

Shopping Experiences in the Metaverse:

# Implementation of a white lable Metaverse Solution

# Abstract

While many brands are interested in utilising this new channel, creating them comes with several challenges and uncertainties as many companies lack experience within this field. The scope of this research included the initial requirements analysis, followed by the implementation, and launch of the solution. Throughout the development process, multiple requirements such as resource management, modular design, and payment integration were identified and implemented. Additionally, various store atmospheric elements were utilised in the design of the user interface. The resulting solution was successfully launched and was able to attract eight customers who leased a store within the mall. Furthermore, the mall was visited by 145 users within the first three weeks following the launch.

Keywords: ['virtual', 'metaverse', 'store', 'channel']

# Introduction

“The metaverse is here, and it’s not only transforming how we see the world but how we participate in it“ . However, with companies racing to integrate the metaverse into their strategy, there appears to be a considerable amount of scepticism and confusion surrounding the topic. Searching the term on Google, one will quickly find an abundance of articles with titles that go along the lines of “What exactly is the metaverse?”. No matter what side of the debate one is on, the metaverse promises to provide consumers and companies with new and exciting possibilities in numerous industries. While looking at various use cases, this thesis will mainly explore the metaverses' potential as a platform for creating immersive shopping and advertising experiences. This thesis will analyse the current state of this field of study and show a practical example of how metaverse shopping experiences can be implemented.

Keywords: ['metaverse', 'term', 'consumers', 'businesses']

## Objectives and Scientific Approach

Firstly, to establish some theoretical groundwork and clear up possible confusion surrounding the metaverse, a literature review will be conducted. The reviewed literature will be used to explain some of the basic metaverse concepts and technologies and cover the platforms that offer metaverse experiences today. Lastly, as the basis for the practical part of this thesis, the review will cover various aspects related to the development process of 3D spaces within the metaverse. The literature review will be followed by the main part, which will be practical and will follow the implementation of a white-label metaverse solution at the company Worldline. Lastly, the development process and the resulting solution will be analysed and critically assessed before concluding the thesis.

Keywords: ['metaverse', 'experiences', 'review', 'solution']

# Literature Review

Additionally, some key concepts and terms will be explained and defined using opinions from various academic sources. Lastly, this section will end by reviewing several options for developing on metaverse platforms and going through some of the key concepts related to the development of virtual worlds.

Keywords: ['metaverse', 'review', 'key', 'concepts']

## The Metaverse

The metaverses' first mention can be dated back to the year 1992 when the term was coined by science fiction author Neal Stephenson in his book Snow Crash. As with previous advances in the field, new technological concepts and advances have been the main driving force behind these new platforms and the increased interest in them. It is also these advancements in technology that have led to the metaverse gaining mainstream appeal. The domain of virtual commerce has been at the forefront of the commercialization of virtual worlds. However, while companies try to leverage the metaverse and the excitement surrounding it is ever-growing, it is important to remember that the metaverse remains without a clear definition. As such, there remains a lot of confusion about the metaverse.

Keywords: ['metaverse', 'virtual', 'world', 'platforms']

## What is the Metaverse?

As mentioned in the section above, academic literature currently does not offer an agreed upon definition of what a metaverse is . However, while the metaverse remains undefined, the number of competing definitions i growing quickly. Table 1 showcases five metaverse definitions from research papers used as part of this literature review. If the metaverse is a virtual world, what characteristics make it different from just being a virtual world? The development of virtual worlds precedes the metaverse and can be traced back to the creation of multi-user dungeons (MUD) in the 1970s. Since then, the development of virtual worlds has been categorised into five distinct phases starting from the 1970s and leading up to the present day . Current metaverse developments fall into the fifth phase of virtual world development, which mark the transition from virtual worlds to the metaverse. Even though the aspect of interoperability is mostly accepted, other researchers see the combination of the physical and virtual worlds as the main metaverse drivers. Such views focus heavily on the interfaces used to interact with the metaverse, such as VR and AR. Dwivedi et al. go as far as saying “any metaverse cannot exist without AR and/or VR” , which disqualifies many of the current virtual worlds as being a metaverse. However, even though AR and VR are often quoted as being central building blocks of the metaverse , other researchers don’t see these technologies as being mandatory . As new metaverse platforms emerge, the need for a clear-cut definition is becoming increasingly urgent.

Keywords: ['metaverse', 'virtual', 'worlds', 'definition']

## Metaverse building blocks

Current research tries to establish an architecture for the metaverse, which has resulted in the creation of several models that try to organise individual building blocks logically. Additionally, some of the core technologies will be highlighted to clarify their application within the metaverses technology stack.

Keywords: ['metaverse', 'innovations', 'technology', 'stack']

## Metaverse Architecture

Trying to create a more holistic view of the metaverse, various research papers try to organise technological, as well as non-technological dimensions, into a single structure. Such structures are generally referred to as “architectures”, “Layers” or “Components” of the metaverse. While these models don’t align perfectly with each other, most of them propose a layered structure. . propose a thorough model which not only defines distinct layers but also maps the relevant technologies. Other researchers have opted for similar layered approaches but have put less emphasis on the concrete technologies that these contain. Duan et al. propose a similar layered architecture, which places components in an infrastructure, interaction, and ecosystem layer. Similarly, there have been attempts to use the OSI reference model as the basis for a standardised metaverse model. The authors claim that having decoupled layers, as with the OSI reference model, will give each layer more freedom in its development . As mentioned before, there is currently no standardised model or architecture for the metaverse , however, the proposed models mentioned above show many similarities.

