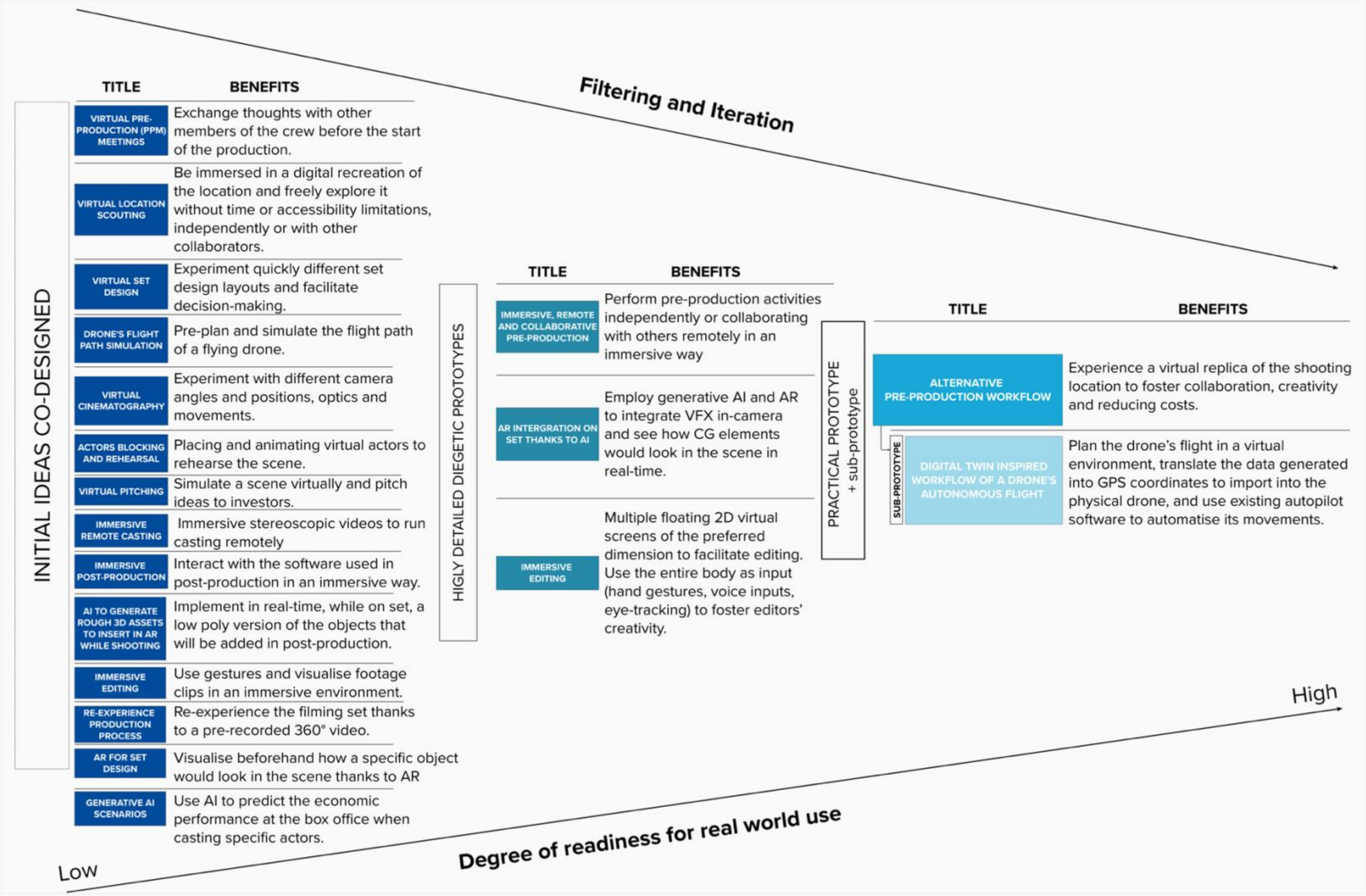

Figure 8.2 Brief Description of Each Output Generated Throughout the Research

8.1.2 Discussion on the Final Practical Output

In DS-IV, a specific process was designed and tested by employing pre-existing hardware devices and software services. It should be noted that more advanced products may replace these proprietary products in the future because the rapid pace of technology, especially immersive technologies, is evolving. However, the core functionalities and uses are likely to remain the same for years. The capturing software Polycam may be replaced by other applications capable of generating a better output quality. More lightweight and ergonomic headsets will substitute VR headsets such as the Meta Quest 2.

In this regard, Blessing and Chakrabarti (2009, p. 34) explain that PhD researchers often spend time defining the specific features of the design support developed. However, *'the core research contribution often lies in this concept. The aim of a research project is rarely to develop a commercially viable support'.*

In agreement with Blessing and Chakrabarti, the findings generated from this research suggest recommendations for a real-world implementation of the design support that was co-created throughout the iterative phases of the research.

<u>Ease of Use Is Key</u>

The findings reveal how much attention was bestowed upon the ease of use of the final design support. Throughout the research, especially after the evaluation phase in DS-IV, participants shared excitement and surprise towards the technologies presented as well as caution when discussing the integration of the proposed alternative workflow in their workplace. Research participants wondered whether the trade-off in time and effort to learn how to operate with new tools would prove to be convenient or if it would unnecessarily complicate issues.

Because of the intrinsically collaborative nature of filmmaking, many participants initially expressed that everyone should be proficient and skilled while operating the proposed VP process. However, after discussing this matter, participants agreed that some AV personnel might benefit from simply wearing a VR headset and being immersed in the virtual location without interacting with controllers or taking advantage of the virtual tool set (drawing tool, virtual camera, importing assets, lighting, etc.). Additionally, these lesser technologically proficient professionals can be guided by more skilled collaborators participating in virtual meetings, which is similar to the user testing session where the researcher or facilitator was sufficiently skilled to guide the group and respond to most of their requests (e.g., '*Is it possible to resize this element? Is it possible to take notes? It is possible to create a copy of this element?'*).

Providing the necessary tools and instructions for users to autonomously adopt the VP process in a real-world scenario and later asking for feedback on their experience could cast further light on this matter.

Role-Specific Interfaces and Tools

Established editing software commonly used by AV professionals, such as Adobe Premiere (2022), offers the possibility to have pre-existing UIs, depending on the intended task (e.g., editing, colour corrections, effects, audio, review, etc.). Further, they also allow users to customize their unique interfaces according to their preferences and needs.

It is therefore argued that designing different VR UIs specific to each role (director, cinematographer, producer, etc.), may contribute to a better UX overall. AV professionals, while accessing the VR pre-production application, could select their role-specific interface and visualize only those tools appropriate for accomplishing their role-specific tasks. Consequently, this would lead to a higher degree of usability for end users. Because of convenience, it was decided to rely on Gravity Sketch, whose UI and UX were designed with product designers in mind, not filmmakers.

Consistency of Interactions Across Immersive Applications Is Yet to Be Defined

Testing the alternative VP process in DS-IV and interacting with Gravity Sketch highlighted the different outcomes users expected from specific buttons, especially if they previously experienced other VR applications (e.g., games). For example, the Meta Quest 2 controller (Figure 7.10) has one trigger for the index finger and one for the middle finger. In Gravity Sketch, the index finger trigger is responsible for interacting with the UI elements, such as tabs. Conversely, the trigger pressed by the

middle finger allows one to grab an object and reposition it in the virtual space. Some participants were confused about the different interactions because, in other VR applications, these functions worked in the opposite way.
This specific example can be extended to non-immersive software, such as mobile applications, and even hardware devices, such as smartphones. Today, when unboxing a new smartphone, it is often only a matter of seconds before the user locates the side button and presses it to power the device. This immediacy in actions can be attributed to the fact that, over the years, product designers as well as UX and UI designers aligned their designs to be consistent across different hardware and software products. Consequently, this consistency – this common language – facilitated users' understanding of how to interact with machines. This consideration extends beyond the current research but is important for creating better and more intuitive immersive applications.

Visual Representation Improvements

> ‘What is the difference between the real world and the virtual one?’
>
> Yuuki Asuna, Sword Art Online II, Episode 01

Oculus VR founder Luckey (2016) answered this question without hesitation: *‘The quantity of data, that's all’*. Putting aside the philosophical aspect of such a question, Luckey is correct regarding the amount of information a computer can process and the degree of visual fidelity available as the output of this computation. As explained at the beginning of this research, filmmakers have a keen eye for images. The research demonstrates that the visual fidelity of the virtual elements experienced in the VP process are an important factor. As explained by PW09, if the virtual environment is not represented faithfully, then potentially false assumptions can result when assessing the location. This may translate into serious troubles when arriving at the physical location during the shooting phase. To reduce misinterpretation of the space, participants noted during the testing and evaluation of the prototype that they could also study real photographs that faithfully represent the location while being immersed inside the virtual replica. Overall, the visual representation presented in DS-IV was considered acceptable if used as a tool for becoming familiarized with the real location before an in-person visit or shooting. On this matter, more technical effort should be made. Future work should focus on improving the visual representation of the virtual elements without exceeding the computational capabilities of immersive consumer devices and software. Alternatively, future research may experiment with techniques such as *cloud computing*, which require immersive devices to stream the video output from the computation performed by powerful centralized servers. The gaming industry has already been providing these services for playing video games (Nvidia, 2023) without requiring users to own powerful personal computers; only an internet connection with a large bandwidth is necessary.

Relighting Environments, Objects, and People

One of the limitations of scanning technologies, such as Polycam, is that the capture generated is relatively simple in 3D geometric and texture mapping. Many other factors are needed to recreate a realistic representation of real objects. One of the most crucial is lighting since each object and surface reflects light differently. Lighting proprieties in CG is a field of its own that has been investigated since the '70s (Gouraud, 1971). Relighting virtual environments when such information is missing is a challenging task. In recent years, some researchers have begun to explore this exciting field, taking advantage of the possibilities offered by machine learning and proving that it may be possible to relight objects (Sang & Chandraker, 2020) or people (Pandey et al., 2021).

In the context of the proposed alternative VP for pre-production, future advancements may enable cinematographers to relight the location captured, experiment with diverse lighting setups, and pre-visualize the final output they want to achieve during the production phase.

Semantic Segmentation of the Location Captured

During DS-IV, some participants, especially PT18, expressed interest in repositioning or removing some set design elements of *La Casa Gassia* (Figure 7.1). However, the location captured and proposed was part of a single 3D geometric texture. It was not possible to interact with the single elements present in the scene. In the field of computer vision, researchers such as Yadav et al. (2022) suggest that machine learning advancements could allow the technology to automatically recognize and label different elements of a room, such as furniture, doors, or walls. Once again, such a technique combined with the practical prototype proposed would make it possible to separate each element of the scene and provide AV professionals, especially set designers, the freedom to interact with the location on a more granular level.

Avatar Representation

Participants noted that Gravity Sketch's avatars were basic in visual representation. With such low-level realism, avatars could not convey facial expressions and other gestures, which are crucial, just as they are when people communicate in person. Maloney, Freeman, and Wohn (2020) have the same conclusion. To further improve the usability of the proposed VP process, it is suggested to explore how avatars of other collaborators can be represented in the VR or MR environment.

Involvement of actors and actresses in the Co-Design Process

Recreating more realistic avatars could also be beneficial when introducing the VP process to actors and actresses. Such figures were not involved in this research because of the limited resources at their disposal. However, future work should also engage with these fundamental stakeholders to collect insights and test different VP processes when these personnel are involved.

In addition to familiarizing themselves with the location, they could rehearse in VR, which is an approach that is beneficial, according to Bouvilee, Gouranton, and Arnaldi (2016).

> *'If I had the time on set, I like to tell the actors to try anything, had the time to fail – just go ahead, try this, try that – You need that freedom'.* Martin Scorsese (Masterclass, 2020)

Of equal importance is the effort required in searching for technologies capable of optimally representing their performances in the virtual or mixed environment. Motion capture suits have been used for this purpose for decades, but they can be burdensome and difficult to set up (Meske et al., 2022). However, a promising technique is brought by the advancement of computer vision. Some researchers (Yu, Park, & Lee, 2021; Stenum, Rossi, & Roemmich, 2021) and existing commercial software (Move.ai, 2023; Plask, 2023) have demonstrated that it is feasible to extract people’s body movements from bi-dimensional videos.

Furthermore, Bennett (2020) researched acting in virtual environments and outlines that investigating new technological systems is required to address some limitations, such as the occlusion of people's faces when they wear a VR headset. At the time of writing, Meta claims that through face-tracking sensors, their VR headset *Meta Quest Pro* (Meta, 2022) is capable of mimicking users’ facial expressions and overcoming Bennett's findings.

From VR to Mixed Reality

In DS-IV, specifically when assessing Location 03: Mont-Saint-Michel, participants experimented with the Passthrough feature offered by Gravity Sketch. This viewing mode received positive feedback since participants could see the real world (room and collaborators) and also the virtual elements (virtual location, objects, interfaces). It was considered less disconnected from reality than the VR viewing they experienced moments earlier. This finding suggests the need to further explore the integration of MR, perhaps by using more advanced headsets, such as the Meta Quest Pro or HoloLens 2 (Microsoft, 2023), in the VP process.

Virtual Production as Support, Not as a Replacement

Another important finding is that participants perceived that integrating their current production process with immersive and emerging technologies should occur with caution and vigilance. Participants believed that changing habits in the working environment is a sensitive matter. In many cases, when involving new participants in the study, their first concern was replacing their current in-person activities and tasks, which are often conducted in collaboration with other colleagues, with virtual and solitary ones. These initial instinctive answers may have been influenced by the physical confinement imposed by the pandemic, in which participants lived or were still living at the time of the data collection phase. After discussing the different aspects of immersive technologies, they opted for a more balanced view of such technologies. Most agreed that these processes should support their current process rather than replace them. The same is true when assessing other emerging technologies, such as AI, as discussed in Chapters 5 and 6. It is of primary importance for AV professionals to have the final word in creative or technical decisions. Introducing AI in their decision-making process raised scepticism since they would feel deprived of such decisions.

The initial mistrust towards immersive and emerging technologies may be due in part to the scarcity or complete lack of personal experience in interacting with them. Therefore, the researcher wonders whether their prejudices and conjectures could be demystified if they were provided with these technologies for an extended time and allowed to experiment on their own. This could instil a more objective stance towards these technologies based on practical experience.

8.1.3 Recommendations for Virtual Production Applied to Small and Medium Productions

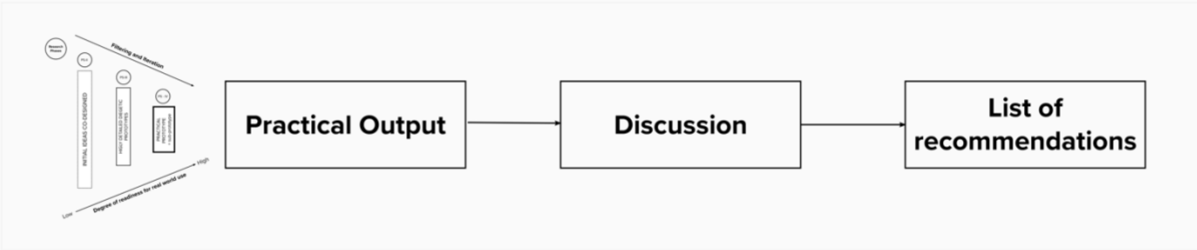

Figure 8.3 Representation of How the Research Contribution Was Generated

Since the first data collection phase began, it was clear that the VP process required specific characteristics to be successfully adopted by SMPs. The initial insights contributed in answering to RQ 1.2 “*What are the challenges that SMPs face due to limited resources?”* and became increasingly evident after each iteration of evaluation, which started with initial ideas (DS-IIB) and was followed by diegetic prototypes (DS-III) and testing the practical prototype (DS-IV).

This investigation revealed four main aspects considered crucial by AV professionals working within SMPs when adopting any VP process in a real-world scenario: *usefulness, affordability, ease of use, and accessibility.*
A conceptual framework that summarizes these aspects and compares them with the current high-end VP processes is presented in Figure 8.5.

