VILNIUS UNIVERSITY
BUSINESS SCHOOL

DEEPTECH ENTREPRENEURSHIP

Kasparas Kralikas

THE FINAL MASTER'S THESIS

Leveraging 3D Object Capture Technologies in C2C Marketplaces	***3D objektų atkūrimo technologijų įsisavinimas vartotojas-vartotojui tipo internetinėse prekyvietėse***

Supervisor: **lect. Jurgita Petrauskienė**

Vilnius, 2024

Summary

VILNIUS UNIVERSITY BUSINESS SCHOOL
DEEPTECH ENTREPRENEURSHIP STUDY PROGRAMME
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Supervisor – lect. Jurgita Petrauskienė
Master thesis was prepared in Vilnius, in 2024.
Scope of Master's thesis – 60 pages.
Number of tables used in the FMT – 1 pc.
Number of figures used in the FMT – 15 pcs.
Number of bibliography and references – 76 pcs.

The FMT described in brief:

This study investigates the integration of 3D object capture and virtual item preview technologies in consumer-to-consumer (C2C) e-commerce marketplaces, a less explored area compared to business-to-consumer (B2C) sectors. Focusing on the challenges and opportunities of implementing these technologies, the research combines a literature review, case studies of B2C pioneers like IKEA, eBay and Shopify as well as an analysis of consumer behavior and technology trends. Findings highlight a technological gap between consumer and professional-grade solutions but also indicate a trend towards more accessible 3D scanning technologies. A key contribution is a proposed business model extension for Vinted, introducing a consignment service for high-value fashion items with professional 3D object capture, as a result effectively mitigating current technological limitations. The study concludes that while there are significant opportunities for enhancing customer experiences in C2C platforms, success depends on overcoming technological barriers and aligning with strategic business objectives.

Problem, objective and tasks of the FMT:

Problem: How can 3D item preview and virtual try-on technologies be effectively transferred and adopted in C2C marketplaces for enhanced customer experience and competitiveness?
Objective (the aim of the work): identify key opportunities and challenges in adopting 3D object capture technologies within C2C marketplaces and propose an actionable strategy for their effective implementation.
Tasks:

1. Examine existing literature and studies on 3D object scanning, item preview, virtual try-on technologies and its adoption in e-commerce platforms.
2. Perform a multi-faceted case study of companies that successfully adopted the aforementioned technologies.
3. Analyze the leading technologies and state-of-the-art research prototypes in 3D/AR/VR tech field.
4. Identify changes in consumer habits concerning 3D/AR/VR consumption and assess their impact on e-commerce.
5. Propose a business model extension for a specific C2C marketplace focusing on the adoption of these technologies.

Research methods used in the FMT: Literature analysis, secondary data analysis, and comparative analysis of B2C marketplaces, SWOT, Ansoff Matrix, and Gap analysis for a selected C2C marketplace to develop a business model extension.
Research and results obtained: This research identified a significant gap between consumer and professional-grade 3D object capture solutions, identified promising prototypes as well as current technologies for immediate use, and analyzed key trends in strategic use of 3D/AR/VR technologies. It also observed an increasing consumer interest in these technologies and proposed a business model extension for Vinted to mitigate current technological limitations.
Conclusions of the FMT: The thesis concludes that while 3D object capture technologies offer significant opportunities for C2C marketplaces in enhancing customer experience and operational efficiency, their success depends on overcoming current technological challenges and strategic alignment, with the proposed model for Vinted effectively addressing these issues and preparing marketplaces for wider adoption as the technology becomes more consumer-friendly.

Santrauka

VILNIAUS UNIVERSITETO VERSLO MOKYKLA
AUKŠTŲJŲ TECHNOLOGIJŲ VERSLO STUDIJŲ PROGRAMA
KASPARAS KRALIKAS

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Literatūros šaltinių skaičius darbe – 76 vienetai.

Trumpas darbo aprašymas:

Šis darbas tiria 3D objektų atkūrimo bei virtualių daiktų peržiūros technologijų integraciją vartotojas-vartotojui (C2C) tipo e-komercijos platformose. Tai mažiau nagrinėta niša lyginant su verslas-vartotojui (B2C) sektoriumi. Fokusuodamasis į šių technologijų implementavimo iššūkius bei galimybes, šis tyrimas apima literatūros analizę, konkrečių įmonių, tokių kaip IKEA, eBay ar Shopify, atvejų nagrinėjimą bei vartotojų elgsenos ir technologijų tendencijų analizę. Darbo rezultatai bei išvados indikuoja ženklią technologinę atskirtį tarp įprastiems vartotojams skirtų ir profesionalams skirtų technologijų, bet taip pat atskleidžia tendencingą artėjimą prie lengviau įprastiems vartotojams prieinamų 3D skenavimo technologijų. Kertinis darbo rezultatas yra Vinted įmonei skirtas verslo modelio plėtros pasiūlymas. Siūloma įdiegti konsignacijos servisą aukštos vertės naudotoms žinomų dizainerių prekėms, kuris apimtų profesionalų įmonės viduje vykdomą 3D objektų atkūrimą. Tokia verslo modelio plėtra sėkmingai apeitų esamus technologinius ribojimus. Tyrimas prieina išvadą, jog rinkoje jau egzistuoja sprendimų, galinčių reikšmingai pagerinti vartotojas-vartotojui tipo e-komercijos platformų vartotojų patirtį, bet įsisavinimo sėkmė ribojama technologinių barjerų bei suderinamumo su bendraisiais verslo siekiais.

Darbo problema, tikslas ir uždaviniai:

Problema: Kaip 3D daiktų peržiūros bei virtualaus pasibandymo technologijos gali būti efektyviai pritaikytos vartotojas-vartotojui tipo e-komercijos įmonėse, siekiant pagerinti vartotojų patirtį bei įgyti konkurencinį pranašumą?

Tikslas: identifikuoti kertines galimybes bei iššūkius pritaikant 3D objektų atkūrimo technologijas vartotojas-vartotojui tipo e-komercijos įmonėse bei parengti šių technologijų efektyvaus pritaikymo strategiją.

Uždaviniai:

1. Išnagrinėti esamą mokslinę literatūrą bei tyrimus apie 3D objektų atkūrimą, 3D daiktų peržiūrą bei virtualaus pasibandymo technologijas ir jų pritaikymą e-komercijos platformose.
2. Atlikti įmonių, kurios sėkmingai pritaikė šias technologijas, atvejų analizę.
3. Išanalizuoti pažangiausias technologijas ir naujausius mokslinius prototipus 3D/AR/VR technologijų srityje.

4. Identifikuoti vartotojų įpročių pokyčius, susijusius su 3D/AR/VR technologijų naudojimu, ir įvertinti jų poveikį e-komercijai.
5. Parengti verslo modelio išplėtimo pasiūlymą pasirinktai vartotojas-vartotojui tipo e-komercijos įmonei, skirtą efektyviai pritaikyti 3D objektų atkūrimo technologijas.

Naudoti tyrimo metodai: Literatūros analizė, antrinių duomenų analizė ir lyginamoji įmonių analizė, SWOT, Ansoff matricos bei kertinių trūkumų analizė pasirinktai įmonei, siekiant sukurti verslo modelio plėtinį.

Tyrimo rezultatai: Šis tyrimas identifikavo reikšmingą atskirtį tarp įprastiems vartotojams prieinamų bei profesionalių 3D objektų atkūrimo technologijų bei produktų, identifikavo potencialius mokslinius prototipus bei egzistuojančias technologijas, tinkamas dabartiniam panaudojimui, išanalizavo kertines 3D/AR/VR technologijų strateginio panaudojamumo versle tendencijas. Tyrimas taip pat atskleidė didėjantį vartotojų susidomėjimą šiomis technologijomis bei pasiūlė išplėsti „Vinted“ verslo modelį, sušvelninantį esamas technologines limitacijas.

Darbo išvados:

Pagrindinė darbo išvada – 3D objektų atkūrimo technologijos vartotojas-vartotojui e-komercijos verslams gali reikšmingai pagerinti vartotojų patirtį bei padidinti verslo procesų efektyvumą. Visgi, technologijų įsisavinimo sėkmė priklauso nuo esamų technologinių limitacijų bei suderinamumo su strateginiais verslo siekiais. Pasiūlytas Vinted verslo modelio išplėtimas sėkmingai išsprendžia pagrindinius iššūkius ir paruošia įmonę sėkmingam ateities augimui, kuomet technologijos taps labiau prieinamos įprastiems vartotojams.

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List of Abbreviations

AR. Augmented Reality – a technology that superimposes a computer-generated image on a user's view of the real world, thus providing a composite view.

VR. Virtual Reality – a simulated experience that can be similar to or completely different from the real world.

VTO. Virtual Try-On – a technology that allows users to virtually try on various items like clothes, glasses, or accessories using digital devices.

3D/AR/VR. Umbrella Term for Digital/Augmented/Virtual Medium – collectively refers to technologies that create or enhance digital, augmented, and virtual experiences, often in a three-dimensional space.

C2C. Consumer-to-Consumer – A type of e-commerce where consumers trade products, services, or information with each other, typically facilitated by a third-party platform.

B2C. Business-to-Consumer – A type of e-commerce where businesses sell products or services directly to consumers, typically through online platforms.

LiDAR. Light Detection and Ranging – A method for measuring distances by illuminating the target with laser light and measuring the reflection with a sensor.

API. Application Programming Interface – A set of routines, protocols, and tools for building software and applications, facilitating communication between different software components.

1. Introduction

The rapid expansion of digital medium and augmented/virtual reality (AR/VR) technologies has a major impact across various industries, including the e-commerce field. Research findings back up the positive affects of 3D item previews and virtual try-ons and suggest an increase in buyer confidence, perception of usefulness and enjoyment (Zhang, Dr Wang, et al., 2019). At the same time, it has the potential to significantly reduce product returns, suggesting the practical potential of such technologies to optimize business processes and operational costs (Hwangbo, Kim, et al., 2020). However, the majority of 3D item preview and virtual try-on technology adoption is happening within business-to-consumer (B2C) type e-commerce marketplaces. There is a notable gap in research and technology adoption regarding consumer-to-consumer (C2C) e-commerce marketplaces. The underlying critical dependency for 3D item previews and virtual try-ons is effective 3D object scanning and recreation capability which is not yet mature enough to be easily accessible for regular consumers (Han et al., 2021). Thus, the current technological development trends suggest that C2C marketplaces will significantly lag behind B2C marketplaces in terms of 3D/AR/VR tech adoption. This thesis aims to address this gap by investigating the practicalities and implications of leveraging 3D object capture technologies in C2C marketplaces.

The novelty of this research lies in its focus on a less explored niche in the e-commerce field - C2C marketplaces — and aims to provide practical suggestions for the successful integration of 3D item preview and virtual try-on features in such marketplaces.

The primary problem this research aims to solve is: How can 3D object capture and virtual try-on technologies be effectively transferred and adopted in C2C marketplaces for enhanced customer experience and competitiveness?

1.1. Aim of the Work

This thesis aims to identify key opportunities and challenges in adopting 3D object capture technologies within C2C marketplaces and propose an actionable strategy for their effective implementation.

1.2. Objectives

To achieve the aim mentioned above, the following objectives have been set:

1. Examine existing literature and studies on 3D object scanning, item preview, virtual try-on technologies and its adoption in e-commerce platforms.
2. Perform a multi-faceted case study of companies that successfully adopted the aforementioned technologies.
3. Analyze the leading technologies and state-of-the-art research prototypes in 3D/AR/VR tech field.
4. Identify changes in consumer habits concerning 3D/AR/VR consumption and assess their impact on e-commerce.

5. Propose a business model extension for a specific C2C marketplace focusing on the adoption of these technologies.

1.3. Research Methodology and Scope

The first part of the study will focus on literature analysis of recent academic research. The analysis will focus on overview of 3D/AR/VR technologies - the evolution, historical and recent adoption within e-commerce companies. The literature analysis will also cover technology adoption theory to better understand business-level drivers and implications of aforementioned technology adoption. Finally, research on different business strategies for practical technology adoption is analyzed.

The second part of the study will focus on in-depth secondary data analysis of B2C marketplaces that could inform strategies for C2C platforms. The data sources will include recent academic research, industry reports, company press releases and independent case studies. Comparative analysis will focus on comparing and contrasting how different e-commerce platforms have implemented 3D object capture and virtual try-on technologies, noting the outcomes, challenges, and various strategies employed. The main focus will be on understanding the key factors that contributed to the successful integration of these technologies and the obstacles that were encountered with the ultimate goal of translating the findings for adoption in C2C marketplaces. To deepen the analysis, the study will investigate the latest technological and consumer behavior trends in 3D object capture and AR/VR technologies, focusing on advancements that are particularly relevant to e-commerce field. A specific C2C marketplace will then be selected as a research subject. The selected C2C marketplace will be researched using SWOT, Ansoff Matrix and Gap analysis. The data collected and insights made will then be used as a basis for preparing a business model extension for a selected C2C marketplace.

1.4. Research Questions

1. What are the driving factors behind the adoption of 3D object capturing and virtual try-on technologies in online marketplaces?
2. How are specific companies like eBay, Shopify, and Ikea utilizing existing technology, and what can C2C platforms learn from them?
3. What are the current leading technologies and state-of-the-art prototypes in the field of 3D/AR/VR tech?
4. How are consumer habits evolving concerning AR/VR technologies, and what is the impact of early adopters in shaping these habits?
5. How can such technological adoption lead to improved customer experiences, increased sales, and reduced returns in both B2C and C2C platforms?

1.5. Structure of Work

1. Introduction: Setting the scope and outlining objectives, tasks, and methodologies.
2. Literature Review: Examining existing research on 3D object capturing and its role in e-commerce, including prototypes and productization.
3. Case Study of Companies: In-depth evaluation of how specific companies have successfully utilized 3D object capture and AR/VR technologies.
4. Analysis of Leading 3D/AR/VR Technologies: In-depth evaluation of leading technological research and prototypes.
5. Consumer Behavior Analysis: Examining the role of AR/VR technologies in shaping consumer habits, with a specific focus on e-commerce and the influence of early adopters.
6. Business Model Extension: Outlining how a specific C2C platform can integrate these technologies effectively based on the findings from previous research steps.
7. Conclusions: Summarizing the key findings of the research.

1.6. Practical Implications

This study aims to provide C2C platforms with insights and actionable strategies for adopting 3D object capture, 3D item preview and virtual try-on technologies. By gaining deeper understanding about technological adoption journey of B2C platforms, C2C marketplaces can utilize these findings for their own needs and gain a competitive advantage.

1.7. Difficulties and Limitations

One of the major challenges encountered during this study includes the limited availability of private sector data – on internal business strategy and technological details. Additionally, the rapidly evolving nature of 3D/AR/VR technologies might outdate the current research quickly.

2. Literature Review

2.1. Overview of 3D/AR/VR Technologies

The roots of VR technology can be traced back to 1962 when Morton Heilig created and patented the first stationary virtual reality machine called Sensorama that was capable of stimulating multiple senses, offering a 3D visual display, stereo sound, and even aromas and wind to immerse the viewer in a multisensory experience as published in (Heilig, 1962). The next major step was the "Sword of Damocles" - it was one of the first head-mounted displays (HMDs) for virtual reality, developed in 1968 by Ivan Sutherland and his student Bob Sproull at the University of Utah (Boas, 2013). The name "The Sword of Damocles" was chosen because of the way it was suspended from the ceiling hanging over the user's head, similar to how a sword hanging by a single thread or horsehair directly above Damocles' head in the well-known legend.

The next breakthrough for VR technology was the move toward more practical applications. The most notable milestone in 1986 was achieved by Dr. Thomas Furness, often referred to as the "grandfather of virtual reality, who developed the "Super Cockpit" - a high-tech flight simulator for the U.S. Air Force. This was an advanced human-computer interface designed to improve the performance of the airforce pilots. The Super Cockpit utilized immersive multi-sensory (primarily visual and auditory) displays, voice recognition, touch panels, and even force feedback mechanisms to allow pilots to control and interact with the aircraft more intuitively and rapidly. The main goal was to improve situational awareness and response times in complex combat scenarios. The project was one of the most significant early steps in developing virtual reality technologies for practical applications (Baumann, 1993).

After the initial conceptualizations and first practical adoptions, it came time for consumer-level adoption. In 1995, the Nintendo Virtual Boy was among the first consumer-oriented products marketed with a "virtual" experience in mind. The Virtual Boy was intended to create a unique 3D gaming experience by displaying red monochromatic graphics using stereoscopic 3D technology. The player would place their head and eyes up with the console, similar to a set of binoculars. However, due to its very limited color palette and graphics, lack of portability, discomfort during use, and a limited game library, the Virtual Boy was not successful and was quickly discontinued the following year. Despite its commercial failure, the Virtual Boy remains a notable entry in the history of video game hardware and virtual reality technology as concluded by (Boyer, 2009).

