Raising the Volume!

A qualitative study into LED Volume, a virtual production technology

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ABSTRACT

Raising the Volume! A qualitative study into LED Volume a virtual production technology. This is an explorational research study about the impact of virtual production technologies like the LED Volume on the process of production, roles and responsibilities, decision-making, and business models of media companies*. As* the production technology is recent and there are limited research studies on it yet. The main research question of the study is how virtual production technologies like LED Volume affected the production process and business of media companies. A qualitative method of data collection was used for this study with semi-structured expert interviews. 10 semi-structured in-depth interviews were conducted with industry experts in the field of virtual production with experience with LED Volume. The method of analysis used was inductive thematic analysis. The main findings of the study were that the virtual production industry combines the two industries of gaming and filmmaking to collaborate and work together. While the technology of LED Volume could be a tool, the operator or the communicator of the technology is the utmost essential role that has emerged. The virtual production supervisor is the role that emerged within the communication gap between the industries. They act as mediators between the two industries. A part of using the technology causes a workload and budget shift from post-production to pre-production this requires a decent amount of pre-planning for the proper execution of the technology. The industry has shown a mixture of Diffusion of the Innovation curve with the Gartner Hype Model for the growth and adoption of virtual production. There were multiple studios that emerged during the pandemic across the world but post-pandemic a majority of full-scale Volumes were dismantled. A new trend of business model emerging in the field of virtual production is 'Pop-up' Volumes. These are Volumes that are portable, they can be dismantled and carried to the shoot location which provides more flexibility to the rigid wall of Volume that is fixed to a studio space. While there was not any direct impact on the creative process of the storyline and production timeline this could shift gradually to have more imaginative scripts, according to the data.

KEYWORDS: *Virtual Production, LED Volume, Impact, Business, Process*

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1. Introduction

A filmmaker and a magician play similar roles in creating an illusion for the audience. The greatest and the most common trick for a filmmaker is to create an illusion of the environment the character is in, even though they are not in that environment. Virtual production technologies support the filmmaker by improving this illusion for the audience (DeGuzman, 2023). Technologies like Augmented Reality (AR) and Virtual Reality (VR) have been used to add digital elements to the physical world and immerse viewers in a virtual world, respectively for the last decade (Winter, 2021). Artificial reality builds on artificial layers of reality like Snapchat filters and Pokémon Go, while virtual reality takes you into a new world. Understanding how these technologies work is essential to understand the impact of the technology on the media industry and its business.

Virtual production, as we see it today, has been an output of the gaming industry (L'Italien, 2022). Epic Games, a video game and software development company, developed the Unreal Engine, which with every new version plays the most essential role in the growth of virtual production in filmmaking as we see today. The Unreal Engine is a powerful software tool that combines the virtual and the augmented worlds with CGI and real-life footage. Epic Games has emerged as a leader in the space of virtual production where they have created the tool as well as a free knowledge-sharing base with publicly available learning resources like the 'Virtual production Field Guide' that helps share more insights on how the technology could be used (Kadner, 2019). The Unreal Engine is used to create virtual worlds that are used by filmmakers by displaying them on LED screens.

The real-time rendering of the Unreal Engine helps production crews to get instant feedback on how a scene would appear while shooting it, instead of waiting to see the results in post-production and then making changes, which could lead to a lengthy process (Perkins & Echeverry, 2022). The latest engine generation is the Unreal Engine 5, launched in April 2022. This was created in partnership with Lux Machina and Sony and was written in C++. It is portable as it supports usage on desktops, mobiles, and virtual reality platforms. The Unreal Engine 5.2 engine is the latest version, which makes it the world's most advanced real-time 3D creation tool (Unreal Engine, 2023). The tool creates hyper realistic environments and characters. Epic Games provides constant updates and project samples that would help anyone learn how to utilize the Unreal Engine through the process of production (Epic Games, 2023). Epic Games has made constant efforts to help spread knowledge on virtual production and its utilization (Perkins & Echeverry, 2022).

In 2018-2019, a few filmmakers and producers blended the use of this Unreal Engine along with huge LED screens by displaying the virtual world on the screen, creating a stage for production to be shot in (Perkins & Echeverry, 2022). Allowing the viewers and the creators to immerse themselves in this world like they would in the real world (Gupton, 2017).

One of the emerging technologies in film and TV production has been 'The Volume' which is a 6-meter tall and 23-meter-long set of curved LED screens. 'The Volume' covers a large part of the set, with a total of 270 degrees. The crew enters 'The Volume' to capture a virtual world, which

creates an immersive experience as the scene and the environment looks and feels real, not just for the audience but for the production crew and the cast as well. 'The Volume' recreates the Unreal Engine's virtual pre-designed environment on the screen, and the production crew creates a real environment within the curve with tangible elements (Netflix Production Technology Resources, 2022). 'The Volume' was used in the live-action Star Wars series The Mandalorian (Winter, 2021).

The demand for virtual production increased during the pandemic, leading to numerous studios and production houses setting up their own LED walls, 'The Volume' during that initial boom period of the technology (Eriksen, 2021). 'The Volume' is an interesting case study to consider for the study of virtual production technologies and their impact on the business of the industry. The technology comes with many visible benefits; though it could have tons of challenges as well that might cause resistance to the technology (Pennington, 2023). They need to be studied to provide better solutions for future technology resistance. The terminology of LED Volume and 'The Volume' are used interchangeably throughout the paper. 'The Volume' is the name while LED Volume is the technical terminology.

The social relevance of this study is to understand the possible impact a new technology like LED Volume has on the business of production. The entertainment industry has undergone a significant transformation due to the rapid development of emerging technologies during the pandemic (Adgate, 2022). This transformation showed potential for growth using technology, as the industry will need to constantly adapt and evolve to survive (Ryu & Cho, 2022). The transformation to a more technology-focused growth significantly impacted the production of films and series. The rise of streaming platforms along with the pandemic has led to viewers demanding content faster, which could be achieved using virtual production technologies (Netflix Production Technology Resources, 2022). Virtual production technologies would aim to have a faster turnaround of the production of content without compromising on quality (Bennett & Carter, 2014). The technology could potentially provide a fast turnaround of content, which could increase the content in the market. LED Volume could cause a significant impact on changes in business models, changes in creative processes, and cost of production and could lead to multiple new roles emerging from it (Deloitte, 2020). The study explores these new emerging changes and their impact on societal aspects. Therefore, this study is highly relevant to society.

The academic relevance of the study is that LED Volume is a new technology that started being used for content production in and around 2018-19 (Perkins & Echeverry, 2022). There has not been academic research conducted on LED Volume and its use of it for content production of TV series or film production. The aspects of the LED Volume on content production, process, and business have not been academically researched yet. Thus, there is a gap in this field of study that could be filled with this thesis.

The objective of this thesis is to study the LED Volume, as a case study of virtual production. It will be an exploratory study to understand the effect virtual production has on the

process of a series, film, or commercial production as well as the business of production. The research studies the following research question by breaking it down into the three sub-research questions below. These three sub-question together support to answer the main research question below:

RQ: How have virtual production technologies like LED Volume affected the production process and business of media companies?

Sub-question 1: What is the role of the virtual production technology LED Volume in impacting the creative process, storytelling, and decision-making of the media companies?
Sub-question 2: How do virtual production technologies impact the production timeline, cost, and revenue generation of media companies?
Sub-question 3: How do virtual production technologies impact the roles and responsibilities of the production crew and the business models of media companies?

These questions are addressed using a qualitative research method of semi-structured in-depth expert interviews. A purposive sampling approach has been adopted that carefully selected the sample of 10 industry experts in the field of virtual production with experience in working with LED Volume. The data collected will be analyzed using inductive thematic analysis to identify common themes and patterns related to the research question. A brief overview of the chapter is given below,

The research starts by introducing virtual production technologies and how they can be used, which covers the social, and academic relevance as well as the objectives of this study. The theoretical framework dives deeper into an explanation of what virtual production is, the capabilities it has, the history and the current boom it incurred along with theories related to business and technology are thoroughly discussed. The theoretical framework supports the study by providing an overview of concepts and theories that are relevant to the study of virtual production, using LED Volume as a case study. The theoretical framework explores how virtual production with LED Volume is transforming the media landscape, alongside the challenges and business as well as creative opportunities the technology brings with it. Thirdly, the methodology explains it involves sampling, operationalization, and the method of data analysis. This is followed by the chapter on results which is used to showcase the results from 10 interviews by categorizing them into two broad themes of impact & change in process and impact on business & industry. The thesis ends with a discussion and conclusion that answer the research questions while discussing the theoretical, and societal implications of the study along with the limitations faced in this study and the future implications of virtual production in the media industry.

2. Theoretical Framework

Virtual production technologies have been growing exponentially in the media industry since 2019. Virtual production is an umbrella term for the use of multiple digital technologies such as a virtual setup including 3D software, motion capture, and virtual camera systems which create a visual interaction using a real-time virtual environment (Bennett & Carter, 2014). The use of these digital technologies helps create and manipulate a virtual environment with objects and characters in real time. The real-time engine in virtual production supports filmmakers to visualize and change scenes in real-time as they are being filmed. The technology could potentially impact the business of filmmaking and save time and money with a lot of pre-planning when compared with traditional methods of post-production (Maddock, 2021). One of the path-breaking technologies in the space of virtual production is the use of LED Volume in filmmaking (Fair, 2023). LED Volume combines the virtual and physical world, which creates an immersive environment where films and series can be produced with ease. A simpler way of understanding this would be media companies shooting live in front of huge television screens the size of a curved wall (Latvis, 2023). Virtual production technologies like the LED Volume are revolutionizing the process of producing media products like films, series, and commercials (Hatch, 2022). Emerging technologies like the LED Volume impact beyond the technological production process, supporting an evolution of the business in the media industry as well (Lee et al., 2019).

The study of virtual production is essential as it has been changing the space of visually telling stories through different forms of media. Filmmakers now have the opportunity with the help of virtual production techniques to create characters, worlds, and show stories that are even more realistic and immersive than earlier (Kavakli & Cremona, 2022). Virtual production technologies can create a space for freedom and flexibility in the process of production, which could reduce the time and cost involved in creating complex visual effects. Virtual production technologies like the LED Volume could reshape the media industry. It could impact the production process and the people involved in the production process including but not limited to producers, filmmakers, scriptwriters, actors, technicians, and more. The study of key theories and concepts in relation to virtual production could provide a better understanding of the process and its current as well as potential impact on the industry.