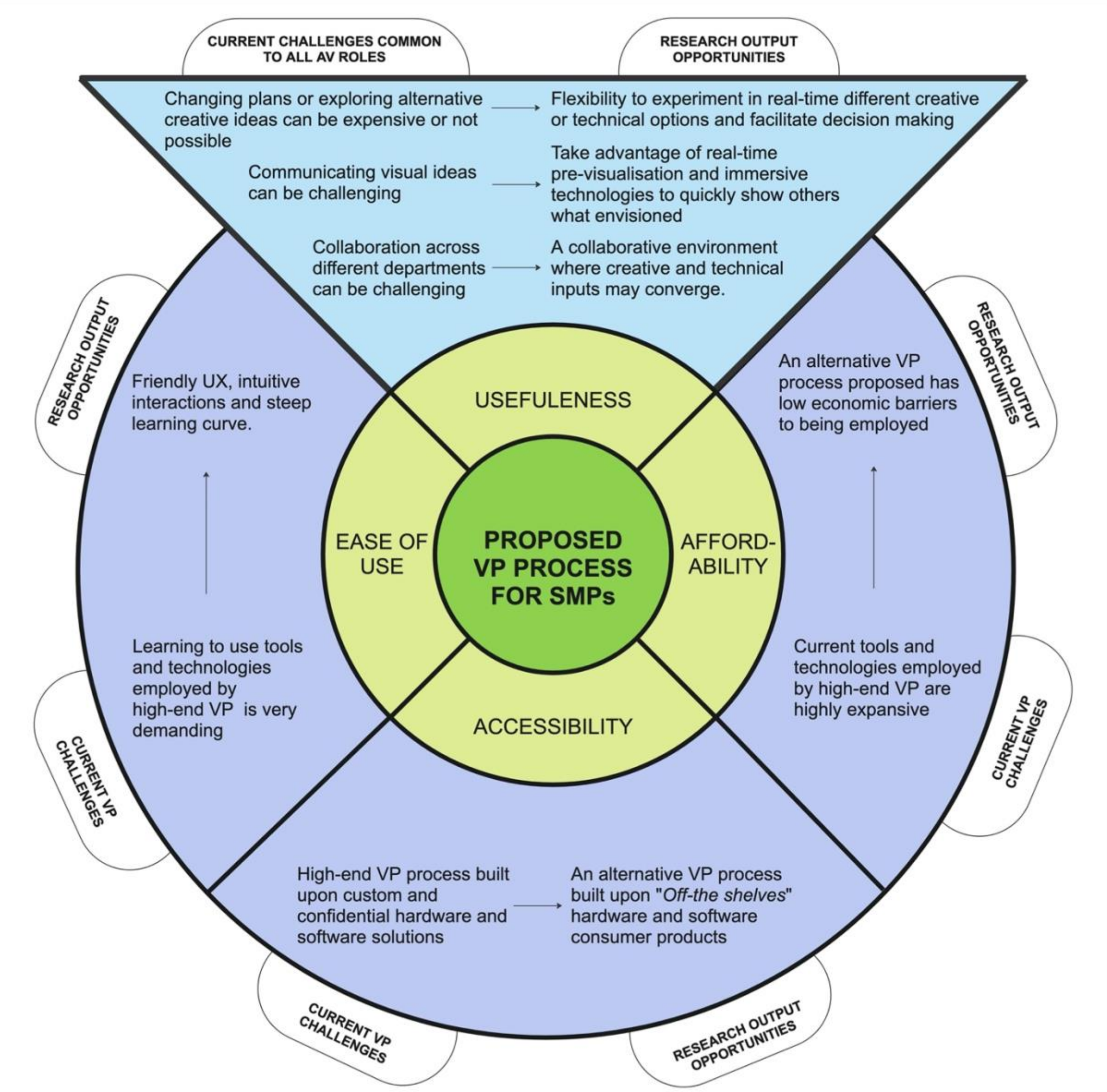

Figure 8.4 Conceptual Framework Proposed for Virtual Production Processes Applied to Small and Medium Productions

Table 15 Summary of Figure 8.5

	Current Challenges Common to all AV Roles	Research Output Opportunities
Usefulness	Changing plans or exploring alternative creative ideas can be expensive or not possible	Flexibility to experiment in real-time different creative or technical options and facilitate decision making
Usefulness	Communicating visual ideas can be challenging	Take advantage of real-time pre-visualisation and immersive technologies to quickly show others what envisioned
Usefulness	Collaboration across different departments can be challenging	A collaborative environment where creative and technical inputs may converge.
Affordability	Current tools and technologies employed by high-end VP are highly expansive	An alternative VP process proposed has low economic barriers to being employed
Accessibility	High-end VP process built upon custom and confidential hardware and software solutions	An alternative VP process built upon "*Off-the shelves*" hardware and software consumer products
Ease of Use	Learning to use tools and technologies employed by high-end VP is very demanding	Friendly UX, intuitive interactions and steep learning curve.

Usefulness. Any VP process applied to SMPs has to be evaluated as useful by the stakeholders. Some key factors identified throughout the research highlight how VP processes that offer opportunities to reduce costs and time while fostering creativity are considered valuable by AV professionals.

Additionally, specific opportunities offered by VP could be common to all team members; for example, virtual meetings could ensure that everyone is on the same page.

Alternatively, some opportunities may be role-specific within the same VP process through certain features or tool sets that aid specific professionals.

Cinematographers, for instance, may experiment with different lighting or camera movements. More details on role-specific usefulness are provided in Figures 8.6, 8.7, and 8.8.

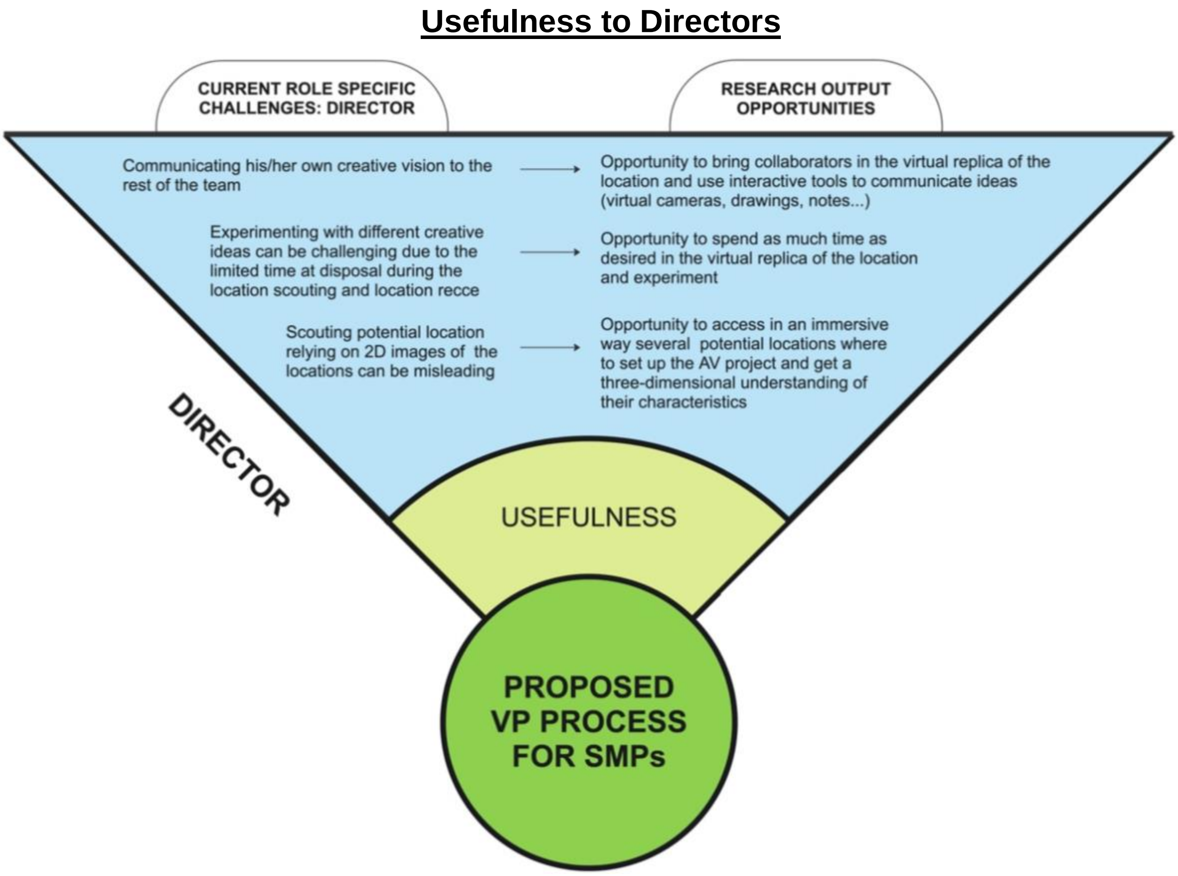

Figure 8.5 Usefulness to Directors

Table 16 Summary of Figure 8.6

DIRECTOR	**Current Challenges Common to all AV Roles**	**Research Output Opportunities**
Usefulness	Communicating his/her own creative vision to the rest of the team	Opportunity to bring collaborators in the virtual replica of the location and use interactive tools to communicate ideas (virtual cameras, drawings, notes...)
Usefulness	Experimenting with different creative ideas can be challenging due to the limited time at disposal during the location scouting and location recce	Opportunity to spend as much time as desired in the virtual replica of the location and experiment
Usefulness	Scouting potential location relying on 2D images of the locations can be misleading	Opportunity to access in an immersive way several potential locations where to set up the AV project and get a three-dimensional understanding of their characteristics

Usefulness to Producers

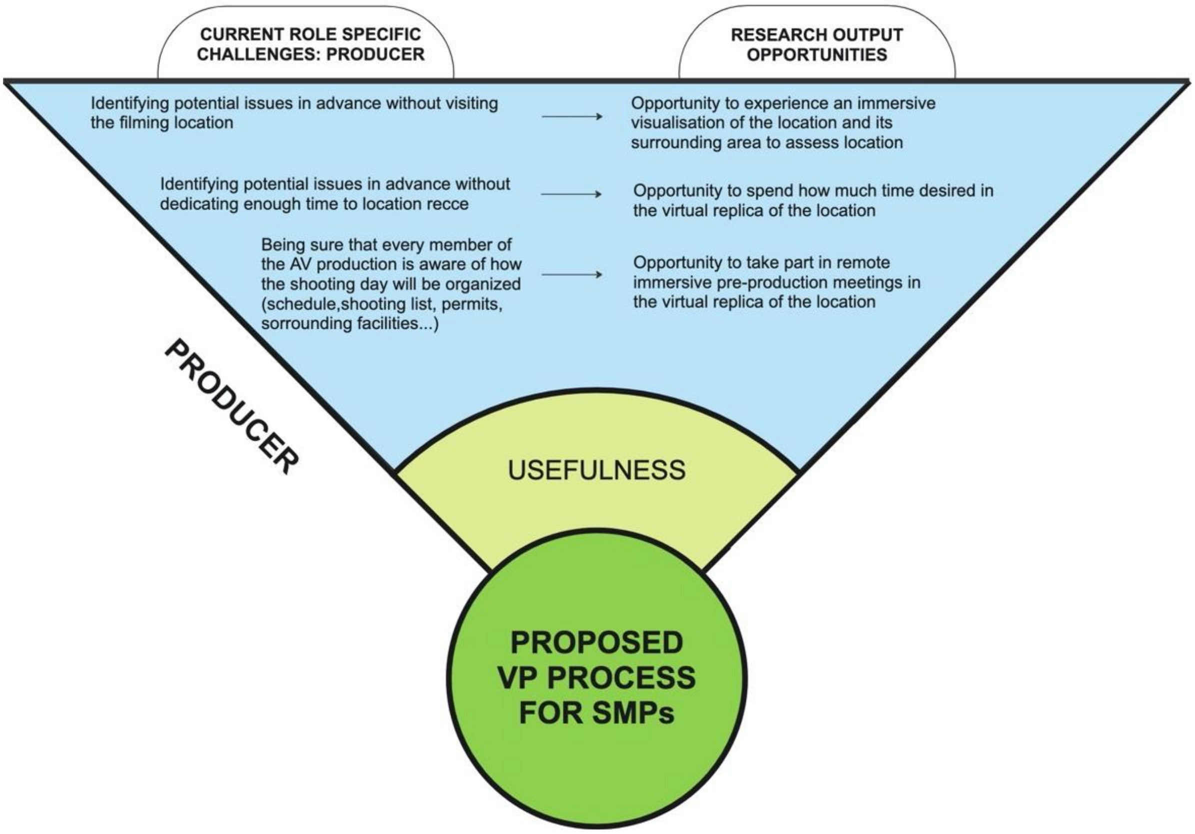

Figure 8.6 Usefulness to Producers

Table 17 Summary of Figure 8.7

PRODUCER	**Current Challenges Common to all AV Roles**	**Research Output Opportunities**
Usefulness	Identifying potential issues in advance without visiting the filming location	Opportunity to experience an immersive visualisation of the location and its surrounding area to assess the location
Usefulness	Identifying potential issues in advance without dedicating enough time to location recce	Opportunity to spend how much time desired in the virtual replica of the location
Usefulness	Being sure that every member of the AV production is aware of how the shooting day will be organised (schedule, shooting list, permits, surrounding facilities...)	Opportunity to take part in remote immersive pre-production meetings in the virtual replica of the location

Usefulness to Cinematographers

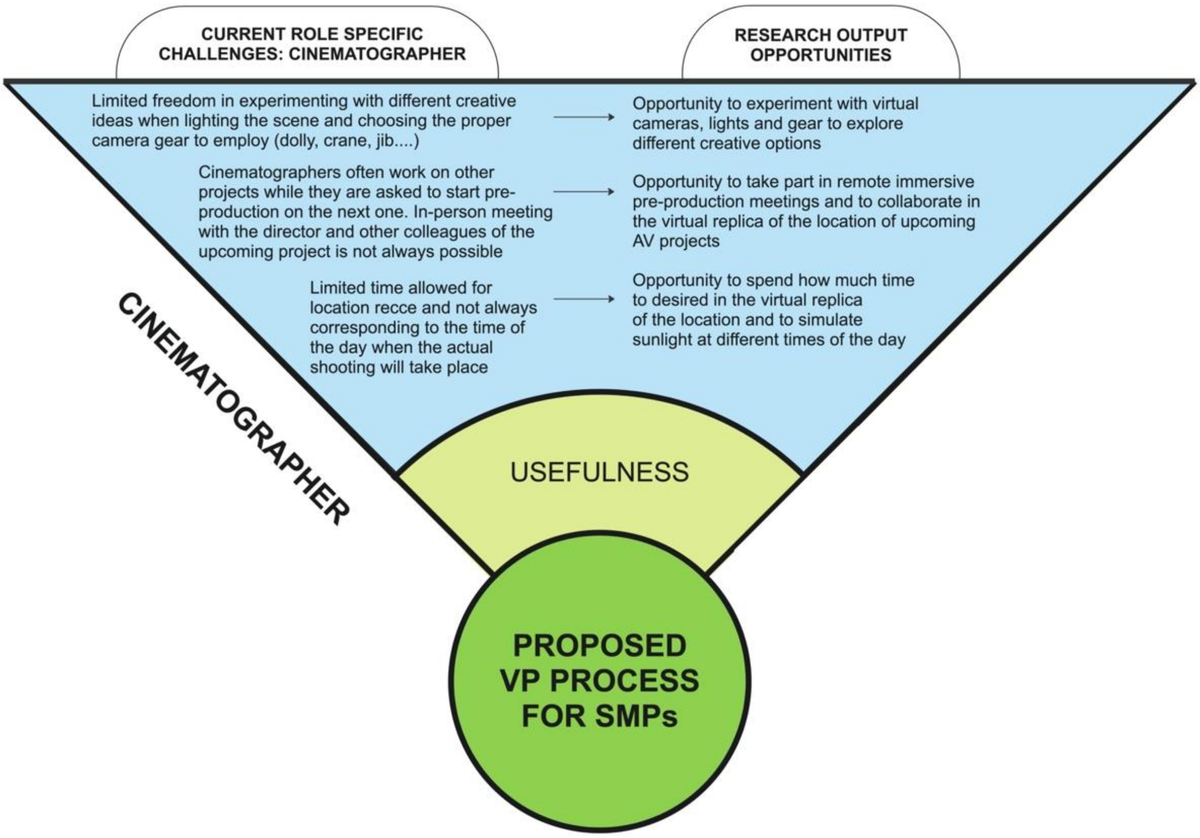

Figure 8.7 Usefulness to Cinematographers

CINEMATOGRAPHER	**Current Challenges Common to all AV Roles**	**Research Output Opportunities**
Usefulness	Limited freedom in experimenting with different creative ideas when lighting the scene and choosing the proper camera gear to employ (dolly, crane, jib....)	Opportunity to experiment with virtual cameras, lights and gear to explore different creative options
Usefulness	Cinematographers often work on other projects while they are asked to start pre-production on the next one. In-person meeting with the director and other colleagues of the upcoming project is not always possible	Opportunity to take part in remote immersive pre-production meetings and to collaborate in the virtual replica of the location of upcoming AV projects

Usefulness	Limited time allowed for location recce and not always corresponding to the time of the day when the actual shooting will take place	Opportunity to spend how much time to desired in the virtual replica of the location and to simulate sunlight at different times of the day

The opportunities in terms of usefulness of the proposed VP process can also be extended to professionals in other departments (directing department, production department, and camera or lighting department). The same can be valid for other people involved in the pre-production phase, such as set designers while deciding how to act technically and creatively regarding which set design elements to integrate, replace, or reposition in the scene.

Affordability. The cost of these VP processes was consistently at the centre of the conversation. The decision to spend any amount of money in SMPs is meticulously reviewed. The VP process that was designed during PS-IV requires fewer financial resources than those employed by high-end productions; however, participants recognized that any expense between several hundred and a couple of thousands of dollars (depending on how many people participate in the proposed VP process) is a decision to be weighed and discussed with the crew.

Ease of Use. This factor was perceived as difficult to evaluate by reading the design fiction scenarios presented in DS-III. This led to development of a practical prototype (PS-IV) that was later tested and evaluated by participants (DS-IV).
Findings revealed that the alternative VP process for immersive pre-production was straightforward. However, participants agreed that becoming skilful in actively operating the process would require some time. Alternatively, some participants, especially PT04 and PT05, suggested that only one person within the team needed to become proficient in the use of this VP process *(in their words, 'Master of VR' or 'Master of Gravity Sketch' PT25, producer*) to guide the other members of the team. They likely came to this conclusion after participating in the user testing session where the researcher guided and facilitated the adoption of the proposed VP process.

Accessibility. AV professionals noted that they wanted to have at their disposal any gear and instruments needed to adopt any kind of VP. Using *off-the-shelf* products is therefore considered the ideal strategy since high-end VP processes in many cases are kept confidential for economic reasons. Additionally, it is important to consider that some products may be complex to import or export because of the policies present in some countries, which may exclude AV professionals working in those regions.

8.2 Research Process

8.2.1 Discussion of Essential Elements

The Need for a Practical Output

To assess the potential value brought by VP, participants working in SMPs needed to personally experiment with the practical prototype of such a VP process. Consequently, (Figure 8.1) the DRM framework was adopted since it is widely used when attempting to develop design support, according to Chakrabarti and Blessing (2009, p. 33), which is the ultimate goal of design research.

Consequently, relying on existing *off-the-shelf* hardware and software products proved strategic and aligned with the researcher’s resources, as explained in Section 7.4.1. Many previous researchers have supported this approach to developing practical prototypes. The literature review chapter explained how they adapted existing consumer devices and services to develop their VP processes.