2.1.1. Modern Developments of AR/VR Tech

The modern history of virtual reality kicks off with the Oculus Kickstarter campaign which launched in August 2012. Oculus VR, founded by Palmer Luckey, set out to create a high-quality, consumer-focused virtual reality headset. The Kickstarter campaign sought funding to produce development kits of the Oculus Rift for game developers to begin creating VR content. The campaign was an unexpectedly massive success, raising nearly 2.5 million dollars from over 9,500 backers, far surpassing its initial goal of 250,000 dollars. This indicated a strong interest in VR from both developers and the general public. The success of the Oculus Kickstarter caught the attention of the tech industry and led to significant investments and developments in VR. In 2014, Facebook acquired Oculus VR for approximately 2 billion dollars, signaling the tech giant's belief in the potential of virtual reality. The Oculus Rift Kickstarter and subsequent developments acted as a catalyst, prompting other major tech companies like Sony, Google, and HTC to explore and invest in VR technology. As a result, the mid-2010s saw a resurrection in VR, leading to the emergence of a new generation of VR hardware and software available to consumers (Gleasure & Feller, 2016).

Whereas the modern history of Augmented Reality does not have a single breakthrough event like the Oculus Kickstarter campaign. However, several notable milestones eventually build up the modern pillar-stone of AR technologies. In 1999 Hirokazu Kato developed ARToolKit - an open-source computer tracking library that allowed developers to overlay computer graphics onto video stream, effectively creating basic augmented reality experiences. This was one of the earliest tools that made AR more accessible to developers (Kuusisto, 2015).

Then, in 2009 Layar, a Dutch-based company, released one of the first mobile augmented reality browsers. It allowed users to see digital overlays on real-world objects using their smartphone cameras. The next incremental step was made by Google and its release of Google glasses in 2013. It was an eyewear-mounted mini computer that provided augmented reality experiences. While it wasn't broadly adopted by consumers and faced some backlash regarding privacy concerns, it marked a significant investment in AR by a major technology company. In 2016, Niantic developed Pokémon GO. This mobile AR game became a massive global phenomenon. Even though its AR capabilities were relatively basic - overlaying Pokémon onto the real world using a smartphone's camera - its viral popularity introduced many people to the concept of AR. Finally, modern AR application development was greatly bootstrapped by the release of Apple ARKit and Google ARCore in 2017. These platforms enabled developers to create more sophisticated AR applications in an easier way for a broad range of smartphones, pushing AR capabilities into the mainstream (Chen et al., 2019).

This gradual technological evolution and mainstream adoption eventually led to many productized applications observed today in gaming, e-commerce, healthcare, the automotive industry, and other fields.

2.2. 3D Object Scanning and Virtual Try-on Technologies

2.2.1. 3D Object Scanning

3D scanning, at its core, is a technology that captures the geometry of physical objects using laser beams, structured light, or other methods, converting this information into digital 3D models. This technology has been utilized across many sectors, including manufacturing, archaeology, medicine, entertainment, retail, e-commerce and more.

Although the basic principles of photogrammetry (using photographs to measure and map objects) existed long before then, the 3D scanning, in its rudimentary form, can be traced back to the 1960s. Advancements in this decade paved the way for more complex three-dimensional reconstructions. The early methods for capturing the 3D geometry of an object involved projecting a pattern of light onto an object and then capturing the shape of the pattern on the object. In the late 1970s, efforts were concentrated on structured light methods, where a known light pattern (often a grid or set of stripes) was projected onto an object, and the deformation of this pattern was used to infer the object's shape.

The 1980s and 1990s witnessed significant advancements, including the introduction of laser triangulation methods. These systems emitted a laser line or spot onto an object and utilized a camera, often positioned at an angle, to determine the distance from the laser source to the object's surface. This period also saw the popularization of time-of-flight laser scanners, which measured the time it took for a laser pulse to travel from the scanner to an object and back to determine the distance. Industrial and medical applications began emerging, with industries leveraging 3D scanning for quality control, reverse engineering, and rapid prototyping (Breuckmann, 2014).

2.2.1.1. 21st Century Uptick in 3D Scanning and Tracking

Whereas, the 21st century saw an increase in software capabilities and a comeback of enhanced photogrammetry techniques as a result. While the early days of 3D scanning were dominated by industrial-grade, high-cost equipment, this century has experienced a democratization of the technology. This transition has been significantly influenced by tech giants like Microsoft, Intel and Apple introducing consumer-friendly solutions.

Originally developed as a motion-sensing input device for Xbox, the Xbox Kinect quickly became a favorite for do-it-yourself enthusiasts for its depth-sensing capabilities. While not its original intent, its affordability made it one of the earliest widely adopted consumer-grade 3D scanning tools. Before the Kinect, depth-sensing technology was prohibitively expensive for the average consumer or hobbyist. The Kinect brought this capability to a consumer price point, making it an approachable option for those looking to experiment with 3D scanning and depth perception without spending a lot of money. Microsoft initially resisted the idea of the Kinect being used outside of their closed Xbox ecosystem. However, after seeing the potential and the popularity generated by hobbyist communities, they embraced it. The release of official SDKs (Software Development Kits) and the efforts of the open-source community made it easier to use the Kinect for various applications on PCs. The Kinect combined RGB video with depth sensing, which enabled it to see in 3D. This was achieved using an infrared projector that cast a speckled pattern, and an infrared camera that picked up the distortions in this pattern caused by objects and surfaces. This way, the Kinect could gauge the distance of objects from the camera, effectively creating a 3D map of the environment. In time, while the Kinect as a gaming peripheral might have been overshadowed, its legacy in DIY, developer, and academic circles has left a lasting impact. The device acted as a stepping stone, showcasing the potential of depth-sensing technology and democratizing access to it, paving the way for future advancements and devices in the field of computer vision and augmented reality (Spring, 2020).

The true revolution began when 3D scanning capabilities started merging with devices people use daily. The start of it was marked in 2014 June when Google introduced the Tango project. The technology combined computer vision and sensor fusion techniques to allow devices to understand their position and orientation in the world, making it possible for them to create detailed 3D maps of their environment. This technology had a lot of potential applications, including Augmented Reality, indoor navigation, 3D mapping and scanning as well as gaming. However, while Project Tango was groundbreaking, it was ahead of its time and faced challenges in terms of adoption. The need for specialized hardware made scaling across the vast Android ecosystem difficult. However, the idea of spatial awareness in mobile devices persisted. In 2017, Google decided to shift its focus from Project Tango to ARCore, a software-based platform for augmented reality apps that didn't require specialized sensors, following a similar fashion by Apple who then has recently released an equivalent ARKit library for the Apple ecosystem. ARCore (as well as ARKit) achieves a similar objective, albeit with lesser accuracy and detail compared to Tango, but has the advantage of broader compatibility since it doesn't rely on specialized hardware (Alkandari et al., 2019). So, while Project Tango might not have become mainstream, it paved the way for future innovations in spatial perception and augmented reality on mobile devices similar to how Nintendo Virtual Boy paved the way for Virtual Reality headsets.

Apple and Google are actively investing in ARKit and ARCore respectively to this day. Apple has consistently updated ARKit over the years, adding features like multiplayer AR experiences, object detection, body tracking, and more. The integration of the LiDAR scanner in some iPad and iPhone models also boosted ARKit's capability by enabling better depth sensing and more accurate placement of virtual objects. Like ARKit, ARCore allows for motion tracking, environmental understanding, and light estimation. Over time, Google has also enhanced ARCore's capabilities, introducing features like Augmented Faces and Cloud Anchors. In 2018, Unity, a popular game development platform, released AR Foundation as a framework to enable AR development for both ARKit and ARCore. Instead of developing separately for iOS and Android, developers can use AR Foundation to write their AR apps once and deploy them to both platforms. This has been a great improvement for AR developers, making the development process more streamlined and efficient according to (Oufqir et al., 2020).

The introduction of depth sensors into mainstream smartphones was another breakthrough step towards more consumer-friendly 3D object scanning. In late 2019 Samsung integrated Time-of-Flight (TOF) sensors into its Galaxy S10 5G and Galaxy Note 10+ models. These sensors measure the time it takes for infrared light to bounce back from objects, thus capturing depth information. In 2020 March, Apple introduced the iPad Pro with a LiDAR (Light Detection and Ranging) scanner. This is Apple's first device with a true depth-sensing hardware feature designed specifically for augmented reality and 3D scanning. Later that year, in October, Apple released the iPhone 12 Pro and 12 Pro Max, both featuring the LiDAR scanner, enhancing AR experiences and 3D scanning possibilities.

As per (Miller et al., 2022), Apple iPhones, specifically the iPhone 12 Pro and 13 Pro, offer a fast and cost-effective method for LiDAR data acquisition when compared to traditional ground-based scanners such as the FARO Focus 350. However, while this mobile LiDAR technology promises efficiency, the data sets' accuracies varied significantly. Factors like the scanning method, app settings, subject matter, and the nature of the scanned object (e.g., black vehicles) influenced the reliability of the data. In comparisons with the baseline FARO scans, discrepancies arose in terms of alignment, feature recognition, and scaling. The research concluded that further research is still needed and it should encompass understanding accuracy thresholds, developing best practices, identifying limitations, and honing processing techniques. This suggests that consumer-friendly 3D object-scanning solutions are available for experimentation but they are still far from industry-grade solutions.

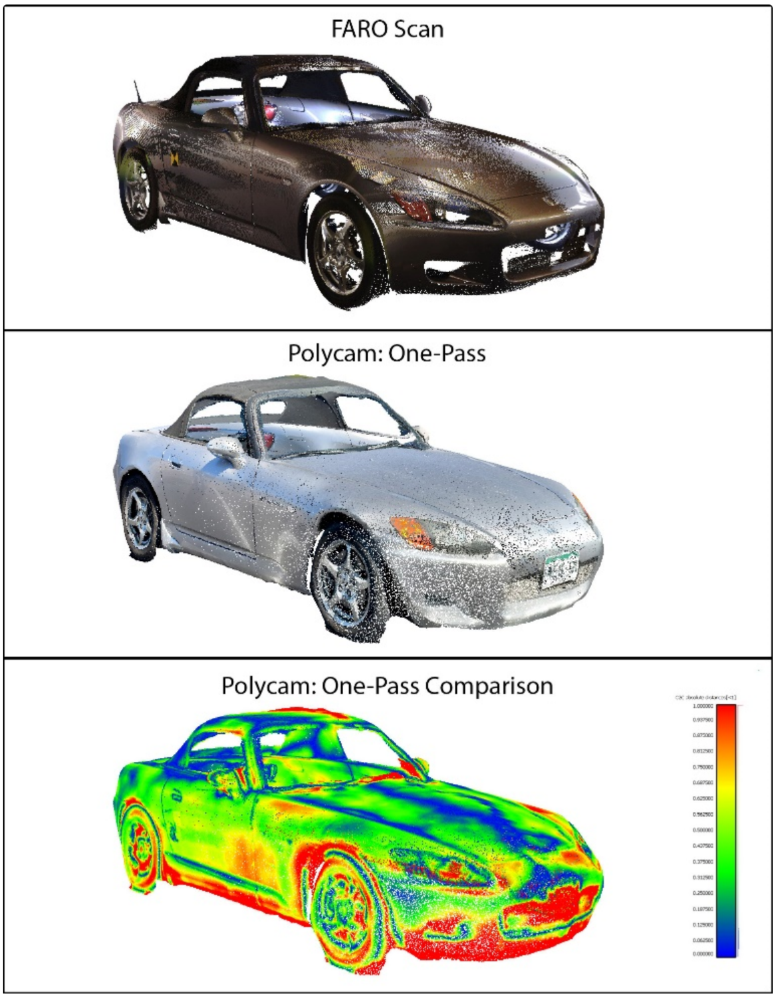

Figure 1. A visual comparison of the Polycam app vs. FARO, grey 2003 Honda S2000 scans: blue = .25 inches or less in variance. Red = greater than .75 inches in variance (Miller et al., 2022)

The Polycam scans when compared to the FARO data (as seen in Figure 1), revealed that 38% were closely aligned within 0.25 inches. However, 30% showed a deviation of 0.75 inches or more. While there are concerns regarding precision, the data suggests that there's significant potential in mobile 3D scanning capabilities given the rapid technological advancements.

2.2.2. Virtual Try-ons

Today the fusion of technology and user experience gives rise to innovative solutions that transform conventional user needs and consumer habits. Among the most notable of these innovations is the concept of virtual try-on technologies. At its core, virtual try-on allows users to virtually "wear" apparel, accessories, or even cosmetics, providing a digital representation of how these items might look in the real world. This interactive technology is a response to the dynamic shifts in consumer behavior and the drive towards more personalized and convenient shopping experiences.

Virtual try-on technologies hold significant relevance in today's market landscape. With the boom in e-commerce and the global shift towards online shopping (Shanthi & Desti, 2015), particularly in the fashion and apparel sector (Ladhari et al., 2019), there's an evident need to bridge the gap between the tactile experience of physical shopping and the convenience of online shopping. Traditional online shopping often involves guesswork when it comes to fit, size, and appearance, leading to higher return rates and, consequently, increased costs for retailers and environmental concerns. Virtual try-on tools aim to ameliorate these challenges, offering a solution that brings the physical dressing room experience into the comfort of one's home (Hwangbo, Kim, et al., 2020).

The concept of virtual try-on can be traced back to the late 1990s and early 2000s. As e-commerce began to gain traction, the need to emulate the physical shopping experience online came into play as well. The early versions of virtual try-ons were rudimentary, often consisting of simple overlays on digital photos. They were primarily used in the eyewear and jewelry sectors, where the fit and style were relatively easier to simulate. One of the first wider-scale rudimentary examples is "Virtual Mirror" - introduced by Ray-ban on their website in the late 2000s. It was an application that allowed users to try on sunglasses virtually using their webcam. The system would identify the user's face and overlay different sunglass models to provide a virtual try-on experience (Rese et al., 2015).

The further advancements went hand in hand with the AR/VR and 3D object scanning tech development covered in earlier sections. Recognizing the potential and demand for virtual try-on tools, several brands have made notable strides in this domain.

Sephora, a brand renowned for its consumer-centric approach, decided to experiment with customer engagement with its 'Virtual Artist' in 2016. It enabled users to virtually test a wide range of lipstick shades and eyeshadows. By embedding this augmented reality tool into its mobile strategy, Sephora positioned itself as one of the first forward-thinking players in the beauty retail sector and virtual try-ons niche. This initiative can be seen as a strategic bet on changing consumer behavior, where digital-native consumers increasingly seek personalized shopping experiences (Lele & Shaw, 2021).

Another major step indicating increasing business interest in the niche virtual try-ons and augmented beauty tech specifically is L'Oréal's acquisition of ModiFace in 2018. Amidst the evolving digital landscape, this move could be interpreted as L'Oréal's commitment to leading the "augmented beauty" sector. ModiFace itself was originally founded in 2006 as a spin-off from the University of Toronto. The company aimed to leverage advanced facial recognition and simulation technology for a variety of applications. Eventually, its focus settled on the beauty industry, developing apps and tools that allowed users to virtually try on makeup, hair colors, and other cosmetic changes. Their AR technology provided users with real-time video and photo makeup simulation using proprietary facial recognition algorithms. After the acquisition, ModiFace continued to work on its AR technologies and partnered with various brands within and outside the L'Oréal group. They've also played a key role in L'Oréal's digital transformation, with several brands under the L'Oréal umbrella integrating ModiFace's AR tools into their apps and e-commerce platforms. All in all, the ModiFace was one of the most notable and successful exits in the AR virtual try-on industry (Berman & Pollack, 2021).

Another big segment where virtual try-on adoption is relatively easy with the current tech is the footwear sector. Adidas ventured into an interesting collaboration with Snapchat in 2017. Recognizing the potential of reaching a younger, digitally native audience, Adidas introduced an AR shopping experience directly within Snapchat. The feature allowed users to virtually "try on" a selection of Adidas shoes using the platform's camera and AR filters. With a simple point of the camera at their feet, users could see a realistic overlay of the shoe, adapting in real-time to movements and different angles. This not only offered an engaging and novel way to showcase products, but it also tapped into the social sharing nature of Snapchat, encouraging users to share their virtual try-ons with friends and followers. Moreover, the integration allowed for seamless transitions from virtual try-on to purchase, with embedded links directing users straight to the Adidas online store. This strategic partnership highlighted the convergence of social media, e-commerce, and augmented reality, pointing towards a future where shopping becomes an increasingly interactive and social experience. Though, this approach was more about marketing, engagement, and brand visibility, not about practical and functional improvements - the AR try-ons did not take into account the factual size of the footwear (Rathore, 2017).