Keywords: ['metaverse', 'model', 'layer', 'ecosystem']

## Metaverse Technologies

As the metaverse will be a (or many) virtual world(s) at its core, game engines are an essential part of the creation process. Basic features include graphics rendering, physics engines, lighting systems and collision detection, which are required for almost any virtual world. While big game developers typically build their own in-house game engines, the majority of today’s video games are developed on pre-built engines. The market for such pre-built solutions is dominated by the open-source solution Unity, developed by Unity Technologies and the Unreal engine by Epic Games . Virtual and Augmented Reality: Virtual reality (VR) and augmented reality (AR) are believed to be the primary interface through which users experience the metaverse . In the case of VR, the user is blocked off from the outside world and fully immersed inside the virtual space. AR, on the other hand, overlays virtual assets onto the physical world, letting the user experience the real world through a see-through display. To give users the impression of full immersion, VR headsets have to mimic the human visual range, which requires a FOV of 200° x 130°. While current displays can get close to this visual range, it requires the use of displays with at least 6K horizontal resolution, making such headsets extremely expensive . Additionally, there is the problem of motion sickness, which is a phenomenon many users experience while using VR headsets that causes feelings of nausea and dizziness. This data structure is stored on all nodes participating in the blockchain network, making the network completely decentralised. Additionally, a new block can only be added through a so-called consensus algorithm, which forces all nodes to agree on the validity of a newly added block . In combination, these techniques lead to a system that is almost impossible to manipulate or control, while remaining completely decentralised . Decentraland has even gone a step further and created a Decentralised Autonomous Organization (DAO) through the use of smart contracts. This organisation votes on issues including land and estate features, marketplace fees etc., which all community members can participate in . Artificial Intelligence: Artificial Intelligence (AI) is an umbrella term for all technologies “that enable machines to learn, think and behave like humans do” . State-of-the-art AI techniques include machine learning, reinforcement learning and deep learning, which have numerous applications inside and outside of the metaverse . One of the main use cases for AI inside the metaverse will be controlling non-player characters (NPCs). Such characters are used to interact with users in the form of assistants, enemies, or characters in a story . AI-powered NPCs, which will be trained through customer interactions, will be especially important for the purpose of consumer interactions, offering users unique interactions. Researchers are expecting AI-powered NPCs to play a big role in the metaverse and predict that the majority of interactions will not be human-to-human but human-to-AI . While the potential for AI is very promising, the models on which these applications run are complex and resource intensive, making them unfit for mobile devices . Running a virtual world requires a vast amount of computing resources to simulate the world's physics, collisions etc. Older virtual worlds such as Second Life have used centralised servers, often in the cloud, for such computational efforts. With increasing data and computational demand, this approach can limit the number of users in a certain space and cause latency issues . It addresses the latency issues by distributing computing resources and data storage closer to the end-user . As latency is one of the primary influences on a user’s sense of immersion, minimising it is extremely important.

Keywords: ['virtual', 'metaverse', 'world', 'use']

## Metaverse Platforms

Within the last two years, the number of mobile apps that have added “metaverse” to their description or name has drastically grown . Without a general definition of the metaverse, it is almost impossible to differentiate, which platforms are part of the metaverse, and which are not. Despite this, there have been attempts to categorise the current metaverse platforms based on various dimensions. Kshetri proposes a model, which classifies metaverse platforms based on the type of interface they offer and whether their economy is decentralised or not. Two-dimensional virtual spaces are being utilised in platforms such as Gather Town, which specialises in collaboration within virtual spaces , as well as decentralised social games. This approach defines two axes, resulting in 4 quadrants, each defining a metaverse category . The axes defined by the model differentiate whether the utilised technologies result in an external or intimate experience and a simulated or augmented experience. The vertical axis, on the other side, distinguishes whether technology is used to bring virtual assets into the real world or simulate the physical world within the virtual world. Augmented Reality Worlds, which add virtual assets to the physical world. Mirror Worlds, simulate aspects of the physical world within a virtual space. Life Logging, in which aspects of the physical world are sent to a virtual space to be tracked. And lastly, Virtual Worlds, offer users a virtual space, completely separate from the physical world in which they can immerse themselves .

Keywords: ['virtual', 'world', 'metaverse', 'platforms']

## Shopping Experiences in the Metaverse

The following section will focus on the metaverse as a means to create shopping experiences to participate in the newly emerging field of virtual commerce. The findings of these studies will be explained and compared. Lastly, some of the most notable virtual shopping experiences that are currently available will be showcased.

Keywords: ['virtual', 'metaverse', 'shopping', 'experiences']

## Virtual-Commerce

This new form of commerce is abbreviated as “v-commerce” by many sources (cf. de Regt and Barnes, p. 20, 2019; cf. Martínez-Navarro et al., 2019, p. 475), however, other research also refers to it as metaverse commerce (cf. Lee et al., 2021, p. 34) or VR shopping (cf. Shen et al., 2021, p. 3). Companies are utilising these technologies to create new virtual channels in which they can demonstrate products, hold events, and interact with their customers to create new products. Users can access these spaces through numerous VR interfaces including, regular PC monitors, smartphones connected to VR headsets, head-mounted displays and more (cf. Martínez-Navarro et al., 2019, p. 476). Additionally, the incorporation of blockchain technologies, such as NFTs has been one of the main factors enabling the market for digital assets. The aspect of interoperability is a big departure from traditional virtual assets, which have always been restricted to their particular space (cf. V-commerce as a channel, promises to solve problems related to time and space (cf. and provide new possibilities for creating immersive experiences (cf. de Regt and Barnes, 2019, p. 20), which other digital channels lack (cf. Within virtual spaces, store owners can display products without taking up any physical space similar to current e-commerce solutions. However, as opposed to 2D images, customers view products in an immersive manner that is closer to the experience provided by traditional brick-and-mortar stores (cf. Martínez-Navarro et al., 2019, p. 476). Martínez-Navarro et al., 2019, p. 481). At the same time, such spaces offer a much greater degree of accessibility as they are available at all times and from all places (cf.