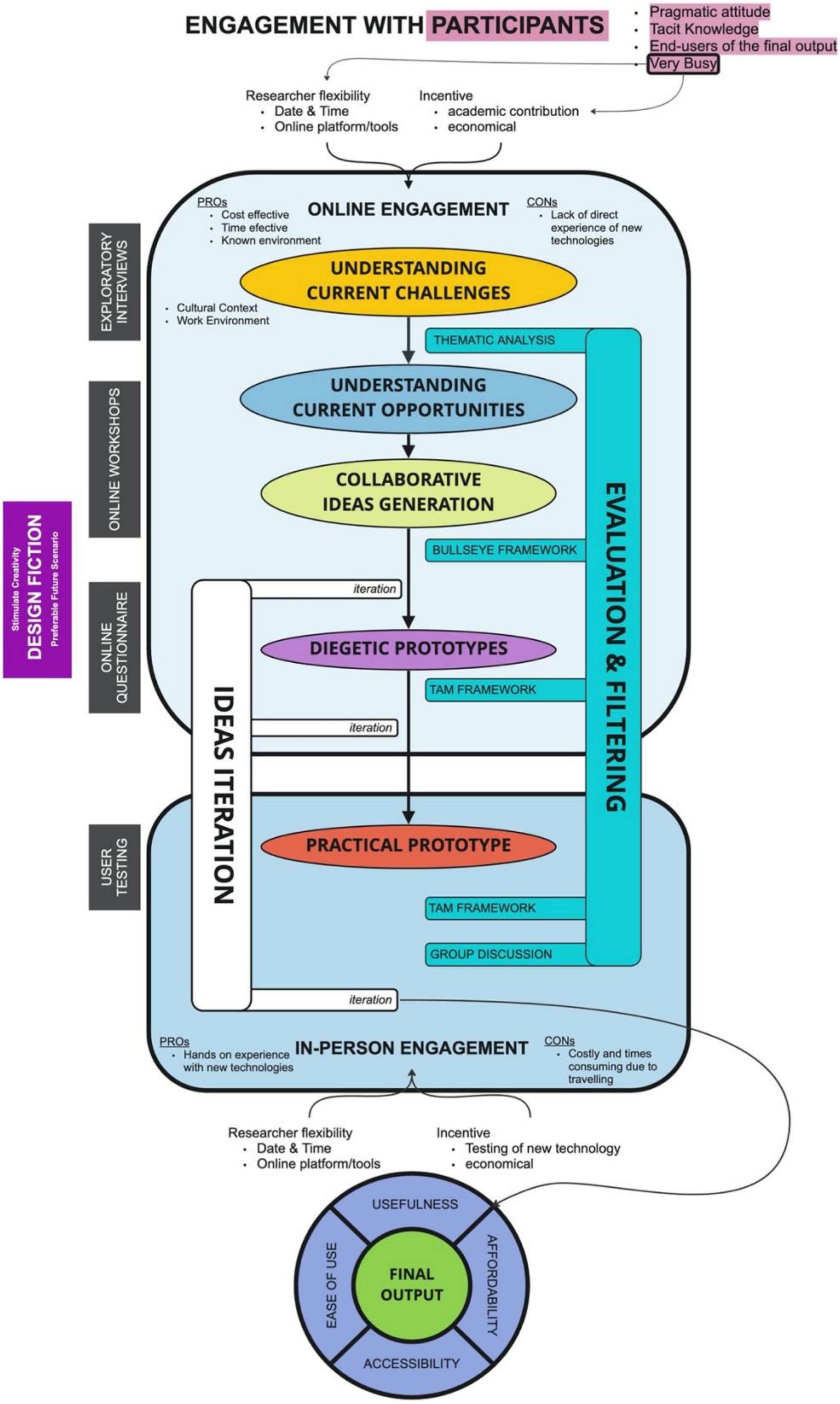

Figure 8.8 Alternative Representation of the Final Research Process

Co-Design Approach

Deciding to involve participants according to co-design principles, from the beginning of the exploratory study through the end of the design research process, enabled the researcher to determine the broader context of VP's applications to SMPs.
Conducting such work independently without considering multiple perspectives on the research subject could have generated a less complete output and caused the researcher to miss important aspects and insights.

Design Fiction

A technique such as design fiction prompted participants towards the generation of innovative ideas. Setting their thinking in the future enabled them to remove from their minds the technical constraints of current technologies. Limitations are often noted instinctively and promptly by this kind of participant. By nature, they are pragmatic, and their opinions are based on how they experience the world in the present.

Evaluation Frameworks

Actively interacting and prompting participants to contribute to the research proved crucial in collecting the initial user requirements, shaping initial ideas, extending these ideas into design fiction scenarios, and designing practical prototypes.
The strategy to employ and adapt pre-established evaluation frameworks, such as the bullseye framework (Rayo et al., 2018) and TAM (Davis, 1986; Bertrand & Bouchard, 2008; Horvat et al., 2022), was crucial for rigorously categorizing and analyzing the information collected during each study. The findings from each evaluation phase contributed to identifying and improving the final design support and meeting the researcher's goal and scope.

8.2.2 Methods Recommendations

Recruiting AV Professionals

One of the main challenges in this study was recruiting participants, which is a crucial component that enriched this work. Overall, having 74 unique professionals who worked in the AV industry be actively involved during the research process is substantial, considering the limited resources at the disposal of the researcher. Certainly, engaging with a larger sample would contribute to generating a more robust study. In this regard, it is suggested to build a strategic partnership with existing institutions, associations, organizations, and networks (e.g., Producers Guild of America, British Film Institute, AIR3, Asia-Pacific Broadcasting Union) by convincing them to believe in the value of the research project with which they are presented. This strategy should facilitate recruitment by future researchers who need these participants and allow them to engage with a larger sample. The network with which these players can engage, as a result of years of networking activities and initiatives, is far greater than what single researchers can achieve on their own.

Primary Study Conducted in the Field

While the restrictions imposed by the pandemic outbreak were a limitation to conducting in-person exploratory studies, future researchers should collect initial insights by joining an AV production that is about to start and asking to be an observer for the duration of the production process.

Prototype Evaluation in a Real-World Scenario

Similarly, for future scholars interested in testing the alternative VP workflow presented in this work or a different prototype, it is suggested to contact SMPs that are starting a new project and invite them to integrate the prototype designed herein into their process. Consequently, it would be possible to interview these professionals and ask how such integration impacted their work.

Research Assistant

Collecting data using audio and video recorders and ensuring that the VR and AR devices and applications were working correctly while accurately executing the testing procedure proved challenging for a single researcher not only in DS-IV but also during all other data collection phases. Therefore, when approaching a similar study, recruiting one or more assistants who could fulfil some responsibilities and tasks while doing fieldwork is suggested.

8.3 Chapter Summary

This chapter provided suggestions for future researchers on the design strategy to use while investigating such an emerging field.

Additionally, it presented recommendations based on the practical prototype that was co-designed, tested, and evaluated by participants. Key aspects to consider when applying VP to SMPs were identified and discussed.

Chapter 9

CONCLUSIONS AND FUTURE WORK

9. Conclusions and Future Work

This chapter highlights the contributions arising from this work and outlines future research activities.

9.1 Research Overview: Objectives and Outcomes

This research was inspired by the scant research undertaken by previous researchers in an emerging field such as VP combined with the lack of design support that was actively co-designed with AV professionals operating in SMPs. To answer the main research question formulated in Chapter 1 (*To what extent can VP combined with immersive technologies be employed by AV professionals in SMPs?*), the researcher thought it appropriate to divide this enquiry into three sub-questions. Accordingly, Table 15 illustrates how the research objectives were achieved.

Table 18 Illustration of the Research Questions and Defined Objectives

Research question	Objectives	Chapter
<u>Research question 1.1</u> **What research already exists on this topic, and to what extent is VP already developed and employed by industry players in their making process?**	To REVIEW the academic literature and pre-existing processes employed by industry players regarding VP.	<u>Chapter 2</u> Literature review
<u>Research question 1.2</u> **What are the challenges that SMPs face due to limited resources?**	To INVESTIGATE the challenges faced by AV professionals who work on SMPs.	<u>Chapter 4</u> Exploratory Study
<u>Research question 1.3</u> **What alternative VP process can be co-designed and developed to enable SMPs' adoption of VP?**	To CO-DESIGN with participants alternative VP processes combined with immersive technologies.	<u>Chapter 5</u> Idea co-generation <u>Chapter 6</u> Evaluation of the preferred design fiction scenario
	To TRANSLATE the outcomes of Studies 1-3 into a practical prototype to be tested and evaluated (study 4) by AV professionals.	<u>Chapter 7</u> Practical development of a prototype and sub-prototype
	To DISCUSS and self-reflect the implications of such prototype in Study 5 and provide a set of recommendations upon which future work may advance research on the VP process applied to SMPs.	<u>Chapter 8</u> Discussion of the research process and practical output leading to recommendations <u>Chapter 9</u> Summary and future research opportunities

9.1.1 Meeting the Objectives Set to Answer Research Question 1.1

The first part of this research was aimed to understand the latest advancements in VP by analyzing and reviewing relevant case studies. The same attention was also invested in searching the academic literature produced by previous researchers investigating this emerging field.

RQ1.1: *What research already exists on this topic, and to what extent is VP already developed and employed by industry players in their making process?*

Objective A: *To review the academic literature and pre-existing processes employed by industry players regarding VP.*

The literature review (Chapter 2) highlighted that, in recent years, the private sector has invested in advancing VP since it could represent an economic advantage in creating AV products. High-end industry players developed a custom VP process for the needs of specific projects, but these do not extend to every AV production, which presents the lack of a VP process that considers the needs and distinctive traits of SMPs. Academic literature offers some exciting studies where SMPs were considered to be the end user of previous researchers' designs. However, the engagement with the end users occurred only at the end of the process while evaluating what was proposed by researchers. Additionally, these academic studies often presented alternative workflows centred around only one AV role or department. A more inclusive VP process that could better represent the 'choral' work of many different professional figures and departments while producing an AV product was missing.

9.1.2 Meeting the Objectives Set to Answer Research Question 1.2

Previous experience in the industry matured the researcher and played a vital role in extrapolating participants' tacit knowledge and enabling better empathizing with them when they discussed their working habits.

RQ1.2: *What are the challenges that SMPs face due to limited resources?*

Objective B: *To investigate the challenges faced by AV professionals who work on SMPs.*

The second sub-question was designed to explore the daily and practical difficulties AV professionals who operate in SMPs encounter when working with limited economic and human resources. Consequently, through the preliminary study described in Chapter 4, it was possible to collect crucial insights and form multiple perspectives on the user requirements for a VP process that aligned with participants' needs.

Further insights were also collected throughout the research. When speaking with participants, they mentioned anecdotes and stories about the difficulties and issues they encountered in past projects and how they related to the proposed alternative VP process. Therefore, through the end of the research, rich details about their challenges while working on AV productions were collected.

9.1.3 Meeting the Objectives Set to Answer Research Question 1.3

This third sub-question was aimed to co-design, develop, test, and evaluate with participants an alternative VP process combined with immersive technologies.

RQ1.3: *What alternative VP process can be co-designed and developed to enable SMPs' adoption of VP?*

Objective C: *To co-design with participants alternative VP processes combined with immersive technologies.*

As highlighted by the literature, no systematic researcher has yet co-designed VP processes with participants from the beginning of the design process. It was considered opportune to approach the research following co-design principles and actively engage with participants. The remote co-design workshop described in Chapter 5 contributed to achieving the goal of conceptualizing possible designs for alternative VP processes that were potentially beneficial for AV professionals working in SMPs.

Objective D: *To translate the outcomes of Studies 1-3 into a practical prototype to be tested and evaluated (study 4) by AV professionals.*

The outcomes that emerged from the co-design workshops, specifically PS-II, as well as the iteration and evaluation of the scenario perceived as most valuable in DS-III were used to develop an alternative VP process in PS-IV to support the pre-production process of AV professionals working in SMPs. The different phases of such a proposed alternative VP process were described in detail in Chapter 7.

Objective E: To discuss and self-reflect the implications of such a prototype in Study 5 and provide a set of recommendations upon which future work may advance research on the VP process applied to SMPs.

Through the in-person testing and evaluation phase described in Chapter 7, it was possible to draw conclusions about the proposed alternative VP process that led to further considerations and a presentation of a conceptual framework to aid future scholars interested in enriching knowledge on VP applied to SMPs.
Suggestions on undertaking an investigation in this field and identifying an effective design research strategy are discussed in Section 9.4.1. Moreover, Section 9.4.2 presents a list of recommendations for future researchers interested in employing the prototype developed in this work in a real-world scenario.

9.2 Research Contributions

Research Process

As discussed in the literature review, little research has been conducted on VP because the recent development of immersive and emerging technologies. Additionally, the combination of the necessary multidisciplinary knowledge (immersive technologies, AV industry, design research), technical expertise (necessary to create a working prototype), and networking capability (necessary to involve hard-to-reach participants, such as AV professionals) to undertake such an investigation led to two contributions:

I. An extensive review and organization of recent studies is present in the academic literature and in those innovative designs developed by industry players. These are the first step in decoding and organizing the work to date, both in academia and the industry as well as current needs. Although it cannot be classified as a systematic review, this thesis contributes to enabling future researchers to quickly navigate ever-evolving subjects, such as VP, and strengthening the bridge between academic knowledge and industry practice.

II. The planning and execution of this research process occurred during an unprecedented event: the COVID-19 pandemic. In the first phases, this scenario required the research to be conducted through design methods that could be performed remotely. Hence, Chapters 5 and 6 presented and adapted some design methods to collect data using online services and tools. Both drawbacks and opportunities from this approach were discussed and may serve future researchers when operating in a similar scenario.

Research Output

This exploratory study contributes to a richer understanding of VP and its benefits for SMPs. The design research strategy adopted enabled the co-design of innovative ideas with AV participants, which were extended if participants perceived them to be valuable.

Existing VP processes were discussed in Chapter 2, explaining that many AV professionals are not provided with affordable and easy-to-use technologies required to adopt VP. The findings in DS-I further confirm this consideration, and interviewed participants expressed their interest in employing VP tools and a workflow aligned to their needs and capabilities.

The major practical contributions of this research are as follows:

I. Design support was delivered via an alternative pre-production VP process that was tested and evaluated in a controlled environment (Chapter 7).

II. Three highly detailed design fiction scenarios were co-designed with stakeholders and may benefit future researchers interested in further developing such scenarios into practical prototypes (Chapter 6).

III. Stakeholders evaluated 14 initial ideas as potentially valuable and worthy of further extension and prototyping (Chapter 5).

Contribution to Knowledge

This research concludes with the development of design support that produced additional general conclusions on the topic under investigation. This contribution is represented by

I. A list of recommendations upon which future developments in VP processes applied to SMPs can be based.

The literature review process revealed that VP is a new field that has attracted attention among researchers. Some previous scholars (De Goussencourt, 2015; Zimmer et al., 2017; Muender, 2018; Spielmann, 2018; Ardal, 2019; Kuchelmeister, 2020) have aimed to develop specific solutions that take advantage of immersive technologies to assist AV professionals operating in SMPs. However, in such studies, AV professionals were involved only at the end of the design process, when they were asked to test and evaluate researchers' independent ideations and developments.

Involving AV professionals from the beginning of the design process, collecting and organizing their requirements, taking advantage of their tacit knowledge when prompting them to generate innovative concepts that align with their needs and, finally, asking them to test and evaluate a practical prototype as the output of the previous iterative phases is the main contribution of this research. A co-design-led investigation in the VP area is missing in the current literature.

Adopting a co-design approach facilitated mutual learning derived by engaging with the end users of the design that the researcher intended to create. Participants were guided on the potential of immersive technologies through the provision of knowledge they did not have. Additionally, they shared with the researcher their challenges, habits, abilities, and operating context. This exchange of knowledge has been considered by other researchers (Robertson & Simonsen, 2012; Sanders & Stappers, 2008) as beneficial for generating context-specific and impactful new designs. Evidence of this belief is found in the outputs generated in PS-III and PS-IV that were positively evaluated in DS-III and PS-IV, respectively. All diegetic and practical prototypes earned an average score over > 3.50 (*Agree*) when asked if the co-designed alternative VP process could facilitate technical, productive, and creative aspects compared to their current production process.

The reflection on the different outputs of PS-II (initial concepts), PS-III (diegetic prototypes), and PS-IV (practical prototype) in Section 8.2 allowed four necessary aspects of VP to be identified and described: usefulness, affordability, ease of use, and accessibility. These key elements emerged frequently throughout the research, thus confirming their crucial importance when designing a VP process whose end users were AV professionals working in SMPs.

This researcher recognized a core component of all AV productions: the filming location. The importance of a scene's setting is considerable and influences technical, logistical, and creative choices, thus affecting almost all AV professionals involved in the production process.
Practitioners in the AV industry recognized the potential of VP combined with LED volumes. Projecting the location on the LED walls in the background allows the whole crew to work in a controlled environment (the film studio) and provides the illusion of shooting in the real location while offering related benefits (pre-visualization, collaboration, communication, and rapid iteration). With the same purpose, today and in the past, countless AV productions have relied on green screen studios (where actors' and actresses composites are placed inside real or fictional locations) or have physically built a film set (a strategy used since the early 20th century).

The need and attempt to reconstruct locations has been a constant in the history of AV production, and consequently, it is not surprising that modern VP processes are centred mainly around LED volumes (Abramas et al., 2016; Favreau et al., 2019; Pohl, 2019; Netflix Studios, 2022) that are capable of partially immersing AV professionals in the digital replica of the location.

However, the VP process can have many forms (Thacker, 2012) and therefore limiting research to LED volumes is a missed opportunity.
Instead, this work contributes to knowledge by proving that alternative VP processes that employ more immersive technologies, such as VR and AR, are considered useful by stakeholders. Furthermore, the practical prototype developed as a result of the iterative co-design process has at its core the construction of a digital replica of the filming location, which favours creativity, decision-making, pitching, and reducing AV professionals' ecological footprints. This prototype, which is ready to be implemented in a real-world AV production, enriches the current literature by offering an alternative VP process that takes advantage of immersive technologies to answer stakeholders' need to reconstruct the filming location, similar to what is attempted by adopting LED volumes, green screen studios, or physically building film sets.

Finally, to further extend the boundaries on this emerging research area, this work contributes by defining several insights useful for future work (Section 8.2.1), which are summarized in the following paragraph.

To be adopted, a VP process has to be easy to use by the stakeholders (*ease of use is key*), and developing custom interfaces for each role can be helpful (*role-specific interfaces and tools*). Ease of use is currently addressed by the discrepancy present among today's immersive tools and interfaces, and although researchers have no control over this matter, they should be aware of its existence (*consistency of interactions across immersive applications is yet to be defined*).
Because AV professionals have a keen eye for images, they expect a better visual representation in future VP processes (visual representation improvements), especially regarding correct lighting (relighting *environments, objects, and people*). On this aspect, groundbreaking researchers are obtaining promising results (*semantic segmentation of the location captured*). Because of the collaborative nature of AV productions, when those in different roles work together in a virtual environment, their avatars should better represent them (*avatar representation*). Another core component of AV production is provided by actors and actresses, and their perspective on VP should be included (*involvement of* actors and actresses *in*

the co-design process). Additionally, stakeholders felt that working in a MR environment was more comfortable and reassuring; this should be further investigated (from VR to MR).