Virtual production could create equality, a horizontal power structure industry by providing access to the technology, even to independent filmmakers and smaller production companies. They too can create high-quality content with out-of-the-box storylines like larger studios (Rounds, 2023). While there might be plenty of benefits that virtual production brings, there could be challenges as well. For example, the need for especially skilled experts with knowledge of the technology as well as the filmmaking aspects. The technology comes at a high cost, including hardware and software. The technology might still need to break through the existing traditional power structure of the media industry (Rounds, 2023).

2.1 Virtual Production

The company Epic Games which designed the Unreal Engine which enables virtual production, defines virtual production technically as a broad term referring to a spectrum of computer-aided production and visualization filmmaking methods. Weta Digital defined virtual production as a space where the physical and digital worlds merge like a stage. The Moving Picture Company (MPC) adds to the definition of Weta Digital with more technical information including augmented reality with CGI and game-engine technologies along with virtual technologies to allow production crews to see their scenes unfold as they are composed and captured on set (Perkins, 2019).

A major part of virtual production today is using the Unreal Engine to display images or videos on an LED screen. These LED screen displays come in various sizes and forms. They can be 8 meters in height to 180–360 degrees curved walls (virtual production Studios, 2023). LED screens that are the size of a wall, which are used in creating virtual production sets are often called the 'Volume' or the 'Stage'. Making visual content using the Volume involves blending the foreground, which is the physical set and the background, which is the screen. Combined, this creates a beautiful but concrete stage for the actors to perform on. The Unreal Engine's real-time rendering causes the background to change dynamically with the movement of the cameras (Latvis, 2023).

The Volume is often used as an alternative to green screen backgrounds. Green screens have become extremely common though they were considered a challenge for traditional filmmakers (Li et al., 2022). The Volume does help some traditional filmmakers and actors that like to see the environment to understand the shot or the scene, creating more realistic content instead of just a green screen. The Volume takes away the heavy load that comes to the post-production crew, optimizing the budget and the time taken to complete a project (Mutter, 2021). LED Volume can create a Moiré effect while shooting, which is a pattern formed by LED pixels like mesh like a TV screen. This acts as a challenge for the filmmakers who are restricted at moving the camera at a faster pace as it takes a toll on the processing power to render a virtual background with the camera movements in real-time, which would lead to lagging as the processing power of the engine cannot take the load (Oseman, 2022).

As an industry trend, the use of virtual production has seen rapid growth from films, series to car commercials with Unreal Engines and real-time rendering technologies (Samsung Display Solutions, 2022). The flow of production while using virtual production technology can be explained with a clean division between the three processes of pre-production, in production, and post-production.

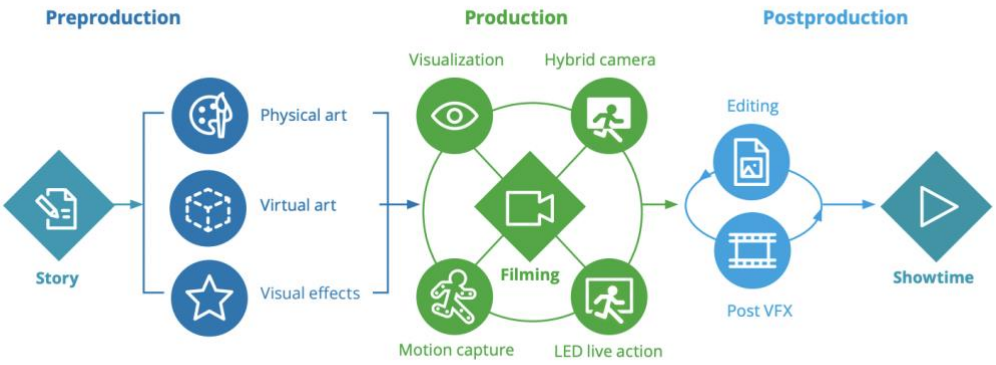

Figure 1: Virtual Production Cycle

(Deloitte, 2020)

2.1.1 History and Evolution of Virtual Production

Virtual production is often used to describe different types of virtual technologies in production. The start of virtual production can be linked to the beginning days of cinema with filmmakers using physical effects with paintings, miniature, optical composting, and even projections to create immersive cinematic worlds. These techniques with constant improvements and refinements are what have led to virtual production today that helps create a better illusion for the audience in terms of realism, interactivity, immersiveness, and flexibility (DeGuzman, 2023).

The next big step towards the current state of virtual production was the introduction of Computer-Generated Images (CGI) in the 1970s, 1980s, and 1990s as new techniques emerged like green screen and matte paintings which supported creating an environment virtually post the shoot. This helped filmmakers create and manipulate various digital elements that could not have been possible using physical methods of production for example shooting a series in space. While CGI was indeed pathbreaking it was still an expensive and time-consuming process with a lot of energy put into integrating live footage with post-production work, which led to filmmakers often using the phrase “We will fix it in post” (James, 2017). During the 1980s and early 2000s, there were multiple new technologies and techniques like pre-visualization, real-time rendering, performance capture, and virtual cameras used in filmmaking that led to a more seamless and interactive way of production. This gave space for capturing actors and object movements in a digital environment. Filmmakers could now adjust scenes before shooting and change camera angles accordingly (Oseman, 2022). James Cameron’s film Avatar in 2009 was one of the first films to use virtual production with real-time rendering. Avatar created an immersive world using real-time rendering that showcased the capabilities of virtual production with visual effects for a new] way of storytelling to the industry (Bennett & Carter, 2014). The last decade has had a wave of technologies appear in filmmaking such as artificial intelligence, machine learning, augmented reality, virtual reality, and

mixed reality that helped filmmakers work on various virtual production projects that bring physical and digital worlds together. This helps create an experience that is immersive and close to reality for the creators and the audience in a virtually enhanced world.

In the past three years of the COVID-19 pandemic, virtual production emerged as a solution to increased demand for content along with shooting restrictions while maintaining protocols and more strict legal regulations. It was a challenge for filmmakers because of travel restrictions and social distancing protocols to meet the demands of content to be produced (Eriksen, 2021). The advancement of the technologies with virtual production helped create a safe shooting environment with reduced to no amount of travel, the virtual worlds could be created remotely, and the set was usually in one location. Filmmakers in early 2020 from the United States of America started using virtual production technologies including production houses like NBC, MTV, and ABC. This involved using a robot camera to remotely shoot the actors (Grand View Research, 2022).

2.1.2 Mandalorian and 1899

The Mandalorian was the first of its kind series to use the virtual production technology The Volume for its production. The Mandalorian is a series available on Disney+ set in the Star Wars Universe about a lone bounty hunter known as the "Mandalorian" who wears shiny silver armor. It showcased what the potential of the technologies if used well could do for production. It created a new path for all the others to follow. The producers of the show Mandalorian wanted to create a similar quality as the movies but with the fast episode production turnover of a series (Tangcay, 2020). The Mandalorian used an LED Volume display of 270-degree immersive stage for the actors (Coldewey, 2020). It was shot in a studio in LA encompassed by the Volume (Pennington, 2020). The Volume used was developed by Industrial Light & Magic to create a circular stage set up with the ceiling and walls covered with LED panels that would simulate the Star Wars world. It provided the crew and the actors with an interactive environment creating a more authentic shot as compared to using green screens (Weisenberger, 2022). Mandalorian could have the fast episode turnover that was needed by saving time and cost of scouting for locations and for constructing sets. The Volume provided a space that was immersive and realistic at the same time which was essential to the process of the show (Tangcay, 2020). Virtual production with LED Volumes gave the team the freedom to be creative with storylines, locations as well as costumes. Thanks to the Volume, the armor of the Mandalorian could be silver and reflective as it could now bounce the light from the environment in real-time, the environment being the LED screen instead of green screens. The green screen would have increased the workload in post-production of painting the green out of the reflection. Even the ship could now be made of a reflective mirror material (Taylor, 2020). According to Jon Favreau, the Mandalorian is shown with a synthesis of filmmaking prowess and video game software which leads to creating an incredible sense of reality with each scene. Nothing like the Mandalorian has been ever attempted in filmmaking (Taylor, 2020).

Netflix's series 1899 was shot extensively using virtual production techniques. 1899 is a mystery series set on a ship carrying migrants from Europe to America. It was shot in the Dark Bays virtual production stage at Studio Babelsberg in Germany (Kadner, 2021). They, like the Mandalorian used an LED wall for the production. The stage near Berlin allowed different production departments including the physical and the virtual art department to work building it together as an extension of the Volume (Coldewey, 2022). This was a challenge as 1899 was supposed to be filmed in lavish locations with an international star cast on an actual ship but due to the COVID-19 pandemic, they had to come up with alternatives. They were inspired by the Mandalorian's use of LED panel Volume to shoot the series and so they went all in to build a Volume stage in Germany (Kadner, 2021).

2.2 The Process

The process in terms of filmmaking and production could be divided into the creative process of production and the production process. The creative process involves a complex set of social interactions and maintaining relationships among groups (Brunet, 2004). Technological determinism theory explains how the technology we use has the potential to shape human behavior and how society operates (Jan et al., 2020). The theory suggests that there are social, economic, and political changes driven by new technologies that society will change and try to adapt to the new technologies (McLuhan, 1962). The theory plays a role in shaping the social, cultural, and creative processes. The theory suggests that the adoption of technology could lead to transformative changes in storytelling, the creative process and decision-making by providing new tools to the community (Hauer, 2017). In the case of virtual production, the advancement in virtual production technologies like motion cameras, real-time rendering, and LED Volume are transforming the media industry by how filmmakers are changing the way of telling stories through technology. The virtual world is evolving the way humans and technology interact (Yengin, 2017). The production process follows a real-time production methodology (Bluff et al., 2020). This might see a shift in the production process with a lot of time being added to pre-production instead of post-production, which would be the case with green screens (Winter, 2021). The new technology like the Volume has reduced production time and saved up on reshoots for the crew of the Mandalorian (Taylor, 2020). Compared to traditional filmmaking, virtual production is changing the creative process with out-of-the-box thinking and immersive storytelling which were the limitations faced by traditional filmmakers. virtual production provides creative liberty and gives back control to production. (Highton, 2023). There is a new space to produce shows similar characteristics to traditional methods of shooting like seeing the actual shot before and actual the shoot which is limited to a green screen. This could provide filmmakers with the opportunity to save money, and time and provide flexibility with increased visibility (Entertainment Partners, 2022).