Keywords: ['p.', 'virtual', 'commerce', 'spaces']

## vs. e-commerce

In sum, this leads to e-commerce catering to customers that value convenience over social, and atmospheric aspects as well as younger demographics that are accustomed to the internet . Some authors see v-commerce as a subset of the greater e-commerce genre, which distinguishes itself from other forms of e-commerce through its virtual interface . The 3D interface and the possibilities it offers, has however led others to see v-commerce as the evolution of e-commerce . While it is not clear how v-commerce should exactly fit into the e-commerce typology, the existing literature has widely covered how the shopping experiences between these two vary. The value a shopping experience provides is classified as either a hedonic or utilitarian shopping value. Utilitarian shopping values are non-emotional and are created when the shopping transaction, including the acquisition of information as well as buying the product, is convenient and efficient. In contrast, hedonic shopping value focuses on the emotional value an experience can provide through “multisensory, fantasy, and emotive aspects of consumption” . Research on shopping values focuses on the relationship between hedonic and utilitarian aspects and their influence on the so-called critical outcome variables. Critical outcome variables include satisfaction with the retailer, word of mouth, re-patronage anticipation and re-patronage intention. Research on these argues that only re-patronage intention is mainly influenced by utilitarian factors, while other outcome variables rely on hedonic values . However, the shopping experience, in terms of excitement and stimulation, is very limited compared to traditional in-store shopping . While still a digital channel, v-commerce provides customers with an experience that is unique and interactive. Thus, it caters to experience-oriented customers that are looking for an interactive shopping experience that provides hedonic shopping value. Going on from the provided shopping value, shopping in virtual spaces further differentiates itself from a technological point of view. In terms of technological differences, the correlation between the technological intensity of an experience and the possibility for co-creation it offers has been a topic of study for researchers. suggest that possibilities for co-creation through personalisation, customisation etc., increase with the technological intensity of an experience. For the latter technology assists co-creation, while it is a prerequisite for an experience built using virtual technology .

Keywords: ['commerce', 'shopping', 'e', 'experience']

## Influencing factors on the virtual shopping experience

This section will seek to find the factors influencing virtual shopping by evaluating various research results. The reviewed literature includes papers that examine current metaverse platforms as well as earlier virtual worlds.

Keywords: ['virtual', 'shopping', 'experiences', 'interest']

## V-commerce products and spaces

The review found that 37.35 % of virtual retail environments were used to create single retail stores, followed by supermarkets (16.87 %) and product shelves (16.87 %). Meanwhile, virtual shopping malls were only found in 4.82% of the reviewed literature. In terms of products, food and non-alcoholic beverages were displayed most commonly (30.12 %), followed by mixed products (20.48 %) and, clothing (14.48 %). It is however questionable whether such a major preference for head-mounted displays over monitors would also be found among regular consumers, as they present a substantial investment. Meanwhile, comparisons between numerous interface devices have shown, that head-mounted displays offer customers the best experience and generate a better consumer response in turn .

Keywords: ['virtual', 'shopping', 'head', 'aspects']

## Influencing factors

As such, numerous research papers have studied how virtual shopping spaces affect a consumer’s purchase intention and have tried to isolate the influencing factors . The findings of this research are being used by current metaverse studies, which try to evaluate, how store atmospherics translate from physical to virtual retail spaces . Research on online atmospherics shows that its influence on purchase decisions is stronger compared to in-store shopping and is essential for creating engaging virtual communities . With the move from in-store and (2D) online commerce to v-commerce, multiple authors have attempted to create an updated or entirely new typology of influencing factors. While some of the evaluated studies focus specifically on atmospherics, others examine the virtual shopping experience as a whole. Wu et al. performed a study including 170 undergraduate participants and evaluated virtual retail stores created by the participants in a 3D modelling software. The study concluded that atmospheric elements could be classified into pathfinding assistance features, environment features or as product presentation features. Additionally, they highlight the effectiveness as well as the necessity for pathfinding features, which eased the navigation of the store and helped to maintain user engagement . Using these categories to compare virtual and physical stores, the research found that in terms of atmospherics, virtual stores borrow much more from physical stores than from 2D websites. However, compared to physical stores, store interior elements are often used for entertainment, as opposed to functionality or aesthetics. While small stores display products as two-dimensional images, which take up less space, bigger stores tend to display products as 3D models . Looking beyond atmospheric, additional research has focused on virtual store layouts and how these compare to the layouts utilised in physical stores. Commonly used retail store layouts include the grid, racetrack, and freeform layout. The layout a store implements has been shown to influence the shopping experience and as such layout choice is very much dependent on what the store sell. Grid layouts, which offer easy navigation, are often used for stores in which customers demand utilitarian value, such as grocery stores. Freeform layouts, on the other hand, are “perceived as the most pleasant, entertaining, and stimulating layout by consumers” . Consequently, freeform layouts have been identified as the ideal layout for virtual stores, as they complement the hedonic nature of virtual shopping experiences . While the above-mentioned studies focus on internal factors influencing the shopping experience, other studies have focused on or included external factors. Research on the acceptance of v-commerce has shown that next to shopping value, age is one of the main determinants for technology acceptance. Younger (18-34) technology-aware consumers are more motivated to partake in virtual shopping than older consumers, who feel less inclined to give up their shopping habits. As in physical retail, the number of external and internal factors influencing consumer behaviour is quite large. Through a systematic literature review, Shen et al have created a list of 15 external and internal factors, which ultimately influence the consumer purchase decision. More interestingly, the identified model was used to propose a reference model of design artefacts and requirements for v-commerce applications. Each requirement can be mapped to various design artefacts that influence purchase intention, examples of which can be seen in figure 5. The model offers a starting point for businesses building v-commerce applications, as well as a basis for researchers to evaluate them .