Finally, AV professionals enjoy the collaborative component and human connection derived from their work environment. The total replacement of certain activities and current processes may be seen with fear and scepticism (*VP as support, not as a replacement*).

9.3 Limitations

This research presents some limitations on the topic under investigation and data collection.

9.3.1 The Topic

Because a strong technological component characterizes the nature of this topic, it is changing rapidly. Although this research provides several valuable findings and insights, immersive devices and software advance rapidly.

As new technologies develop, this situation may change over the course of the next 5 to 10 years. In the near future, other workflows and tools may be adopted and preferred by filmmakers when creating their AV products. Nevertheless, core aspects of every AV production, such as *collaboration, communication,* and quick *iteration*, will continue to be at the centre of the scope of the VP process. It is probable that the same will also be valid for the findings characterizing VP processes for SMPs: *usability, affordability, ease of use, and accessibility*. These critical factors presented in the conceptual framework in Chapter 8 will likely remain significant in the long term.

9.3.2 COVID-19 Pandemic

The COVID-19 outbreak significantly affected this project, as it disrupted traditional research workflows involving face-to-face involvement of participants. Such an event complicated the development of this study, requiring suspension of in-person data collection for a significant part of the research. In a scenario not affected by the pandemic, the researcher, for instance, may have been involved as an active observer during the creation of an AV production. This approach, especially during the exploratory phase, would have enabled the researcher to better understand professionals’ challenges and behaviours in their work environment. Furthermore, as restrictions were gradually lifted, AV professionals’ attention and endeavours were focussed on seeking paying jobs. Asking them to contribute time and effort to academic research was difficult and required flexibility on the researcher's side.

However, these limitations in some cases became opportunities for exploration of remote online approaches with the potential to facilitate accessibility while reducing travel costs and carbon footprints. As discussed in Section 5.6, future adoption of hybrid approaches to data collection with participants could be advantageous if one combined advantages from traditional in-person and remote online techniques. One option is for online workshops to focus on those aspects of the research in which access to physical prototypes and in-person interaction is unnecessary. In contrast, face-to-face events can be restricted to those activities that most benefit from implementation in a physical venue.

9.3.3 Data Collection

This investigation had some limitations when data were collected during DS-IIA (*induction to VP*) and PS-II (*co-design initial ideas and iteration*) due to the design methods employed.

9.3.3.1 Data Collection for DS-IIA and PS-II

Part of the first workshop (DS-IIA) was dedicated to explaining the current state of the art of VP (induction) and describing the different technologies that can be integrated. Social distancing restrictions during the pandemic significantly limited

options concerning data collection with participants and prevented the implementation of face-to-face co-designed activities in which participants could have benefited from hands-on experience with physical prototypes.
The mere verbal and visual explanation (supported by videos) of experiential technologies, such as VR and AR, may have limited imagination and creativity when participants were asked to brainstorm ideas in the next PS-II phase.

9.3.3.2 The Role of the Researcher

The researcher was a facilitator when engaging with participants during the remote workshops (DS-IIA, PS-II, DS-IIB) and the user testing session (DS-IV). His role ensured that the procedure was correctly executed, and he provided explanations and guidance to the participants when needed. It is possible that his presence when participants were testing the practical prototype in DS-IV may have influenced the participants' perception of the prototype's ease of use. The facilitator aided participants when they encountered confusion on how to operate the prototype. When participants were asked to evaluate the prototype's ease of use, the facilitator reminded them to consider the help received during the user testing session.
This limitation indicates that future scholars should design a testing procedure where the aid of the facilitator is not present.

9.3.3.4 Geographic and Cultural Biases

Research participants mainly worked in three countries: the United Kingdom, Italy, and the United States. An attempt was made to involve professionals working in other countries and regions, especially while spreading the online questionnaire. This intention resulted in collecting few responses from professionals in the Central American and South-East Asian region. Nevertheless, it is crucial to mention that current AV production processes are similar worldwide (Goldsmith, 2010; Lotz, 2021) when it is tried to reach a certain professional standard, as described in Section 3.5.3. Additionally, the goal for the research output was to increase knowledge of a scarcely researched topic, which represents, therefore, a first step in this direction. The contribution represented by this research is open to further development for specific cultural and geographic contexts. Finally, focussing on contexts with limited resources is one of the main characteristics of this investigation. Therefore, the research output may be extended to various geographic and cultural contexts. In any case, for more robust validation of the findings, an effort is needed to further investigate VP applied to SMPs while considering the perspectives of AV professionals working in additional regions of the world.

9.3 Suggestions for Future Work

Overall, AV professionals are intrigued by the innovation brought by immersive technologies, and the direct experience allowed them to better understand the product's fundamentals, limitations, and possibilities. Their opinions on how the VP process can be used by SMPs and their evaluation of the tested prototype prompted directions for future works in the field.

9.4.1 Adaptability

Following the discussion on both the research process and the practical output described in Chapter 8, it is possible to speculate on how the VP processes applied to SMPs may be adopted and adapted in different fields and contexts.

<u>*High-End Productions*</u>

During the exploratory study, PI05, one of the two leading experts working on high-end VP, stated that he also employed common consumer devices, such as an iPad, during the production of a blockbuster movie: *'It's not only about a democratization,* [consumer] *technology can benefit everyone, at any level* [from high-end to SMPs]'. This statement is further demonstrated by the design process Jutan and Ellis (2017) established when integrating *off-the-shelf* hardware devices into their high-end VP process. Jonathan Bach (Bach, 2022) states on his Instagram page that, while working on *Avatar: The Way of Water* (Cameron, 2022), he used Gravity Sketch while initially designing one of the movie's scenes. Therefore, the output of this research can be extended beyond SMPs and towards high-end productions.

Education

The practical output of this work and the recommendations listed can also find a place within the education sector.

The implementation lectures regarding real-time rendering applied to filmmaking have already been integrated in some film schools and digital media courses, according to PT22 and PT23, who recently graduated and approached Unreal Engine 4 in a bi-dimensional way (using mouse, keyboard, and 2D monitor). Considering the pace at which technology in the immersive and VP fields is advancing, it is possible to expect increasingly advanced visual representations of virtual environments. Thus, future work may build on the output of this research to create a ‘playground’ for aspiring AV professionals, such as an alternative immersive workflow for experimenting with different shooting techniques that may involve expensive or burdensome gears (camera optics, lights, dolly, set design, props, etc.) or difficult-to-access film studios or real locations. A potential drawback was raised by PT14 when explaining that an alternative immersive workflow that is drastically different from the dynamics of the real working environment may create a discrepancy in the learning process of young students: *‘[Film courses] should teach filmmaking processes according to the current market standards and trends’.* Concurrently, incorporating awareness of the VP process in recent graduates' curriculum may increase their chances of being hired in the future, considering the lack of workers who have this skill set (Bennet et al., 2021).

The findings from this research raise new and exciting areas for future researchers eager to investigate the role of immersive technologies and VP in media and film courses.

9.4.2 Further Research Opportunities: Emerging Technologies

The technological advancements humankind are producing and witnessing are unprecedented. Many are the new and emerging technologies that can shape the future of AV productions, and further research is needed.

Real-World Digital Twins

The attempt to encapsulate the real world in a digital likeness that is as faithful as possible is both a philosophical fascination and a technical effort claiming to bring many useful applications, as briefly presented in Section 7.6.1.

Several companies (Bluesky, Maxar Technologies, Terra Metrics) provide 2D and 3D satellite images of extensive areas of the globe with increasing accuracy. In the future, the process described in Section 7.4.2 of manually capturing existing locations may be replaced by seeking the desired location within the vast libraries that such companies may make available.

A different approach is needed when the aim is to create a digital replica of the interiors of such locations. The challenge is represented by the endless number of interiors that cannot be automatically scanned with satellites and by the legal permits to capture these often private locations. An attractive option could be relying on user-generated captures that may be then made available for free or for purchase on pre-existing 3D asset marketplaces. PT13 raised questions about the rights of digital captures, and PT14 answered that it would work similar to photography rights. In his opinion, the answer depends on the eventual constraints of the specific location. AV professional Alex Harvey depicts a possible future scenario in his post on LinkedIn:

> *'In the future, you might be limited to how many photos you are allowed to take inside a national heritage site or museum to stop people creating and selling unauthorized photogrammetry 3D models online'* (Harvey, 2022).

For the practical prototype developed, both photogrammetry and LiDAR scanning technology combined with photogrammetry was used to capture existing spaces. An alternative technique that is gaining traction among researchers (Mildenhall et al., 2021; Martin-Brualla et al., 2021) is neural radiance fields (NeRF), which is based on the opportunities offered by deep learning and should be further investigated in relation to VP.

Generative AI

Of no less importance and requiring researchers' attention is the current and future potential of generative AI. A initial attempt to understand perceptions and potential uses of generative AI was made during the co-design workshops in Chapter 5. In that research phase, participants expressed a mix of scepticism and concern about the images produced by OpenAI's *Dall-E* generative algorithm (Ramesh, 2021). They clearly expressed that its use should aid and not replace their creative freedom.

The pace at which generative AI developed in recent years and the media attention on the subject is immense. The technology is capable of generating images as well as text, audio, and videos. ChatGPT3, a chatbot capable of formulating textual responses to users' questions, is a rising concern among academic leaders because it can be used by students and researchers to automatically write their essays or, at least, provide them with a draft. To these critiques, OpenAI CEO Sam Altman replied, saying that education will adapt as it did in the past when calculators were introduced in schools (Mok, 2023). The doctoral researcher and author of this work finds it natural to wonder about the following provocative question: is this one of the last PhD theses not aided by ChatGPT3?

Along similar lines, it is worth mentioning another project called *Dramatron* (Mirowski et al., 2022), a language model developed by Deepmind which received positive feedback from professional screenwriters while testing the usability and capabilities of this co-writing tool.

When generating ideas during the second workshop, PW14 formulated the concept of having an AI '*to predict the economic performance at the box office when casting* *certain actors*'. AI algorithms do not yet seem to be capable of such economic valuations; however, it was notable to see a similar idea applied by developer and designer Dan Leveille while using the text-to-image generator mentioned previously to create counterfeit posters portraying the potential cast of Netflix's live-action Zelda project (Leveille, 2022). Such cases may be useful to casting directors and executive producers when deciding whether a specific actors and actresses may be suitable for specific roles.

However, a more important consideration exists than today's output generated by AI algorithms: Plausible 2D images can now be generated by entering prompting text; in the future, it is likely that this trend will be transformed into text-to-video (Ho et al., 2022; Villegas et al., 2022) or even text-to-3D. An early example is GET3D, which was developed by researchers at NVIDIA (Gao et al., 2022) and enables the creation of 3D textured geometries starting from the user's text prompt.

Final Pixel in VR

The advancements in capturing and generative technologies lead to further thinking when envisioning the future of AV production. If it is possible to acquire a realistic representation of all necessary assets, actors and actresses included, will that enable what can be called the *final pixel in VR*? This newly coined term takes inspiration from the current term *final pixel on set*, which refers to scenes shot inside a LED volume that do not require any post-production intervention (Pohl, 2019).
In this regard, it is likely that the first AV genre to be produced entirely in a virtual environment may be animation, which is often characterized by a visual style that diverges from the faithful representation of reality. A wave of filmmaking in VR is already in action. *Into the Metaverse* (Metacosm Studios, 2021) is a 90-minute action-adventure film produced entirely using the social platform VR Chat, a social VR platform. *Tales from Soda island* is a short film created using the sketching and animating tool *Quill* (Hayden, 2022).

The realm of emerging technologies is dense and constantly evolving, and the impact in transforming the current AV production process can be outstanding.

However, even more disruptive changes that have not been seen before may derive from their ingenious and wise combination.

9.4 Summary

This chapter described the contribution represented by this research. A systematic approach enriched the current literature with new knowledge regarding VP applied to SMPs and offered both practical and conceptual outputs on which other researchers can base their future work. The challenges implied by investigating a topic such as VP were described, and recommendations on how to approach the subject were provided. Because of the exploratory nature of this PhD work, further and more specific studies are required and should employ additional and different design methods.

The design research adopted led to several alternative VP processes for SMPs operating in the AV industry. This output was generated through a co-design approach that involved AV professionals from the first phase of the research. The researcher ascertained the current challenges among different personnel working in SMPs, which allowed the exploratory and iterative nature of the research to produce several innovative ideas.

Such ideas were developed and evaluated in each subsequent phase. They were filtered based on the participants' perceptions of the different values attributed to each idea. At the end of the design process, one concept was developed into a prototype, which was tested and evaluated by participants.

Finally, recommendations were provided for designing other VP processes and implementing them in a real-world scenario. Additionally, general guidelines were provided to advise future researchers interested in advancing knowledge on the VP field applied to SMPs.

This work offers a conceptual and practical contribution to the current literature and the AV industry.

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Appendix I – Diegetic Prototypes

Story #1 – DEPERO

Vincent is a set designer based in Liverpool while Martin is a cinematographer in Madrid. The two are working on their next short film and as usual they are using “DEPERO”.

“DEPERO” is a virtual reality application commonly used by small teams of filmmakers during the pre-production phase to collaborate remotely and to carefully plan the shots. All the data are on the cloud and so accessible from everywhere and anytime if you are granted access to the project. Also, thanks to the advancements of 3D scanning technologies, is today possible to create a photorealistic digital replica of real-world locations both indoors and outdoors.

The two are immersed within the digital replica of an old farmhouse situated in the middle of Andalusia. That’s the location where they are going to shoot some scenes in three months. The scan was already available on DEPERO’s “locations” and was considered the ideal setting for their short film.

Using a controller, Vincenzo lift and reposition the virtual table in different positions to find the best spot. “Good, I think Chris will like it” says Martin.

In that exact moment Chris, or better, its avatar shows up in the virtual location “Hi guys! Sorry for the delay”. Chris is the director of the short film and he’s currently connecting from London.

“What a timing Chris, we were just talking about you…” says Martin and continue “…We were working on the dining scene, what do you think?”.

Chris presses a button on his controller to activate the viewfinder mode. He starts walking curiously around the dining room of this old farmhouse keeping the controller pointed like a camera, looking for the best angle from where to capture the scene. He starts experimenting with different virtual camera lenses that he can quickly switch. At some point he stops and locks mid-air the viewfinder saying “Well… I think that the 35mm would work. Martin, can you simulate a slow dolly movement from here?” “Sure thing” replies Martin.

Martin moves towards the floating viewfinder and interact with it to select the “camera movements” mode. From this tab he can decide what camera movements to simulate. A virtual dolly appears in the scene and Martin starts simulating the camera movement requested by Chris.
Chris looks at the result and quickly changes his mind “Wait, I got a different idea. What if we simulate a crane movement from outside the window for this shot? Let’s use the crane to slowly move the camera toward the window”.
With the click of few buttons, Martin quickly makes the dolly disappear, teleports himself outside the room and place in the scene a seven-meters long crane and starts using it. “Lovely!” exclaims Chris “This is exactly what it’s needed for this shot”.

Uncertain, Martin asks: “I like it too Chris, but wouldn’t be too expansive to rent a Crane?”. Chris replies “You’re right, but I’m sure that we can pitch to the Exec. Producer this new idea exporting a quick pre-viz draft from DEPERO. Hopefully that will justify the extra budget…I think this shot really adds something to the scene guys”.

“Also, me and Martin were thinking about using diegetic lights to illuminate the scene, we were thinking about placing some candles here on the table” Vincent uses its controller to sketch in the space three different circles where he thinks would be better to place the candles. “Nice” exclaims Chris. Martin then selects “candles” from the “lighting” tab while Vincent materializes two dummies to place around the table. “Oh well, that’s a little bit too bright. Let’s go for just two candles then" says Chris and concludes "Sorry guys but now I got to go, please share this with our new Producer Miriam to keep her posted. See you!"

Figure I.1.0.1 Visual prompt for Story #1 - DEPERO

Story #2 – ALNINE

6:30 AM. Hana's alarm starts ringing to wake her up.
"It's going to be a long drive" she thinks "but I'm happy to direct such project…even if the budget isn't high".
Hana lives in the suburbs of Tokyo and is headed to the city of Fujiyoshida. This is in fact the chosen filming location for promoting the commercial of "National Dance Championships" taking place later that year.

The script of the project Hana received from the creative agency it's about a professional dancer performing some moves immersed in nature. All the scenes will be characterized by a unique background: the majestic mount Fuji. Also, in the script it's indicated how different animals are going to interact and dance with the performer. More specifically butterflies, little birds and fireflies.

Fifteen years ago such result could be achieved only through an advanced, long and expensive post-production process manually modelling, animating and compositing all these creatures in the live action footage. But since the introduction of "ALNINE" the making of digital visual effects changed radically. Thanks to the generative AI technology ALNINE combined to Augmented Reality, it is possible integrate in the real scene 2D and 3D elements in real-time. How? Just asking ALNINE to do so.

Even if there is still space for improvement, most of the times is it possible to obtain the so-called "Final-pixel-in-camera" while shooting and so without dedicating much time in further finalizing the image in post-production.
Today, almost every professional camera have ALNINE feature already integrated…like it was for the "autofocus" feature back in the days. For Hana and her team such technological solution enabled them to explore more creative ideas without the fear of adding VFX later in the process.

As always Hana is the first one to arrive on set but after not much time, everyone

else shows up.
After setting all the gear, Hana is closely observes the scene through her director monitor, giving indications to his Steadicam operator Hideo on how to move the camera in relation to the dancer.

After some rehearsals Hana exclaims “Alright, let’s see now how we can integrate the creatures…ALNINE generate a butterfly with orange and black wings”. In a couple of seconds ALNINE is capable to analyze Hana’s voice input and generate the requested output. Thanks to its data set of millions of images and videos of butterflies and it’s complex Ultra Generative Adversarial Network (UGANs), it is able to create an original and never seen three-dimensional model of the animal.