Building on Adidas strategy, Nike in 2019 introduced a Nike Fit application. Utilizing a synergy of computer vision, data science, AI, and recommendation algorithms, the application aimed to provide users with optimal shoe size recommendations by scanning their feet via a smartphone camera 2. It focused on improving the online and in-store shopping experience by providing accurate size recommendations. The objective was functional, aiming to address a longstanding issue in shoe shopping – getting the right fit, especially when shopping online. This innovative approach was integrated both in-store with the assistance of store associates and online through the Nike app. While the technology promised a transformative shoe-shopping experience, its reception was still mixed. While it offered an interactive, innovative, and engaging way to ascertain shoe size, and held the potential to decrease online returns due to size-related issues, it still faced usability issues, occasional accuracy discrepancies, and a lack of awareness or education: it was concluded that it was possible that some consumers weren't even aware of the feature or didn't understand its benefits fully (Pathak & Prakash, 2023).

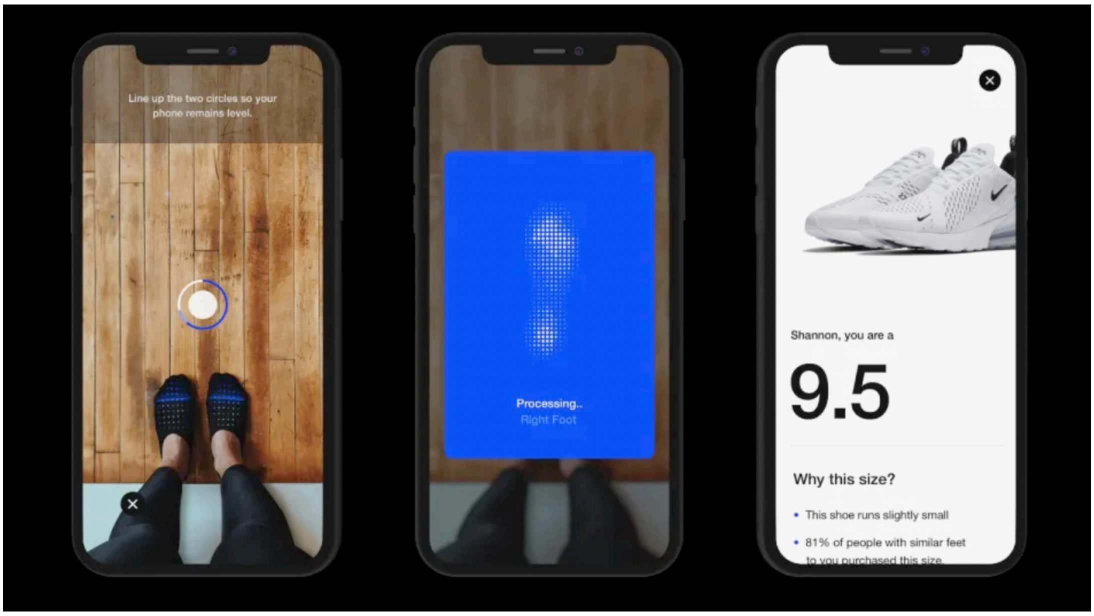

Figure 2. Nike Fit AR application foot scanning and shoe matching workflow (Alvarez, 2019)

Clothing constitutes a significant portion of the e-commerce market, and the challenges of online clothing shopping are manifold: fit, style, drape, and color. Given these intricacies, virtual try-on technologies in the apparel sector are just as important as it is for the footwear section covered before.

In 2018, Zara, a leader in the global fast-fashion arena, ventured into the augmented reality space with the launch of their AR app. This initiative represented an effort to blend the tactile experience of in-store shopping with digital innovations. When customers pointed their smartphones at specific markers in select Zara stores, they could see virtual models showcasing the brand's latest offerings, providing an immersive blend of the physical and digital realms. However, the actual reception of this technology by consumers was mixed. While some applauded the company for its forward-thinking approach and saw the AR experience as a novel way to engage with products, others found it to be more of a showcase tool for marketing purposes, not substantially enhancing their shopping experience. The efficacy of the app in driving sales, as opposed to just generating publicity, was a point of discussion among industry observers. The Zara AR app, therefore, stands as another example of a continuous balancing act between innovation, practicality, and genuine consumer value (Caboni & Hagberg, 2019).

2.2.2.1. 3D Item Previews

One form of a more approachable manifestation of virtual try-ons is the incorporation of 3D item previews, a progression beyond static images and two-dimensional representations but not having the technological complexity that full-on virtual try-ons bring. This technology facilitates a more detailed interaction with a digital representation of the product, providing views from multiple angles and a deeper understanding of its structure and design.

The motivation for integrating 3D item previews into e-commerce platforms arises from the recognized limitations of static imagery. Two-dimensional images may not always convey the complete structure or intricate design elements of a product, potentially leading to discrepancies between consumer expectations and the actual product, essentially building on the same motivations that full-on virtual try-ons are based on (Hewawalpita & Perera, 2017).

The feasibility of integrating 3D visuals into e-commerce has been facilitated by advancements in web rendering technologies such as WebGL. These advancements have allowed for the creation and manipulation of detailed 3D models within web environments, providing more comprehensive visual data to potential consumers (Geelhaar & Rausch, 2015).

Several e-commerce platforms and brands have begun to experiment with this technology:

For instance, Wayfair has incorporated 3D visualization tools to enhance the consumer's ability to assess furniture and decor items. This integration may assist users in visualizing how items might integrate into existing spaces, potentially aiding in purchasing decisions Cook et al., 2020.

Apple, recognized for its attention to design details, offers 3D visualizations for the majority of the physical products on its platform. These visualizations allow users to assess design elements more critically, potentially enhancing their understanding of the product's aesthetics and functionalities (Cook et al., 2020).

It's also worth noting that 3D item previews might address some sustainability concerns. By providing consumers with a more comprehensive view of products, it is postulated that return rates might decrease, resulting in reduced logistical challenges and associated environmental impacts (Hwangbo, Kim, et al., 2020).

While 3D item previews provide an enhanced visualization of products, they do not replicate the tactile experience of physical product interaction. Future developments in this domain might explore the integration of haptic feedback or more immersive virtual environments to address this limitation Batool, Mou, 2023.

2.2.3. Summarized Technological Evolution Timeline

The technological evolution timeline is well summarized by Agarwal et al., 2020. The timeline details five distinct phases of technological evolution. It is in the fourth stage, beginning around 2002, that we start to see small but important indications of early productization and commercialization in the realms of 3D object scanning, augmented reality, and virtual reality. A more substantial shift towards mass adoption is indicated as beginning in 2015, marked notably by the popularization of the Oculus headsets, which is attributed to the modern success of virtual reality market. This period also witnesses significant mobile advancements, such as the releases of ARKit and ARCore, which greatly simplify the development of AR applications and contribute to the wider adoption and acceptance of these technologies.

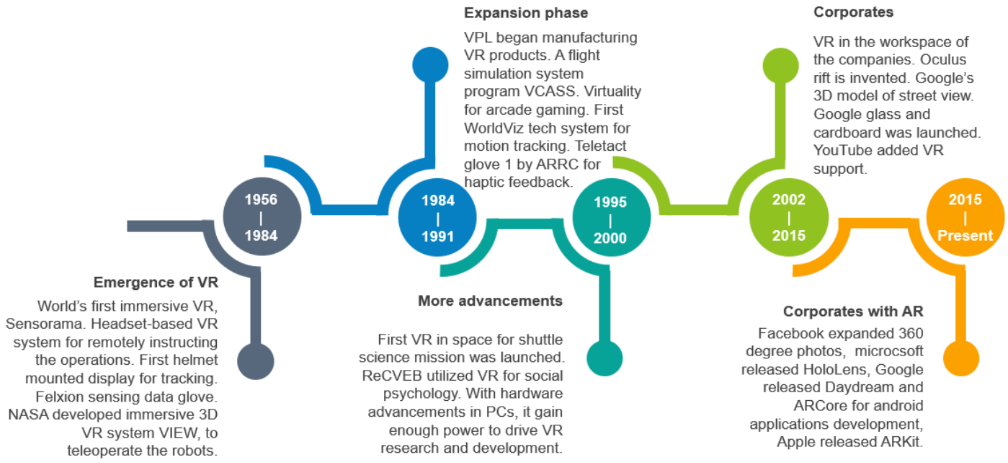

Figure 3. Timeline of AR/VR technologies (Agarwal et al., 2020)

2.2.4. Today's State-of-the-art Research Solutions

While, there is already a good variety of accurate and productized 3D object scanning solutions used in the industry, they are too complex or requires specific hardware and environmental setup to be used effectively. As a result, deeming them inefficient to be used by regular consumers. Therefore, today's state-of-the-art research on 3D object scanning is notably focused on democratizing the 3D object visualization process to bring it to the masses.

There are two notable research developments within the last year in this field. The first one is OnePose model by SenseTime - one-shot object pose estimation without pre-defined CAD models. Firstly, the shift from CAD model-dependent methods to novel keypoint-free approaches for object pose estimation marks a significant evolution in the field as previously, models relied on knowing the rough structure or category of the object beforehard. This approach, leveraging a keypoint-free pose estimation pipeline and a novel keypoint-free Structure from Motion technique, enables the reconstruction of semi-dense point-cloud models directly from photographs (X. He et al., 2022).

The second research is BundleSDF model by Nvidia. It boasts a near real-time method for 6-degrees of freedom tracking and neural network-based 3D object reconstruction (scanning) of unknown objects. The method functions efficiently even with minimal visual texture. It uses a Neural Object Field in tandem with a pose graph optimization process to create comprehensive 3D representations of objects. Its ability to handle challenging conditions such as large pose changes and untextured surfaces, as demonstrated on industry-standard datasets like HO3D, YCBInEOAT, and BEHAVE, significantly outperforms existing approaches (Wen et al., 2023). An example of a recreated table object can be seen in Figure 6.

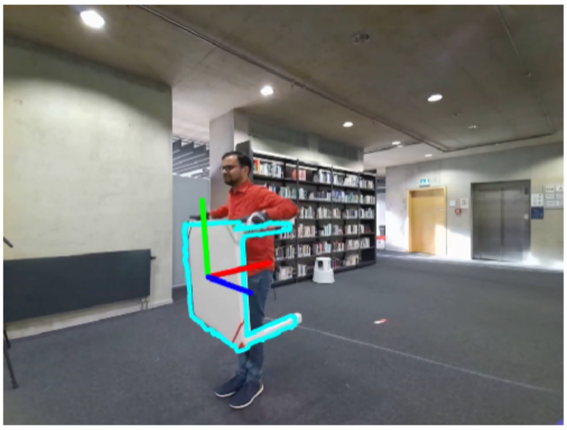

Figure 4. Video frame and a recreated table 3D object by BundleSDF (Wen et al., 2023)

This field of research focuses on speed, ease of use, and minimum amount of data required while trying to achieve maximum quality given these constraints. These two research breakthroughs hold the potential to pave the way for a breakthrough in digital C2C commerce, with an introduction of extremely consumer-friendly and easy-to-use 3D object scanning and recreation tools.

Whereas, the virtual-tryons field is led by the recent Google Research publication – TryOnDiffusion. The state-of-hte-art virtual try-ons model addresses significant challenges in garment visualization under varying body shapes and poses. This research made an important leap from previous methods, which either preserved garment details without effectively accommodating pose and shape variations or allowed for the desired shape and pose try-ons but at the cost of losing garment details. The core of TryOnDiffusion's success lies in its innovative Parallel-UNet architecture. This dual UNet structure harmonizes the process of garment detail preservation and warping, a significant improvement over the sequential processes used in earlier methods. The cross-attention mechanism in this architecture implicitly warps the garment, ensuring a seamless blend between the garment warp and the person's image. This unified approach is pivotal in maintaining photorealism and detail accuracy, especially in scenarios involving significant pose and body shape changes. Despite its breakthroughs, TryOnDiffusion isn't without limitations. Key challenges stated by Google include garment leaking artifacts, identity representation (failure to preserve body tattoos, for example), limited support for complex backgrounds, and small scope of supported clothing – the research is limited to upper body clothing, leaving the domain of full-body try-ons unexplored (Zhu et al., 2023). The model results are displayed in the middle picture of Figure 5, where the left picture is the input of the shopper and on the right is the picture of the garment to be fitted on.

Figure 5. A virtual try-on produced by TryOnDiffusion model (Zhu et al., 2023)

In summary, the recent advancements in the fields of 3D object scanning and virtual try-ons indicate a significant uptick in technological innovation, with promising prototypes like OnePose, BundleSDF, and TryOnDiffusion. These developments demonstrate advancements in ease of use, speed, and data efficiency, showcasing the potential for revolutionary changes in digital consumer-to-consumer (C2C) commerce and virtual garment fitting. However, despite these impressive breakthroughs, the technology is still not consumer-ready. Acknowledged by the researchers themselves, some inherent limitations and challenges limit these technologies from achieving widespread consumer adoption at present. Issues such as the complexity of the systems, the need for specific hardware or environmental setups, and the limitations in handling diverse scenarios and garment types highlight the gap between current capabilities and consumer-friendly applications. Moreover, the lack of substantial productization efforts in the business sector further underscores this argument. While these prototypes are exciting and hold immense promise, they represent a transitional phase in technology, where the path from research breakthrough to reliable, user-friendly consumer products is still being researched and discovered on.

2.3. Technology Adoption Theory

With the technological evolution of 3D/AR/VR technologies depicted, it is important to understand underlying business-level drivers and implications of such technology adoption. These frameworks provide a foundational academic understanding of how individuals and organizations perceive, adopt, and integrate new technologies into their operations and daily lives. These models serve as a lens through which the case studies and empirical data can be analyzed and interpreted. By applying these theoretical frameworks, the research can systematically assess and compare the technology adoption strategies of various organizations, providing a structured approach to understanding their successes and challenges.

The Technology Adoption Curve, UTAUT, and the Dynamic Capabilities Framework provide important insights for shaping business strategies. It helps identify how different user groups adopt technology, from early innovators to late adopters, enabling targeted marketing and product development. The UTAUT model's focus on factors like user expectations and social influence, along with UTAUT2's emphasis on consumer behavior elements like hedonic motivation, guides businesses in optimizing product design and user experience. Meanwhile, the Dynamic Capabilities Framework highlights the need for strategic adaptability in rapidly changing tech environments, emphasizing resource reconfiguration and innovation for competitive advantage. Collectively, these theories offer a holistic view of technology adoption, essential for businesses to develop forward-thinking strategies and maintain market relevance (Sharma & Mishra, 2014).

2.3.1. Technology Adoption Curve

In the domain of technology adoption, various theoretical frameworks have been developed to understand and predict the dynamics of how individuals and organizations embrace and adopt new technologies. Central to this understanding is the relationship between rapid technological advancements and the inherent barriers to the acceptance of new products and services. Pioneering this discourse, Hoenig and Lai (P. Lai, 2016) emphasized the significance of this interplay in the evolution of payment systems. Among the key theories is Rogers' Diffusion of Innovations which describes the stages through which an innovation is communicated and adopted within a social system, culminating in an S-shaped adoption curve. This curve categorizes adopters into innovators, early adopters, early majority, late majority, and laggards – called technology adoption curve (Rogers, 1995).

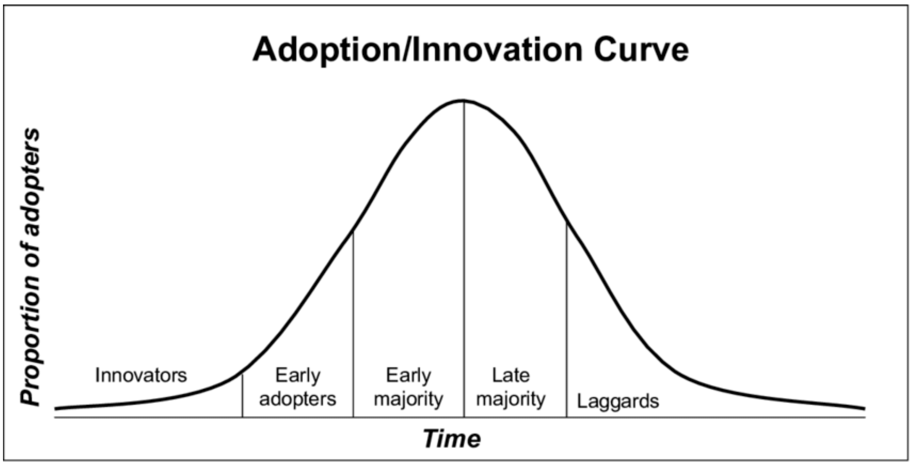

Figure 6. Technology Adoption Curve adapted from (Rogers, 1995)

2.3.2. Unified Theory of Acceptance and Use of Technology

Delving deeper into the specifics of technology adoption, the Unified Theory of Acceptance and Use of Technology (UTAUT) stands out as a pivotal model in contemporary research. Developed by Venkatesh and others in 2003 (Venkatesh et al., 2003), UTAUT offers an integrative view by amalgamating constructs from various established models, including the Technology Acceptance Model and the Theory of Planned Behavior, thereby presenting a more comprehensive picture of technology adoption dynamics. Central to UTAUT are four key constructs: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions, each playing a critical role in shaping user acceptance and usage behavior. This theory has been widely validated across diverse technological contexts, demonstrating robust predictive capabilities. Its adaptability is further exemplified in its extension, UTAUT2 (Venkatesh et al., 2012), which incorporates additional factors like hedonic motivation, price value, and habit, thus enhancing its applicability to consumer technology adoption scenarios. UTAUT's enduring relevance in technology adoption studies is a testament to its robustness and the nuanced understanding it offers of the multifaceted nature of technology acceptance, adoption, and continued use (P. C. Lai, 2017). Both models are depicted in Figure 7.