Keywords: ['virtual', 'factors', 'shopping', 'stores']

## Current virtual shopping experiences

Within the virtual space, users can explore the virtual headquarter, collect items, and join matches of various sports-themed games. Three months after the release of NIKELAND, Nike acquired RTFKT studios, a company specializing in virtual apparel and items, further cementing their dedication to the metaverse . Prices for Nike’s virtual sneakers currently range between USD 248 – 8.647 on the NFT marketplace OpenSea . In April 2021 urban apparel brand Vans released their virtual skateboard park Vans World. Similarly, to NIKELAND, Vans World tries to engage users through games, in the form of a skating park game. When users are not playing, they can purchase virtual vans apparel within the virtual stores . Italian fashion brand Gucci has been among the front runners, within the luxury fashion segment. In 2021 the brand opened a virtual replica of their Gucci Garden for 2 weeks within Roblox, where users could buy virtual accessories, such as handbags. Representing consumer electronics, Korean company Samsung released its 837X Experience store on the Decentraland platform in January of 2022. The space, which is based on Samsung’s 837 experience store in New York City, consists of a virtual theatre, stage, and forest section. Users visiting the space can earn NFTs by completing objectives and are able to experience various art, fashion, and music influences . As the above examples showcase, the metaverse is drawing attention from various Companies and industries. However, companies outside the apparel industry are also creating experiences for their customers and are showing interest in the metaverse. Meanwhile, other companies are in a state of anticipation, waiting to see the outcomes of these initial steps into the metaverse.

Keywords: ['virtual', 'metaverse', 'Nike', 'apparel']

## Metaverse Development

The topics covered in this section will offer an overview of development practices but mainly provide the theoretical background necessary for later practical sections.

Keywords: ['section', 'virtual', 'development', 'main']

## Building Virtual Worlds

The process of creating 3D graphics involves the use of 3-dimensional data, which is transformed to be displayed on a 2-dimensional interface. Without going into too many intricacies, the rendering pipeline starts with vertices as its initial input data. By combining three vertices, triangles are formed and combined, leading to the 3D object being interpreted as a series of connected triangles. As rendering is done continuously, the computational effort associated with it is high and is thus often outsourced to dedicated graphics processing units (GPU) . While 3D rendering pipelines are an essential part of displaying a 3-dimensional environment, the applications simulating the virtual world are referred to as Realtime Interactive Systems (RIS). Simulations managed through RIS consist of entities, that populate the virtual space and tasks or events, which in combination with the entities create a virtual narrative . Similarly, Wiebusch and Latoschik describe the virtual environment as data in the form of the environment's state, which is altered through events, creating a sequence of changing states . By traversing this scene graph the system knows, which parts of the scene require rendering . As figure 6 shows, the ECS architecture fundamentally differentiates between the application's data, in the form of entities, and the systems which act on the data. On the data side, components play a critical role as they contain the actual application data. Meanwhile, entities are initially empty objects, which can add or remove components as they are needed . Throughout the application's lifecycle, component data must react to certain events, which leads to a change in state. In the classical object-oriented programming paradigm, data and the systems acting upon it are typically encapsulated together within classes. It should also be noted that the algorithms defined within the systems run continuously once added to the engine. The ECS approach is a stark contrast to typical object-oriented design patterns, which becomes especially apparent through its preference for data composition over inheritance. The composition approach is favoured since it allows for more flexibility at runtime, as components can easily be added or removed .

Keywords: ['data', '3D', 'virtual', 'systems']

## Virtual World Platforms & User Generated Content

Being a platform, these services offer metaverse developers an environment in which they can develop and publish their virtual experience, which can be explored by the platform’s users . As of today, a multitude of these platforms exist, with popular examples being Roblox , Decentraland, Second Life, The Sandbox, Spatial and Fortnite . Such assets are referred to as user-generated content (UGC) and encompass all virtual assets created by the platform’s users rather than the platform itself. While most video games do not provide any official means to create UGC, metaverse platforms, which try to promote UGC, incorporate various kinds of UGC editors. Such editors provide a toolkit for users to create UGC within the platform and without the need for third-party software. The editor’s functionality varies from platform to platform and can mainly be differentiated by the degree of autonomy it allows its users. Roblox offers its Roblox Studio editor, which includes a visual editor and scripting functionality . Similarly, Decentraland offers a basic visual builder tool as well as a software development kit (SDK) for more advanced content . Other tools such as The Sandbox’s Game Maker do not require any programming skills . The combination of a virtual world and the tools to construct it has been called an Integrated Virtual World Platform (IVWP) by Matthew Ball in his book “The Metaverse

Keywords: ['UGC', 'virtual', 'platform', 'metaverse']

# Methodology

As such, this section will describe the development and implementation of a white-label shopping solution for the metaverse. Following the introduction, the focus will switch to the actual implementation of the solution, starting with the development process and the technologies utilised to build the solution.