In an instant, both on Hana’s and Hideo’s respective monitors a static butterfly appears in the middle of the frame. “Do you want to animate this butterfly?” adds ALNINE. “I do. I want the butterfly to fly around the human subject” replies Hideo. “Sure, give me a moment to recognize the human body and track the environment….done” The butterfly starts animating. The dancer makes few steps forward and the little animal follows her smoothly. “Good. Now let’s try with five butterflies, maybe two-thirds of the current size…mmm…also I want the orange to be more reddish on the wings…nice I like it, we can start recording a first clip…Hideo you ready?” “Rolling” “aaaaaand action!”.

Observing the scene in the backstage, the Art Director is astonished by the seamless integration of the virtual butterflies in the shot. Sometimes he’s confused when alternating his view from the monitor to the real scene and not seeing the butterflies around the dancer. Thanks to the “Final-pixel-in-camera” process, the Art Director can look at the final result and so it’s easy to give its approval to Hana on the current scene and move to the next one. Perhaps they will finish shooting before the sunset and enjoy the amazing view.

Figure I.1.0.2 Visual prompt for Story #2 - ALNINE

Story # 3 - OSMOS

Alfonso, early-twenties, is a video editor living in a small apartment in the centre of a vibrant city.
As usual, he loves to start the working day making his own coffee. At some point a notification sound comes from a pair of glasses on the dining table. The notification sound is followed by a voice assistant saying “Jenna just sent you a vocal message”. Jenna is a film Director in her early thirties, working mainly on music videos and fashion web contents. Alfonso turns toward the glasses saying: “play message” and Jenna’s message starts “Hi dear, we completed the LAST shot of the LAST scene of David’s new single…we finished yesterday at 11PM…how exhausting! Anyway, you got all the clips on the shared Cloud folder. Take look and hit me up when you feel confident with the first edit. Take care!”

Alfonso downs the remaining coffee, put the mug in the sink, seats at the table and wears his Osmos 3 smart glasses.

In the last years, Osmos devices became the standard device both in workplaces and daily lives of people, replacing2D screens. These smart glasses are capable to offer both Augmented Reality and Virtual Reality functionalities combined to advanced features such as ultra-high display resolution, eye-tracking, hand-tracking, 6G cloud connectivity and Brilliant AI just to name a few. All in a lightweight form factor. “Editing rooms” filled desks, bulky 2D monitors, PCs cases, mouses, keyboards, hard drives and wires, are a memory of the past. Something Alfonso never had to deal with.

Once he put on the glasses, a number of tabs elegantly appears all around Alfonso. He starts rearranging them and adding new ones to start working on Jenna’s project. He starts working in the “AR mode” and so he can still see the real environment. Alfonso uses gestures such as opening his fist to open folders or use voice commands to quickly navigate through the file directory and retrieve all the various clips.

When watching the footage, every time he finds something interesting and that might use in the final edit, he pitches with his fingers that specific clip creating a timestamp that he will be able to quickly retrieve later.

After some hours, Alfonso thinks to have identified all the clips he needed to start the actual editing of the music video.
Time for a break before the next phase. Here’s where the real creative process begins, here’s when it’s time to “enter the zone”.

Alfonso stands up and proceeds to the living room where there is more free space around him. It feels good to do some movement after being seated all that time. He then pronounce “switch to VR” and the glasses switch instantly to the “VR mode” where the real world fades out leaving space to only the main clips selected and the virtual environment in the background. Since David produces electronic music, Alfonso decides to go for a cybernetic setting and select as background an environment similar to the one portrayed in the movie “Tron”. It’s now time to create. Alfonso starts playing David’s track at high volume and starts grabbing clips, manipulating them, applying effects, distortions, filters….From outside VR, Alfonso looks like an orchestral director, rapidly moving his hands around, making elegant gestures and sometimes performing little dance moves. “I’m so convinced that this thing of immersing yourselves and visualizing and interacting with 2D footage leads you to explore and iterate different creative ideas” said Jenna once after one of the first projects together.

Time passes and Alfonso is quite satisfied with this first edit. He switches to AR mode while going back to the dinning table, turns the music down and makes the final adjustments before sending this “work in progress” to Jenna for feedback.

Figure I.1.0.3 Visual prompt for Story #3 - OSMOS

Appendix II – Online Questionnaire

Questionnaire - Design Fiction Scenarios

This survey should take about 20 minutes to complete.

* Required

Welcome!

This survey is conducted by researchers from Brunel University of London. With this survey, we want to understand your opinion about the design fiction scenarios proposed. If you would like to discuss any aspect of the research, please email aimone.bodini@brunel.ac.uk.
Your responses are saved completely anonymously. You can stop the survey at any time and do not need to give a reason. Once the survey is completed we will not be able to remove your data from the research database for a period of time. Your anonymised data will be accessible to team members from Brunel University. This data may later be used by other researchers and/or deposited without any identifying information in data sharing archives. Please feel free to ask the researchers any questions before you participate. This study is run under the jurisdiction of the Research Ethics Committee at Brunel University.

Ethical Approval
By beginning this study, you indicate that:
i) You have read this information about the study in full
ii) You have had the opportunity to ask questions by emailing the researchers
iii) You have received satisfactory answers to any questions that you have asked
iv)You understand that you are free to withdraw from the survey at any time without

1

If all these statements are correct, please tick 'I agree' below. If not, please feel free to stop completing the survey. *

- ◯ I agree

Introduction

First of all, THANK YOU for being here!
Your contribution is crucial, precious and will lead to new discoveries in this branch of knowledge.

After answering to some general questions about yourself and your current job, you will be told three different stories, all set in the future.
In these scenarios, technology has advanced a lot and this brought new habits and approaches when ideating, planning and making audiovisual contents.

After reading each story, you will be asked to answer to some close-ended questions and open-ended questions (very important!) . These stories aims to prompt and stimulate your imagination. Think about the future implications of immersive (VR, AR, XR...) & emerging technologies (AI, IoT, Digital Twins...) in the audiovisual industry.

Don't be shy and freely express your thoughts!

Let's start!

Generalities

2

Did you take part in the previous phases of this research? *

- ◯ Yes
- ◯ No

3

How old are you *

- ◯ 18-24
- ◯ 25-34
- ◯ 35-44
- ◯ 45-54
- ◯ 55+

4

In which country do you work more often? *

Select your answer

5

What department are you currently working in? (i*f "Other" please specify)* *

- ◯ Development department
- ◯ Production department
- ◯ Art department
- ◯ Camera department
- ◯ Directing department
- ◯ Post-production department
- ◯ Other

6

In what segment of the audiovisual industry do you work the most? *(if "Other" please specify)*

- ◯ Feature films
- ◯ Short films
- ◯ Documentaries
- ◯ Advertising
- ◯ Television
- ◯ Web Content Creator
- ◯ Art
- ◯ Exhibits and Fairs
- ◯ Other

7

What is the average team size of the projects your are involved in? *

- Less than 5 people
- 6-10
- 11-20
- 21-50
- More than 50 people

8

What is the average budget of those projects your are involved in? *

- Less than 5.000$
- 5.000$ - 20.000$
- 20.000$ - 50.000$
- 50.000$ - 100.000$
- More than 100.000$
- I do not know

9

How many years of professional experience in the audiovisual industry do you have? *

- No previous experience
- less than 5 years
- 6-10
- 11-15
- More than 15 years

10

How knowledgeable do you think you are about new technologies? (Virtual Reality, Augmented Reality, real-time graphic engines, Artificial Intelligence, Digital Twins, Internet of Things...) *

0	1	2	3	4	5	6	7	8	9	10

Not knowledgeable at all

Very knowledgable

Story #1

Vincent is a set designer based in Liverpool while Martin is a cinematographer in Madrid. The two are working on their next short film and as usual they are using "Depero".

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With the click of few buttons Martin quickly makes the dolly disappear, teleports him-

With the click of few buttons,Martin quickly makes the dolly disappear, teleports him-self outside the room and place in the scene a seven-meters long crane and starts us-ing it. "Lovely!" exclaims Chris "This is exactly what it's needed for this shot".

Uncertain,Martin asks: "I like it too Chris, but wouldn't be too expansive to rent a Crane?". Chris replies "You're right, but I'm sure that we can pitch to the Exec. Produ-cer this new idea exporting a quick pre-viz draft from Depero. Hopefully that will justi-fy the extra budget…I think this shot really adds something to the scene guys".

11

Considering DEPERO's specific features, select which are "Must have", "Nice to have" or "Not necessary" *

	Must have	Nice to have	Not necessary
Virtual-Pre Production meeting	○	○	○
Virtual Location scouting	○	○	○
Virtual Set Design	○	○	○
Virtual Cinematography	○	○	○
Virtual Pitching	○	○	○
Virtual Rehearsal	○	○	○
Cloud Connectivity	○	○	○

12

Compared with the current pre-production workflow of the segment of the audiovisual industry where you are working in the most... *

Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
...Using DEPERO may facilitate communication with other collaborators	◯	◯	◯	◯	◯
...Using DEPERO may lead to explore more creative opportunities	◯	◯	◯	◯	◯
...Using DEPERO may be more helpful in the decision making process.	◯	◯	◯	◯	◯
...Using DEPERO may be more helpful when pitching ideas asking for fundings	◯	◯	◯	◯	◯
...Using DEPERO may reduce filmmakers' ecological footprint (travelling, energy consumption...)	◯	◯	◯	◯	◯
...Using DEPERO may improve filmmakers' well-being (mental health, safety, inclusivity, equity...)	◯	◯	◯	◯	◯

13

Also... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning to use DEPERO may be easy for me	○	○	○	○	○
I may be interested in in testing DEPERO first-hand	○	○	○	○	○

14

After reading this story, in your opinion, what is something that may stop you from adopting DEPERO ?

15

After reading this story, in your opinion, what additional features would you like to have when using DEPERO ?

Story #2

6:30 AM. Hana’s alarm starts ringing to wake her up.
“It’s going to be a long drive” she thinks “but I’m happy to direct such project…even if the budget isn't high”.
Hana lives in the suburbs of Tokyo and is headed to the city of Fujiyoshida. This is in fact the chosen shooting location for promoting the commercial of "National Dance Championships" taking place later that year.

The script of the project Hana received from the creative agency it’s about a professional dancer performing some moves immersed in nature. All the scenes will be characterised by a unique background: the majestic mount Fuji. Also, in the script it’s indicated how different animals are going to interact and dance with the performer. More specifically butterflies, little birds and fireflies.

Fifteen years ago such result could be achieved only through an advanced, long and expensive post-production process manually modelling, animating and compositing all these creatures in the live action footage. But since the introduction of “ALNINE” the making of digital visual effects changed radically. Thanks to the generative AI technology ALNINE combined to Augmented Reality, it is possible integrate in the real scene 2D and 3D elements in real-time. How? Just asking ALNINE to do so.

Even if there is still space for improvement, most of the times is it possible to obtain the so-called “Final-pixel-in-camera” while shooting and so without dedicating much time in further finalising the image in post-production.
Today, almost every professional camera have ALNINE feature already integrated…like it was for the “autofocus” feature back in the days. For Hana and her team such technological solution enabled them to explore more creative ideas without the fear of adding VFX later in the process.

As always Hana is the first one to arrive on set but after not much time, everyone else shows up.
After setting all the gear, Hana is closely observes the scene through her director monitor, giving indications to his steadicam operator Hideo on how to move the camera in relation to the dancer.

After some rehearsals Hana exclaims “Alright, let’s see now how we can integrate the creatures...ALNINE generate a butterfly with orange and black wings". In a couple of seconds ALNINE is capable to analyse Hana's voice input and generate the requested output. Thanks to its data set of millions of images and videos of butterflies and it's complex Ultra Generative Adversarial Network (UGANs), it is able to create an original and never seen three-dimensional model of the animal.

In an instant, both on Hana's and Hideo's respective monitors a static butterfly appears in the middle of the frame. "Do you want to animate this butterfly?" adds ALNINE. "I do. I want the butterfly to fly around the human subject" replies Hideo. "Sure, give me a moment to recognise the human body and track the environment....done" The butterfly starts animating. The dancer makes few steps for-

16

Considering ALNINE's specific features, select which are "Must have", "Nice to have" or "Not necessary" *

	Must have	Nice to have	Not necessary
AI Assistant	◯	◯	◯
2D/3D real-time elements generation	◯	◯	◯
2D/3D real-time elements animation	◯	◯	◯
Augmented Reality compositing	◯	◯	◯

17

Compared with the current production workflow of the segment of the audiovisual industry where you are working in the most... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
...Using ALNINE may facilitate	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

facilitate communication with other collaborators	◯	◯	◯	◯	◯
...Using ALNINE may lead to explore more creative opportunities	◯	◯	◯	◯	◯
...Using ALNINE may be more helpful in the decision making process.	◯	◯	◯	◯	◯
...Using ALNINE may be more helpful when pitching ideas asking for fundings	◯	◯	◯	◯	◯
...Using ALNINE may reduce filmmakers' ecological footprint (travelling, energy consumption...)	◯	◯	◯	◯	◯
...Using ALNINE may improve filmmakers' well-being (mental health, safety, inclusivity, equity...)	◯	◯	◯	◯	◯

18

Also... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning to use ALNINE may be easy for me	○	○	○	○	○
I may be interested in in testing ALNINE first-hand	○	○	○	○	○

19

After reading this story, in your opinion, what is something that may stop you from adopting ALNINE ?

20

After reading this story, in your opinion, what additional features would you like to have when using ALNINE ?

Story #3

Alfonso, early-twenties, is a video editor living in a small apartment in the centre of a vibrant city.
As usual, he loves to start the working day making his own coffee. At some point a notification sound comes from a pair of glasses on the dining table. The notification sound is followed by a voice assistant saying "Jenna just sent you a vocal message". Jenna is a film Director in her early thirties, working mainly on music videos and fashion web contents. Alfonso turns toward the glasses saying: "play message" and Jenna's message starts "Hi dear, we completed the LAST shot of the LAST scene of David's new single…we finished yesterday at 11PM…how exhausting! Anyway, you got all the clips on the shared Cloud folder. Take look and hit me up when you feel confident with the first edit. Take care!"

Alfonso downs the remaining coffee, put the mug in the sink, seats at the table and wears his Osmos 3 smart glasess.

In the last years, Osmos devices became the standard device both in workplaces and daily lives of people, replacing 2D screens. These smart glasses are capable to offer both Augmented Reality and Virtual Reality functionalities combined to advanced features such as ultra-high display resolution, eye-tracking, hand-tracking, 6G cloud connectivity and Brilliant AI just to name a few. All in a lightweight form factor. "Editing rooms" filled desks, bulky 2D monitors, PCs cases, mouses, keyboards, hard drives and wires, are a memory of the past. Something Alfonso never had to deal with.

Once he put on the glasses, a number of tabs elegantly appears all around Alfonso. He starts rearranging them and adding new ones to start working on Jenna's project. He starts working in the "AR mode" and so he can still see the real environment. Alfonso uses gestures such as opening his fist to open folders or use voice commands to quickly navigate through the file directory and retrieve all the various clips.

When watching the footage, every time he finds something interesting and that might use in the final edit, he pitches with his fingers that specific clip creating a timestamp that he will be able to quickly retrieve later.

After some hours, Alfonso thinks to have identified all the clips he needed to start the actual editing of the music video.

Time for a break before the next phase. Here's where the real creative process be-gins, here's when it's time to "enter the zone".

Alfonso stands up and proceed to the living room where there is more free space around him. It feels good to do some movement after being seated all that time. He then pronounce "switch to VR" and the glasses switch instantly to the "VR mode" where the real world fades out leaving space to only the main clips selected and the virtual environment in the background. Since David produces electronic music, Alfonso decides to go for a cybernetic setting and select as background an environment simil-ar to the one portrayed in the movie "Tron". It's now time to create. Alfonso starts playing David's track at high volume and starts grabbing clips, manipulating them, ap-plying effects, distortions, filters....From outside VR, Alfonso looks like an orchestral

21

Considering OSMOS 3's specific features, select which are "Must have", "Nice to have" or "Not necessary" *

	Must have	Nice to have	Not necessary
AI Assistant	○	○	○
Augmented Reality Workspace	○	○	○
Virtual Reality Workspace	○	○	○
Natural Gestures Input	○	○	○
Eye-tracking	○	○	○
Cloud Connectivity	○	○	○

22

Compared with the current post-production workflow of the segment of the audiovisual industry where you are working in the most... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Strongly Disagree Disagree Neutral Agree Strongly Agree

	-	-		-	-
...Using OSMOS 3 may facilitate communication with other collaborators	○	○	○	○	○
...Using OSMOS 3 may lead to explore more creative opportunities	○	○	○	○	○
...Using OSMOS 3 may be more helpful in the decision making process.	○	○	○	○	○
...Using OSMOS 3 may be more helpful when pitching ideas asking for fundings	○	○	○	○	○
...Using OSMOS 3 may reduce filmmakers' ecological footprint (travelling, energy consumption...)	○	○	○	○	○
...Using OSMOS 3 may improve filmmakers' well-being (mental health, safety, inclusivity, equity...)	○	○	○	○	○

23

Also... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning to use OSMOS 3 may be easy for me	○	○	○	○	○
I may be interested in in testing OSMOS 3 first-hand	○	○	○	○	○

24

After reading this story, in your opinion, what is something that may stop you from adopting OSMOS 3 ?

25

After reading this story, in your opinion, what additional features would you like to have when using OSMOS 3 ?

Final Questions

26

Which of the three different scenarios do you think is the most valuable for professionals working in the audiovisual industry? *

- ◯ Story #1
- ◯ Story #2
- ◯ Story #3

27

How do you motivate your previous answer?

28

Did you keep a consistent level of focus when answering to all the previous questions?
(There is not a "right" or "wrong" answer) *

- ◯ Yes
- ◯ No

29

Why not? Please motivate your previous answer *

30

And... *

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
I think that the materials provided for the three different stories (written text and supporting images) were sufficient for me to answer with confidence to the questionnaire.	○	○	○	○	○

To Infinity and Beyond!