Through the new process, roles and responsibilities seem to have changed. New roles have emerged with the use of virtual production technologies in filmmaking. Some of these roles are the virtual production supervisor who is on the set and is responsible for the communication between the virtual production team and the crew. They are the lead throughout the process from pre- to post-production. They work with the director, the DOP, and the production director so things run smoothly on the set. The other new role is the Volume Operator which works on the motion capture that is used in capturing the motion of objects. The Volume Operator is another role among a few other roles that have emerged including LED Engineer, VFX Supervisor, Real-Time 3D Artist, and Engine Operator. Many of these roles originate from the gaming or animation industry. The people who work in these roles do not have enough experience to be on set. They usually work in a room from behind the screen with minimum physical social interaction which has now turned around with virtual production (Makinson, 2023). There is a significant gap in the market with the demand for roles available in the virtual production industry for specialists being extremely high yet the supply for the same has been low. There are new opportunities beyond the roles mentioned above. There is a pace for multiple new roles as the technology and the way of work are constantly evolving and needs new skills. In the virtual production space, there is a role for everyone including veterans to newcomers (Kadner, 2022). Actor-Network Theory revolves around the relationship between the actors and the network they form (Latour, 2005). These networks are constantly shifting. Actors in this case could be human or non-humans (Walsham, 1997). According to the theory, non-human actors like technology in the case of virtual production technologies could have an influence in the social system depending on how it interacts (Partners, 2023). This is a sociological theory but is still relevant to filmmaking and virtual production. The success or failure of virtual production could be based on the Actor-Network Theory. Here the actors are not only human filmmakers but also technology. Filmmakers completely immerse themselves in this virtual world (Cypher & Richardson, 2006). Technologies and filmmakers are the actors that must work together and form a network of workflow that would provide the most successful outcome for example using a certain technology like real-time rendering with a motion camera with 270-degree Volume could lead to the best result while for some it could just be using only an 8-meter LED Panel could work as well. It is essential as a part of the theory one must consider what context the network functions in. As part of the Actor-Network Theory factors such as the social, economic, and cultural structures must be considered in terms of virtual production. Virtual production in filmmaking brings in new technical roles which need to collaborate with other prominent roles like the filmmaker who makes decisions. Analyzing the hierarchy, and the power structure needs to be considered while using the theory to understand the network. Using the Actor-Network Theory in virtual production could help the producers and the filmmakers make better decisions that would help them provide a more efficient workflow. Actor-Network Theory, when applied to virtual production, will help understand the relationship between

the actors and elements involved in the production process and what leads to the success or failure of the projects (Cypher & Richardson, 2006).

Virtual production as an emerging technology in the business is bringing change to existing structures and processes (Deloitte, 2020). Resistance management theory focuses on the resistance that comes with the change. Change is inevitable with growth and resistance is inevitable as well to the change when the structure changes which could bring in challenges, but these challenges should be well managed for the success of the business (Lapointe & Rivard, 2005). In the case of virtual production, identifying the specific aspects of challenges leading to resistance to the technology could help the diffusion of the technology. Resistance management theory can help with the success of technology in the industry (Jobin, 2022).

2.3 Business of Virtual Production

Virtual production is evolving the way stories are being told (Priadko & Sirenko, 2021). The market share of the virtual production market was valued at 1.82 billion dollars in 2022. The expected expansion rate at a compound annual growth rate (CAGR) is 18.2% from 2023 to 2030 (Grand View Research, 2022). Virtual production techniques are a new step in filmmaking. It will be more prevalent for the filmmaking team including the cinematographer, camera person, director, and producer, as stakeholders and members in the media industry would need to know the potential and the optimized way of usage of virtual production for their business's growth (Priadko & Sirenko, 2021).

During the last decade, there has been a trending shift from reduced consumption of content like movies in cinemas or multiplexes to over-the-top (OTT) consumption of series and shows which is driving the major growth in the market. The filmmakers now need to produce the same quality of content as films which would take years to much faster turnover than these seasons of shows need. The revenue share of the television market including OTT is said to outshine the movie market and would hold a larger total market revenue (Grand View Research, 2022). Producers and creators need to be prepared for this incoming shift and investing in virtual production would be supportive to them for this. As per the Grand View Research report, the post-production market had the largest revenue in comparison to the markets of pre-production and production, accounting for 51.2% of the revenue share in 2022. The market share could rise with faster turnover, as post-production is a lengthy process but with virtual production it can be quicker. In 2021, the Today Show crew filmed an entire segment of the Super Bowl Weekend in just one week using virtual production technologies (Grand View Research, 2022).

Companies need to adapt and innovate their business models constantly. The business model innovation theory uses new technology to create value in the business (Foss & Saebi, 2016). According to the theory, when a new technology is adopted, it can lead to formation of innovative business models. The theory emphaisez that companies in the case of virtual production, media

companies including film and gaming companies need to adapt their business models to enjoy the benefits of the technology and meet the demands of the market which in case of virtual production was a need for constant quality content production even during a pandemic because of rising consumption patterns (Deloitte,2020). Virtual production is part of the film industry, the business models derived from the film industry could fit the virtual production usage in the industry as well. There are four major types of business models that include studio-based models, independent production, co-production, hybrid models, and business model 2.0 (Vitkauskaitė, 2020). Studio-based models would be studios that own the technology and the rights of the content. The financial resources and distribution network needs to be strong for this one, but they provide higher returns as well. An example for this could be Disney+ Mandalorian owning all rights to the content. An independent production model is where filmmakers operate outside the studio system where they finance using private investors or government grants (Vitkauskaitė, 2020). An example of this could have been 1899, if Netflix did not have the streaming and distribution rights for the same. 1899, falls under co-production where multiple agencies are involved in the production of a series. A hybrid model is where independent filmmakers partner with studio spaces this could be explained with an example of car commercials being shot in the Volume. Virtual production as a new growing industry is seeing various types of business models come in and go (Deloitte, 2020). During the pandemic there were a lot of virtual production studios set up worldwide. Virtual production studios are spaces that offer everything and every service a production would need while working with a new technology including the technology, expertise, crew to work on the technology, involvement from the script development to pre-production, planning, production, and of course post-production as well. They are all-in-one packages. A lot of these virtual production studios have a full 180-to-270-degree Volume installed and are ready to use like DNEG (LBBOnline, 2022). The other types of virtual production businesses include virtual event production that works on the experience, execution as well as post-event analytics (Michelson, 2022). Now this can be a completely virtual event as well as physical events that use virtual production technology of LED Volumes. The latest big-scale event to that was Eurovision 2022 (Priestley, 2023). Some other business models include businesses that create virtual content to be used on the technology screen or even the metaverse (Polaris, 2022). For this research, the study will be focusing on the virtual production studios that are used for film and series production.

The Diffusion of Innovation theory is the best way to explain the business growth of virtual production, especially the Volume as a case study. The theory explains how an emerging technology is used by the population. Technology goes through the curve of being used by the innovators followed by the early adopters which in the case of virtual production is the series Mandalorian and even Netflix's 1899. The early adopters tend to be the opinion leaders in the space. This stage is followed by a peak stage of the early majority (Dearing & Cox, 2018). A new study on the adoption of virtual production using the diffusion of innovation theory talks about maintaining "a cautious

optimism" while adopting the technology (Jobin, 2022). The theory also suggests that early adopters form a group or a community to exchange knowledge and information (Rogers, 1962).

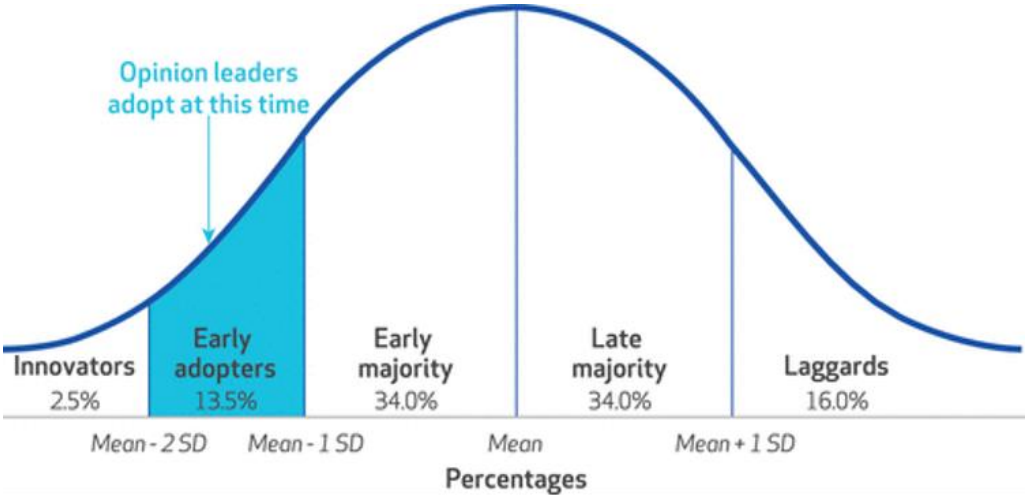

Figure 2: Diffusion of Innovation Graph

(Dearing & Cox, 2018)

3. Methodology

The study uses a qualitative research approach to answer the research question How have virtual production technologies like the LED Volume affected the production process and business of media companies? The main research question will be addressed by exploring the following sub-questions:

Sub-question 1: What is the role of the virtual production technology LED Volume in impacting the creative process, storytelling, and decision-making of the media companies?

Sub-question 2: How do virtual production technologies impact the production timeline, cost, and revenue generation of media companies?

Sub-question 3: How do virtual production technologies impact the roles and responsibilities of the production crew and the business models of media companies?

The impact of virtual production, specifically the Volume on the production process as well as the business in the media industry, is a study that has not been conducted before. The study was conducted through a qualitative method approach. The data was collected through semi-structured in-depth interviews with experts in the virtual production industry, including producers, studio owners, writers, technical directors, and virtual production supervisors. The data was analyzed using qualitative thematic analysis.