Keywords: ['solution', 'section', 'development', 'overview']

## Context & Motivation

The department has had previous metaverse experience with its Worldline Showroom, a virtual space within the Decentraland platform, used to display and promote the Worldline brand and certain solutions. Within the payments industry, processors and acceptance providers such as Worldline traditionally operate within the realm of physical in-store payments and e-commerce. While these channels are already being utilised and are characterised by a competitive landscape, the metaverse and more specifically v-commerce, represents a new and unexplored channel. With consumers spending more time in virtual spaces, spending in these spaces has increased as well. Additionally, the metaverse platform Roblox has generated transactions exceeding USD 14 billion in 2018-2020 . Worldline and companies like it, recognize a significant opportunity to establish v-commerce as a third major payments channel, in which they can offer payment acceptance solutions. Hence, the white-label metaverse solution can be seen as Worldline's initial steps in establishing itself as a major player in the emerging metaverse space and the v-commerce channel.

Keywords: ['metaverse', 'Worldline', 'payments', 'solution']

## The Solution

To this end, the white-label solution has taken on the shape of a virtual mall, comprising individual stores, which serve as the solution’s white-label component. Upon entering the mall, users can view the products displayed in the stores, receive information on them, and are able to purchase them. For the launch of the initial solution, which is covered in this thesis, the virtual mall offers a maximum of 15 stores. In addition, the mall building features a virtual event space, which can be utilised to host as well as live stream events. Regarding the platform, users can access the virtual mall on the Decentraland metaverse platform, which it was specifically developed for. While the social functionalities are limited for guest users, this takes away an entry barrier, especially for new users. Like many other platforms, Decentraland has its own cryptocurrency called MANA, which is an Ethereum-based token that can be used to make purchases within the platform. Ownership of the land, as well as other assets, is handled through the Ethereum blockchain, where the ownership of each parcel is tracked as a unique token or NFT. With their purchased parcels, landowners can utilise the land as they please, either building their own virtual space or renting the space to other users. Land rentals are supported by Decentraland, which offers users access to a virtual marketplace, where landowners are able to create listings. Like in real-world real estate markets, prices and rental periods are decided upon by the owners and are thus influenced by supply and demand. This leads to parcels in highly frequented regions demanding higher rents and prices than those in less frequented regions, typically those furthest from the centre of the virtual world. As the virtual mall housing the stores is supposed to contain 15 stores, multiple parcels were required for the solution. While the 4x2 plot is only able to accommodate five stores, landowners can build vertically to maximise the use of their space. Thus, the mall was conceived as a four-floor building, with the first three floors containing the white-label stores, and the top floor being utilised as the event space.

Keywords: ['virtual', 'users', 'Decentraland', 'stores']

## Business Model

Within worldlines virtual mall, customers are quickly able to set up a store, which will be customised to fit the company's look and feel. Furthermore, Worldline can help customers set up targeted metaverse advertisements as well as phygital, AR and VR versions of their products. Given that the stores are being maintained and run in the customer’s name, it is essential to provide each customer with personalized support. As each customer will be managed personally, the account manager will be their primary contact, with which they can discuss changes and improvements to their store. Establishing such direct and clear communication channels will help strengthen the customer relationship and help create cross-selling opportunities within the white-label solution or for other Worldline products. The development of the solution, including the initial design, as well as the implementation, will be the main value-creating activity. With the base solution developed, implementing individual stores, and adjusting them to meet the customers' expectations will be key. Furthermore, after the first iteration of the solution is completed, development on the solution will continue with the aim of implementing further improvements and features. The solution uses a subscription-based revenue model, in which customers pay a recurring fee to gain access to a shop inside the virtual mall. The standard subscription plan includes a single store that Worldline will implement according to the client's preferences, including the products and adverts they want to incorporate. However, customers have the choice to buy additional add-ons. Additionally, as Worldline provides the means of accepting fiat currencies within the Decentraland platform, customers will be charged a transaction fee for each successful purchase.

Keywords: ['solution', 'customers', 'Worldline', 'business']

## Solution Development

This will include the development process, requirements and design artefacts that culminated in the final launch product. Subsequently, the requirements of the solution will be defined followed by a review of the design artefacts used to meet each requirement.

Keywords: ['development', 'process', 'section', 'solution']

## Development Process

Starting from the beginning, the identification of functional and non-functional requirements was an essential first step in creating a blueprint for the implementation of the solution. Requirements were identified through multiple brainstorming sessions, which included the developers, the project manager and other relevant stakeholders. The resulting requirements were documented and ranked in terms of priority and mapped to one or multiple design artefacts. While most requirements were defined during the initial analysis, further requirements were added during the preceding implementation phase. With the requirements mapped to individual design artefacts, the implementation of the base solution was started. In terms of the duration of the project, this phase was the most time-consuming. Within weekly sprints, artefacts were picked with respect to their priority, implemented and presented to the project owner. With nine initial slots sold, the mall was launched onto the live Decentraland servers.