31

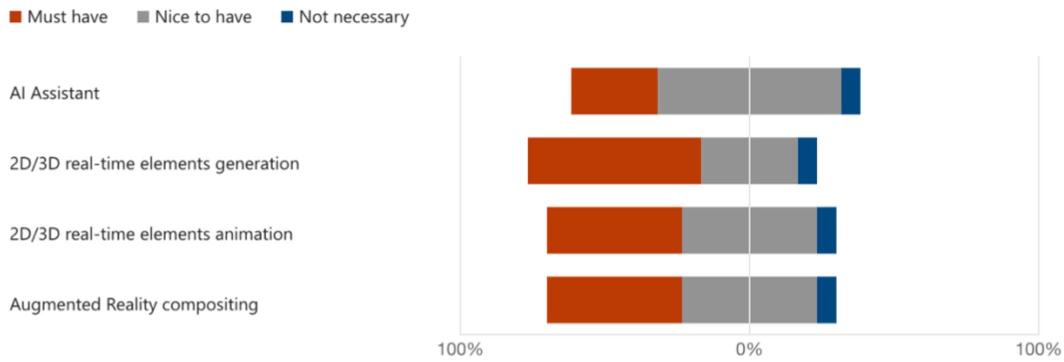
Our research on the future of filmmaking continues beyond this survey. If you would be open to being informally interviewed by a Brunel University researcher, please indicate this by adding your @email here. The interview will take approximately 20 minutes, and you will greatly contribute in this branch of knowledge!

ANSWERS TO Story #2 AND Story #3

Q16 - Considering ALNINE's specific features, select which are "Must have", "Nice to have" or "Not necessary"

16. Considering ALNINE's specific features, select which are "Must have", "Nice to have" or "Not necessary"

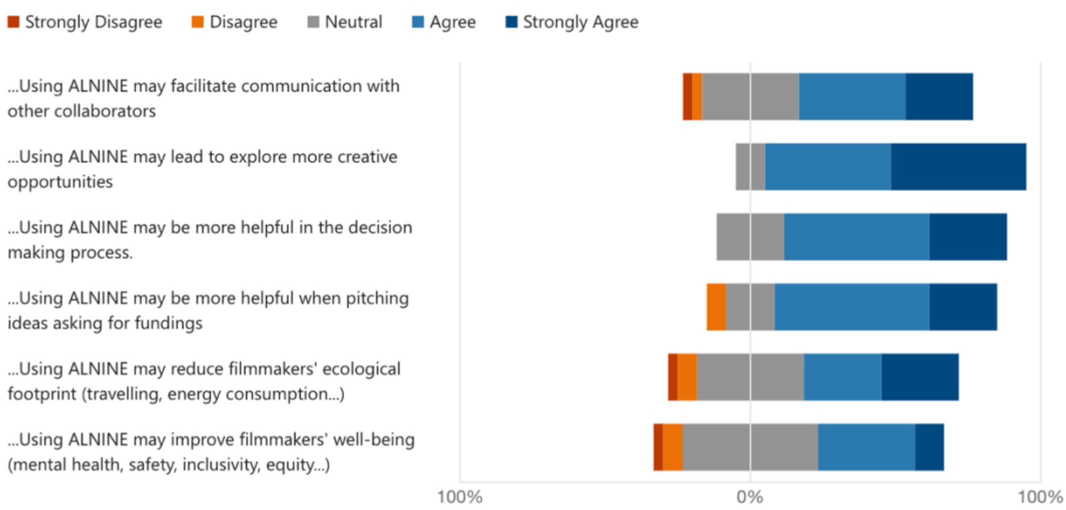
More Details



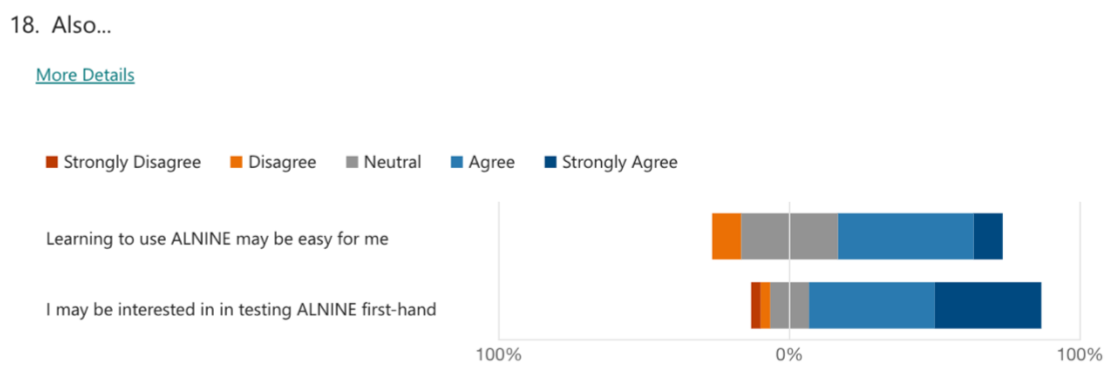
Q17 - Compared with the current production workflow of the sector of the audiovisual industry where you are working in the most...

17. Compared with the current production workflow of the segment of the audiovisual industry where you are working in the most...

More Details



Q18 – Also…



Q19 - After reading this story, in your opinion, what is something that may stop you from adopting ALNINE ?

Some glitches due to the preset animation
It seems super cool. Maybe the fact that you record live, you cannot change the model of the recreated elements later.
Since I'm not using vfx a lot, I think that cameras may be more expensive to have a app integrated which will be useless for me.
The usual agency and client workflow
Other connections
The same of the previous story
A too complicated interface / software that i could not handle or test myself
Difficulty in use
Don't know
The Price

An integration that still seems very difficult to make work (see voice assistants still very inefficient), but if the technologies will make it work as told it is very promising!
Nothing
Sector of industry I'm working with, relying on what's happening for real in front of the camera rather than fiction/generating specific scenarios.
Nothing, from a production point of view. It more depends on the director.
How realistic ALNINE can compose visual
Nothing - I would encourage its use
Cost,
Pricing
Same as before, price maybe for Mexico standards.
The need to have a fast and easy Interaction Design, the ability to change the path, shape and any other kind of movement and speed of the 3D generated
Not too in line with what i do
Reliability and such technology causing us to slowdown versus the current method of just recording camera & movement metadata for handoff to a VFX team and the Director doing their job of getting the talent to imagine what will be happening in post, which this tech still wouldn't help with unfortunately.

Q20 - After reading this story, in your opinion, what additional features would you like to have when using ALNINE ?

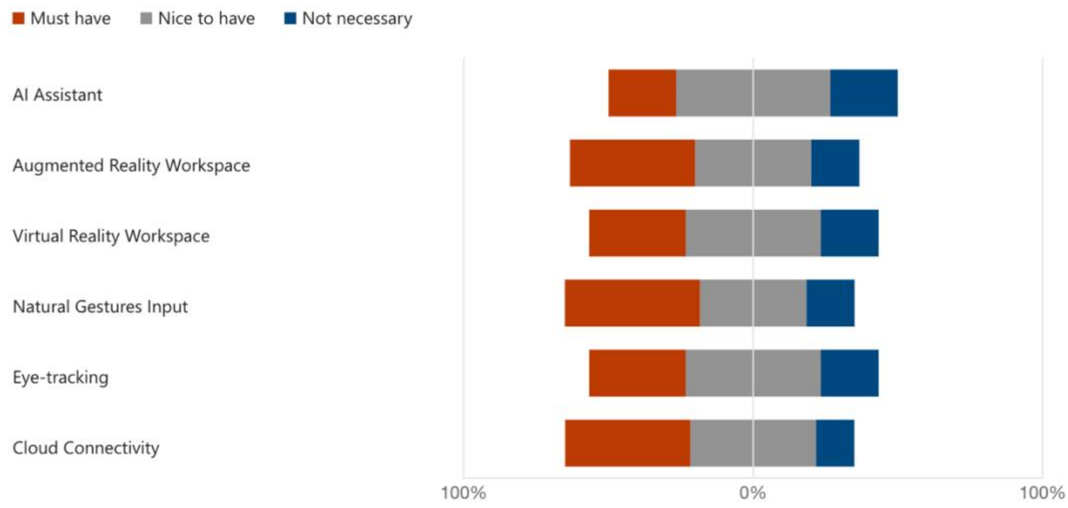
It seems alright to me
Maybe the chance to have a kind of “raw file” of the created elements that you can play a bit around after the shoot, like changing colors, fine tuning animation…
It would be great being able to create some elements with a unique design with ALNINE, just talking with it and seeing the result in real time
I think tracking models can be usefull for those who use vfx in their videos
Budget control

An Ai that give you hints to improve the shot and give you the info of the species, in this case of the butterflies, if you want shoot someting real. For example, give you the real butterflies that lives on mt. Fuji
Exporting both final real-time composition and the real footages Then it must also provide the alpha channel.
Don't know
The possibility to create a preview/pitch of the shot before going on location
It already looks a lot like that!
Meets for a team work
Available library of different options when generating an animal/image? Also "path control" for the virtual animals.
Layer replacement in post production work
Sound design
Seems already very complete
None
None
Backup RWA image storage without the ALNINE intervention, behavioral setting, pre-production 3D modeling capabilities and behavioral checking to upload on the cloud
Some way of the talent understanding were they should be looking or reacting in a virtual space, at the moment thats done by either a tennis ball on the end of a stick or a green mockup of something that will later be animated.

Q21 - Considering OSMOS 3's specific features, select which are "Must have", "Nice to have" or "Not necessary"

21. Considering OSMOS 3's specific features, select which are "Must have", "Nice to have" or "Not necessary"

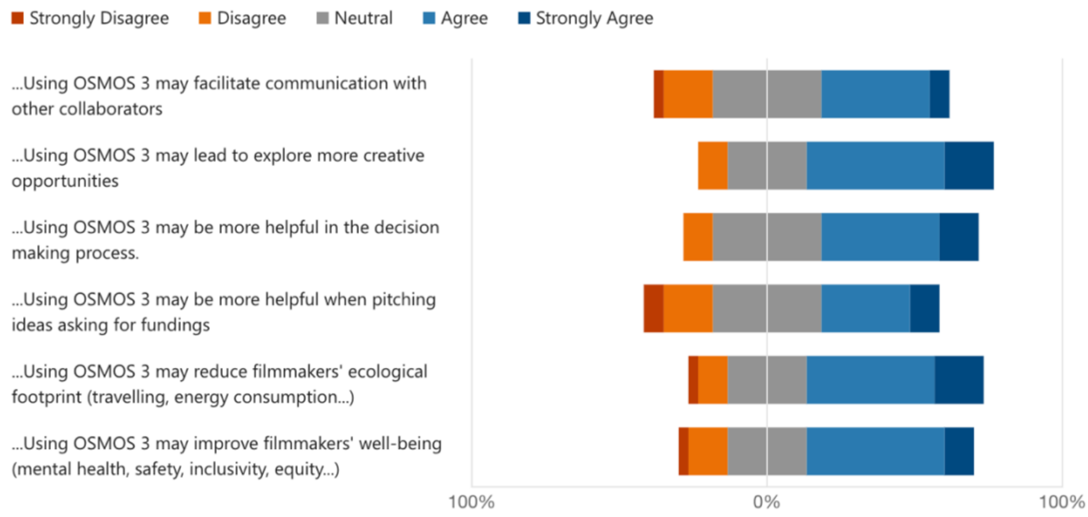
More Details



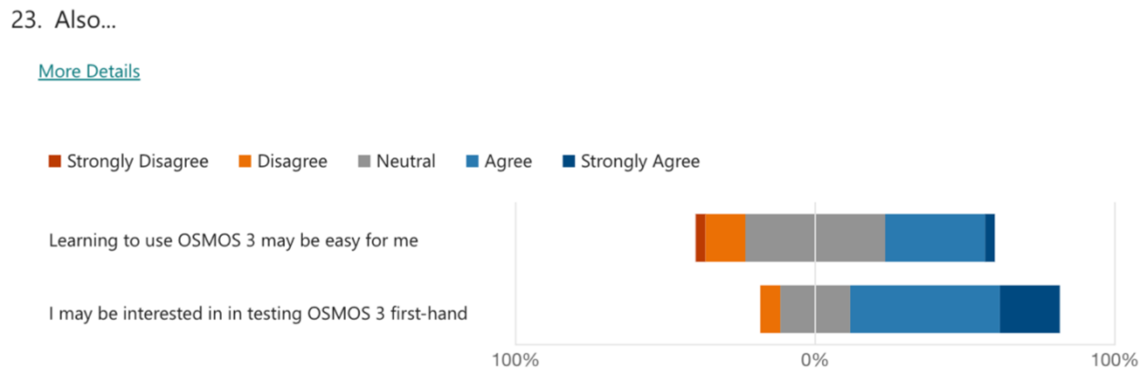
Q22 - Compared with the current post-production workflow of the sector of the audiovisual industry where you are working in the most...

22. Compared with the current post-production workflow of the segment of the audiovisual industry where you are working in the most...

More Details



Q23 – Also..



Q24 - After reading this story, in your opinion, what is something that may stop you from adopting OSMOS 3 ?

Just some fears of headache from the VR mode, but I'll definitely try it
I dunno as I am not really involved on the editing that much, it is really hard for me to figure it out
I think I can get distracted even in an immersive vr environment. I feel I can have the same results in the real world.
Editing is already stressing our eyes. I dont think we need an immersive virtual workspace to make our work better. It's just not my cup of the...
Relations with other members project
Always the usabilty
making a process faster and more approximative does not necessarily translate in higher quality output
cost
Don't know
The Price
certainly the ergonomic part is essential, wearing a viewer for many hours should not weigh down a traditional procedure. The resolution and the computing power will have to be up to par, as well as the imput tools. Find ways to replace a keyboard and mouse without losing their convenience and speed.
Nothing

Probably the VR mode. AR mode feels a good in between but VR would feel quite daunting as being completely immersive.
It only need to be very easy to use - otherwise this would bring me to say "let's go back to my computer". If very well constructed, if dynamic, if easy to use - I would use it right away!
gesture fatique cause by hand movement within normal space.
The potential damage that this technology could have on our eyes health
Having been an editor, I understand the importance of getting up and moving around while working is key, I honestly don't believe editors want to be wearing something on their face and having to use their hands and arms so much to edit -- it could be tiring. The ease of sitting at a desk and just having to use one finger to click a mouse while resting your arm is fine. Though I believe the strain on the eyes of looking a big monitor all day is something that needs to be amended, I just don't think a eye piece device is going to be an industry norm anytime soon. I mean look what happened with Google Glass. Also editing stations don't take up a ton of space and can be quite compact even if you're in a tiny apartment. This just seems like a very drastic change in workflow and would take an editor a lot of time to get used.
The huge frustation when a complex precision technology doesn't work as well as I hope, it happens with Premiere too. OSMOS 3 seems to make it even more complex.
Money
I'd need to know what the workflow is like, how well it handles camera formats, how well it can export files to other production software for audio or colour engineering.

Q25 - After reading this story, in your opinion, what additional features would you like to have when using OSMOS 3 ?

I dunno as I am not really involved on the editing that much, it is really hard for me to figure it out
Interactivities with all crew

Ai that suggests the best shot to use
it should be more of a "first feels pass" than a editing software. it feels like this could add a new step in the workflow, taken out of an editing software.
For me it will be impossible to mange this virtual studio honestly. I have to touch my devices materially
Don't know
I would be interested in understand how the storage of the footage, and how to change it in terms of codecs, formats etc.
The possibility of having a viewer not in direct contact with the face to reduce the burden of prolonged use. A lot of resolution so as to reach reality.
Meeting rooms for the team
I would say collaborative mode, with different team members entering the VR mode. Basically for Jenna and Alfonso to discuss feedback directly immersed in the edit.
Possibility to work together in the same virtual space - but maybe it already has this option. Both as editor mode or viewer mode. So the editor can work with the director or colorist but maybe the client, when connected, can only be viewer!
simulated weight on hand to reduce gesture fatique
A notification that alerts you when you’ve been using the glasses for too long
I could see this being a useful device for 'editing on the go'. For instance if you don't have the luxury to edit in your home or an edit suit/office -- i.e. if you need to get some editing done while traveling/while on the go, while in a taxi / Uber, on a plane, etc.
The space required to implement the tech on a small office.
A mouse or tracking gloves, AI that understands not only your movement but also your next intention
Strong intergration with other existing industry tools like Davinci Resolve, Pro Tools and Nuke so that collaboration is seemless.

Appendix III – User Testing Procedure

User Testing Study - Overview

<table>
<tr><th colspan="2">Objective</th></tr>
<tr><td colspan="2">1) Collect feedback about the degree of usability and ease of use of the immersive pre-production workflow proposed.</td></tr>
<tr><th colspan="2">Sample Size and Description</th></tr>
<tr><td colspan="2">• 29 participants divided into 11 groups
• Each group is formed by stakeholders of the audiovisual industry covering different roles (Director, Producer, Director of Photography…) and working on small and medium productions.
• Because participants are professionals working in the industry who’s time and knowledge is extremely valuable, they are gifted with a 50£/€ Amazon voucher.</td></tr>
<tr><th colspan="2">Duration</th></tr>
<tr><td colspan="2">120 minutes including:
• 5 min break after 40 min (Introduction + AR activity + VR activity 2.0)
• 5 min break after 25 min (VR activity 2.1)
• 5 min break after 15 min (VR activity 2.2)</td></tr>
<tr><th colspan="2">Researcher</th></tr>
<tr><td>Aimone Bodini (Brunel University)</td><td>Moderating the study
• Assessing participants feedback
• Conducting the survey
• Controlling time
• Ensuring users feel supported and understood
• Demonstrating VR/AR tasks for the participant
• Safety control of the study</td></tr>
</table>

	• Monitoring the work status of all devices
Equipment	
• VR headset and controllers (Meta Quest 2) • Laptop • Smartphone	• Video cameras • Audio recording equipment • Tablet
Data Capture	
• Video recording of participants as they interact with the hardware and content • Audio recording of participant comments in response to hardware, content and interview • Screen recording of VR content	
Covid Measures	
To mitigate covid spread, it will required to participants to sanitize their hands before and after the session. Sanitizer will be provided by the researcher. In addition, all the equipment that will be used (controllers, VR headset, iPad…) will be properly sanitized using wraps. Wraps will be provided by the researcher. Also, window will be kept open for a better air circulation in the room. Researcher will take a covid-19 test 48 hours prior each session.	
Location	
On-campus and Off-campus, in UK and Italy. Further details can be found in the "Risk Assessment form" document.	