3.1 Research Method

The study uses qualitative research methods to understand in more detail how virtual production can affect the media industry. A study into virtual production, especially the LED-wall Volume in reference to business, organizational process, and workflow. This study provides an exploratory stance to the subject. The use of qualitative research with semi-structured in-depth expert interviews gives the space to explore the topic. This helps understand the experiences and perspective of the media industry experts in the field of virtual production. Qualitative research for an explorative study could help produce rich data that provides detailed insights and understanding. Semi-structured in-depth interviews supported the exploratory study by providing the research with the flexibility of following up as per the response of the interviewee, which led to some unexpected discoveries (Elman et al., 2020). In-depth interviews give the researcher the flexibility to adapt a question as per the participant's experience and expertise (Johnson, 2011). Qualitative research provides the researcher with an opportunity to gain an in-depth understanding of the subject matter and can uncover the intrinsic meanings and experiences of the participants (Ritchie & Lewis, 2003).

The method used for this qualitative study is semi-structured in-depth expert interviews. These in-depth interviews are used to gain insights into the views and experiences of experts in the field of virtual production that work with this new technology of LED Volume. In-depth interviews,

the researcher's goal was to go beyond surface level information and understand the motivations that shape the thoughts of the interviewees (Johnson, 2011).

These experts are from the field of virtual production, although the field has very diverse roles. The research incorporated participants from a diverse background and fields of study, a semi-structured method supported this with space for follow-ups. The follow-up questions could provide the participant with space to elaborate on topics that could be interesting for the researcher and the study. A semi-structured model of interviewing allows for flexibility with open-ended and follow-up questions that could lead to some interesting discoveries and exploration (Johnson, 2011).

The expert in-depth interview method aims to understand the process of virtual production, differences within the industry, challenges, and other experiences the experts had while working with the new technology.

3.2 Sampling criteria

For the research, the primary data collection method was to conduct in-depth interviews. 10 in-depth interviews were conducted with experts in the field of virtual production. All these experts have worked with the technology of LED Volume in one way or another. Some of the experts were producers who were involved in acquiring the technology, while there were experts who worked on the backend by building content to be shown on the screen. Some other experts were communicators between the team handling the technology and the film crew as they worked on set with the technology of LED Volume. All experts were selected through purposive sampling, which involves selecting participants based on specific criteria of expertise and accessibility (Boeije, 2010). In this case, the criteria for selection will be based on the participants' expertise and experience in the field of using virtual production technologies such as 'The Volume' for production of a series or a movie. The researcher conducted sampling to assess other experts who may not have previously worked on a series or a film project but have relevant experience using LED Volume in other productions like commercials. The experts from the media industry are not easily accessible and have limited time availability due to their dynamic schedules. This method of sampling is suitable for this study as it provided an efficient way to access the participants (Boeije, 2010).

The experts for the interviews were selected by searching for industry experts and leaders on LinkedIn. For the study, experts were reached out to by messaging them on LinkedIn or by emailing them based on their expertise and experience in the field. A total of 45 participants were reached out for the interview. 10 of these participants responded and out of which their availability aligned with the study's timeline as well. The sampling criteria were very clear. The participants needed to have worked in industry and have an overall experience of minimum 2 years working with virtual production. The technology had not completely picked up 2 years ago, therefore these participants were involved with the technology before the spurt growth of the LED Volume. They were all part of the early adopters or the early majority at the best and had experience of or working with the Unreal

engineer or LED Volume. Most of the participants are industry leaders in the field. There was a data saturation point post the 8th interview. The saturation was through repetition of the themes and with similar information being shared with the questions that were asked (Boeije, 2010). A limitation to the sampling criteria is that all the participants in the study were male.

3.3 Data collection

The study conducted 10 semi-structured interviews from April-May 2023 with industry experts in the field of virtual production. The interviews were conducted via Zoom video calls. The interviews were between the duration of 40 to 65 minutes, including the icebreakers. The interviews were recorded on Zoom with the consent of the participants.

For the research, prior to the interview, recording provided an overall context of the study to the participants. The researcher assured confidentiality if needed and asked for consent to record the conversation. Verbal consent was given by the participants before and during the recording of the call to have it on record as well. All participants did verbally agree in using the data from the interviews as part of this study. The researcher-maintained anonymity for all participants by changing their original names with the number of orders in which interviews were conducted.

Table 1: Overview of In-Depth Interview Participants

Interviewee	Role
Interviewee 1	Pipeline Technical Director at Virtual Production Company
Interviewee 2	Creative Technologist for Virtual Production
Interviewee 3	Virtual Production Studio Owner | VP Consultant | VP Speaker | VP Trainer
Interviewee 4	Virtual Production Supervisor
Interviewee 5	Filmmaker & Virtual Production Specialist
Interviewee 6	Virtual Production Supervisor & Producer
Interviewee 7	Virtual Production Expert for Live Broadcast, Films & XR Stages
Interviewee 8	Senior Virtual Production Technical Director
Interviewee 9	Senior Writer for Virtual Production – Writer of a VP Field Guide
Interviewee 10	Executive Producer and Managing Director at a Virtual Production House

3.4 Operationalization

The aim of the study is to explore the evolution of the business and production process in the field of virtual production for films, series, and commercials. To understand those aspects, the research question 'How have virtual production technologies like the LED Volume evolved the production process and business of media companies?' was formulated. The research question was then broken down into three sub-questions to get a more profound understanding of the concepts. To provide a structure to the semi-structured interviews, the researcher worked on creating a list of relevant concepts based on the research sub-question. The concepts that supported building the interview guide were derived from the research question. There were three main concepts that emerged from the research question which were the virtual production technology, process, and business of media companies. The three sub-questions further broke down the concept of process into a creative process and production process. The concept of business of the media companies was further broken down into three concepts of roles and responsibilities, cost and revenue and business models. The concepts were operationalized based on the theoretical framework. This formulated the interview guide attached in Appendix B. The concepts were further operationalized below based on the sub-questions:

The sub-question 1, 'What is the role of the virtual production technology LED Volume in transforming the creative process, storytelling, and decision-making of the media companies?' focused on the part of the production process with more creative aspects including the creative processes, storytelling and decision-making. The second set of questions in the interview guide were based on this sub-question revolving around the 'Creative Process'. The foundation for this sub-question was based on the technological determinism theory developed by Marshall McLuhan, which was discussed extensively in the theoretical framework. The variables of storytelling and decision-making were derived from the technological determinism theory (McLuhan, 1962). 'Creative Process' as a concept includes ideation, formulation, and execution of ideas including decision-making through the process of production using LED Volumes. There were three variables that emerged from the concept of 'Creative Process': Role of LED Volume in the creative process, Impact of LED Volume on storytelling and Influence of LED Volume on decision-making processes. Each of the variables has a set of indicators, for example, the role of LED Volume in the creative process has indicators such as the extent of importance an interviewee gives the LED Volume technology during the creative process.

The sub-question 2, 'How do virtual production technologies impact the production timeline, cost, and revenue generation of media companies?' narrowed down to the aspects of timeline, cost and revenue, as per the Diffusion of Innovation theory by Everett Rogers, these three aspects are affected with adoption of a new technology in the system (Rogers, 1962). Based on these, the concept of 'Production Process' was used for section three in the interview guide. The study selected

these measurable variables for the concept of ‘Production Process’, production timeline, production stages, production cost, resource allocation and production output. The questions in the interview guide were based on the indicators for these variables. These indicators were addressed through the practical experiences of the participants working in the field of virtual production.

The sub-question 3, ‘How do virtual production technologies impact the roles and responsibilities of the production crew and the business models of media companies?’ breaks down the aspects from the sub-questions into questions under the concept of ‘Roles and Responsibilities’, and ‘Business Models’. This has been based on the foundation of Actor-Network Theory, which states that roles and responsibilities can evolve through the process of a new technology emergence (Latour, 2005). The shift in responsibilities lead to the emergence of new roles and business models with new technology. Responsibilities are a dominant concept that emerged from the framework, and hence it was included as a concept in the interview guide. The measurable variables for the concept of ‘Roles and Responsibilities' were, the job titles, level of specialization, training, and skill development as well as collaboration. The indicators for these variables through the interview questions would be the time they spent learning a new skill, their role evolving, the type of work they participants were assigned and if this had shifted. The measurable variables for the concept of ‘Business Model’ were adaptability and innovation in their business, market position, value proposition and revenue stream. The indicators for these variables were through the questions on adaptation of the participants' companies or businesses to virtual production technologies.

Besides these, the concept of ‘Community’ is included as an additional section to understand the involvement of the participants with the virtual production technology and other participants. Based on the Diffusion of Innovation theory discussed earlier as this helped the research understand where the participants stood in terms of adoption of the technology. Based on the theory, the early adopters often form a community (Rogers, 1962). Therefore, questions regarding the community aspect in the field of virtual production were introduced inductively after analyzing the profiles of the participants. The concept of community is broken down into variables of participation, knowledge sharing and the time of adoption. Indicators for these variables were formulated into a question in the interview guide regarding the participants' experience of the industry and if other members were easily accessible for them.

3.5 Data Analysis

To analyze, the data was collected through in-depth interviews. These semi-structured interviews were transcribed for the purpose of analysis and were used as the primary data. During the interview process, notes were taken for emerging themes and quotes were noted down which supported the analysis process. For this study with limited numbers of interviews to be analyzed inductively, it was rather efficient to manually code the interviews. The notes from during the interview process supported the analysis, making the manual search for codes easier through the

transcripts. The study uses a thematic analysis to analyze the data. This was executed with the process of an inductive thematic analysis where the themes within the data were identified, analyzed, and used to understand concepts and patterns (Braun & Clarke, 2006).

The transcripts were read through while listening to interviews multiple times that helped familiarize with the data set. The initial notes from during the interview process were developed further during this process of repeated listening of the interviews. This helped to develop a more in-depth understanding of the participants' perspectives. An inductive thematic method is a build-up approach, the initial codes are generated from the data instead of building them in the theoretical framework and then finding them in the data set of the interviews (Braun & Clarke, 2006). The initial coding process started during the interviews through the notes and quotes, followed by another round of coding when the transcripts were prepared. The code labels were created based on the content of the interviews in relation to the research question. The coded data was then used to identify themes. For this method of analysis, there needs to be a constant comparison between the interviews to identify recurring patterns. This provided help with identifying the similarities in the data. There were multiple themes that emerged related to virtual production through this process of coding.