Keywords: ['requirements', 'solution', 'implementation', 'launch']

## Technology Stack

Being a superset, all valid JavaScript code is also valid TypeScript code, making the transition from JavaScript to TypeScript very easy. Furthermore, the addition of types increases the readability of the code, thereby easing future modifications. While the platform itself is built on top of the Unity game engine, Decentraland requires developers to utilise its software development kit (SDK) to develop for the platform. It requires the use of TypeScript and utilises an entity-component-system architecture with the addition of some basic object-oriented elements. VS Code is the recommended code editor for Decentraland development and offers the official Decentraland Editor extension, which can be installed from the VS Code extensions tab. It provides an extensive 3D creation suite featuring 3D creation functionality such as 3D modelling, animations, rendering etc, which are utilised for the creation of 3D models . Within the development process, Blender was used for 3D modelling, 3D animations as well as the editing of existing models. The tool was especially effective in decreasing triangle counts of 3D models, with its built-in Decimate modifier, which was often necessary to remain below the scene resource limitations. Inkscape is a vector graphics editor that is utilised to create and edit vector images as well as other image formats. Like Blender, Inkscape is an open-source software and completely free of charge. While customers received a template stating the exact specification, many of them supplied their marketing material in the wrong formats and dimensions. Inkscape was used to reformat such images to meet the exact requirements, while not compromising image quality. Moreover, the tool was used in conjunction with Blender, which can utilise vector graphics as the base for 3D models. Inkscape offers a multitude of options for tracing vector images from bitmaps. Using these capabilities, customers' marketing material could be imported to Blender, where it was used to create 3D models. The Awesome Repository is a publicly available GitHub repository that was created by the Decentraland DAO and has been maintained and extended by community contributors . The repository links to over 50 Decentraland scenes, which act as examples of how common features can be implemented. As the Decentraland documentation is rather limited, these example scenes were an extremely helpful resource during the implementation. In addition, all assets used in the repository, such as 3D models and textures, are publicly available.

Keywords: ['3D', 'Decentraland', 'TypeScript', 'development']

## Solution Requirements

While requirements will be explained in this section, the implementation of design artefacts will be covered in section 3.2.3. Requirements were grouped using the five design requirement categories for virtual commerce platforms proposed by Shen et al. .

Keywords: ['design', 'requirements', 'artefacts', 'requirement']

## Forms of Immersive Technology: Accessible Virtual Space

In order to provide a sense of immersion and an engaging experience, users must be able to move freely within this space without being limited to any fixed paths. This should result in a user-friendly experience, which encourages potential new users to try out the solution.

Keywords: ['users', 'space', 'solution', 'virtual']

## Interface: Sense of Presence

In terms of the store’s offerings, the products on display must look and feel authentic. Additionally, these should allow the user some degree of interactivity and provide responsive feedback, adding to the 3D authenticity.

Keywords: ['user', 'mall', 'store', 'sense']

## Interface: Scalability

The interface, in this case, refers to the visual appearance of the mall and the virtual stores it showcases. Therefore, the interface must provide the flexibility to display relevant virtual stores to the users based on their respective regions. Additionally, stores should be implemented in a clean and maintainable manner, which supports fast adjustments and quick customer onboarding.

Keywords: ['solution', 'stores', 'virtual', 'interface']

## Performance: Resource Management

The platform has set these limits for performance reasons, to ensure that the world's overall performance is not limited by certain scenes that require extensive rendering. Furthermore, as parcels are only counted on the two horizontal axes, scenes with multi-floor buildings, such as the mall, receive even fewer resources per building floor. Since scenes that exceed these limits will not be rendered, managing the available resources efficiently is a basic functional requirement.

Keywords: ['scene', 'resources', 'parcel', 'platform']

## Performance: Scene Performance

Having a smooth frame rate is of utmost importance for the solution, as it influences usability as well as the immersive experience. Users experiencing low frame rates will find it difficult to navigate and interact with the environment, which makes for a frustrating experience. Achieving an expectable frame rate is thus a functional requirement, while high framer ates, that increase the level of immersion, will be seen as a qualitative requirement.

Keywords: ['frame', 'scene', 'requirement', 'performance']

## Intelligence: Modular Store Design

Component modules must be created for the store's branding, products, advertisement, social media and video and audio options. Additionally, the stores themselves should be implemented as self-contained modules that can easily be moved around without any effect on the store’s interior.

Keywords: ['store', 'modules', 'Stores', 'modular']

## Function: Payment Integration

Therefore, the solution must offer store owners the option of accepting regular fiat currency from within their virtual store. The integration of the payment acceptance method should be as seamless and convenient as possible and conducting a transaction should not require the user to leave the platform.

Keywords: ['platform', 'store', 'virtual', 'cryptocurrency']

## Function: User Analytics

Furthermore, the collected data should offer insights into user behaviour, such as the preferred areas and stores of the mall. These insights will help monitor the solution's performance in terms of usage and provide a better understanding of user preferences, which will help inform future design decisions.

Keywords: ['user', 'solution', 'usage', 'preferences']

## Implementation

The following table provides an overview of all solution requirements, which have been clustered using the requirements categories proposed by Shen et al. . These artefacts will be covered in this section, with the focus lying on their implementation and how they met their matching requirement.

Keywords: ['requirements', 'implementation', 'requirement', 'section']

## Virtual Shopping Mall

As figure 9 shows the mall building constitutes the root element of the scene and contains four direct sub-scenes in the form of the building’s floors. Each floor scene, except for the event space, contains a total of five stores, which was the maximum number the land plot could accommodate. Concerning the modelling, it was decided to create individual building components, such as the walls, floors, glass, and the roof, as opposed to a single building model. While this required the components to be individually arranged, subsequent changes to the building would be easier to make. This was made use of to implement multiple operating modes through which the building could quickly be switched from three to four floors, depending on customer demand. In terms of the buildings' look and feel, glass materials were used on the street phasing sides, allowing users to view the stores from the outside. A detailed explanation of the design features will be given in the following section and additional pictures of the mall exterior and interior are available in the appendix.

Keywords: ['building', 'mall', 'scene', 'floors']

## Mall Atmospherics and Layout

In order to build an experience, which creates these sensations, multiple pathfinding, environmental and product presentation features were implemented to promote the scenes' atmospheric design.