Study Procedure

Set-Up

- Make sure you have consent form for participant
- Check iPad Pro 2020
- Check Meta Quest 2 headset and controllers

- Check video camera setup for recording
- Check microphone setup for recording

General Introduction	5 min

Thank you for agreeing to participate in this study. Throughout this session I will be reading from a script to ensure that I give identical instructions to all participants.
As a participant in this study, you will execute a number of tasks using an app called Polycam and one called Gravity Sketch. I will guide you and observe you as you interact with these immersive software applications. Afterwards, I will interview you about your experience. Finally, I will ask you to fill out a short questionnaire. This session will be recorded with a camera and a microphone and your data will be anonymized.
Consent Form
Before we begin, I will go over important information about the study with you. Your participation in this study in is voluntary and you are free to stop at any time. The risks of participating are minimal. At any point during this session you are free to ask me questions.

Here is information about the study you can review and keep. Take as much time to read over it as you need and let me know if you have any questions or when you are ready to begin.
[After receiving back the consent form signed by participants]
Now, throughout the session, I will also be the Wizard, capable to give you the illusion of some additional features that do not actually exist within these software because of their current limitations. If you maintain this suspension of disbelief during the session, it will help us to further extend the discussion.

Polycam – iPad Pro	15 min

INTRODUCTION & DEMONSTRATION (5 mins)

To use Polycam, you will need to use the iPad Pro 2020. This device integrated a LiDAR scanner capable to capture geospatial data of the surrounding space and so, thanks to a software such as Polycam, to create a 3D object of the same space.

Facilitator Demonstration

i. You use the iPad Pro by holding the device in your hands.
ii. To start scanning you have to tap on the record button.
iii. Then you can point iPad Pro's camera around the room to scan the surrounding. You will see little triangles forming meaning that you are capturing data. For a better output, you should scan all the blue areas as shown by the software.
iv. Once the area is scanned, you can tap on the red "*stop*" button
v. Tap the "*process"* button.
vi. Now you can observe the so called *the 3D textured mesh of scan.*
vii. Now you can upload on the cloud your scan tapping the upload button

STUDY PORTION – Polycam (10 mins)

Task Instructions

While you are using the iPad, I will be sit here and I'll assist and observe you while you use Polycam. I'm now going to ask you to perform a scan of the space around us.

Please remember to think aloud while you are performing the tasks.

1.1 Hold the iPad Pro with your hands. [Hand over iPad]
1.2 Tap on the *"record button*" icon
1.3 You can now scan the room moving the iPad Pro around capturing the room from different perspectives. Try to cover all the blue area.
1.4 You can now tap on the "*stop*" red button.
1.5 Tap the "process" button.
1.6 Now observe and interact with your capture on the 2D display of the iPad.
1.7 Tap now on the "upload" button to sync the capture on the cloud.

- [Hands back iPad Pro 2020]
  Do you have any questions?

Use of the "Wizard of Oz" method….the capture is magically imported into the VR software "Gravity Sketch" which will be used of the next activity.

Gravity Sketch – Meta Quest 2	80 min

INTRODUCTION & DEMONSTRATION - Gravity Sketch (20 min)
To use Gravity Sketch, you will need to use the Meta Quest 2. You use the Meta Quest 2 by putting on that headset and holding those controllers.
While you are using the Meta Quest 2, I will be use another one too and I'll be present in the same virtual environment with you to guide and observe you. I will be observing how you use Gravity Sketch. I will ask you to perform several tasks using this software.
First I will briefly explain you how to use the Meta Quest 2 controllers
[Facilitator explain buttons and triggers to participants]
I'm now going to give you a quick demonstration on Gravity Sketch functionalities to plan your pre-production phase but first I ask you to wear the headsets.

[Facilitator gives headset#1, #2 and #3 to participants]
How to wear Meta Quest 2
After you get the headset on, I will explain you how to adjust the:

- Head placement
- Head straps
- Eye lenses
- Play area limited by *Guardian*

Let me know when you are ready to begin, or if you have any questions.
Facilitator Demonstration
2.0 Virtual Location: La Casa Gassia (Interior)

Pre-production activities

- General assessment of the location (*)
- Import real photos of location
- Import Google Maps location
- Assess lights to remove
- Assess set design elements to replace
- Import props (softbox light) (*)
- Import puppet characters (*)
- You can think about the lighting (Wizard of Oz)
- We can now simulate a static shot
- We can now simulate the crane movement (Wizard of Oz)
- We can select the "*tape*" measures (*)
- Day & Night (*) (Wizard of Oz)
- Sunlight position in a specific location given a specific date and time (*) (Wizard of Oz)
- Budgeting chart updated in real-time depending on what elements are added (props, light equipment, camera equipment…) (*) (Wizard of Oz)
- You can now tap on "Export screenshots"

* Activity suggested by participants who responded to the previous questionnaire

[Hands back all headsets]
Do you have any questions?

Break (5 mins)
Feel free to take off the headset and take a break. On the table you can find some water bottles.
[…]
All right, let's jump back in VR

STUDY PORTION – Gravity Sketch (40 mins total)
Now is your turn!

Please remember to think out loud as you perform these tasks and to communicate with your collaborators. I will be with you in the virtual environment in the case you don't remember how to access and use certain tools.

2.1 Virtual Location: Stairs (Interior) (20 min)

Basic interactions

2.1.1 Look at your hands to see the different icons

2.1.2 Press the rear trigger on your right hand to draw

2.1.3 Place your controller inside the drawing and then press and hold the lateral trigger on your right controller to grab the drawing and reposition it in space

2.1.4 Press the blue menu button icon on your left controller to open the menu and import the 3D asset named “stairs”.

2.1.5 Repeat the process and now import its texture.

2.1.6 Navigate the directory to select the matching texture for the location

2.1.7 Apply texture using your controller's buttons

2.1.8 Scale Location

2.1.9 Navigate/Teleport across location using the banana pointer

Pre-production activities

[Facilitator imports Script in the scene] “Now let's read the script”

Script prompt “In this scene Alex is walking down the stairs when he finds that his gang is waiting for him in the lobby of the building. It's a surprise for Alex and asks them to what he owes the pleasure. After some silence, the gang sarcastically informs Alex on how things have changes lately due to Alex's absence in the last days and so on how he's not going to be the leader anymore. The conversation they are having seems calm with smiles an sarcasm but underneath there is palpable tension growing between them.

Set design prompts: “The lobby is dirty, trash is everywhere on the ground and the painting on the wall is vandalized with graffiti. In addition, there are two chairs”

Asses the location (*) as it is now (empty, no imported assets). [If needed Facilitators prompt them…"What do you think about the colour of the walls? About the light source?....]

Now I will give you different tasks

2.1.10 Participant X Import props (garbage, chairs…)(*)

2.1.11 Participant Y Import puppet characters (*)

2.1.12 Participant Z Import reference images (painting)

2.1.13 Participant Z Take the measure on the wall in order to have the painting 2meters high (*)

2.1.14 Participant Z Scale the painting accordingly

2.1.15 Participant Y Apply the texture to the puppets

2.1.16 Participant X Apply texture on the objects

2.1.17 Participant XYZ Vandalize the painting with graffiti using your drawing tool with your right controller.

[Meanwhile Facilitator fill the scene importing other assets if needed to make the process smoother and quicker]

2.1.18 We can now simulate a static shot pressing the purple icon on our left controller and selecting the "view points" tool.

2.1.19 Now we can move around choosing the right angle to convey the tension we have in this scene.

2.1.20 You can ask the wizard to change the time of day from Day to Night (*) (Wizard of Oz)

2.1.21 You can now tap on "Export screenshots"

-

  * Activity suggested by participants who responded to the previous questionnaire

[Facilitator saves the sketch did by the group. "Save as" 02_groupX]

-

Break (5 mins)

Feel free to take off the headset and take a break. On the table you can find some snacks.

Also, take a look at this video:

[Facilitator show "*Clockwork Orange*" scene]
If you feel ready, we can start the last activity wearing once again the VR headset.

2.2 Virtual Location: Mont-Saint-Michael (Exterior) (20 min)
Script prompt**:**
The regional committee of tourism of Normandy asks you to promote a landmark such as Mont-Saint-Michael. They specifically ask you to make a spectacular long take shot with a drone. Plan your flight.

- Now I will teleport you to the location and import for you a 3D drone in the scene.

2.2.1 Now discuss and draw the drone flight path you want to achieve. To draw the path, remember to use the "brush" tool
2.2.2 You can take notes what camera angle you want at each moment.
2.2.3 You can take notes on the drone speed.
2.2.4 Now switch on the "passthrough" feature to have a mixed reality viewing experience.

[Facilitator saves the sketch did by the group]
Also, take a look at this video:

[Facilitator show reference video]

Break (5 mins)
Feel free to take off the headset and take a break.
[…]
Now, we are about to start a group discussion and talk about what you have done in the previous activity. If you like, we can jump back in VR and discuss in the virtual environment. Alternatively, we can have the group discussion in the traditional way around the table.
[Facilitator saves the sketch did by the group. "Save as" 03_groupX]

Group Discussion / Post Study (30 mins)

We can now proceed to the interview portion of the study.

[Main questions in **bold**, eventual sub-questions *italic*]

OVERALL FEEDBACK

Q.1 How was your overall experience of the workflow?

LOCATION SCOUTING & VISUAL REPRESENTATION

Q.2 How was the experience of being immersed in the location where you are going to shoot?

Q.2.1 sub-question: How was the experience of navigating around the environment?

Q.2.2 sub-question: How visually realistic did you find the experience?

Q.2.3 sub-question: Is photorealism a deal-breaker?

Q.2.4 sub-question: Do you think that doing location scouting physically is still needed in the pre-production phase?

COMMUNICATION AND COLLABORATION

Q.3 How did you find communicating your ideas with the other participants in the virtual environment?

Q.4 How did you find collaborating at the same time with the other participants in the same virtual environment?

INTERFACE AND INTERACTIONS

Q.5 How did you find interacting with the interface proposed?

Q.6 What did you find most difficult when interacting with the interface?

Q 6.1 sub-question: Do you think it could have been easier to use your hands rather than the controllers to interact with the virtual interface?

INTENTION TO USE THE PURPOSED WORKFLOW

Q.7 Would you use this exact workflow presented in a real-world scenario? Why or why not?

Q.8 What would you stop from using this workflow?

Q.8.1 sub-question: How much did you enjoy working in a virtual environment?

Q.8.2 sub-question: What did you enjoy the most about this experience?

ECONOMICAL ASPECT

Q.9 **Do you think this workflow may be helpful in saving time and therefore money? How?**

Q.9.1 sub-question: *How much are you willing to pay for a service offering a similar workflow (hardware and software)?*

EXTRA QUESTIONS

Q.10 Was there anything you wanted to do while planning your production that you were unable to do?

Q.11 How the purposed virtual pre-production workflow compare to the traditional pre-production?

Follow-up Question:

• Could you tell me more about …?

Thank you for answering all the questions. For the final part of this study, could you please fill out this questionnaire?
[Get hard copies out, and hand them to participants]

Questionnaire (5 mins)
Based on the experience you just had, for each statement, place a mark in the cell that best reflects how much you agree with each statement.

Perceived Usefulness

Compared with the current pre-production workflow you are experiencing in the AV industry, the proposed pre-production workflow...

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
...may facilitate communication with other collaborators					
...may lead to explore more creative opportunities					
...may be more helpful in the decision making process					
...may be more helpful when pitching ideas asking for fundings					
...may reduce filmmakers' ecological footprint (travelling, energy consumption...)					
...may improve filmmakers' well-being (mental health, safety, inclusivity, equity...)					

Perceived Ease of Use

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Learning to use the proposed workflow may be easy for me					
It would be easy for me to become skilful at adopting the proposed workflow					
My interaction with the proposed workflow would be clear and understandable					

Wrap-up (5 mins)

- Thank participants for coming in

Appendix IV – Ethical approvals and participant information sheets

Participant Information Sheet for undertaking research

Study title

Virtual Production in Audiovisual Industry

Invitation Paragraph

You are being asked to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask me/us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the purpose of the study?

The aim of this observation is to understand how immersive technologies (Virtual and Augmented Reality) can be employed and exploited in the pre-production phase of an audiovisual-production.

Why have I been invited to participate?

You are considered by the researcher as a potential stakeholder or expert of the subject of the study.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form indicating your willingness to be involved. If you decide to take part you are still free to withdraw up until one week after the interview time without giving a reason.

What will happen to me if I take part?

You will be invited to share your experiences and comments about; 1.) the actual pre-production process with an emphasis on location scouting 2.) your knowledge of immersive and real-time technologies in terms of functioning and opportunities.

Are there any lifestyle restrictions?

There are no lifestyle restrictions

What are the possible disadvantages and risks of taking part?

There are no anticipated disadvantages or risks associated with taking part in this study.

What are the possible benefits of taking part?

The results of this study will be used as a part of my PhD research to better understand how Virtual and Augmented Reality could be exploited to solve everyday challenges when doing location scouting and approaching pre-production in the AV industry.

What if something goes wrong?

The person to be contacted if the participant wishes to complain about the experience should be the Chair of the relevant Research Ethics Committee

Will my taking part in this study be kept confidential?

All information that is collected from you during this research will be kept strictly confidential and anonymized.

Will I be recorded, and how will the recording be used?

Audio of the interview will be recorded using specific computer software.

It will be kept confidential and stored on university devices until the end of study.

What will happen to the results of the research study?

The research findings will be communicated to designers and researchers wanting to gain insights into engaging the public with Virtual Production and issues related to that.

Who is organising and funding the research?

The research is organized and funded by the "StoryFutures" initiative.

What are the indemnity arrangements?

Brunel University London provides appropriate insurance cover for research which has received ethical approval.

Who has reviewed the study?

The study has been reviewed by Professor Hua Zhao

Research Integrity

Brunel University London is committed to compliance with the Universities *UK Research Integrity Concordat*. You are entitled to expect the highest level of integrity from the researchers during the course of this research

Thank you for acknowledging the Participant Information Sheet.

Contact for further information and complaints

Researcher name and details:

Aimone Luca Bodini. If you have any queries about this research please contact – Aimone Luca Bodini: PhD Researcher, Brunel University, Uxbridge, UB8 3PH; E-mail aimone.bodini@brunel.ac.uk

Supervisor name and details:

Dr. Vanja Garaj. Head of Design, Brunel University, Uxbridge, UB8 3PH; E-mail vanja.garaj@brunel.ac.uk

For complaints, Chair of the Research Ethics Committee:

College of Engineering, Design and Physical Sciences Research Ethics Committee Chair – Professor Hua Zhao (Hua.Zhao@brunel.ac.uk)

Appendix IV – Ethical approvals and participant information sheets

1. Ethical approval for undertaking Exploratory Interviews

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

22 June 2020

LETTER OF APPROVAL (CONDITIONAL)

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 01/07/2020 AND 31/01/2023

Applicant (s): Mr Aimone Luca Bodini

Project Title: Virtual Production in Audiovisual industry

Reference: 23285-LR-Jun/2020- 25953-2

Dear Mr Aimone Luca Bodini

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **Please ensure that you monitor and adhere to all up-to-date Government health advice for the duration of your project.**
- The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.
- **Ethical Approval is granted only for the research activity included in this Ethics Application**. We note that your research end date is 31 January 2023, therefore any changes, additional activity must be done through an Amendment or a new Ethics Application.
- Please ensure that participants information and any data collected is anonymised as soon as possible. You should use code names/references to ensure participants anonymity, as your project spans over a 3 year period. *Further advice on data storage can be found here: https://www.brunel.ac.uk/life/library/SCO/Storing-and-backing-up-research-data*

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Brunel University London

when you get the Final Ethical Approval, you will need to ensure that you follow the agreed protocol to conduct this research. Any changes to the agreed protocol will require you to either submit an 'Amendment' or a new Ethics Application.

In the light of the above, **please note that the revisions/information required must be provided, and approved, before the study can commence**. Please make the relevant changes to your original BREO application and resubmit, along with any amended documentation.

- In order that your research is not unduly delayed, it is in your best interests to resubmit your application as soon as possible (preferably within the next 10 days). Please note that applications awaiting changes for longer than three months will be archived, and a new one will need to be submitted.

Please direct any queries relating to your application to CEDPS-Research@brunel.ac.uk

Kind regards,

Professor Hua Zhao

Chair

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London

Page 2 of 2

2. Ethical approval for undertaking Online Workshops

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
UB8 3PH
United Kingdom

www.brunel.ac.uk

19 May 2021

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 19/05/2021 AND 31/01/2023

Applicant (s): Mr Aimone Luca Bodini

Project Title: Virtual Production in Audiovisual industry

Reference: 23285-A-May/2021- 32676-2

Dear Mr Aimone Luca Bodini

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **Approval is given for remote (online/telephone) research activity only. Face-to-face activity and/or travel will require approval by way of an amendment.**
- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- In addition to the above, please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Professor Hua Zhao

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Brunel University London

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3. Ethical approval for undertaking Online Questionnaire

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
Kingston Lane
Uxbridge
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United Kingdom

www.brunel.ac.uk

5 April 2022

LETTER OF APPROVAL (Conditional)

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 01/07/2020 AND 31/01/2023

Applicant (s): Mr Aimone Luca Bodini

Project Title: Virtual Production in Audiovisual industry

Reference: 23285-A-Mar/2022- 38984-1

Dear Mr Aimone Luca Bodini

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **Approval is given for remote (online/telephone) research activity only. Face-to-face activity and/or travel will require approval by way of an amendment.**
- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**
- Please do not use Google Forms due to GDPR issues please use Microsoft Forms or JISC Surveys as an alternative. **This point can be addressed outside of the BREO system.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Simon Taylor

Professor Simon Taylor

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Page 1 of 2

Brunel University London

4. Ethical approval for undertaking in-person User Testing

College of Engineering, Design and Physical Sciences Research Ethics Committee
Brunel University London
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www.brunel.ac.uk

9 June 2022

LETTER OF APPROVAL

APPROVAL HAS BEEN GRANTED FOR THIS STUDY TO BE CARRIED OUT BETWEEN 01/07/2020 AND 31/01/2023

Applicant (s): Mr Aimone Luca Bodini

Project Title: Virtual Production in Audiovisual industry

Reference: 23285-A-Jun/2022- 39657-1

Dear Mr Aimone Luca Bodini

The Research Ethics Committee has considered the above application recently submitted by you.