After the coding process, the themes were then identified and developed by reviewing the codes from the interview data. There was a constant back and forth of examining and critically analyzing the themes and the codes. The process of review supported capturing themes from the data set that were significant to the research question. Each of these themes were analyzed in detail and a thorough check was conducted for each quote or note that supported the derivation of each theme. There were various branches explored and analyzed within each theme. The coded data was organized under each theme, leading to a well-organized system. The coding process with inductive analysis was a constant process as there can be new themes arising with each interview until the 8th interview when a saturation point was attained. The final analysis of the data helped provide a complete overview of the study with the help of the themes. A broader conclusion could be formed and evaluated further for the study. The researcher followed the practice of condensing data into the themes and then working on understanding the complexity of the themes to expand them further through continuous examination that helped develop a structure within the categories.

3.6 Validity, Reliability, and Credibility

The validity of data collection was ensured through an interview guide that provided some structure and consistency to the interviews, as the method of the interviews was semi-structured. The interviewees would often talk on a different tangent than the question, which was helpful for an inductive thematic analysis. The probes from the interview guide provided support and ensured the validity of all 10 interviews. The validity of the findings was ensured through recordings and transcripts of the interviews. The transcripts were then reviewed and coded to identify common themes and patterns in the data. There was a constant comparison made between the old and the new

set of interviewees (Silverman, 2011). To increase the reliability of the findings, a peer-debriefing process was conducted, where the coding scheme and data analysis were reviewed and validated by a peer with expertise in qualitative research. The research forms credibility through purposive sampling that ensured that the data set selected were reputed industry leaders from the field of virtual production. There was transparency maintained throughout the paper to ensure the study conducted is reliable. The language used in the paper was simple with detailed descriptions, making it easy to understand for any reader who has no previous knowledge about the topic (Silverman, 2011). The validity, reliability, and credibility of the research were given utmost importance, as the way the data was collected through semi-structured interviews and the way the data was analyzed. All these smaller actions together contribute to more reliable, credible, and valid research.

3.7 Ethical considerations

Ethical considerations were necessary for this research. The media industry is a competitive industry with extensive gatekeeping. During the expert in-depth interviews, there was a need to be ethically considerate given the nature of the industry. There was consent taken from all participants about the recording and the use of the data from the interviews. Some participants wanted to have their own copy of their recording, which was shared with them. Participants have assured the use of the data for strictly academic usage only and were assured anonymity would be maintained for the research. Apart from one, all other 9 industry experts were open to sharing their details and roles for the purpose of the research. They were informed about the purpose of the research at the beginning. They all provided their verbal consent to record the interview for using it in the study. One of the participants insisted on maintaining anonymity, which was assured, and would not have their name or role, or the company mentioned throughout the paper. The study during the interviews focused more on questions about the interviewee's own experiences with the technology and what their thoughts were about virtual production, rather than focusing on their current role or company. The study ensured anonymity by substituting the participants' names in all databases. The interviewees were informed that they could avoid or skip a question or leave at any stage. They were reassured that this study is not for personal gain but for academic fulfillment as the field and industry are up and coming and face a lot of competition. Inductive thematic analysis helped in an in-depth, bottom's understanding of virtual production processes and the business models it works in. The themes from the analysis provided insights into the perspectives of the experts in relation to the research question and sub-questions. This was further discussed in the following section with the results.

4. Results

The analysis of the ten interviews with experts from the field of virtual production, specifically LED Volume, has led to the formulation of 5 themes. These were created from 12 axial codes which were combined from over 280 open codes which were formulated from the relevant quotations for the study. Virtual production technologies like the LED Volume have changed the way of the production process and business of media companies. The results section dives deep into the two main themes which are the impact and change in process and the impact on business & industry. There were multiple sub-themes in these two main themes which are about the impact of the virtual production technology production process, business along with the benefits of choosing the method of virtual production, and future implications for the industry. They are analyzed in depth in this chapter.

4.1 Impact & Change in Process

Virtual production is a technology that transformed the traditional production process. New technology could play a crucial role in shaping social, cultural, and creative processes (Hauer, 2017). This section breaks down the complexity of various process aspects and concepts to understand the dynamics of virtual production with the workflow processes including efficiency, challenges, the transformation of roles, the learning curve with the technology and the creative possibilities for the process.

4.1.1 Enhanced Workflow Efficiency

The production workflows have substantially changed and developed with virtual production. In many cases such as commercials, virtual production has supported speed up the process of production where multiple projects can be shot in a limited amount of time. Interviewee 2 recalls the process speeding up, “shoots where we don't know, literally spent a day making the assets and then shooting the next day kind of thing as well.” The interviewee further added that the speed of a production process is relative and would depend on the scripts and the kind of worlds that are needed for the shoot. There is a significant increase in efficiency that can be seen with the use of virtual production. Virtual production provides the production crew and the creators of the content with the flexibility of shooting at multiple locations within a few minutes. Switching through locations with virtual production is extremely simplified which in case of traditional method of production would be a weeklong schedule can now be completed in hours. Interviewee 2 builds on this by giving an example of car commercial shoot which would require multiple locations and would need to ship the car around the world which could be complex. This is simplified with virtual production, and they see virtual production making a big impact on short form content like advertising. The team could leave with the final shot on the same day. Virtual production if planned

well can be highly cost-effective and deliver content of the same quality or better much faster than traditional methods. Interviewee 3 built on this in the interview.

> As well as being able to do it incredibly rapidly, you know, you can, swap between, you can change filmmaking, you can change location… from a spaceship to the school within minutes. Yeah. Now there might be some DoP work needed to do that, but in a technical way, it takes minutes. It doesn't take, it's not half a day, it's not a day. You don't have to ship anyone anywhere, right?

For an efficient workflow, virtual production requires pre-planning which would need the involvement of the production and technical crew from the stage of script development. The involvement of the virtual production team from pre-production instead of at the end in post-production simplifies the workflow by giving a more accurate estimate of the production timeline as the time in post-production is accounted for in pre-production, needs, budget, assets, and more. A close to-accurate workflow leaves less space for future uncertainties. Interviewee 6, a virtual production supervisor, explains the production process can be divided into a three-step processes of pre-production, in production, and post-production. Post-production has always been the stage that takes the most time and costs more money traditionally depending on the time of content compared to pre-production. In the below comment from the interview, Interviewee 6 explains the time efficiency through the production process,

> Filmmaking is typically like this kind of a shape where you're doing a little bit of work up here and then you film and then like most of the work is down here (indicating at the bottom funnel with hand gestures) when you're in post-production, now you kind of have to do it like this where you do all of that visual development work before you shoot and then post-production is relatively simple because you don't have all these composites you need to complete.

The shift to virtual production started with The Mandalorian as the trendsetter showing the path to all shows and movies that followed it. It shifted the outlook for series producers, they realized that they did not have to shoot in front of a green screen anymore. Interviewee 9, a senior virtual production writer & an expert in the industry explained this need for efficiency in their interview giving insights into the reason why Mandalorian was shot using virtual production,

> The main reason why they developed that for the Mandalorian is they wanted to be able to do something that looked like a Star Wars movie, the kind of visual expectations people have for that world, but do it on a TV streaming schedule, which means you gotta knock out 10

> episodes in like a year. So, I mean, you can't take two years of post-production, you gotta have it like we shoot and then we're ready to basically stream it within the month. So that's, you know, it, it, it would've been very challenging I think to do those kinds of series without either just taking years to complete them or, you know, not having that quiet level of visual scope that they achieved.

Overall, virtual production has affected the workflow of production by making it more efficient through more involvement of the virtual production team in the pre-production, including script development as it is necessary to know the possibilities and the time it would take while writing the script. Virtual production has led to limit the amount of location changes and detailed planning. The planning not only helps with time efficiency but also cost efficiency; for example, with the Mandalorian, an episode costs about $15 million to make (Brajer, 2023). While a Star Wars movie budget has gone beyond $300 million (Polo, 2022).

4.1.2 Role Transformations

Traditional filmmaking roles have transformed completely with virtual production. In this subsection, we go through different types of roles that needed to be transformed and new roles that have emerged from the adoption of this technology. Virtual production did not just transform the role of filmmakers on the set but especially the post-production workers and visual artists from the gaming industry had to adapt to a new workspace and work culture. They needed to learn the language of the film crew to communicate with them. Communication here is the key that is needed for the easier shift for the roles. Interviewee 2, a creative technologist in the field, talks about the new emerging roles here about new roles being added to the production include roles like a Virtual production Supervisor or a VFX supervisor who works closely with the two teams from both the industries. They are involved in matters such as decision-making including budget, negotiation for the resources, including the bigger part which is the 3D development side which involves building the environment and working on getting the content ready. This would include a new set of talent and roles for people who work on the Unreal Engine. They are responsible for bringing the filmmaker’s vision to life making it optimized to film as a part of a live environment. There are environment artists, who are responsible for creating individual assets in the environment and are involved here as well that make sure that the physical and digital blend together. Interviewee 2 adds to this by emphasizing the change in existing roles with the change in demand,

> A lot of new roles, but also it changes some of the existing roles as well because like a director of photography or a lighting person will need to have an understanding of the, the fact that they're lighting two sets, they're lighting the physical set and the people in the Volume, but they're also lighting the virtual set and the, the virtual like the digital twin effectively of the, of the, of that world kind of thing.

Interviewee 2 builds on that by giving an example of producing commercials which have a fast turnaround. The process of producing a commercial is that post receiving the details, script, requirements of the commercial in form a brief the shooting starts within three to four weeks. Projects like commercials have a shorter timeline than films or series. The turnaround time is much quicker. In this short period of time, it could be difficult to explain the technology and changes in process that comes with it to the crew. Working with crews with no previous experience or knowledge about the technology for a short project could be challenging as there needs to be clarity about their role and knowledge about the technology among these roles. According to Interviewee 1, a pipeline technical director that works with the unreal engine at an animation and VFX company, talks about there being a separate dedicated support team at play. They mention roles of people from their technical team shifting to more creative on set roles as supervisors so they can meet the demand and handle communication. They had to bring in people to work on Unreal technology with expertise in using the technology and with virtual reality. There were more specialized roles that were formed. This opened many opportunities within the company as there was a need for specialized talent. People that work on building creatives have a different way of communication compared to filmmakers. Interviewee 4 emphasizes that this is a gap which the role of a virtual production supervisor fills in. They act more as a translator between the two industries,

> They're used to being able to point or draw or somehow visually tell, hold a camera, put it here, I want the camera here. We don't have that luxury always with virtual production, especially in the beginning stages. So, somebody that understands what a production might be looking for, but also understands the technical side of things to be able to translate from production to technical and then our needs or concerns or questions from the technical side, back to production in the right questions is really important because whenever it's, it's instantaneous, you see how it doesn't work. When you see that communication pipeline breakdown where, you know, a level artist or a 3D artist is asking, you know, a director who knows nothing about 3D design a question like, you know, what, what shape is the river supposed to be?