Keywords: ['features', 'Virtual', 'store', 'atmospherics']

## Environmental features

Thus, in terms of the building’s facade, glass materials were used whenever possible, with the addition of wooden materials on the building’s backside and floors. In addition, neon light strips were utilised to outline the building's edges, giving it a distinct look. While each floor utilises Decentralands global light source, the store’s interior received additional light sources, making for a much brighter environment. The additional lighting helps users view the 3D models within the stores, as these look more vibrant with additional lighting. As stores were individually configured, content varied from store to store.

Keywords: ['building', 'lighting', 'store', 'theme']

## Product presentation features

These product types can vary from product to product, allowing stores to display a combination of them. Product information is displayed by hovering over the product, in form of a short description, and by clicking the product, which leads to a specified description page. In addition, custom components and systems were implemented to bring products to life and increase 3D authenticity. This included the addition of animation systems to add rotation as well as vertical and horizontal movements to products.

Keywords: ['product', 'products', 'features', 'information']

## Pathfinding features

This includes an overview of the mall at the mall's entrance, showing users which stores are located on each floor. Additionally, signs pointing players to the teleporters were utilised as using these to switch floor levels is not as obvious as the use of stairs. While customers are able to choose the exact layout of their store, a standard store layout was proposed. While customers can request other layout options such as a grid or freeform layout, this layout was chosen as it promotes an intuitive store traversal. Additionally, dividing products between the centre and outside of the store limits the amount of visual clutter.

Keywords: ['layout', 'stores', 'floor', 'store']

## Geo-Location

As such the geoPlugin API was chosen, which offers access to an encrypted API endpoint for a small yearly subscription. Using this information, the database is queried for the respective regions' store data. The data is returned by the function and further utilised to render the stores for the user. At the time of writing, geo-location specific stores are not yet being utilised as there is simply no demand for them at present. However, should specific regions display interest in the future, this is an effective measure to easily scale the solution to additional customers. Additionally, users could be given the option of switching to different regions, after initially being shown the stores in their region, further increasing the amount of content.

Keywords: ['API', 'location', 'solution', 'regions']

## Scene Management

After building and store contents were initially implemented, the scene exceeded the triangle, material, and texture resource limits by more than double, meaning it could not have been deployed. The scene management module provides a framework which allows the scene to be divided into multiple sub-scenes, which can be individually managed in terms of rendering. This is done through the SubScene-class, which represents sub-scenes as invisible box entities, referred to as trigger entities or trigger areas. Using these events, allows sub-scenes to be rendered only when the user sees them, i.e., when the user enters the trigger area. Furthermore, sub-scenes can use two lazy load strategies, which are specified through a flag within the BaseEntityWrapper class. Depending on the chosen strategy the sub-scene entity is either completely removed from the engine while not visible or is kept in the engine but not rendered. These strategies provide different benefits and make use of the fact that most scene resource limits only apply to entities that are rendered. Alternatively, the sub-scene can remain in the engine but remain invisible while not being viewed. Using this setup gives full control over the sub-scene lifecycle, from the scene’s initialisation on to all subsequent visits by the user. The possibilities further increase when considering how these strategies extend to the entities that live within the sub-scene. The SubScene-class can manage entities, which upon being added to the sub-scene are wrapped into an EntityWrapper-object. As figure 11 shows, the EntityWrapper-class, like the SubScene-class, extends the BaseEntityWrapper, giving entities within sub-scenes access to the rendering strategies described above. This is very powerful as it allows for some interesting combinations of loading and rendering strategies on the sub-scene and entity levels. Utilising this framework, each building floor was implemented as its own sub-scene, leaving the building’s facade as the only statically loaded model. Utilising sub-scenes within sub-scenes saved additional scene resources, as models within the stores only require rendering when the user is in viewing distance. In sum the scene management and the lazy loading it allows reduced the scenes resource usage by almost 70 %, which was crucial in complying with the resource limitation. The implementation was a very laborious process, as the scene was initially implemented without any kind of lazy loading in mind and the integration required fundamental reworks. Developers building resource-intensive scenes should as such consider integrating this approach from the ground up.

Keywords: ['scene', 'sub', 'scenes', 'engine']

## Modular Stores

With the scene containing up to 15 stores, each containing over ten entities, it was essential to use a structured approach to manage the scene's content. Content modules were defined for every configurable aspect of the store, resulting in five modules at the time of launch. These modules include the product, branding, advertising, social media, and media module. Since the same script is used for all stores, separating these components minimises code duplications as well as the implementation, and modification effort. With the individual content modules implemented, this approach was further expanded to the store level. Instead of directly adding each module to its respective store, modules are packaged into a single content package, which is set as a child entity of the store entity. This information is then used by the implementation script to add the package to the correct store. Separating the base store from the content package was an advantageous approach during the implementation of customer stores, particularly in light of the frequent alterations to the store arrangement.

Keywords: ['store', 'content', 'entities', 'modules']

## Payment Links

The payment links are created using Worldlines online payment solution Saferpay, which is commonly utilised for accepting payments in e-commerce use cases and business applications. The solution also enables merchants without online shops to include payment links in their invoices, which their customers use to pay . As with regular Saferpay transactions, Worldline will receive a transaction fee for every successful transaction.

Keywords: ['payment', 'links', 'solution', 'virtual']

## Crypto ATM

Like other cryptocurrencies, MANA can be bought on various popular crypto exchange platforms, which requires users to access another platform. Through these ATMs, users can add the necessary funds to their crypto wallets from within Decentraland. The ATMs offer a user interface where users can choose whether they would like to buy or sell currency. For users, this is an easy way of buying the necessary MANA funds, which they can spend within the mall or in any other scene. Within the SDK the ATMs are represented as custom entities, that extend the base entity class, and encapsulate business logic and further entities.