The Chair, acting under delegated authority has agreed that there is no objection on ethical grounds to the proposed study. Approval is given on the understanding that the conditions of approval set out below are followed:

- **The agreed protocol must be followed. Any changes to the protocol will require prior approval from the Committee by way of an application for an amendment.**
- **Please ensure that you monitor and adhere to all up-to-date local and national Government health advice for the duration of your project.**

Please note that:

- Research Participant Information Sheets and (where relevant) flyers, posters, and consent forms should include a clear statement that research ethics approval has been obtained from the relevant Research Ethics Committee.
- The Research Participant Information Sheets should include a clear statement that queries should be directed, in the first instance, to the Supervisor (where relevant), or the researcher. Complaints, on the other hand, should be directed, in the first instance, to the Chair of the relevant Research Ethics Committee.
- Approval to proceed with the study is granted subject to receipt by the Committee of satisfactory responses to any conditions that may appear above, in addition to any subsequent changes to the protocol.
- The Research Ethics Committee reserves the right to sample and review documentation, including raw data, relevant to the study.
- If your project has been approved to run for a duration longer than 12 months, you will be required to submit an annual progress report to the Research Ethics Committee. You will be contacted about submission of this report before it becomes due.
- You may not undertake any research activity if you are not a registered student of Brunel University or if you cease to become registered, including abeyance or temporary withdrawal. As a deregistered student you would not be insured to undertake research activity. Research activity includes the recruitment of participants, undertaking consent procedures and collection of data. Breach of this requirement constitutes research misconduct and is a disciplinary offence.

Simon Taylor

Professor Simon Taylor

Chair of the College of Engineering, Design and Physical Sciences Research Ethics Committee

Brunel University London

Page 1 of 1

5. Ethical approval for undertaking drone experiment

Person(s) completing this assessment:
(Person carrying out or managing/supervising the activity day-to-day)

Name Aimone Luca Bodini Title Doctoral Researcher Signature Date 06/10/22

Person approving this assessment:
(Person with overall responsibility for the activity Director of Professional Service (or delegated individual, e.g. manager or head of department), Senior Academic or Manager/Supervisor)

Name Vanja Garaj Title Academic Staff Signature Date 06/10/22

Review of assessment, and revision if necessary
(For continuing work: the assessment must be reviewed for each visit in a series; when there are significant changes to government guidance, to work materials, equipment, methods, location or people involved; and if there are accidents, near misses or complaints associated with the work. If none of these apply, the assessment must be reviewed at least annually)

REVIEW DATE	13/10/2022	25/10/2022	--/--/----	--/--/----
Name of reviewer	Hua Dong	Paul Josse		
Signature				
No revisions made				
Changes to activity, hazards, precautions or risks noted in text.	Corrected Risk Rating calculation 1 (highlighted in red)	Reviewed and risk controls added for take off and landing of drone		

Appendix V – Images Miscellaneous

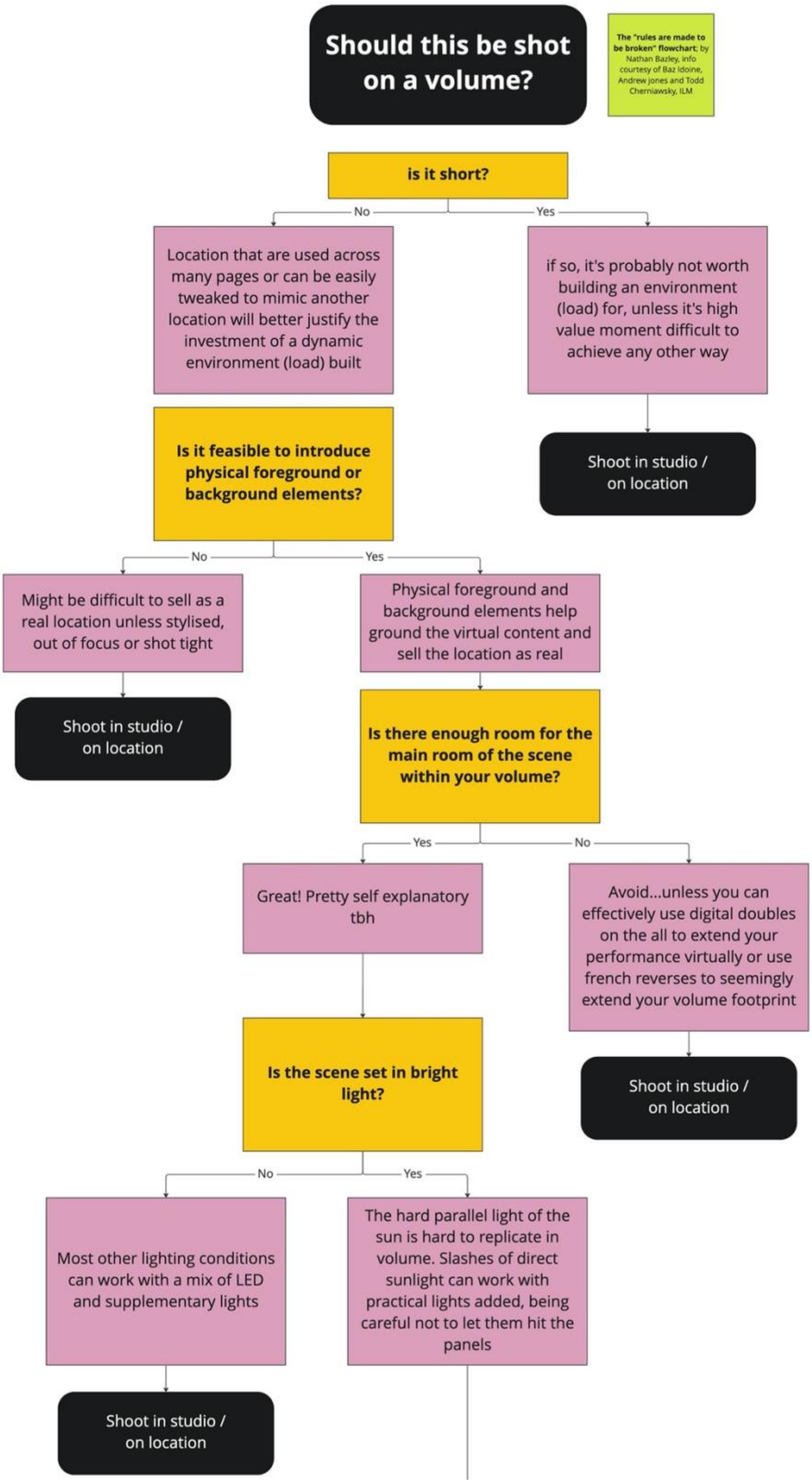

Figure V.1.0.1 VP Staging Flowchart designed by Bazley (2022) - part 1

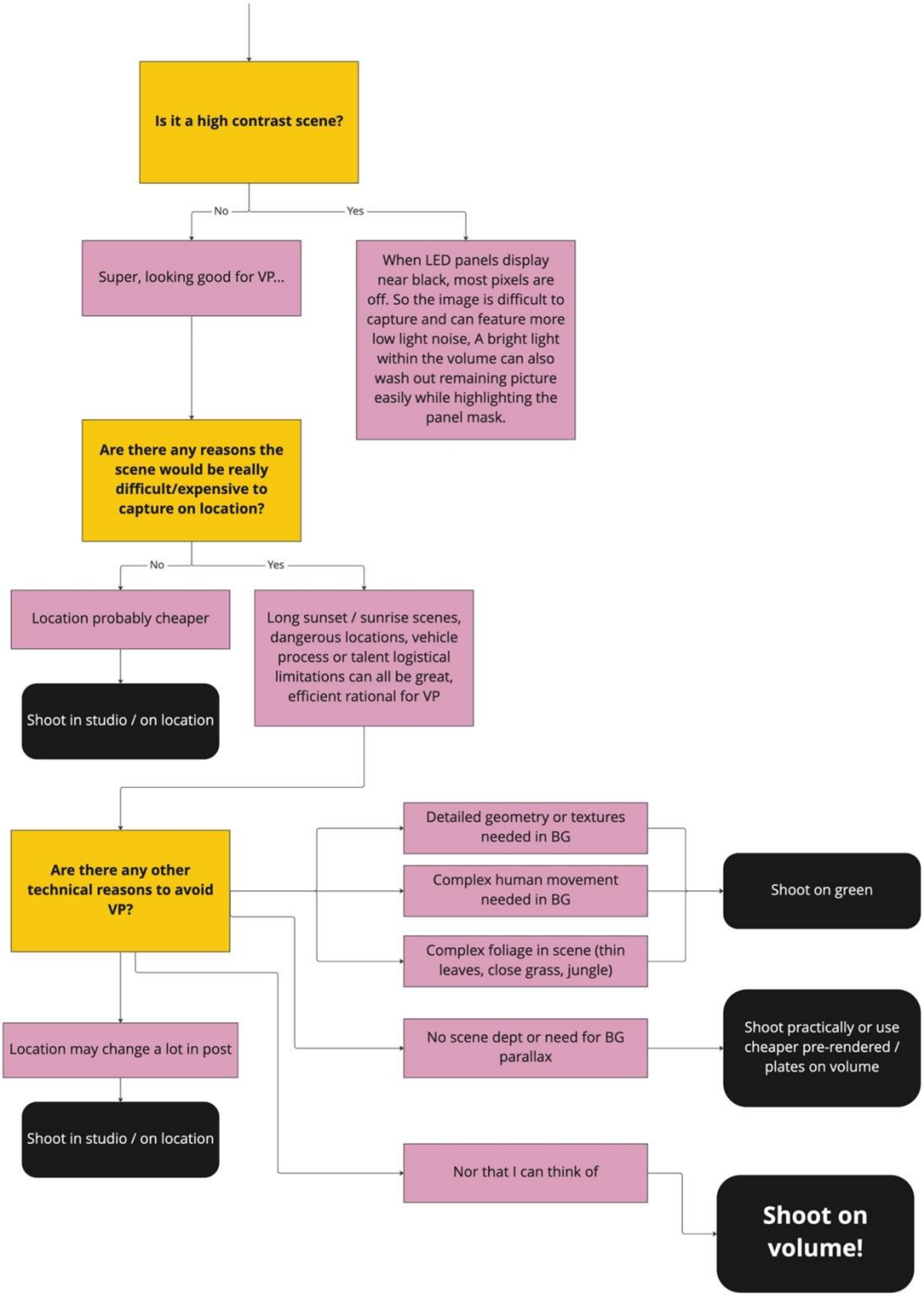

Figure V.1.0.2 VP Staging Flowchart designed by Bazley (2022) - part 2

Figure V.1.0.3 Complete dataset of images captured by DJI Mavic 3

Figure V.1.0.4 Captures created by participants using Polycam

Figure V.1.0.5 Image generated using AI algorithm Stable Diffusion

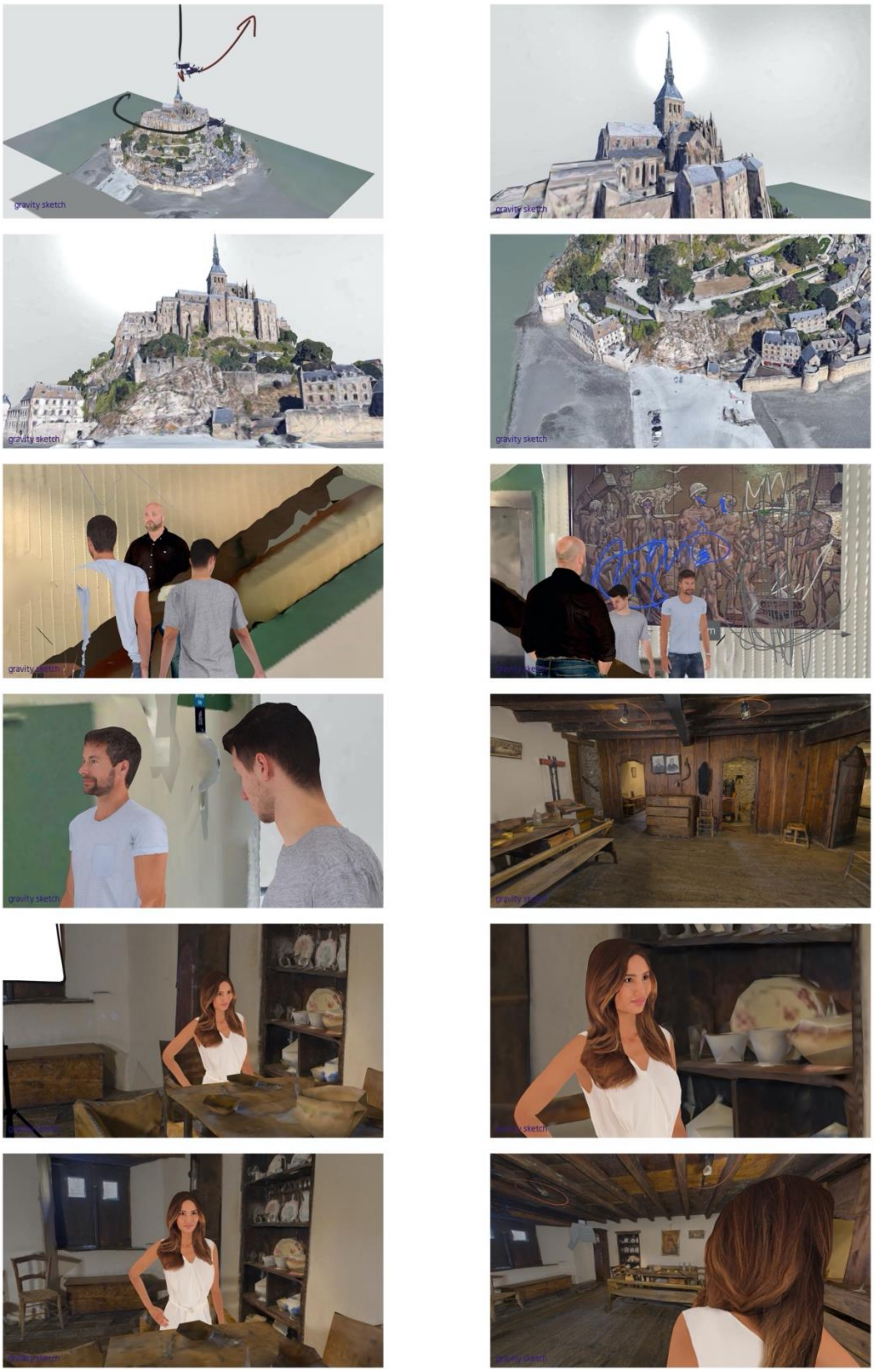

Figure V.1.0.6 Experimentation of VR Storyboarding made by participants

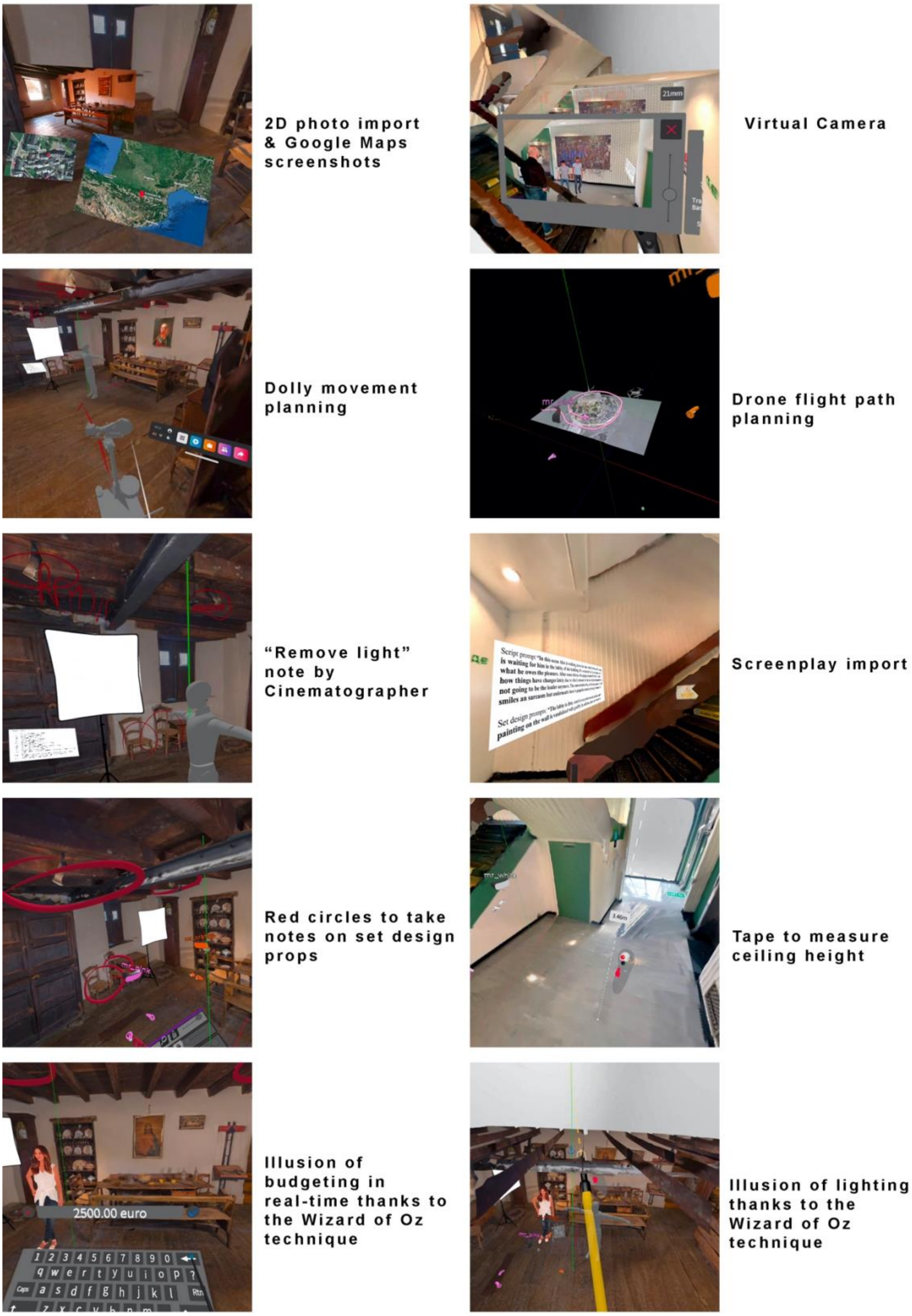

Figure V.1.0.7 Some of the tasks and activities done in the virtual environment