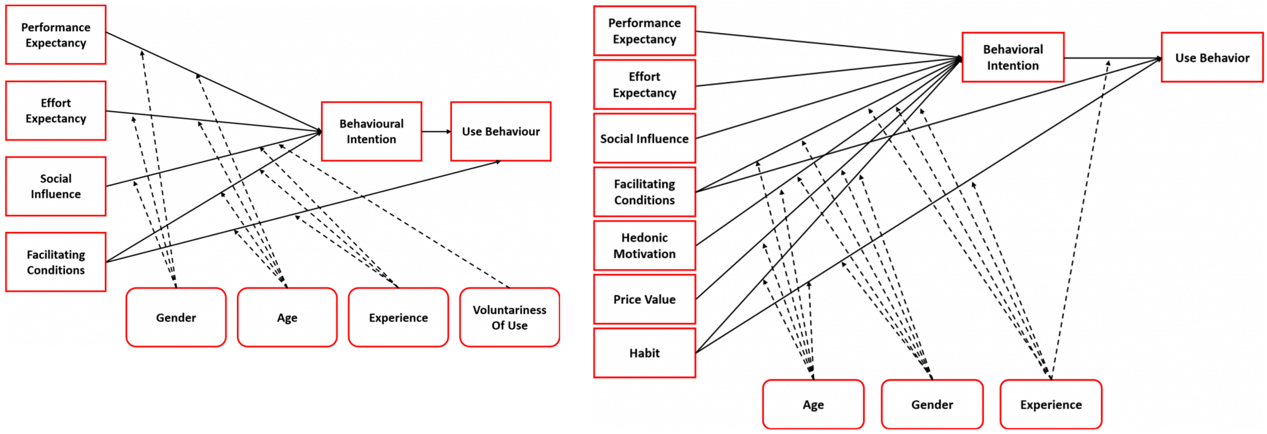

Figure 7. Graphs depicting UTAUT (Venkatesh et al., 2003) and UTAUT2 (Venkatesh et al., 2012) models.

2.3.3. Dynamic Capabilities Framework

In addition to the theories focusing on individual and organizational adoption of technology, the Dynamic Capabilities Framework (DCF) offers a strategic lens to view how firms gain competitive advantage in rapidly changing environments. Introduced by Teece, Pisano, and Shuen (Teece et al., 1997), this framework underscores the role of a company's abilities to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments. Central to DCF is the concept of 'dynamic capabilities', which are the firm's processes that use resources - specifically the processes to integrate, reconfigure, gain and release resources - to match and even create market change. Dynamic capabilities thus reflect an organization's ability to achieve new and innovative forms of competitive advantage given path dependencies and market positions. As such, DCF is particularly relevant in the context of technology adoption, where the speed of technological change requires organizations to continually adapt and evolve. This framework complements the individual and organizational focus of models like UTAUT, by adding a strategic, company-level perspective on how to navigate and capitalize on technological advancements (Teece et al., 1997).

2.4. Strategic Implementation

With the theoretical frameworks and technological evolution covered, it is important to understand the practical and strategic application of these technologies in the business context. This section delves into how organizations operationalize technology adoption theories and concepts in real-world settings, highlighting the intersection of theory and practice. It explores the significance of strategic business partnerships, examines the emerging trend of internal spin-offs and divisions within larger corporations as a strategy for fostering innovation, and analyzes the competitive advantage gained from early technology adoption.

2.4.1. Strategic Business Partnerships

The effectiveness of strategic partnerships in technology adoption is backed up by recent research, which highlights several key concepts and issues. Firstly, it is emphasized that the role of strategic alliances in adopting emerging technologies is critical, especially in industries where technology is rapidly evolving. Studies indicate that these partnerships are pivotal in overcoming the challenges associated with novel technologies, by pooling resources, knowledge, and expertise. This collaborative approach not only accelerates technology adoption but also facilitates more effective integration into existing systems and processes (Babu & Weber, 2019).

Additionally, the literature reveals that the rise of new digital technologies like data analytics, IoT, and AI has transformed traditional alliance models. These technologies enable more flexible and dynamic partnerships, which are essential in today's fast-paced technological landscape. The evolving nature of these alliances, often characterized by ad-hoc and virtual collaborations, demonstrates the adaptive strategies organizations must utilize to remain competitive and innovative in technology adoption (Q. He et al., 2021).

However, the additional complexity inherent in strategic partnerships is highlighted as a common problem. Aligning organizational strategies with technological innovations presents multifaceted challenges, requiring a careful balance between collaboration and competition. The research emphasizes that while these alliances can be complex, they still offer a collaborative advantage crucial for navigating the technological advances and market uncertainties of the modern business world (Q. He et al., 2020).

In summary, the literature points towards a consensus that strategic partnerships are increasingly vital in the context of novel technology adoption. They not only enable access to new technologies and markets but also provide a framework for resource sharing and innovation, making them a vital tool in the arsenal of modern organizations seeking technological advancement.

2.4.2. Internal Spin-offs

The concept of internal spin-offs and divisions within larger corporations has emerged as another pivotal strategy for driving innovation and facilitating technology adoption. Key research in this area indicates that these internal ventures are crucial in bridging the gap between research, development, and commercialization of new technologies. This approach allows companies to leverage their existing resources and capabilities while fostering a more focused and autonomous environment for innovation. Spin-offs, in particular, have been shown to enhance innovation performance significantly, especially when they form strategic alliances with other firms or public research organizations. These alliances can provide crucial support and resources, enabling spin-offs to thrive in competitive industries (Festel, 2013), (Hagedoorn et al., 2018).

Moreover, employee-driven innovations within these internal ventures are a critical aspect of their success. Allowing employees to develop their ideas within the framework of a spin-out or an internal division of the parent company can lead to more effective and efficient development and adoption of new technologies. This model promotes a culture of innovation where employees feel empowered and supported to explore and implement their ideas, thereby contributing to the overall technological advancement of the organization (Nikolowa, 2014).

2.4.3. Competitive Advantage of Early Technology Adoption

In the landscape of technology adoption, analysis reveals two key dimensions: the strategic benefits and inherent challenges. The Airbase study highlights how rapid technology adoption, especially during crises like COVID-19, significantly impacts revenue growth, with fast-adopting companies experiencing higher growth rates. This phenomenon signals a shift from cost-benefit analysis to seeking competitive advantage as the primary driver for technology integration (Slauson, 2020). Accenture's 2019 research corroborates this, showing that technological innovators achieve twice the revenue growth of their slower counterparts (Bennink, 2019).

On the other hand, other studies provide a detailed analysis of barriers to digital technology adoption, highlighting the crucial roles of economic development, investment costs, and technology complexity. In economies with higher development, technology adoption is often smoother due to existing infrastructure and resources, while less developed regions face greater challenges. High investment costs can deter smaller organizations, as they need to weigh the substantial initial expenses against uncertain long-term returns. Furthermore, the complexity of new technologies can require extensive training or specialized personnel, increasing the effort and cost of adoption. These factors act as significant hurdles, but when navigated effectively, they can also foster innovation and competitive edge (Kandasamy et al., 2023).

2.5. Gaps in the Literature

Current literature often investigates technological advancements and their business applications separately. There is a notable gap in exploring how 3D/AR/VR technologies intertwine with business strategies, consumer behavior, and market dynamics. Research that bridges these domains could provide more targeted insights into how these technologies are reshaping industries, influencing marketing strategies, and altering competitive landscapes. Understanding this interplay is crucial for predicting future trends and developing more integrated and holistic business models. However, today's research needs to be mostly based on generic studies that are not specifically targeted to 3D/AR/VR technologies.

While technological aspects of 3D/AR/VR are extensively researched, there is a notable scarcity of in-depth practical studies focusing on consumer perception and behavior towards these technologies. A key exception is the study by Kolon Industries ((Hwangbo, Kim, et al., 2020)), which examined the impact of virtual try-on technology on online shopping behavior with objective metrics published. This research showed a significant increase in customer engagement and satisfaction, highlighting the potential of virtual try-ons to enhance the e-commerce experience. However, such studies are rare, and more comprehensive research is needed to understand how consumers adapt to and interact with these emerging technologies in various contexts.

Much of the existing literature focuses on the adoption and application of 3D/AR/VR technologies in large corporations. This emphasis leaves a gap in understanding how these technologies are being utilized in Consumer-to-Consumer (C2C) marketplaces and by small and medium-sized businesses. Research in these areas could reveal unique challenges and opportunities faced by smaller entities and provide insights into how these technologies can be leveraged in more diverse business contexts.

Finally, the fast pace of technological advancements in 3D/AR/VR field creates a challenge for academic literature to remain current. New developments and breakthroughs in these fields occur rapidly, often rendering existing research outdated. This gap calls for a more dynamic approach to research and publication, possibly integrating real-time data and continuous updates, to keep pace with the ever-evolving technological landscape. This is especially apparent with literature overview research work which often ends up having an incomplete picture of the technological landscape.

3. Case Study of Companies

3.1. Methodology

The "Case Study of Companies" section aims to answer two main research questions:

1. What are the driving factors behind the adoption of 3D object capturing and virtual try-on technologies in online marketplaces?
2. How are specific companies utilizing existing technology, and what lessons can C2C platforms derive from their experiences?

To investigate these questions, this research is going to select three major companies based on their 3D/AR/VR technology adoption, market positioning and the role in technological innovation chain.

The data for selected companies will be collected from company reports and publications, market analysis reports, tech news articles from reputable sources, other research articles and/or studies.

The case study of each company is based on on the best practices proposed by (Hancock et al., 2021) and as demonstrated in other research works performing case studies on multiple companies (Urbinati et al., 2019), (Caboni & Hagberg, 2019). With this in mind, it starts with providing an overview of each company's history, market positioning, and role in e-commerce. Then the timeline of how each company has implemented and integrated 3D object scanning and AR/VR technologies is constructed. Afterwards, the level of innovation and associated risks in adopting these technologies is evaluated for each company. Finally, the outcomes and impact of technological implementations on the company is evaluated. This utilizes qualitative/exploratory analysis, timeline building, and theoretical frameworks such as Rogers' Diffusion of Innovations theory ((Rogers, 1995)) parts of Dynamic Capabilities Framework ((Teece et al., 1997)), and UTAUT/UTAUT2 ((Venkatesh et al., 2003) ,(Venkatesh et al., 2012)) constructs to interpret and contextualize findings.

Finally, a comparative analysis is carried out between the findings of each company in order to construct the answers to research questions.

3.2. Case Study Objectives

Based on the methodology defined, a few key objectives for investigation are established:

Technological Adoption Journey: This objective focuses on constructing a detailed chronological timeline that tracks the implementation, key milestones, and product launches related to 3D object scanning and AR/VR innovations in e-commerce. Utilizing the Dynamic Capabilities Framework, the analysis should categorize events into three phases - sensing, seizing, and transforming.

Technological Evolution and Impact Assessment This objective integrates the insights from the timeline analysis to offer a comprehensive view of each company's journey in AR/VR technology adoption, focusing on innovation, risk management, and outcomes. It involves assessing the level of innovation and positioning on the technology adoption curve, along with a thorough evaluation of the risks and challenges encountered. The objective also examines the successes and failures of these technological initiatives, measuring their impact on market positioning and user reception. By combining these elements, this assessment aims to provide strategic insights into the company's technological evolution and its implications for the e-commerce industry, drawing upon constructs from Rogers' innovation attributes and UTAUT frameworks. This comprehensive approach aims to yield a nuanced understanding of how AR/VR technologies have shaped the companies' trajectories and their broader market impact.

Comparative Analysis: Upon completing the individual case studies, this section will undertake a comparative analysis, examining how each company navigated the adoption of 3D object scanning and AR/VR technologies. This comparison will highlight both the commonalities and variances in approaches, timelines, innovation levels, and risk management strategies across the companies. The aim is to identify overarching trends, effective practices, and challenges faced in the industry. By contrasting these diverse experiences, the analysis seeks to offer insights into the broader e-commerce landscape's evolution regarding AR/VR integration, providing valuable lessons for future technological implementations in similar market contexts.

3.3. Company Selection

When selecting companies for the case study on the adoption of augmented reality (AR) and virtual reality (VR) technologies in e-commerce, it is imperative to choose organizations that showcase varied and significant aspects of this technological integration. The selection was based on several criteria: the company's market positioning (B2C or C2C), their role in the technological innovation chain (from product to platform providers), the diversity in their application of AR/VR technologies (ranging from product visualization to customer interaction), and their impact on consumer behavior and market trends. This approach should ensure a comprehensive understanding of the different ways AR/VR technologies can be adopted and optimized in e-commerce settings. The chosen companies – Apple, eBay, IKEA, and Shopify – collectively represent a cross-section of these criteria, providing a holistic view of the technological, operational, and consumer-oriented facets of AR/VR integration in e-commerce. This selection strategy aligns with the research aim of exploring the adoption of 3D object capture technologies in C2C marketplaces and addresses the set objectives by highlighting various implementation models, consumer responses, and the overall impact on the e-commerce ecosystem.

3.4. eBay Case Study

eBay, a pioneer in the online marketplace sector, has evolved from its roots as a consumer-to-consumer (C2C) platform to demonstrate a significant business-to-consumer (B2C) strategic focus. This transition is mirrored in its approach to integrating advanced technologies like 3D object previews and virtual try-ons, which are predominantly geared toward B2C sellers.

3.4.1. Technological Adoption Journey

Starting as early as 2011, eBay began experimenting with augmented reality (AR) in its mobile applications, introducing features that allowed users to virtually try on sunglasses (Dredge, 2011). This feature required the latest available Apple devices at the time - the iPhone 4 or a latest-generation iPod touch - and utilizes the front-facing camera. The ”See It On” feature in eBay’s eBay Fashion app represented a rudimentary form of augmented reality (AR) technology for virtual try-ons. Utilizing the front-facing camera of an iPhone 4 or the latest-generation iPod touch, users could virtually try on sunglasses. The AR implementation was basic, requiring users to manually align their faces within dotted line guides on the screen to ensure the correct placement of the virtual sunglasses. Once aligned, users could select different styles and colors, with the chosen sunglasses model overlaid onto their selfie. It was largely similar to Ray-ban webcam-based application covered in the ”Virtual try-ons” subsection of the literature analysis but this time the feature was brought into the mobile world. This early AR application, primarily focused on enhancing the shopping experience, demonstrated a simple yet innovative use of AR in e-commerce, albeit reliant on user input for accurate alignment. The feature was considered somewhat niche by eBay and while it was not expected to dramatically increase sales, showcases eBay’s commitment to integrating new technologies from the early days.

In 2014, eBay announced the acquisition of PhiSix, a company specializing in 3D visualization and simulation technologies for clothing. PhiSix creates 3D models of garments from various sources and simulates their behavior, enabling consumers to see how clothes fit and move in different environments without physically trying them on. At the time, it was stated that this technology could lead to a virtual fitting room feature on eBay, allowing shoppers to assess fit with realistic simulations and size recommendations based on basic measurements. Also, Steve Yankovich, eBay’s Vice President of Innovation and New Ventures, expressed that this technology could enhance the in-store experience as well, providing virtual fitting rooms and outfit recommendations. The plan was to integrate PhiSix’s technology across eBay’s various properties, including its marketplace, mobile apps, and eBay Enterprise (formerly Magento) services. This integration aimed to reduce the friction of online clothing purchases by offering a virtual try-on experience (Rao, 2014).

In 2016, eBay, in partnership with Australian retailer Myer, launched the world’s first Virtual Reality (VR) Department Store, marking another significant innovation in retail technology. This VR store, featuring eBay Sight Search™, allowed users to browse over 12,500 Myer products in a virtual environment, offering an immersive and personalized shopping experience. The store’s design focused on enhancing browsing, selection, personalization, and efficiency. The company also invested in hardware-level innovations, as evidenced by the distribution of 15,000 'shopticals', their custom-designed virtual reality viewers, enabling a comprehensive and immersive shopping experience. This initiative also utilized underlying PhiSix technology, acquired by eBay in 2014. The integration of PhiSix's 3D visualization capabilities played a role in realizing the VR Department Store's sophisticated and interactive user experience, particularly in accurately representing clothing items in a virtual space, thereby successfully utilizing this technological acquisition (eBay, 2016). However, the store was shut down since then and there were no successive articles published on scaling of the project.