Keywords: ['ATMs', 'MANA', 'users', 'crypto']

## Atlas Analytics

While these metrics do offer some form of insights, they are limited in scope as they only capture weekly users, sessions, and the peak number of concurrent users. Metrics include the number of scene users, their geographic origin, the percentage of guests versus registered users, a scene traffic heat map, as well as device, and browser statistics. This was utilised to track users’ movement between the building's floors as well as how often displayed products were clicked. In terms of integration, the platform presently does not offer an API or npm package. The necessary source code file can be downloaded from the platform's public GitLab repository and has to be placed in the project's source directory. This gives developers access to the platform’s custom component, which will track the scene as well as the specified events, as mentioned above. While the manual integration, without a npm package, is not optimal, the setup was simple, only requiring basic modifications to the custom component.

Keywords: ['platform', 'users', 'analytics', 'scene']

# Analysis

After almost two and a half months of development time, the white-label metaverse solution was launched on the eighth of March 2023 in Decentraland. These results will be followed by a discussion and analysis of the results.

Keywords: ['solution', 'results', 'half', 'months']

## Customers

As mentioned above, a total of nine stores were implemented at the time of launch, which included eight customer stores as well as one store operated by Worldline itself. As such the building was launched with three total stories as opposed to four, with a total of six further stores available for rental. Looking at the company’s origin, all companies, except for the Australian merchant Naked Life, have European origins with five of the eight customers originating from either Switzerland or Germany.

Keywords: ['store', 'total', 'stores', 'customers']

## Store configuration

Going on to the media module, customers had the option of adding triggered videos and audio elements to their store. This module was utilised by all but three customers, who used neither video nor audio elements. Out of the remaining six that did use the media module, four stores used the video and music options in combination, while two included only videos. With regards to the advertisement module, stores could make use of two advertisement spaces, that can each rotate four advertisement banners. The module was made use of by all stores except SNGLR, which chose to utilise this store space for NFTs. Lastly, the social media module was utilised by all customers, who used the social elements to direct users to their social media pages. Instead, they chose to redirect users to the listing of the product on their company’s website. Furthermore, when it came to store layout, all customers used the standard layout proposed by Worldline.

Keywords: ['stores', 'module', 'customers', 'store']

## User metrics

Within the first three weeks, the scene was visited by a total of 145 users, leading to a weekly average of 48 users. Most notably, user numbers peaked during the launch week and declined in the following weeks. This also applies to the maximum concurrent users, which similarly declined after the initial launch week. However, the data shows a slight trend towards wallet users following the launch. Lastly, with an overwhelming majority, 95 % of users accessed the scene through Decentraland’s web application, while only 5% utilised the client.

Keywords: ['users', 'launch', 'scene', 'weeks']

## Discussion

As the solution is the company's first commercial venture into the metaverse, the development of the solution, brought with it several unknowns. Additionally, in terms of company size, the results suggest that SMEs could be a main target segment, which comes back to the aspect of limited resources. While brands see value in the white-label solution, it is unclear whether consumers see any appeal in this kind of virtual experience, as suggested by the low user numbers. However, the user statistics collected as part of this thesis are too limited to draw any conclusion. Furthermore, the total user numbers are hard to interpret, as these statistics are not publicly available. As such there are no reference values from other Decentraland scenes, which could be used as a basis for comparison. Further research could examine how user statistics develop over time, to find out how much consumers demand virtual shopping experiences. While the launch of the solution was an initial success, the focus of this thesis is on the implementation of the solution. The challenges in this project were mainly present due to a lack of prior experience with the platform and more specifically the game development design patterns it utilises. While the ECS architecture offers a lot of modularity, there is a learning curve for developers accustomed to an object-oriented approach. It is thus highly recommended to make use of all additional resources provided by the Decentraland community, such as the Awesome Repository and the Decentraland Discord channel. Furthermore, the challenge associated with creating virtual experiences also lies in the broad skill set it demands. Regarding the solution development, the process was initiated with a thorough requirements analysis. Scene management in particular was an essential aspect of the solution and enabled a more controllable and intelligent allocation of scene resources.

Keywords: ['solution', 'development', 'Decentraland', 'metaverse']

# Conclusion

The creation of such spaces has been facilitated by virtual platforms such as Roblox and Decentraland, which lower the entree barrier by offering users integrated content creation tools. To address the research question, a virtual shopping mall solution was developed for the metaverse platform Decentraland. This solution aimed to offer customers a virtual white-label store, which they are able to configure using their branding and the products and advertising elements they want to display. The design of this solution required an initial requirements analysis, which was used to define the immersive technology, interface, performance, intelligence, and function requirements of the solution. While additional requirements had to be added as development started, all requirements were implemented within the set timeframe. The implementation was followed by the successful launch of the solution with a total of eight customers renting a store within the mall. Furthermore, limited user statistics imply that consumers who visit the virtual space are willing to spend up to 22 minutes within virtual shopping spaces. However, in terms of user numbers, the initial demand was low, with only 145 users visiting the mall over the first three weeks.

Keywords: ['virtual', 'solution', 'metaverse', 'Decentraland']

# Critical Appraisal

Due to the limited time and scope, this thesis is only based on the implementation of the Worldline white-label metaverse solution and its launch. Due to the lack of time, only limited data could be collected following the launch of the solution. Going forward, further user statistics will be collected to get a better understanding of how many monthly users the solution can attract.

Keywords: ['thesis', 'Metaverse', 'solution', 'project']