A virtual production supervisor is someone who understands both the gaming and the filmmaking industry well. They understand how each role functions and the type of communication each one of them uses to communicate. The role requires the supervisor to be creative and practical to communicate the needs and wants of one team to another. They are bridging the gap between the two teams while having the best for production in their mind. The role requires the person to be a great communicator and have an overall knowledge about the functioning of various parts in production. This role emerged recently with the technology; a few of the early adopters seem to have noticed the gap and tried to fill it by a lot of self-learning as Interviewee 6 says, “there is no

supervisor academy". They had to teach everything to themselves and learn by practice in the field through trial and error. The roles have transformed, and new roles have emerged. production designer roles have changed to virtual environment artists or architects. Virtual production supervisors have emerged as communicators in the industry. In the industry of virtual production, there is currently the scope to change roles or transform them into something one might want to do by finding gaps in the business. The media industry is looking for talent in the field of virtual production. There is currently a shortage of talent with hands-on experience (Pennington, 2023).

4.1.3 Challenges

Change is inevitable with the adoption of a new technology which is followed by resistance to the change which could be challenging for the changemakers (Rogers, 1962). Interviewee 10 explains that they have observed resistance to the technology beyond their own company as usage of the technology needs the filmmakers to have a skill of imagination without being in the environment where as many traditional filmmakers and directors cannot imagine until they see the environment in front of their eyes. While tackling these challenges, it is key to manage it well for the success of a business and to create harmony within the team (Lapointe & Rivard, 2005). The subsection studies the challenges faced by the virtual production team and how they work on tackling them.

Collaboration is an essential part of production and virtual production brings in a collaboration that is not just for the technical department and the film crew, but it is an interdisciplinary collaboration. Majority of the teams that have emerged in the virtual production world of filmmaking have been from the gaming industry. Interviewee 4, a virtual production supervisor, reinstates our theory by confirming that "a lot of the crews that work in virtual production are coming from the gaming industry." Interviewee 9 simplifies this by "it's kind of like…this whole new industry sort of showed up in the middle of an existing film industry". There is a need for effective communication between the two industries working on a physical set together. Interviewee 6 explains as a virtual production supervisor what are the communication challenges they face on a set, the hierarchy a traditional set follows and how they can work together to communicate more effectively.

> We've kind of, you need to be able to translate between different languages onset because, well there was, for example, we had a test run, right? And we had for the first time our annual department onset and the, it was, well it was funny because it was a test run, but on the films that there's quite a clear hierarchy, you know, if directors or director says that's the way we do it, you're gonna do it like that. Even if you think, nah, that's not, not, nah, that's not the best case, right? But for example, the one of the unreal artists, he didn't really see it that way and went up to the director and kind of discussed how he would shoot the shot and so on. So it is, you

> know, completely different worlds because in game design it's a, it's mostly a flat hierarchy.

There are different types of organizational structures that are used across industries. Film industry has a clear vertical hierarchical structure. On a film set, a director is the person in charge of everything and has multiple assistant directors under them. Since the director is at the top of the vertical hierarchical chain, they cannot be approached or be given feedback by other people on the chain while the gaming industry has a flat hierarchy. The members of the team can freely communicate with each other. When these two industries merge on a set, unless there are clear instructions being passed on the hierarchy, there will be no clarity on who can be approached by whom to what extent. This would cause chaos, could be considered disrespectful and overall create communication challenges on the set. The need for communication and order on the set was a gap that needed to be filled. This is where the role of the virtual production supervisor comes into play. They act as a communicator between the film crew and the virtual production crew. In the words of Interviewee 8, a virtual production supervisor "translates any requests or any issues back to the people that are, as we call it, the brain bar" which is the virtual production team.

There is scope for learning in the virtual production industry. The diffusion of innovation theory explains that with every new technology entering a new market must go through various stages of adoption. In the first few stages of the innovator and early adopters there is limited knowledge about the technology and how it could be used. The early adopters tend to be the educators as well for the majority (Dearing & Cox, 2018). As for virtual production, there is still a gap in the market with not enough talent who know how to use the technology as well as work on production sets. The team of traditional filmmakers and production need to adapt to the use of technology by developing a new skill set.

The challenge of lack of skill set and knowledge about the actual use of virtual production could lead to cost-implications on the project that is being dealt with by educating and training people. As there were no university courses on virtual production to train existing crew and bring fresh talent in the space. Virtual production companies like Final Pixel have started training programs specifically for teaching and training the crew which was followed by universities developing courses. Breda University of Applied Sciences was one of the early adopters in Europe to teach courses related to virtual production. Interviewee 7, who works in Business Development Virtual Production for a company that provides technology to enable virtual production explains how they are investing in education,

> I think the difficult or the, the bottleneck is training in education. And we're heavily investing in partnerships with academics, so we have two partnerships in England, Wakefield Academy, backstage Academy Park, and in Holland, we are working with

> Breda…University of Applied Technology, and they have set up from US Studio. So, students are learning how to deal with setup, but also how to optimize the technology. And they also have a kind of business approach to it.

The need for educating the people was high as the demand for the technology was rising leading to a ton of free training and knowledge being shared on the various platforms for free. Interviewee 3 explains to us about the free education online. That the education is wasted if the students do not get to use their knowledge gained on practical processes on a day-to-day basis. As the technology is constantly evolving there is a constant need for learning and educating yourself while not losing touch with using the technology itself.

Two of the interviewees, Interviewee 4 and Interviewee 6 were among the early adopters but since they did not belong to a production house, they had limited accessibility. This led to self-learning during the pandemic. They taught themselves with whatever information was available and started re-building the technology as well as shooting with it from scratch. Interviewee 4, a virtual production supervisor, started to upload a video on YouTube of every step they learnt on building and using the technology, eventually turning this free module into a guide, an online course for anyone interested in learning. Interviewee 4 explains the demand of the market for the learning,

> we took all of the things that we were releasing as video series on tutorials and how to do this stuff, and then we switched that into an online course model so that people would, you know, pay for the online course and then have access to all of that material and be able to learn and have access to us for questions and things like that. But it depends upon how big the market grows, and I think they go together.

Education and sharing knowledge play a crucial role in further growth and adoption of virtual production technologies but technical training that follows the education is even more relevant. Interviewee 9 explains that there is more work in the industry than the people who can do the work, building on to the need for training which certain companies like Final Pixel are incorporating,

> I know for a fact they get people like in proper studios and play through scenarios how the set would work and how, you know, how it usually destroys and so on, work on set. But the best thing is basically if you are done with the base training to get on a proper physical set where the stakes are there, the pressure's high, so everybody understands it.

The early adopters of the technology did form a strong community within themselves to exchange knowledge, and information or just to communicate with each other. They have a strong network with the regular conference meet up and an active WhatsApp group administered by

Interviewee 3. The community is not a closed off community, Interviewee 8 confirms that it is spread across different companies and countries so if you are in the field, you are in the community.

While there are new opportunities coming up in the field there is resistance as well. Resistance is a by-product of change, with change there is resistance from the existing structure that follows (Lapointe & Rivard, 2005). Virtual production as an emerging technology in the business is bringing change to existing structures and processes which will as a result cause resistance. Identifying the specific aspects of challenges leading to resistance to the technology could help the diffusion of the technology within the industry. Interviewee 5, an Indian virtual producer, and filmmaker observes that there has been resistance from the people, the crew who have been involved in the traditional way of production. According to them, the crew does not want to shift or change their way of working for a more "easier" way of production. They describe that there is a lot of resistance to the adoption of the technology in India. In Interviewee 5's global network they have experienced resistance across the world. There is a refusal to accept the technology among traditional content producers. They explain that the conventional way of production in India leaves a lot of space for changes while in production, as they go to a shoot location and there is space for improvisation on which angle, spot rather precise direction the filmmakers take the shot while virtual production does not have any space for improvisation. An unreal engine artist would need to create a 360-degree environment to include space for such improvisation. This could take away the cost-effectiveness of using virtual production. Virtual production is a well-planned process that for a traditional filmmaker would require to completely change their thought process. Interviewee 5 concludes that virtual production limits the capacity of a film crew to fix things in post-production. They must stick with how things were pre-planned; this could be a challenge for filmmakers.

Another aspect that causes resistance among the crew that Interviewee 5 highlights that crews they have encountered love to shoot on location. For a big budget production crew in India, the highlight of the shoot is the opportunity that follows to travel outside India for work. While it could be a minor cause for resistance, studies have shown that the technology acceptance and adoption need to be a bottoms-up approach rather than a trickle-down approach as the majority working on set needs to accept it. Interviewee 5 further simplifies this resistance by comparing it to adopting smartphones by their parents. The resistance as a force is strong but eventually, the technology would be not a choice but a need. Interviewee 10, a virtual production series producer recalls not facing resistance on their set but has observed resistance among other production houses. They suggest that the resistance could be overcome by spreading awareness about the technology.

> You need to have a sense for the technology, and you need to have good imagination and control and be a strong decision maker, I think, to run it. So not every filmmaker can do that. Some people, you will be surprised how many directors cannot imagine a thing until they see it in front of them. It is quite common. So, for these kinds of filmmakers, I think it's difficult

> for them to make that stuff work. And therefore, they shouldn't. They shouldn't. I mean, they can try, but they shouldn't, you shouldn't force it onto them. If you feel it's not the right thing for them, don't do it. It'll overwhelm them. It is digital real, it's difficult.