In December 2021, eBay furthered its technological advancements in the online marketplace with the introduction of the '3D True View' feature for sneakers. This initiative, developed in collaboration with Unity, leverages artificial intelligence to provide sellers with an innovative way to display sneakers in a high-definition, interactive 3D view. This feature, a pioneering effort in e-commerce, allows sellers to create a photorealistic 3D image of their sneakers, viewable from every angle, enhancing the buyer's confidence, especially for unique, pre-owned, or high-value goods. The 3D True View technology, designed for select sneaker sellers in the U.S., uses a proprietary app for capturing multi-angle videos of the items. These videos are processed using AI to generate a detailed 3D representation of the sneakers, providing buyers with a realistic view of the product, including details and potential defects. This technology is seen as a significant step in the resale market, offering a level of visualization detail and ease-of-use that was previously unavailable. It's a game changer for both sellers, who can now showcase their items more effectively, and buyers, who can inspect the products thoroughly before purchasing. Dave Rhodes of Unity highlighted the significance of this technology in creating digital twins of inventory, offering buyers a more interactive and compelling experience than traditional static 2D images. eBay's commitment to a tech-led reimagination of the customer experience is evident in this launch, and the company plans to expand this technology to more sellers in 2022. This initiative is part of eBay's ongoing efforts to integrate advanced technologies into its marketplace, enhancing the shopping experience and strengthening its position as a leader in online retail (eBay, 2021).

eBay continues to innovate in the e-commerce landscape with its latest technological advancements, illustrating a strong continuous focus on enhancing both buyer and seller experiences. A significant development is the expansion of the '3D True View' technology, initially introduced for sneaker listings. This feature, now being scaled beyond its initial experimental phase, allows sellers to create comprehensive 3D models of their items, offering buyers an interactive and detailed view from every angle (eBay, 2023a). Alongside this, eBay has innovated in the augmented reality (AR) space, introducing an AR-based packaging tool in its app as a result of an employee-driven innovation (eBay, 2018). This tool aids sellers in selecting the correct packaging size for their items, streamlining the shipping process and reducing inefficiencies. Additionally, eBay is venturing into the luxury consignment market, offering a seamless service for high-value items, where it handles everything from valuation to shipping. This service helps eBay control the listing process and ensures maximum quality of it (eBay, 2023b). While the consignment as a service does not yet explicitly offer '3D True View', it is likely it will be introduced shortly following the strategy used with B2C partnerships.

Overall, eBay has consistently positioned itself as a leading innovator in the e-commerce space, especially in the realm of AR and VR technologies. By 2023, eBay had established itself as a leading patent filer in virtual try-ons as illustrated in Figure 8, underscoring its commitment to pioneering new shopping experiences.

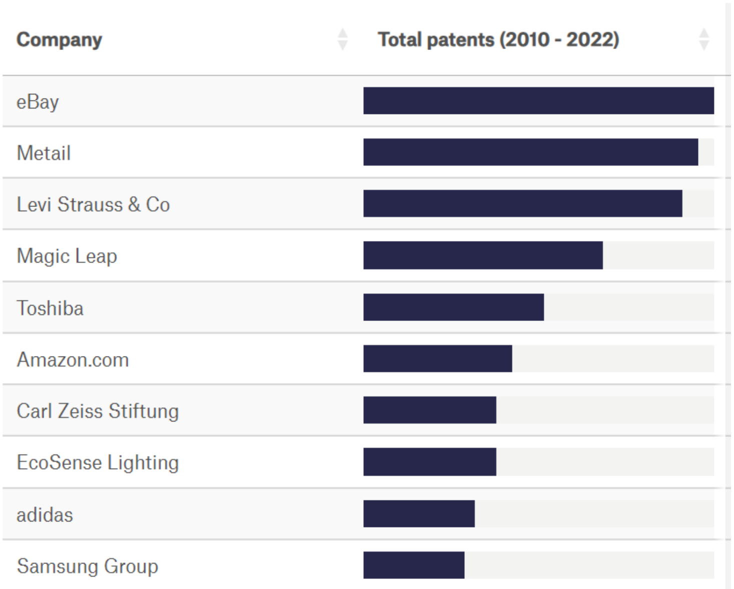

Figure 8. Patent volumes related to virtual try-on platforms (Network, 2023)

Having the Dynamic Capabilities Framework applied on top (Figure 9, it is apparent that eBay has systematically sensed technological trends, seized these opportunities through strategic partnerships and acquisitions, and transformed its platform and services with the wide-range adoption of AR/VR technologies to maintain its competitive edge in the dynamic e-commerce industry.

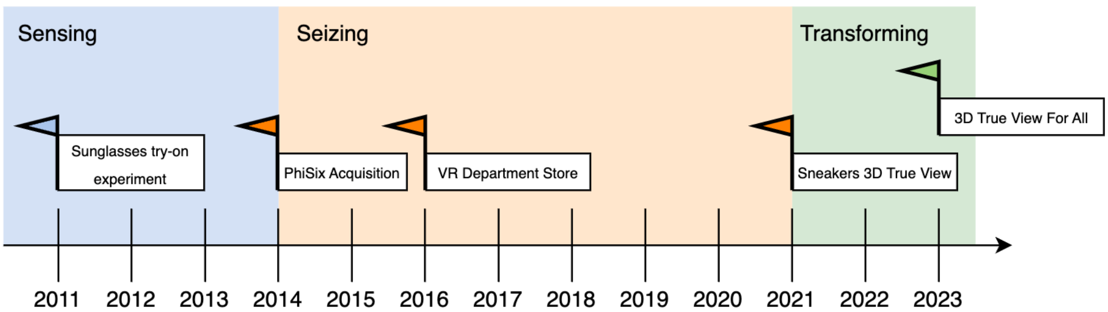

Figure 9. Technological Adoption Journey of eBay

3.4.2. Technological Evolution and Impact Assessment

Innovation, Experimentation, and Risk Management

eBay's technological adoption journey has been characterized by a willingness to experiment and innovate, often ahead of market trends. This approach, while leading to novel developments such as the VR Department Store, also reflects a pragmatic adaptability where eBay is not hesitant to discontinue projects like the VR store when they no longer align with market needs or company direction. The discontinuation of the VR Department Store, despite its initial novelty, exemplifies eBay's flexibility in technology experimentation and its readiness to pivot when necessary.

The company's significant patent filings in virtual try-on technology and its employee-driven innovation initiatives further underscore eBay's culture of experimentation. eBay's approach reflects a balance between exploring new frontiers in AR/VR and focusing on practical, scalable solutions that enhance the user experience.

Outcomes and Impact: Emphasis on 3D Previews and Practical Implementations

eBay's focus has increasingly shifted towards 3D previews and practical implementations of AR/VR technologies. The '3D True View' feature launched in 2021, along with its subsequent scaling, highlights eBay's commitment to providing detailed, interactive 3D models of products. This focus on 3D visualization rather than full-fledged AR/VR experiences aligns with the company's strategy to enhance online shopping in a more universally accessible and user-friendly manner.

These 3D visualization features have significantly impacted eBay's market positioning. They have enhanced the buyer's confidence, particularly in the pre-owned and high-value goods market, by providing detailed, interactive views of products. For sellers, these technologies offer a more effective way to showcase their items, likely leading to higher engagement and sales.

Theoretical Framework Analysis: A Balanced Approach

Analyzing eBay's strategy through Rogers' Diffusion of Innovations theory, eBay positions itself as an innovative entity that experiments with early-stage technologies but also knows when to retract and refocus. The UTAUT framework helps understand how user acceptance of these technologies is influenced by performance expectancy and effort expectancy. eBay's focus on 3D previews and practical AR/VR applications seems to be a strategic decision to offer technologies that are easily adoptable by its vast user base, maximizing utility while minimizing complexity.

Conclusion

eBay's journey in the realm of AR/VR technologies stands out for its blend of bold experimentation and pragmatic focus on scalable, user-friendly solutions. The company's pivot from more ambitious projects like the VR Department Store to more practical implementations like 3D previews demonstrates its adaptive strategy in technology adoption. eBay's focus on enhancing the online shopping experience through realistic and interactive product representations showcases its commitment to evolving with technology while keeping user experience at the forefront. This case study exemplifies how a leading e-commerce platform can effectively balance innovation with practicality, experimenting with emerging technologies while also making strategic decisions based on market reception and practical usability.

3.5. Shopify Case Study

Shopify provides an e-commerce platform-centric view on the adoption of AR/VR technologies. It's an example of how e-commerce platforms can empower businesses, including C2C marketplaces too, to leverage AR/VR for enhanced customer experiences. Shopify's role as a service provider for AR/VR technologies in e-commerce offers insights into the scalability and integration challenges of these technologies in various types of marketplaces.

3.5.1. Technological Adoption Journey

Shopify began its journey towards becoming a 3D-enabled commerce platform by announcing at Shopify Unite 2018 that merchants would soon be able to access free storage of digital 3D models within Shopify. This was part of a limited beta available for Shopify merchants to store 3D models and access 3D modeling, AR app building services through the Shopify Partner Ecosystem (Beauchamp, 2018). In this initiative, Shopify introduced notable partners like Sayduck and Tapcart. Sayduck specializes in creating high-quality, affordable 3D models from product photos, which can be embedded into merchant's web and mobile storefronts. These models, stored in Shopify, can also be utilized for AR, VR, and other future 3D-powered experiences. On the other hand, Tapcart focuses on building augmented reality mobile apps, as demonstrated in their collaboration with Fashion Nova for an AR app that allowed users to mix and match clothing items. In addition, Shopify was adding new partners to its Shopify Partner Program to help merchants create 3D models of their products and find innovative ways to reach their audiences in new mediums like augmented reality (Beauchamp, 2018). These partnerships are aimed at empowering Shopify merchants to offer immersive and interactive shopping experiences, leveraging the latest in 3D modeling and AR technologies.

In September 2019 Shopify enhanced its 3D-enabled commerce platform with the introduction of Shopify AR, offering a comprehensive toolkit for immersive shopping experiences. This toolkit included a marketplace for 3D modeling partners, facilitating merchants in creating and storing 3D models of their products. One significant feature was the 3D Warehouse App, allowing merchants to store and let customers view these products in augmented reality (AR). Furthermore, Shopify integrated support for AR Quick Look, Apple's advanced AR technology, enabling the viewing of 3D models in AR directly through the Safari browser on iOS 12 devices. This integration meant that users didn't require a separate mobile app or headset, making AR experiences more accessible to a broader audience (Stefanova, 2019).

In 2022 Shopify collaborated with UK-based AR platform Poplar Studio to provide a more integrated experience of 3D and AR features. Previously, the full range of 3D and AR features offered by Shopify were scattered across a range of different applications. This new platform provides all these features in a single app, reducing the previously fragmented experience and offering a more seamless AR integration for merchants (Acharya, 2022). Also, as stated by Shopify research, the implementation of 3D AR versions on Shopify has led to higher conversion rates (as high as 94%) and significantly lower return rates (65% lesser). This indicates the effectiveness of AR in enhancing the online shopping experience and customer satisfaction (Acharya, 2022).

Also, Shopify has released plenty of industry reports and insight articles on the topic of 3D and AR features in e-commerce. Shopfiy, as a platform business, is in a unique place where they have to cater diverse set of business when compared to more traditional e-commerce business like eBay and IKEA. It means that they are not that independent and are more reliant on overall market trends when placing bets on new features in this technological space. However, Shopify argues that while the AR market is still in its early stages, it is growing fast and is capturing more segments outside of the gaming and metaverse fields. The main trends for 2023 include social media AR filters, virtual try-ons, virtual showrooms, improved AR hardware, AR mirrors for in-store shopping, and AR gamification in stores (Keenan, 2022).

Finally, in 2023, Shopify announced an integration of an Apple 3D Object Capture technology into its iOS app, specifically for iPhone Pro models running the latest iOS 17. With the help of a partnership with Apple, Shopify was able to become one of the earlier wider-scale adoptors of the latest Apple 3D scanning tech. With this release, Shopify reiterated the main motivators for such functionality - simplification of the traditionally complicated and expensive process of 3D modeling, increased buyer confidence by provideing customers with a clearer understanding of product details, reducing uncertainty, and the minimization of returns a detailed 3D views can decrease returns by providing better product clarity (Ianni, 2023).

Shopify's initiatives, primarily influenced by market trends and the willingness of businesses to adopt such technologies, have shown significant positive impacts on customer engagement and sales conversion. However, as a platform business, their progress in the 'Transforming' phase is constrained as depicted in Figure 10.

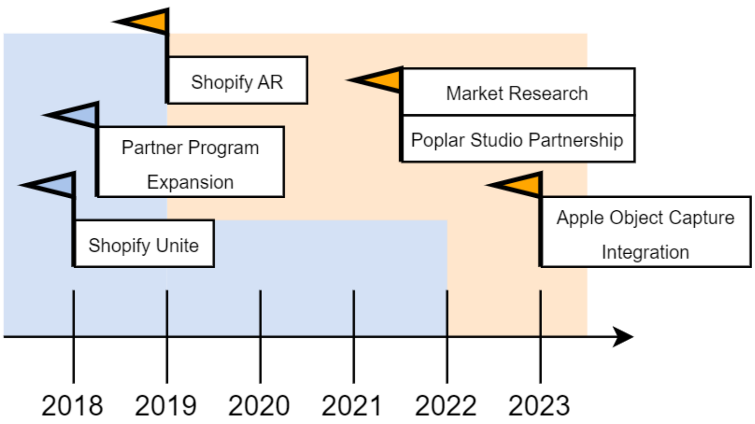

Figure 10. Technological Adoption Journey of Shopify

3.5.2. Technological Evolution and Impact Assessment

Innovation and Market Positioning: The Gap Between Promise and Reality

Shopify's journey in AR/VR technology has been marked by ambitious announcements and partnerships. However, a deeper analysis reveals a discrepancy between their market promises and actual achievements. While Shopify has introduced innovative features like 3D Warehouse App and integrations with Apple's AR technology, these advancements have not yet fully transformed the platform's e-commerce experience. The reality is that Shopify's offerings in 3D/AR/VR remain somewhat limited, reflecting the broader market constraints faced by platform-based businesses.

Risk Management: Navigating Market Constraints

Shopify's cautious approach to AR/VR adoption is evident in its risk management strategies. The company has strategically partnered with specialized firms to mitigate technical and market risks. Despite these efforts, the slower-than-anticipated adoption rate of these technologies among its merchants highlights the challenges Shopify faces in influencing market trends. This slower adoption rate, contrasted with Shopify's optimistic market research and public posts, suggests a gap in their ability to drive widespread transformation in e-commerce through these technologies.

Outcomes: Mismatch Between Expectation and Delivery

While Shopify has reported increases in customer engagement and conversion rates due to its AR/VR features, the overall impact falls short of initial expectations. The platform's progress towards the 'Transforming' phase is hindered by its dependence on the broader adoption of these technologies in the market. The platform's nature limits its ability to fully exploit the potential of AR/VR innovations, as evidenced by the unmet promises of rapid adoption and transformation in the e-commerce sector.

Strategic Insights and Market Realities

Shopify's case provides critical insights into the challenges of implementing emerging technologies in a platform-dependent business model. The company's efforts highlight the complexity of balancing innovation with market readiness and the need for realistic expectations in technology adoption timelines. Despite the limitations, Shopify's initiatives in 3D/AR/VR technologies have contributed to incremental improvements in the e-commerce experience.

Future Prospects and the Path to Transformation

As the market for AR/VR technologies continues to mature, Shopify may find more opportunities to fulfill its transformative potential in e-commerce. The recent integration with Apple's 3D Object Capture technology signals Shopify's ongoing commitment to these innovations. However, the path to reaching the 'Transforming' stage will require not only technological advancements but also a broader market shift towards the adoption and integration of these technologies.

Conclusion

Shopify's adoption of 3D/AR/VR technologies demonstrates the complexities and challenges of driving innovation in a platform-dependent e-commerce environment. The gap between the company's vision and the current reality underscores the importance of aligning market expectations with technological capabilities. Shopify's experience offers valuable lessons for other e-commerce platforms looking to navigate the evolving landscape of AR/VR technology adoption.

3.6. IKEA Case Study

IKEA has been at the forefront of using AR to enhance customer experience, especially through its virtual furniture try-out applications. This case offers valuable insights into the application of AR/VR technologies for product visualization and consumer engagement. As a major player in the retail sector, IKEA's adoption of AR/VR technology provides a perspective on how traditional retail businesses can innovate in the e-commerce space.

Technological Adoption Journey

IKEA's journey in adopting augmented reality (AR) technology for its home furnishing business provides an insightful case study on technological innovation. Here is a detailed look at the stages of their technological adoption journey:

IKEA's initial interest in AR technology was sparked by the realization that 14% of its customers were buying furniture that did not fit their space or aesthetic. This led to the development of an AR feature in the 2014 IKEA catalog. Users could place the catalog in a room and use a smartphone to visualize how different furniture pieces would look in their space. However, this early implementation was limited and required both the physical catalog and the app, with new products not in the catalog being unavailable in AR (Sumra, 2017).

The launch of Apple's ARKit marked a significant leap forward for IKEA's AR capabilities. The IKEA Place app, created using ARKit in 2017, allowed users to visualize furniture in their spaces with high accuracy and ease of use. The app initially included 2,000 items and was praised for its realistic rendering of products and user-friendly interface. IKEA's prior experience in 3D imaging and partnership with Metaio (an AR startup acquired by Apple) contributed to the rapid development of this robust app (Lunden, 2017).

The success of IKEA Place app led to the broader adoption and integration of AR functionality. Recognizing the potential of AR in enhancing customer experience, IKEA continued to innovate and integrate AR technology into its retail strategies. The company's commitment to technological advancements overall was evident in its early adoption of various technologies, including VR, wireless charging, smart lighting, and solar panels. IKEA's leadership believed that AR would fundamentally change the furniture business, prompting an "all-in" approach to its development and integration n(Lunden, 2017). The company leveraged its innovation unit, Space 10, and a network of partner companies to further its tech initiatives, reflecting a strategic approach to technology adoption and application in retail.

The SPACE10 itself, founded by IKEA in 2015, operates as an independent research and design lab dedicated to understanding and responding to major societal and technological shifts. Its mission is to anticipate the future needs of IKEA's customers, focusing on human-centric design and sustainability. SPACE10's projects range from developing IKEA Place, an augmented reality app, to exploring innovative solutions for urban living and environmental sustainability. By doing so, SPACE10 provides IKEA with strategic leverage, enabling the company to integrate cutting-edge ideas and technologies into its product offerings. This proactive approach helps IKEA stay relevant and ahead of market trends, ultimately enhancing the customer experience and contributing to a more sustainable future.(IKEA, 2021). It's a solid example of the company's dedication to early-stage research and experimentation.

IKEA further updated its augmented reality Place app in 2019 to allow users to preview multiple furniture items simultaneously, either handpicked or as part of predefined Room Sets. This update made the app more practical as a home decor tool, allowing users to visualize how different items fit together in their living space. The app also introduced new features like a user profile with a wish list and a "For You" feed offering product collections and suggestions (Fingas, 2019). This version of the app utilized Unity software whereas previously it was not clearly stated what was the underlying technology.

In 2022 IKEA introduced IKEA Kreativ, an AI-driven interactive design experience on its website and app. This feature marked a significant advancement, offering a fully featured mixed-reality design experience that bridged the gap between e-commerce and in-store experiences. IKEA Kreativ utilized spatial computing, machine learning, and 3D mixed-reality technologies, allowing customers to design entire living spaces with a wide-angle 3D projection. This technology, developed by Geomagical Labs (acquired by Ingka Group in 2020), allowed users to erase existing furniture from images and design spaces with items from IKEA's catalog. The aim was to empower customers to design their perfect homes from inspiration to reality, breaking down barriers to shopping for home furnishings (Forristal, 2022).

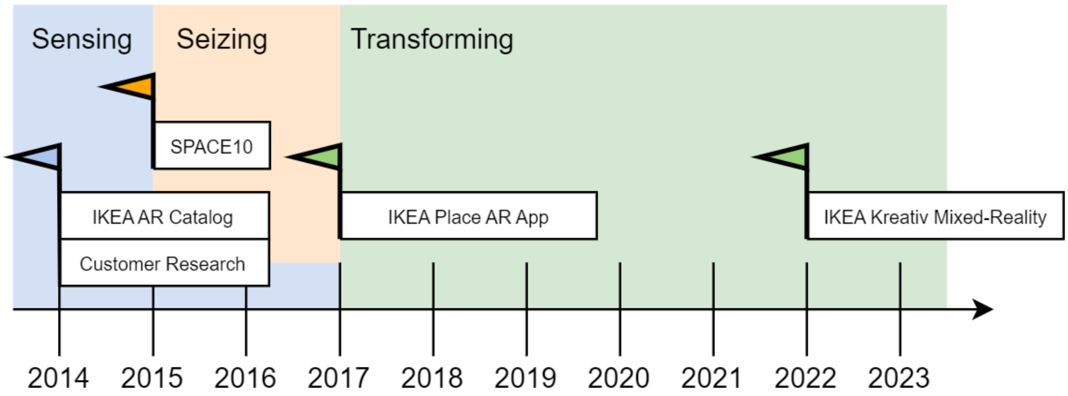

Figure 11. Technological Adoption Journey of IKEA

3.6.1. Technological Evolution and Impact Assessment

Innovation and Strategic Risk Management

IKEA's journey in AR/VR technology adoption is a testament to its strategic foresight and willingness to embrace collaboration for innovation. The partnership with Apple's ARKit and the acquisition of Geomagical Labs exemplify IKEA's approach to leveraging external expertise. These collaborations have significantly accelerated IKEA's technological capabilities, demonstrating a smart strategy of combining internal innovation (via SPACE10) with external technological partnerships. This approach, rooted in the early insight that 14% of its customers were purchasing ill-suited furniture, showcases IKEA's commitment to not just opportunistic experimentation but to a transformative enhancement of its business model.

Outcomes and Market Positioning

IKEA's integration of AR/VR technologies has revolutionized its market positioning. The company has evolved from a traditional furniture retailer to an industry leader in digital retail innovation. The customer-centric AR applications, such as IKEA Place and IKEA Kreativ, have significantly improved the online shopping experience, addressing major customer concerns and likely leading to higher satisfaction and lower return rates.

Impact on E-commerce and Industry Trends

IKEA's successful integration of AR/VR technologies into its business model highlights the transformative potential these technologies hold for the entire e-commerce sector. IKEA's journey serves as a benchmark for digital transformation in retail, showing how traditional businesses can adapt to and thrive in the rapidly evolving digital marketplace.

Theoretical Frameworks and Consumer Acceptance

In the context of Rogers' Diffusion of Innovations theory, IKEA can be positioned as an 'Early Adopter' on the technology adoption curve. This positioning reflects the company's quick uptake and effective implementation of AR/VR technologies ahead of the market curve. Furthermore, according to the UTAUT model, IKEA's use of AR/VR technologies has likely enhanced user acceptance due to its ease of use and perceived usefulness, contributing to the widespread adoption and satisfaction among customers.

Conclusion

IKEA's adoption of AR/VR technology is a prime example of how traditional retail businesses can effectively integrate innovative technologies to enhance customer experience and business processes. The company's strategy of combining internal innovation initiatives with strategic external collaborations has positioned it as a frontrunner in digital transformation within the retail sector. This case study serves as a valuable model for other companies navigating the challenges and opportunities of digital transformation, highlighting the benefits of early adoption and strategic partnerships in staying ahead in a rapidly evolving market.

3.7. Comparative Analysis

Being the earliest adoptor and experimented, eBay has demonstrated a balance between pioneering new technologies and focusing on practical, scalable solutions. Their emphasis has been on enhancing the online shopping experience with realistic 3D product representations. IKEA has transformed its market positioning significantly, evolving from a traditional furniture retailer to an industry leader in digital retail innovation, with customer-centric practical AR applications. Shopify's AR/VR offerings have shown incremental improvements rather than transformative changes. The platform's nature limits its ability to exploit the full potential of these technologies. With these examples in mind, it becomes evident that **innovation and early adoption of technology is more effective in smaller environments, where market exposure factors and dependencies are minimized**. This insight highlights the importance of creating a controlled environment where new technologies can be tested and refined without the immediate pressures of market dynamics. Such an approach allows for a more focused development and assessment of the technology's potential, leading to more informed decisions about wider market applications.

At the present date, all of the 3D/AR applications of each company rely heavily on external partnerships with industry tech leaders such as Apple with its 3D Object Capture and ARKit solutions or Unity with its sophisticated real-time 3D engine. Whereas earlier experimentations with in-house VR tech initiatives for eBay had unsatisfactory results and were not scaled further beyond the initial release of the VR Store in collaboration with Myer. Therefore, it can be concluded that **successful deployment and scaling of advanced 3D/AR features in commercial settings often rely on strategic collaborations with specialized tech leaders, rather than depending solely on in-house development and technology**. These partnerships not only provide access to cutting-edge technologies and expertise but also offer a platform for shared risk and resource pooling, essential in the high-stakes arena of technological innovation. Furthermore, collaborations with tech giants like Apple and Unity bring a level of credibility and market confidence that can be crucial for the successful adoption and perception of new technologies by consumers.

When compared to its direct competitors, all of the analyzed companies can be classified as early adopters or even innovators. However, the tech adoption is often backed by internal research and clear practical implications. This approach reflects a strategic blend of visionary leadership and practical pragmatism, where innovative ideas are supported by empirical research and market insights. These companies demonstrate a keen understanding that while pioneering technology is essential, its successful implementation in the market requires a nuanced understanding of customer needs, market trends, and operational realities. Thus, the success stories of eBay, Shopify, and IKEA reveal that **the effective integration of cutting-edge technologies in commercial applications requires a strong balance between innovation and market pragmatism**. The insights also suggest that the analyzed companies are utilizing an adaptive market strategy. They are willing to pivot based on feedback and emerging trends. This delicate balance ensures that technological advancements are not pursued in isolation but are deeply intertwined with user-centric design and market feasibility. It underscores the necessity of aligning technological innovation with strategic business objectives, ensuring that advancements serve not only as technological milestones but also as meaningful contributions to the company's overall value proposition and market standing.

Despite the varying degrees of success and approaches in their technological journeys, these companies have shown a clear track record of continuous and sustained commitment to this evolving field. This dedication not only reflects their willingness to innovate and adapt but also signals a broader industry trend. It becomes evident that there is an increasing inclination towards the adoption of these advanced technologies in the e-commerce sector, driven by visionary leadership and a pragmatic approach to market demands. **The sustained commitment of these companies to innovation underscores a promising trend toward broader adoption of 3D/AR/VR technologies in the e-commerce sector, setting a benchmark for others in the industry to follow.**

4. Analysis of Leading 3D/AR/VR Technologies

This section focuses on the third objective of this research - "Analyze the leading technologies and state-of-the-art research prototypes in 3D/AR/VR tech field". Such analysis is pivotal for this research because it directly influences the ability to make informed and effective recommendations for the adoption of 3D/AR/VR technologies in C2C marketplaces. It enables a deep understanding of the current technological landscape and its applicability in a less resource-intensive C2C environment, highlighting both the capabilities and limitations relevant to these marketplaces. Furthermore, this thorough examination forms a robust foundation for practical suggestions, ensuring that proposed solutions are not only innovative but also realistically implementable in the unique context of C2C e-commerce. The "Overview of 3D/AR/VR Technologies" subsection of the Literature Analysis, and specifically the parts about "21st Century Uptick in 3D Scanning and Tracking", "Modern Developments of AR/VR Tech" and "Today's State-of-the-art Research Solutions" serve as the informational basis for this section. With this in mind, the full technological map of 3D/AR/VR features in the context of e-commerce can be decomposed into the following key building blocks as depicted in Figure 12:

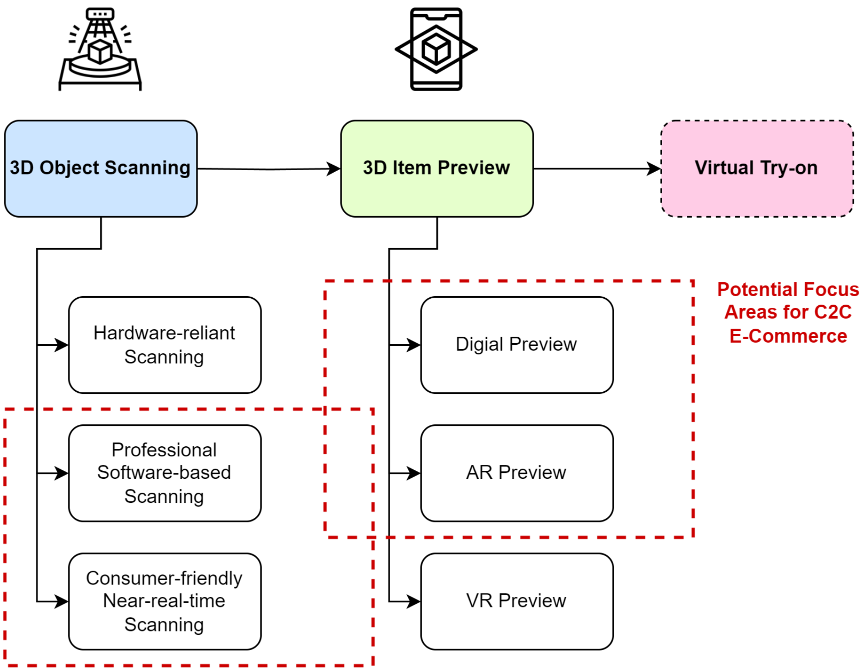

Figure 12. Technological Map of 3D/AR/VR features in E-commerce

Types of 3D/AR/VR features in E-commerce:

- **3D Object Scanning**: the process of capturing and re-creating the physical object in the digital realm. In terms of technological advancement, this can be further divided into Hardware-reliant Scanning (ex. industrial laser scanners), Professional Software-based Scanning (ex. photogrammetry software such as RealityCapture or Apple Object Capture) and Consumer-friendly Near-real-time Scanning.
- **3D Item Preview**: the process of displaying in the re-created 3D object in a digital or

augmented space. This can be further narrowed down to Digital Preview, AR Preview or VR Preview – depending on the type of space medium used for the object visualization.

- **Virtual Try-on**: technically, a more advanced from of a 3D Item Preview, but due to additional complex software requirements and lower adoption and tech maturity levels, it is best categorized as a separate building block.

The areas highlighted with red dashed lines – Professional Software-based Scanning, Consumer-friendly Near-real-time Scanning, Digital and AR Previews – mark the practically accessible technological advancement areas for C2C e-commerce platforms. The Hardware-reliant Scanning and VR Previews are left out from further tech analysis due to low adoption rates even in B2C e-commerce platforms (Keenan, 2022) whereas Virtual Try-ons are deemed too technologically immature and novel even by the current state-of-the-art research prototype solutions (Zhu et al., 2023). This leaves two focus areas – 3D Object Scanning and 3D Item Previews for further tech analysis.

4.1. Leading 3D Object Scanning Technologies

Apple has significantly blurred the lines between professional software-based scanning and consumer-friendly scanning technologies with its innovative Apple Object Capture offering, alongside its LiDAR-equipped Apple iPhone smartphone line (Miller et al., 2022). Initially introduced in 2021 as a photogrammetry API for macOS, Apple Object Capture represented a significant leap in making high-quality 3D object scanning accessible to a wider audience. The technology underwent a major update in 2023, allowing its direct application on iOS, the operating system for Apple iPhones. This update was quickly embraced by major platforms, notably Shopify, which integrated it for enhanced 3D item visualization (Ianni, 2023). The ease of use and integration of Apple's technology into widely-used consumer devices has set a new standard in the field of 3D object scanning.

In contrast, the Android ecosystem currently lacks a direct equivalent to Apple's offering in terms of maturity and market presence. While there are several initiatives and developments in this space, none have reached the level of integration and widespread adoption comparable to Apple's Object Capture.

Regarding state-of-the-art research prototypes, OnePose and BundleSDF have shown promising results in the realm of 3D object scanning. However, despite their innovative approaches, these technologies still face challenges in terms of accuracy and quality, making them less favorable compared to more established solutions like Apple Object Capture. As per the latest research, these technologies are still considered too immature and experimental for commercial productization, as acknowledged by their respective authors (X. He et al., 2022; Wen et al., 2023). Nevertheless, they represent significant potential for future advancements in the field.

Therefore, in the current market landscape, **Apple Object Capture stands out as the default go-to 3D object capture solution for C2C Marketplaces**. Its integration with widely-used iOS devices, relative ease of use, and high-quality scanning capabilities make it an ideal choice for C2C platforms seeking to implement effective and user-friendly 3D object scanning functionalities. However, it's crucial to acknowledge that, despite its prominence and integration in the current C2C marketplace landscape, even **Apple Object Capture and products alike have not yet reached a level of user-friendliness that allows for seamless mass adoption by every consumer**. While it stands out for its ease of use and high-quality results, it still demands a certain degree of effort, knowledge, and skill from users to be utilized effectively. This indicates a gap in the market for an ultra-consumer-friendly 3D object capture solution. The technological advancements required to bridge this gap, promising as they are, remain in a prototype stage. As such, they are not yet mature enough for commercial productization. The journey toward developing an intuitive, effortlessly accessible 3D scanning technology that requires minimal user input and expertise is still ongoing.

4.2. Leading 3D Item Preview Technologies

Most of the 3D item preview technologies are directly derived from the gaming industry, which has pioneered in rendering and interactive 3D environments. As a result, leading gaming technologies, known for their advanced graphics and real-time rendering capabilities, are also dominating the field of 3D item previews. Reflecting on the case study results, notable examples include eBay and IKEA, which utilize the Unity game/3D real-time engine for item visualizations. Unity is not only popular in the gaming industry but is also revered for its versatility and high-quality graphical output, making it suitable for e-commerce applications (Research, 2023). It allows for the creation of detailed and interactive 3D models of products, enhancing the user experience significantly.