Interviewee 10, states not to overwhelm the production crew by forcing a new technology that they feel is difficult for them to get used. The technology does not need to be used by everyone. It can be difficult to adapt to, it changes the workflow and is not a necessity that needs to be used or forced on to a production that is not ready to use it. For filmmakers and content producers, Interviewee 10 views contradict Interviewee 5 views on technology adoption. If the makers are not comfortable with using the technology, it should not be forced on them because that will be reflected. Interviewee 6 emphasizes this, “And if somebody is working kind of against the technology, you're going to notice it in the final shot because it's going to look different on the foreground, on the background.”. Therefore, while there is constant pushback and resistance, it is important to give people the space to accept the technology by creating awareness rather than forcing the use of technology on them because, at the end of the day, it is about creating the best results on the screen.

4.3 Impact on Business & Industry

The adoption of virtual production technologies like the Volume in the film or content production industry is changing the business landscape. The section studies the transformation of business, the market, and the budgets.

Interviewee 3, a Virtual Production studio owner, used the Gartner Hype Cycle to explain how the business of virtual production has progressed since 2019 for the industry. They explain that when a new technology comes in everyone gets excited. On the graph a line starts to build up very similar to the diffusion of innovation model where there is an initial steady growth, the line then reaches a peak on the graph which is followed by a drop-down to the stage called enlightenment. The graph then forms a plateau which is called the plateau of productivity. The Gartner Hype Cycle when correlated to virtual production, it can be observed that the line on the graph started to grow when the Mandalorian was released this led to hype in the industry and there were a lot of virtual production studios set up across the world. In the hype cycle, there was an extreme peak reached and then the realization or the enlightenment set in about maintaining the business and the actual use of the technology is hard to do which leads to problems. As there was still no manual that taught them or provided a successful path to the business. The phase of excitement grew with the big LED Volumes and owning them caught on as a trend. They were previously just used for big events; they were not designed for virtual production. If non-experts shoot in front of these screens with a high-resolution camera, it will not produce the desirable outcome. This leads to the next phase in the cycle which is the drop of trough of disillusionment. Studios started closing. There has been a drastic drop in the amount of big virtual production studios (Mitchelle, 2023). While there are very few articles on

studios shutting down, within the data set 7 interviewees including interviewees 2, 3, 5, 6, 8, 9 and 10 have confirmed dismantling of multiple full-scale Volumes across the world. People started straying away from the technology as they assume that the technology is not mature enough and it is not sustainable to have a Volume installed. According to Interviewee 3, the state of the industry at this point in May 2023 is that it is heading down the slow of the earlier hype. Interviewee 3 explains that the next phase of the slope of enlightenment has been accelerated with awareness, education, manuals, and YouTube videos.

Numerous producers started experimenting with the technologies of virtual production, especially the LED Volume during the pandemic, as it provided them with many advantages, including saving time and cost of shooting on-location. There was no need for a large shooting crew with multiple vans lined up, no need to create extensive sets or interaction with crowds. Shooting could be possible with a small team on location and a remote team for the technology (Grand View Research, 2022). It created a safe bubble for the limited crew required for the shoot. As a result, it reduced the risk of spreading the virus to a minimum while not compromising the quality of the production. The technology provided the team with a hyper realistic environment that used real-time rendering. The production set designers could meet remotely and design the sets in the virtual world. The entire team could work and plan things remotely, reducing the time and days spent in person on the shoot, which was a more productive workflow than before while maintaining safety protocols. Virtual Production during the pandemic provided ease and flexibility to not just the filmmakers but to the entire crew with advantages that even the traditional method of production with physical on-location production could not provide with the ability of easy modifications. It even made re-shoots or changes of locations just a few switches away. It allowed for reducing potential risks by providing flexibility in case of any unforeseen circumstances due to the COVID-19 pandemic – saving the production a lot of costs (Eriksen, 2021).

Integration of the immersive world with virtual production provided actors a space to perform naturally as they would in a real location environment rather than in front of a green screen, giving a more believable performance. Blending elements of the physical and virtual world in one set provides a more involved audience. While early adoption of this technology during the pandemic saw a hike of growth by well-established production houses, smaller budget houses could not afford to spend the amount it takes to acquire the technology of virtual production like the setup of the LED walls, real-time rendering engine and the trained crew that is needed for the optimized usage of the technology. The use of the technology during the pandemic remained limited due to a small fragment of producers that could either afford the technology or had connections to rent and acquire it only.

After the pandemic, virtual production emerged as a supplement to the traditional methods of production where virtual production is used for locations that are a challenge to access or do not exist in the real world. While in certain cases, with some shots and scenes, it is easier and cheaper to shoot on location instead of a virtual environment. Virtual production did show its potential to the

filmmakers during the pandemic, and now it is on the filmmakers on how they would like to use this technology for their production after and in the future (Solon, 2023).

A senior virtual production technical director, Interviewee 8, shares that after the COVID-19 pandemic there are a lot of studios being shut down and Volumes being taken down or dismantled as virtual production was the way around to get content out during a lockdown but as the hype has reduced, people come to realize that it not as easy task to take up virtual production. According to Interviewee 8, the business model now would be to have different companies. One of which is a focused special effects company. This company focuses on building the environment and the assets, they could be from the gaming industry as games require skills in building virtual environments. Whereas a production would need a company with the amount of expertise that can build and operate a LED Volume. They basically divide this into two parts: the technology and the content. Companies that know how to build and operate a wall and companies that have the expertise to provide content to that wall.

Interviewee 6, virtual production supervisor, sees the trend of pop-up Volumes being very popular. Interviewees 4 and 10 mentioned the same trend of pop-up Volumes growing across the world. These 'Pop-up' Volumes are dismantlable and portable. They are being used for creating new business opportunities for virtual production. As the customers in this case the film crew does not have to travel to a fixed studio location. The Volume comes to the crew, and this could provide a more hybrid model of traditional and virtual production which could be more cost efficient as well. Interviewee 6 sees the business growing into a merger between gaming and filmmaking with a lot of games having film adaptation. Interviewee 6 recommends merging the two by using the same virtual assets created for a game or for the movie for the other could really save cost and grow business for example, The Mandalorian could easily use the virtual assets they made for the series to release a video game as the process is the same and the world is already created virtually. This could create a new revenue stream within the same budget.

The process of budgeting for a project with virtual production is a lot different than a traditional project. It could be a difficult balance to keep the costs of production within budget. To save costs while using virtual production it is crucial to spend time heavily into pre-planning of the production. Interviewee 5 expands on this, as the cost implications of changes on the day of the shoot can be very high. Every minute would cost, and one can reduce that cost with virtual production pre-planning. If done well with proper pre-planning and following the plan, it could reduce production time which leads to saving money. Virtual production set up requires heavy investments which could be a lot to own the technology of LED Volume. Interviewee 10 recalls receiving a subsidy from the German government that supported them to buy the technology and it would not have been possible for them without the subsidy. Interviewee 2 shares that it could even cost the same budget to shoot with virtual production than traditional methods of production depending on the type of production, but it gives to the liberty to be more creative with your stories, they give an example for it by

comparing shooting on the moon virtually with shooting on the street with traditional methods of production having the same or similar budget. They do mention that there can be opportunities for cost efficiencies and saving when doing a multi-location shoot using virtual production over traditional on-location shoot methods.

Interviewee 6 shares challenges they have faced with this budget shift working with other clients,

> That's kind of the thing most people fear because if I put in a lot of money beforehand and my result will fail, I still actually would need the same amount in post-production but don't have it anymore because I already spent it in pre-production. And that's kind of the worst-case scenario, which we are trying to avoid at all costs. So yeah, that's kind of (budget) the differentiates just gets moved around the thing, which is interesting, now you can, if you have like a shoot made for virtual production, you can, with the same amount of money, you can achieve better not better, but more pleasing with your result or like more creative potential in that sense, which you would not be able to have before

Interviewee 6 explains that the allocation of the budget has shifted from the post to pre-production as a lot of tasks that were conducted in post-production are now being checked in during pre-production. This could bring a sense of fear among the producers of using their budget for post-production in pre-production which can be seen as pasting upfront before a shoot starts. This could be looked at as a risk by the producers of losing money even before the shoot starts. Virtual production technologies have impacted the business in the media industry in many ways. It could be concluded as a positive or a negative impact. As per multiple interviewees from the data set, there is a future where virtual production technologies will be used more extensively.

5. Discussion and Conclusion

This chapter will discuss the findings from the previous chapter and conclude with this study. It will further discuss the theoretical and social implications along with the limitations of the study and the prospects for future studies.

The use of virtual technologies, specifically the LED Volume is growing exponentially (Deloitte, 2020). This was due to the limitations and restrictions that filmmakers faced during COVID -19, these technologies freed the filmmakers and their creativity from the pandemic restrictions. There was a significant boom in the market with the demand rising which was observed with multiple studios being set up initially and then eventually closing. A lot of creators, filmmakers, and producers adopted this new technology, and its effect on the process of production along with the business seemed to be different for all. The study conducted 10 semi-structured interviews with industry experts with experience working with virtual production, specifically LED Volume technology. These industry experts were all among the early adopters of the technology making them the opinion leaders (Dearing & Cox, 2018). To explore the impact in more detail, the following research question along with three sub-questions were formulated, "How have virtual production technologies like the LED Volume affected the production process and business of media companies?"

Sub-question 1: What is the role of virtual production technology the LED Volume in impacting the creative process, storytelling, and decision-making of the media companies?

Sub-question 2: How do virtual production technologies impact the production timeline, cost, and revenue generation of media companies?

Sub-question 3: How do virtual production technologies impact the roles and responsibilities of the production crew and the business models of media companies?