On the other hand, Shopify, which has adopted a more limited approach to item preview functionality, utilizes native mobile tools such as Apple ARKit. ARKit, developed by Apple, is a framework for building augmented reality experiences on iOS devices. It enables the integration of digital information with the user's environment in real-time, using the device's camera and sensors. This technology is particularly effective for mobile-based augmented reality experiences, where users can preview items in a real-world context through their smartphones.

Furthermore, it's important to highlight that Unity incorporates an abstraction of Google ARCore and Apple ARKit through the Unity AR Foundation Framework. This framework is a comprehensive toolset designed to simplify the development of augmented reality applications. It harmonizes the functionalities of ARCore and ARKit, allowing developers to create AR experiences that are compatible across multiple platforms. Unity's AR Foundation Framework provides a unified API that works with both ARCore and ARKit, enabling developers to write their AR applications once and deploy them across multiple devices.

Therefore, **Unity can be considered a safe, mature, and feature-rich technological foundation for 3D item preview features** - it is adept for both digital-only and augmented-reality representations of items. Its wide adoption, robust support for AR functionalities, and the ability to deliver high-quality 3D visualizations make it an ideal choice for e-commerce platforms looking to implement advanced item preview capabilities.

5. Consumer Behavior Analysis

This section focuses on the fourth objective of this research - "Identify changes in consumer habits concerning AR/VR consumption and assess their impact on e-commerce" to analyze key recent publications on consumer behavior in regards to 3D/AR/VR technologies in e-commerce and draw relevant conclusions that can later be utilized in building business model extension.

A key study in the field of consumer behavior in regard to virtual try-ons was conducted in 2020 by the South Korean company, Kolon Industries (Hwangbo, Kim, et al., 2020). Their research unveils how virtual try-on technology has reshaped the online shopping experience, offering a more interactive and immersive platform for consumers. The introduction of virtual try-ons has led to measurable improvements in customer engagement and satisfaction. Notably, the study highlights a significant increase in the average sales per customer, amounting to an increase of approximately 14000 won (aprox. 10 EUR), coupled with a remarkable 27% decrease in product return rates. These metrics indicate the technology's efficacy in aiding consumers to make more informed purchase decisions that align closely with their preferences in size and fit. Moreover, the enhanced engagement is further evidenced by increased visitor numbers and extended time spent on the website, pointing to a deeper level of customer involvement and interest in the shopping process. This shift in consumer behavior suggests a growing preference for a digital shopping experience that closely mimics the traditional, physical one. The research by Kolon Industries serves as a compelling case study in understanding the broader implications of virtual try-on technology in e-commerce. It underscores the role of innovative digital solutions in not just augmenting the shopping experience but also in driving fundamental changes in consumer behavior, preferences, and expectations in the digital marketplace (Hwangbo, Kim, et al., 2020).

A 2019 survey study (Zhang, Wang, et al., 2019) consolidated findings from multiple research and validated key hypotheses in the field. The results were surprisingly positive and reconfirmed the findings of multiple previous studies. This comprehensive study articulates how consumer attitudes toward virtual try-on technology significantly influence their online purchase decisions. It reveals that key factors like perceived usefulness, enjoyment, privacy risk, and perceived ease of use, play a pivotal role in shaping these attitudes. Interestingly, the study also uncovers that, despite privacy concerns, consumers often favor convenience and downplay initial privacy concerns as a result, illustrating the privacy paradox in online shopping behaviors. The study integrates utilitarian, hedonic, and risk perspectives for predicting consumers' attitudes towards virtual try-on technologies and proves that all three perspectives are roughly equally important which is consistent with other studies. Moreover, it suggests that online retailers must adopt customized strategies for various consumer segments, especially considering the differences in technology adoption and attitude determinants among different age groups. For example, for the younger demographic, it suggests that virtual try-on features can be coupled with social features of the platform to boost adoption. This research complements the findings from Kolon Industries about the practical benefits of Virtual try-on technology in e-commerce and expands the understanding of the underlying psychological and behavioral factors driving consumer engagement and satisfaction in the digital shopping realm (Zhang, Wang, et al., 2019).

Recent 2022 research by Singapore Management University (Tan et al., 2022) analyses the transformative role of Augmented Reality in e-commerce, particularly emphasizing its positive impact on sales, effectiveness across varying product contexts, and its influence on distinct customer segments. A critical aspect uncovered is the significant boost in product sales attributed to the integration of AR technologies. This positive correlation indicates a marked preference among consumers for interactive and immersive shopping experiences, which AR facilitates. Notably, the research elucidates the heightened effectiveness of AR in promoting more expensive items. This suggests that AR's capacity to provide a detailed, virtual representation of products plays a crucial role in mitigating the perceived risk associated with higher-priced purchases, thereby enhancing consumer confidence and willingness to purchase. Furthermore, the study sheds light on the differential impact of AR based on customer characteristics. It reveals that AR technology is particularly influential among new customers and those exploring niche product categories. This finding is especially important, as it suggests that AR can act as a digital bridge, reducing the uncertainty and hesitation often experienced by consumers when faced with unfamiliar products or adopting new shopping platforms. By facilitating a more confident and informed purchase decision, AR effectively broadens the customer base and deepens market penetration for niche products. Overall, this research contributes significantly to the understanding of AR's multifaceted role in e-commerce, highlighting its potential as a powerful tool for enhancing customer engagement, boosting sales, and catering to diverse consumer needs and preferences in the digital shopping landscape (Tan et al., 2022).

From our research, the following observations and conclusions about consumer behavior can be made:

- Despite being in its early stages, the Augmented Reality market is experiencing rapid growth and expanding beyond its initial core user base of gamers and metaverse enthusiasts.
- Multiple studies show that virtual try-on technologies significantly improve customer engagement and satisfaction by increasing time spent shopping and lowering product return rates.
- 3D/AR/VR features are particularly effective in helping sell more expensive items by reducing perceived risk and boosting consumer confidence.
- 3D/AR/VR features are found to be especially influential among new customers and those exploring niche product categories, indicating its potential to attract and retain a diverse customer base for new and emerging market segments.

6. Business Model Extension

This section will focus on the last objective of this work – ”Propose a business model extension for a specific C2C marketplace focusing on the adaptation of these technologies”. A specific C2C marketplace is selected as a research subject. Then SWOT and Ansoff Matrix analysis is performed for the selected company. Finally, a detailed business model extension plan is defined.

6.1. C2C Marketplace Selection

Vinted is selected as the C2C marketplace of choice as a research subject for this thesis. Motivations for choosing Vinted are as follows:

1. **Strong Local Relevance**: Vinted is founded and based in Lithuania with a strong presence across Europe. Such choice allows to contribute to the local business ecosystem by providing insights that could directly benefit a homegrown company.
2. **Market Position and Growth**: Vinted's status as one of the largest C2C marketplaces in Europe makes it a highly relevant and impactful choice for this study. In 2023 Vinted makes it to the list of Top 10 largest marketplaces in Europe (Moitier, 2023). The company's significant user base and market penetration offer a substantial platform for the implementation and analysis of AR/VR/3D technologies. The insights gained can be broadly applicable to other marketplaces in similar stages of growth and market position.
3. **Unique C2C Marketplace Dynamics**: as a second-hand C2C marketplace, Vinted operates under unique dynamics that set it apart from typical B2C and even other C2C platforms that focus on selling new goods. The peer-to-peer nature of transactions involving used items presents distinct challenges in terms of product representation, quality assurance, and customer trust. At the same time, the item returns and likelihood of ”significantly not as described” scenarios pose unique challenges for such an operational business model. Implementing AR/VR/3D technologies in this context could offer novel solutions to these challenges and significantly enhance user experience, potentially benefiting such a platform even more than a traditional C2C platform.

6.2. Vinted Analysis

To better understand Vinted as a business in the context of VR/AR/3D/virtual try-ons tech adoption, a SWOT and Ansoff Matrix analysis is performed.

6.2.1. SWOT Analysis

Strengths

- *Large User Base*: Vinted's extensive customer network offers a wide audience for introducing innovative technologies like AR/VR/3D.
- *Technological Infrastructure*: With its established online presence, Vinted has the foundational tech infrastructure to support new tech integrations.
- *Brand Recognition*: Vinted's strong market presence can help in gaining user trust and acceptance for new features like virtual try-ons.

Weaknesses

- *Tech-Savviness of Users*: Not all users might be technologically adept to utilize complex features like 3D scanning, even with simplified mobile app interfaces.
- *Resource Allocation*: Integrating advanced technologies like AR/VR may require significant resources, posing a challenge for a C2C platform like Vinted.
- *User Resistance to Change*: Some users may prefer traditional online shopping methods, showing resistance to new technological features.

Opportunities

- *Enhanced User Experience*: AR/VR/3D tech can revolutionize customer experience with features like virtual try-ons, potentially reducing returns and increasing satisfaction.
- *Market Differentiation and Expansion*: Adopting these technologies can differentiate Vinted from competitors and can be leveraged following its acquisition of Rebelle and the launch of a high-value fashion segment.
- *Valuable Consumer Data*: Implementing AR/VR offers insights into consumer behaviors, aiding in targeted marketing and inventory decisions.

Threats

- *Complexity of Tech Implementation*: The integration of sophisticated AR/VR/3D technologies might be challenging, demanding a seamless user experience.
- *Competition*: Increased competition from platforms already advanced in AR/VR/3D tech adoption.
- *Internal Value Perception*: The indirect value creation of such tech might be underestimated internally, affecting resource allocation and strategic focus.
- *Privacy Concerns*: The use of advanced tech like AR/VR could raise privacy issues among users, necessitating careful management.

Strengths	Weaknesses
Large User Base Technological Infrastructure Brand Recognition	Tech-Savviness of Users Resource Allocation User Resistance to Change
Opportunities	**Threats**
Enhanced User Experience Market Differentiation and Expansion Valuable Consumer Data	Complexity of Tech Implementation Competition Internal Value Perception Privacy Concerns

Table 1. SWOT Analysis of Vinted

6.2.2. Ansoff Matrix Analysis

The analysis will focus on four constructs of Ansoff Matrix: Market Penetration, Product Development, Market Development, and Diversification. The insights should help identify strategic options for Vinted growth in terms of AR/VR/3D tech adoption for virtual try-ons. Paired with the previously carried out SWOT analysis and the case study of other e-commerce companies, it should help identify potential new opportunities and possibilities for eliminating weaknesses and threats of Vinted.

1. **Market Penetration**
   Current Strategy: Vinted, as an established C2C platform, primarily focuses on strengthening its user base and enhancing the user experience within its existing market.
   Potential Enhancement: With the introduction of AR/VR/3D technologies, Vinted could penetrate deeper into the existing market by offering a more immersive and interactive shopping experience, particularly for its new high-value fashion segment, building on the main value-added constructs proposed by Shopify - higher buyer confidence, willingness to pay more for better buyer experience and significant reduction in return rates.
2. **Product Development**
   New Opportunity: The introduction of a consignment service for high-value fashion items.
   Strategy: By following eBay's strategy of offering a consignment service, Vinted can control the quality and presentation of high-value items. Implementing AR/VR/3D technologies here would allow for detailed and accurate product representations, enhancing trust and reducing the risk of returns.
3. **Market Development**
   Expanding Reach: Leveraging its new high-value fashion segment, Vinted can target a more upscale market, attracting consumers interested in premium products and services.
   Strategy: The consignment service, complemented by innovative AR/VR/3D features, can be marketed to attract a demographic that values authenticity, quality, and a premium shopping experience.
4. **Diversification**
   Exploring New Revenue Streams: Vinted can diversify its business model by becoming a

technology provider in addition to its primary C2C marketplace role with the successful adoption of AR/VR/3D technologies for virtual try-ons.

Potential Idea: Creating a separate business unit or subsidiary focused on the development, maintenance, and sale of the 3D/AR/VR technology platform, catering to a variety of e-commerce platforms beyond the C2C sector.

Addressing SWOT Weaknesses and Threats

By having direct control over the scanning and 3D recreation process in the consignment service, Vinted can ensure a higher level of quality and consistency, thus making the technology implementation less complex and more streamlined. It mitigates the complexity of tech Implementation. The consignment service, coupled with AR/VR/3D, not only boosts the high-value segment but also elevates the overall user experience, presenting Vinted as a pioneer in the C2C marketplace for premium second-hand offerings. The combination of a consignment service with cutting-edge technology can strengthen user trust, reduce the perceived risk of buying high-value items, and create a perception of a premium shopping experience. The early adopter strategy opens up new business avenues for Vinted, reducing its reliance solely on C2C transactions and potentially positioning it as a key player in the e-commerce technology space.

6.2.3. Current Business Model Analysis

Ansoff Matrix analysis and Consumer Behavior analysis already suggest the strongest opportunity within the high-value fashion segment. Therefore, this analysis will try to better understand the current state of Vinted's high-value fashion product offering and try to find the gaps that can be filled with 3D/AR/VR tech adoption.

The current Vinted business flow for the high-value fashion product offering is depicted in Figure 13:

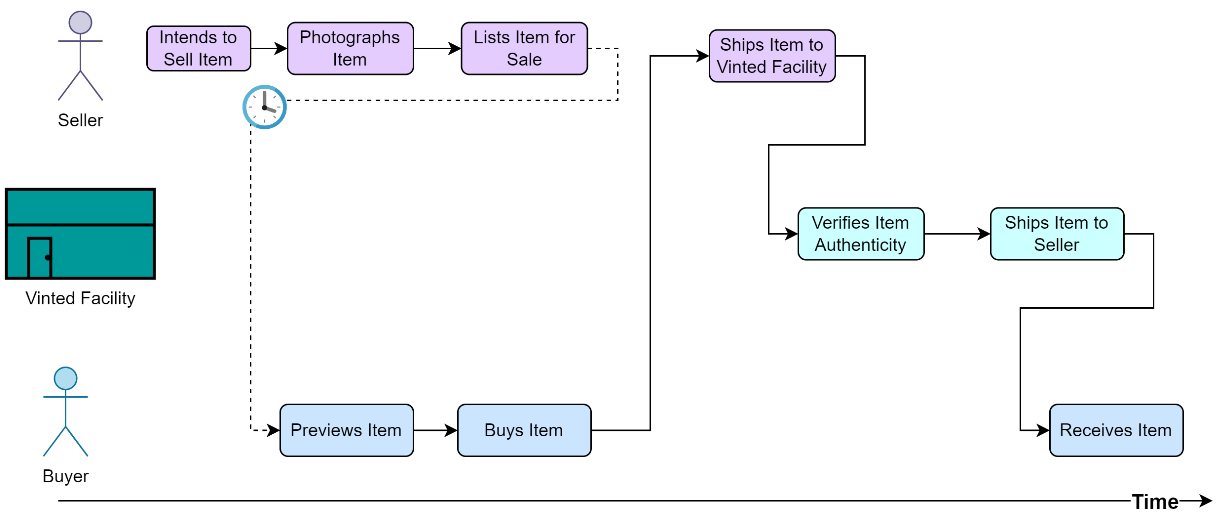

Figure 13. Current High-Value Fashion Vinted Business Flow

Three main actors can be derived – the seller, the buyer, and Vinted itself. The flow kicks off with the seller's intention to sell their high-value fashion item. This is usually followed by the seller preparing the photographs of the item and its description. The item is then listed for sale on the Vinted platform on its special high-value fashion category. The next trigger is the buyer's intention to buy the item. The buyer inspects the item photos and its description, and if everything matches the buyer's expectations, the buying process is kicked off. The buyer pays for the item itself, the shipping, the buyer's protection fee (insurance for the purchase) and a 10 EUR item verification fee (to check the authenticity of the selected designer item) (Vinted, 2023a). Then the seller is responsible for shipping the item with the shipping label provided by Vinted. Afterwards, the parcel with the item arrives at the Vinted Facility where the item verification process is carried out. If the verification succeeds, the item is then shipped to the final recipient – the buyer.

The key unique value proposition here is the item verification service which takes place at Vinted in-house facilities. The service itself is available in France, Italy, Germany, Belgium, and the Netherlands. It is offered for selected brands and items listed in adult fashion categories such as bags, shoes, accessories, jewelry, and watches. The service is applicable for items priced above 100 EUR. The verification service is optional and costs 10 EUR if the buyer chooses to include it in their purchase. The verification fee together with all the buyer's expenses is returned if the desired item fails the authenticity check. The service aims to increase trust in the authenticity of second-hand designer items and combat counterfeiting. It's part of Vinted's broader commitment to making second-hand fashion a preferred choice by providing confidence and authenticity in its offerings. Adam Jay, CEO of Vinted, emphasizes the importance of authenticity and trust in online second-hand shopping and Vinted's commitment to accessible verification services (Vinted, 2023a).

If we try to compare Vinted with analyzed B2C e-commerce companies, a few parallels and gaps can be identified:

- Both Vinted and eBay focus on second-hand high-value fashion segments and offer additional in-house services to boost sales and increase buyer confidence. Vinted offers an item verification service whereas eBay offers a full consignment service for its offerings.
- The item verification service launch is a result of a second-hand high-value fashion marketplace called "Rebelle" acquisition by Vinted. It could be parallelized to the acquisition of Geomagical Labs by IKEA which resulted in the IKEA Kreativ release, or eBay's PhiSix acquisition which influenced the release of the VR Department Store.

6.3. Proposed Business Model Extension

6.3.1. Executive Summary

This section introduces the proposed business model extension for Vinted, an online marketplace for second-hand fashion. The proposed extension aims to enhance Vinted's existing item verification service by incorporating a consignment service for high-value fashion items. This extension is designed to leverage advanced 3D object capture technology to offer detailed digital representations of consigned items, thus enriching the customer experience and increasing transaction confidence.

6.3.2. Rationale for the Extension

The motivation behind such business model extension stems from the following insights gained from the previous research sections:

- **Effectiveness for High-Value Items**: research indicates a marked preference among consumers for interactive and immersive shopping experiences, particularly for more expensive items. Technology's ability to provide detailed virtual representations of products reduces the perceived risk associated with high-priced purchases, thereby boosting consumer confidence and willingness to buy. (”Consumer Behavior Analysis” finding)
- **Enhanced Customer Engagement and Satisfaction**: The introduction of virtual try-ons has led to significant improvements in customer engagement and satisfaction, evidenced by a 27% decrease in product return rates and an increase in average sales per customer by approximately 10 EUR. This reflects the technology's effectiveness in helping consumers feel more confident and make more informed decisions. (”Consumer Behavior Analysis” finding)
- **Market Trends in Luxury Consignment**: eBay's venture into the luxury consignment market, offering comprehensive services for high-value items, reflects a growing trend in the industry. (”Case Study of Companies” finding)
- **Current State of 3D Object Capture Technology**: Current 3D object capture technologies, like Apple's Object Capture, while advanced, are not yet user-friendly enough for widespread consumer use in typical C2C marketplaces. This limitation is particularly evident in the Android ecosystem, which lacks a mature equivalent. To address this, our proposed business model extension for Vinted introduces a consignment service, where professionals manage the 3D capture process, ensuring high-quality digital representations of high-value fashion items and maintaining platform integrity. (”Case Study of Companies” and ”Analysis of Leading 3D/AR/VR Technologies” finding)

6.3.3. Description of the Extended Business Model

In the extended model, as depicted in Figure 14, the seller initiates the transaction by expressing interest in the consignment service for their high-value item. Instead of undertaking the listing process themselves, the seller simply sends the item to Vinted. This change significantly reduces the effort required from the seller, who previously had to prepare photographs and descriptions for their listings, serving as an additional value proposition.

Upon receiving the item, Vinted takes on the responsibility of the listing process. This includes conducting a thorough verification and authentication of the item just like in the current model. The key addition here is the incorporation of the 3D object capture step. Utilizing Apple Object Capture technology, Vinted creates detailed digital representations of the item, providing potential buyers with a more immersive and informative viewing experience. This step is crucial, as it leverages the benefits of 3D technology to enhance buyer confidence and engagement.

The extended model offers the buyer a more interactive and engaging shopping experience. The availability of 3D item previews allows potential buyers to inspect the products virtually in greater detail before making a purchase decision. This feature aims to replicate, as closely as possible, the experience of examining the item in person, thus reducing uncertainty and perceived risk associated with online purchases of high-value items. Once a buyer expresses interest in an item, the subsequent steps of payment and shipping follow the conventional Vinted process. However, the enhanced confidence from the detailed 3D previews is expected to facilitate a smoother and more satisfactory transaction process, potentially leading to higher conversion and lower return rates as well as boosting overall customer satisfaction.

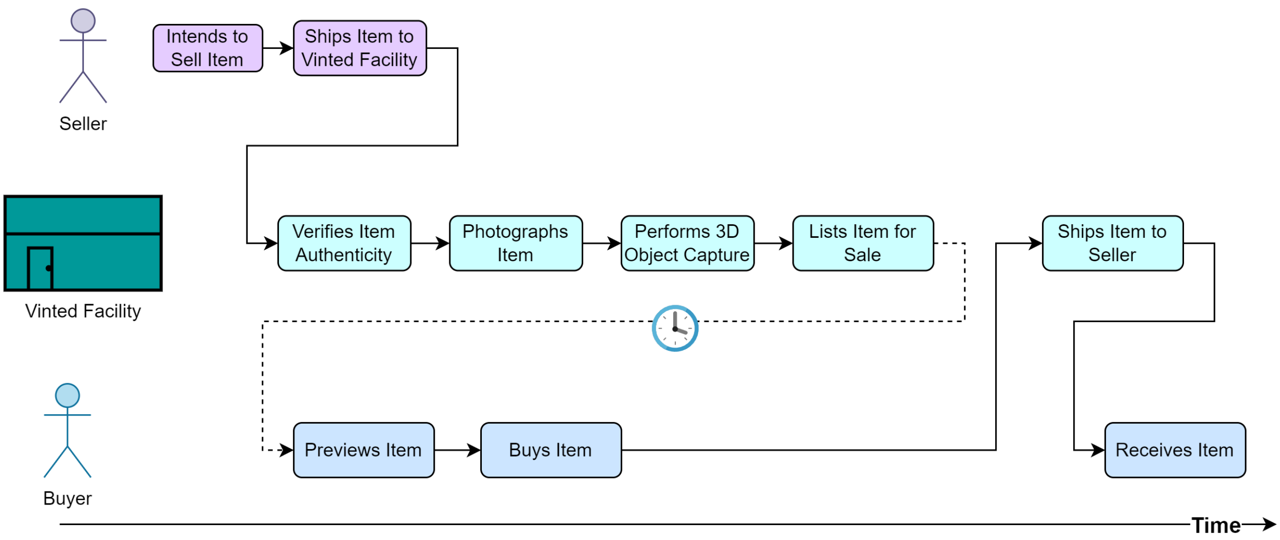

Figure 14. Propossed High-Value Fashion Vinted Business Flow with Consignment Service and 3D Item Previews

6.3.4. Implementation Plan

The key implementation steps for extending Vinted's business model are as follows:

- **Staff Training and Facility Adaptation**: Since Vinted already has facilities and staff carrying out value-added services, the business model extension should require a minimal increase in resources at least for the initial launch. The existing staff handling the item verification service will need to be trained to carry out consignment and 3D object capture duties.
- **3D Object Capture Integration and Technology Partnership**: Since the 3D Object Capture technology is the key value proposition in this business model extension, an establishment of a partnership with Apple for more robust support for Apple Object Capture technology is strategically vital. The Apple Object capture integration would likely require a new small application developed to be used by in-house consignment service providers.
- **Marketplace Application Enhancement**: The Vinted application will need to be updated to support new seller business flows associated with the consignment service. For the buyer part, integration of the 3D item preview functionality will be required utilizing Unity as the rendering engine. Unity Pro licenses will need to be purchased for the software developers involved.
- **Communication and Marketing Strategy**: a comprehensive communication will need to be prepared to inform users about the new service and its benefits. Marketing campaigns appropriate for Vinted channels should be prepared to promote the new feature.
- **Iterative Development and Scaling**: the extended business model should be launched in a phased manner based on sustainable business model innovation concepts (Shakeel et al., 2020). Based on initial feedback and performance metrics, the model and technology should be iteratively revised to continuously enhance efficiency and user experience.

6.3.5. Financial Strategy

The pricing strategy for the proposed business model extension does not have any major changes from the currently established strategy by Vinted. The key distinction from eBay's consignment service is the lack of any fees or commissions paid for the seller to be aligned with current Vinted values of not charging the seller (Vinted, 2023b). The pricing model breakdown can be seen in Figure 15. The Seller's Revenue layer fully reflects the price either set by the seller or suggested y Vinted and accepted by the seller – the seller's asking price. The Vinted Revenue is the dynamic markups added on top of the consignment and item verification costs and shipping costs. The buyer's final purchasing price consists of the seller's asking price, the authenticity fee (Vinted operational costs plus markup) and the shipping price (shipping Costs for the Vinted plus markup). Dynamic markups serve as a pivotal control mechanism in this Vinted's financial model, crucial for ensuring the profitability and sustainability of operations. These markups can be strategically adjusted based on a variety of key factors, such as the demand for specific items, the financial requirements of the business, the price point of the items, and other relevant market variables.

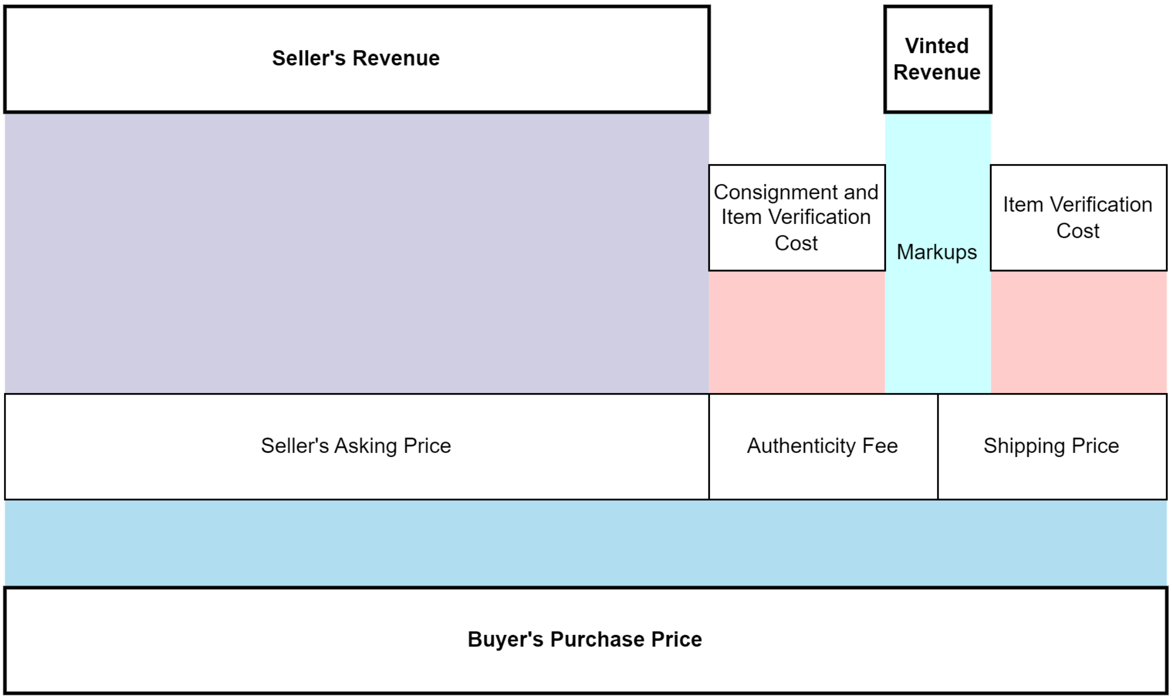

Figure 15. Pricing Model Breakdown

6.3.6. Considerations and Future Opportunities

The proposed extension of Vinted's business model to include a 3D object capture and item preview feature represents a practical, calculated, low-risk approach to the 3D/AR/VR technology adoption in C2C marketplaces. This sustainable model enhancement doesn't require a complete overhaul of Vinted's current operations but instead adds value by leveraging current technological trends. The incorporation of advanced 3D scanning and virtual representation of items could be formulated as a strategic move that aligns with the core values and operational framework of Vinted. This approach ensures that the platform remains cutting-edge while retaining its fundamental business practices and customer base.

Targeting a specific, second-hand high-value fashion segment, this service extension is likely to be utilized by roughly less than 10% of Vinted's user base. While this percentage might seem modest, it represents a crucial and rapidly growing portion of the second-hand fashion market. Focusing on this segment ensures that the extension provides significant value in a domain where it is most impactful. By adjusting to the needs of users dealing with high-value items, Vinted not only enhances its service offering but also strengthens its position in a competitive market.

The in-house management of the 3D capture process is another strategic decision. This setup not only guarantees high-quality digital representations of items but also offers Vinted greater control and flexibility in service management. It simplifies the adaptation to new technologies and market changes, ensuring high standards are maintained. Furthermore, in-house management allows Vinted to rapidly implement changes based on user feedback and technological advancements, maintaining a dynamic and responsive service offering.

By integrating this new service, Vinted essentially creates an innovation hub within its structure. As an early adopter of 3D object capture technology in the C2C marketplace, Vinted positions itself at the front of market trends and technological advancements. This proactive approach not only enhances the consumer experience but also prepares the platform for broader technological integrations and advancements. It sets a precedent for future expansions and adaptations, keeping Vinted ahead of its competitors.

Looking to the future, as 3D capture technology becomes more consumer-friendly, there is potential for Vinted to extend this functionality to its entire user base. This forward-thinking strategy is not just about enhancing the current user experience but is also about preparing for broader market shifts and technological integrations. Such an expansion would not be an integration from scratch, thanks to Vinted's early adoption and experience in the field.

It also opens the door for Vinted to evolve beyond a marketplace, potentially offering 3D capture technology as a service to other platforms. It creates a possibility of Vinted launching a platform-type business spin-off. This new venture could capitalize on the expertise and success gained from the 3D object capture service, offering it as a standalone service to other C2C marketplaces. Such a move would not only create new revenue streams but also reinforce Vinted's position as a technological leader in the marketplace sector.

Conclusions

The 3D object capture was democratized with the release of Google ARCore and Apple ARKit augmented reality mobile frameworks in 2017 and then further enhanced by the introduction of depth sensors in smartphones in 2019. These developments made 3D object capture more accessible and potentially usable by sellers in C2C marketplaces. Despite rapid advancements, these technologies face challenges in accuracy, usability, and consumer awareness. While they offer exciting possibilities, there is a gap between current consumer-grade solutions and the precision of professional-grade solutions utilized by B2C marketplaces. However, recent research, like the OnePose model and BundleSDF, suggests increasing efforts to make 3D object scanning more user-friendly and accurate. These advancements indicate a strong trend towards more accessible and efficient 3D scanning solutions suitable for consumer use.

Case studies on eBay, Shopify, and IKEA, as early adopters of 3D/AR/VR technology in e-commerce, demonstrate a trend of strategic pragmatism. These companies prioritize practical business benefits and data-driven consumer needs in their adoption of such innovations. Their successful deployment is supported by internal research and has clear practical implications, highlighting the importance of aligning technological advances with strategic business goals and customer insights. Additionally, all of the companies rely on strategic collaborations with tech leaders like Apple and Unity. It provides access to cutting-edge technologies, facilitates risk-sharing, and boosts market credibility. Despite these successes, challenges such as the slower-than-expected adoption rate, particularly in Shopify's case, underscore the complexities of integrating emerging technologies in different business environments. Nonetheless, the sustained commitment of these companies to innovation underscores a promising trend toward broader adoption of 3D/AR/VR technologies in the e-commerce sector.

Apple Object Capture can be considered a dominant consumer-friendly solution for 3D Object Scanning. Its integration with widely-used iOS devices, relative ease of use, and high-quality scanning capabilities make it currently the best choice for C2C business use cases. However, it still demands a certain degree of effort, knowledge, and skill from users to be utilized effectively. Therefore, Apple Object Capture and products alike have not yet reached a level of user-friendliness that allows for seamless mass adoption. Additionally, Unity 3D real-time engine is the strongest offering for 3D item preview technology. It is a mature and established tool for businesses to effectively bridge the technological gap in practical e-commerce applications.

Consumer behavior analysis suggests that the augmented reality market, initially popular among gamers and metaverse enthusiasts, is rapidly expanding and reaching a broader audience. 3D item previews and virtual try-on technologies have been proven to have practical benefits, enhancing customer engagement and satisfaction by increasing the time spent shopping and reducing product return rates. Furthermore, 3D/AR/VR features are proving effective in selling higher-priced items, as they lower perceived risk and increase consumer confidence. These technologies also show notable influence among new customers and those exploring niche product categories, suggesting their potential to attract and retain a diverse customer base in new and emerging market segments.

The proposed business model extension for Vinted focuses on enhancing item verification service by incorporating a consignment service for high-value fashion items, responding to the marked consumer preference for interactive and immersive shopping experiences, especially with expensive items. By having professionals manage the 3D capture process internally, this model allows buyers to benefit from high-quality 3D item previews without the complexities often associated with personal use of such technologies effectively mitigating the limitations of current 3D object scanning technology. It is a safe and viable strategy for introducing this technology into C2C marketplaces. By managing the 3D capture process in-house, Vinted not only overcomes current technological limitations but also positions itself for rapid adoption of future advancements, ensuring it remains at the forefront of tech innovation and is ready to transition the process to sellers as the technology becomes more user-friendly.

Overall, the thesis concludes that while 3D object capture technologies present significant opportunities for enhancing customer experience and operational efficiency in C2C marketplaces, their successful implementation is dependent on addressing current technological challenges and aligning with strategic business models. The proposed business model extension strategy for Vinted not only effectively mitigates these existing drawbacks, allowing C2C marketplaces to implement the technology in a limited yet impactful manner today but also positions these marketplaces for more prepared and swift full adoption once the technology becomes sufficiently consumer-friendly.

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