To answer these questions an inductive thematic analysis approach was used to analyse the interviews. There were two major themes that were derived and selected from the data that could help answer the research questions. These themes were the impact and change in process and the second theme was the impact on business and industry. One main finding of the study has been that while virtual production has a significant impact on the production process and the business. A positive or a negative impact could solely depend on how well the users make use of the technology. Through the study's finding all the interviewees are currently working in the field of virtual production actively and have felt a positive impact of the technology. This finding could be a reason for there being an asymmetry of information within the industry some producers that use the technology have a positive view of the technology while others would have a negative view of the same technology. In terms of business, Interviewee 10, the only virtual production technology owner who had recently gone through the process of dismantling their Volume spoke about the need to constantly adapt their business model to thrive in the market. A business would need to constantly

innovate their business model with new technology (Foss & Saebi, 2016). In terms of business model, a hybrid model for short-form content of commercials with the technology being owned by a separate studio would be a cost-effective business. A car commercial and multiple short-form content have performed better based on cost-effectiveness and production efficiency as per the findings. Another finding from the study is that communication is the key in this industry. There is a specific amount of knowledge and skills needed to communicate at a virtual production shoot. The gap of communication is wide in the field of virtual production where virtual production supervisors fit in to mediate tasks between the two industries of filmmaking and gaming which have two different types of hierarchical structures completely. Multiple new roles have emerged in the field of virtual production and finding talent has been a challenge. There was a significant demand for using LED Volumes as part of virtual production during the pandemic although the demand started to slow down after the pandemic where creators realized the amount of work it requires to pre-plan the use of a technology like the LED Volume. Virtual production technology has impacted and brought changes in the creative process, and changed how decisions are made in the industry. The impact of virtual production on the storyline was still not clear post the research. It can reduce the timeline for a project in certain cases whereas it could reduce costs and travel for short-form content where the technology is not owned by the content creator as owning the technology is expensive. Virtual production is affecting how productions are financed as most of the cost that had to be incurred towards the end of the shoot for post-production now needs to be shifted in pre-production for planning and creating what would go on the screen. It could reduce cost and time eventually (Arkenberg et al., 2022). There are roles that have changed while new roles have emerged. The business model changed within studio shoots, instead of on-location shoots which seems to be going back to on-location shoots with the pop-up Volume coming to them. Discussing the two main themes above provides discussions and answers to all three research sub-questions that together answers the main question about How have virtual production technologies like LED Volume affected the production process and business of media companies?

5.1 Theoretical Implications

The theoretical implications of this study from the findings have been significant. This research delves in the business and production process aspects of virtual production. This research contributes with an outlook on the impact of virtual production technologies like the Volume on the process, hierarchy, collaboration within industries, budgeting, cost implications, the shift in roles, in production process, of budgets and the challenges that different people in the industry face. This was an exploratory study on the process and the organizational structure within media companies. This was an existing gap in the research space of virtual technologies that this research hopes to fill through its findings.

5.2. Social Implications

The social implication of the study is that it highlights the gaps in the industry of virtual production. It is an industry that is open to change yet there is resistance to change. There are multiple roles open for anyone who is willing to learn in the field of virtual production. This study could be used as an identifier for new talent in the market. Being part of an industry at the core or even at the early majority is an opportunity that comes through rarely. The study aims to help not only new talent but creators and producers as well. There have been multiple resources in the form of articles, YouTube videos, LinkedIn posts, and others on what the technology can do and how one could use it for their content. Though there has not been a study on the business of virtual production, especially LED Volumes.

5.3 Limitations

The research had limitations for building a stronger academic foundation with previous studies as there have not been many studies on virtual production. Any new development in the field is published on websites, through guides and other resources that are used by professionals in the industry. Their dependence on academic papers is low. The research had a few limitations related to accessibility. The time of the research clashes with the start of multiple shoots. The experts for the interview either had little to no availability, they either had shoots or were on vacation. Being an outsider in the industry, it is difficult to get easy access to the experts that are deeply involved in the process of production. The expert participants are great speakers but also storytellers. There were instances of not following even the semi-structure from the interview guide as they would share stories beyond the questions in the interview guide, yet they would end up answering questions that were not asked yet. This could have skewed the data as some of the answers were not a direct reply to the question but connected to that. All the experts were male which could either lead to impartial data or the conclusion that there are not that many female leaders in this technical industry as about 45 experts were reached out to on LinkedIn and just one of them was female, who did not respond. The sampling data included a diverse background of professions from technical directors to producers, maybe if all the samples were from one specific background or role it would have a different result. The interviews were recorded on Zoom, though that makes the participants aware of them being recorded constantly due to which they are cautious while sharing insider information. Apart from that it takes away the comfort of just a casual conversation replacing it with extremely self-aware interviewees. This was observed by taking two calls with a certain interviewee, the first one was an information sharing conversation call which was not recorded while the next call was on record which might have caused the interviewee to not be as open and be conscious.

There were limited research papers available that studied the subject from a business angle. This was the reason for this study to be an exploratory study, but it would have had more potential if

there could be a previous foundation that could have been built on. In addition to this, the study just focused on one specific virtual production technology which is the Volume and the impact it had. The technology is extremely dynamic that would mean that a limited timeframe of the study would be relevant for only a short period of time.

5.4 Future Research

Virtual production for future research could be studied from so many different aspects. This study focused on just the LED Volume; future studies could focus on the finding from this study on pop-up Volumes growing across the industry. A business angle on how pop-up Volume performs would be an interesting study. A quantitative study using the Technology Acceptance Model for this technology of LED Volume among industry workers could provide some detailed and specific insights into the acceptance of the technology.

To conclude, virtual production has affected the production process by making an impact on the creative process and the production timeline. The business of media companies has been affected by the impact on budget allocation, cost implications, changes in roles and responsibilities, and changes in business models. The technology has been created to make the life simpler of the production crew but without proper guidance on the usage it could be a challenge to foster the benefits of the technology. A team adopting the technology for production needs to be willing to learn more and accept the technology otherwise it would reflect in the final output. LED Volume can, if used properly, make production work more efficient and reduce the costs of production in certain cases that include short-form content or high-budget TV shows like The Mandalorian that compete with the Star Wars movies. In terms of business, studios or production houses are moving away from installing a full Volume in their space and are instead opting for ‘Pop-up’ Volumes.

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Appendices

Appendix A - Sample Description

Interviewee	Role	Base of Work
Interviewee 1	Pipeline Technical Director at Virtual Production Company	Canada
Interviewee 2	Creative Technologist for Virtual Production	United Kingdom
Interviewee 3	Virtual Production Studio Owner | VP Consultant | VP Speaker | VP Trainer	United Kingdom
Interviewee 4	Virtual Production Supervisor	United States of America
Interviewee 5	Filmmaker & Virtual Production Specialist	India
Interviewee 6	Virtual Production Supervisor & Producer	Germany
Interviewee 7	Virtual Production Expert for Live Broadcast, Films & XR Stages	Netherlands
Interviewee 8	Senior Virtual Production Technical Director	United Kingdom
Interviewee 9	Senior Writer for Virtual Production - Writer of a VP Field Guide	United States of America
Interviewee 10	Executive Producer and Managing Director at a Virtual Production House	Germany

Appendix B - Interview Guide

Introduction	1	Introduce yourself	
	2	Thank the interviewee for taking the time to participate.	
	3	Assure about the confidentiality of this research	
	4	Introduce the context of the study	
	5	Ask about the consent to record the interview and use the insights from the interview for further analysis.	
Ice Breakers	1	Could you introduce yourself and provide some background information on your experience with virtual production?	
	2	How did you get started in the field of virtual production?	
	3	Could you describe virtual production especially the volume?	
	4	What does your current role involve in the production of media projects?	
Emerging Technologies and the Volume	1	Can you describe your experience using the Volume on media projects?	
	2	What is the Volume, and how has it evolved the production of the Netflix series, 1899?	Optional
	3	What advantages does the Volume offer over traditional production methods?	
		When should a decision be made to pick between the two?	
Creative Process	1	In what ways have emerging technologies like the Volume transformed the creative process of media projects?	

	2	How does virtual production impact storytelling and decision-making within the media industry?	
		Push: In terms of set design, costumes	
	3	What are some challenges that arise when using virtual production, and how are they addressed?	
Production Process	1	How does virtual production impact the production timeline and cost of media projects, using 1899 as an example?	Optional to use 1899
		Push: Pre Production	
	2	Can you provide some insight into the revenue generation potential of media projects using virtual production?	
	3	What are some ways virtual production can help to mitigate cost overruns?	
Roles, Responsibilities, and Business Models	1	How does virtual production impact the roles and responsibilities of the production crew?	
	2	Have roles evolved? What new roles have emerged as a result of virtual production?	
		Push: In terms of teams on set	
	3	How do media companies need to adapt their business models to accommodate virtual production?	
	4	How has the community experience been for you?	
Conclusion	1	What are your predictions for the future of virtual production?	
		Push: What possibilities do you see? In terms of business models	
	2	What type of media or series or films do you see coming with virtual production in the future?	
	3	What are the major uncertainties that may impact the future of virtual production?	

	4	Are there any final thoughts you would like to share?	
	5	Thank the expert for participating in the interview.	

Appendix C - Coding Frame

First Code	**Second Code**	**Main Theme**
Definition of virtual production	**Definition and significance of virtual production**	**Definitions** and Role of VP
Expanding the definition of virtual production		
Getting into virtual production	Working with virtual reality (VR)	
New field and area	Unreal Engine's role in virtual production	
Changes in the production process due to virtual production	**Workflow optimization, cost reduction, and talent improvement**	**Impact and Changes in Production Process**
Creative possibilities and flexibility offered by virtual production		
Technical aspects and considerations in virtual production		
Challenges and learning curve with LED volume	**Challenges, complexity, and learning curve**	
Technical limitations and adjustments in shooting		
Variety of applications in virtual production	Filming in controlled environments and implementing content	
Flexibility and control in shooting with LED volume		
Collaboration between technical and creative teams	**Role changes, collaboration, and creative possibilities**	
Impact on storylines and scripts		
Role changes and new responsibilities in virtual production		
Increased preproduction time and content creation	State-of-the-art solutions and improved production conditions	Advantages and Benefits

Benefits of a full 3D world in virtual production		
Advantages of virtual production in terms of cost and efficiency	Cost and efficiency advantages	
Cost-saving potential in production		
Impact of virtual production on short-form content and advertising	Impact on short-form content, advertising, and preproduction time	
Time-saving and efficiency improvements in virtual production		

Changes in business strategies and creative possibilities with virtual production	Business transformation, market presence, and installations	**Impact on Business and Industry**
Budget considerations in virtual production	Budget considerations and implications	
Budget implications and considerations in adopting virtual production		

Involving post-production early in the process to address fear and lack of knowledge	Overcoming resistance to change and promoting innovation	Overcoming Challenges and Promoting Innovation
The need for a mindset shift towards sustainability	Promoting green virtual production and sustainability	