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CONTENTS

The Harmful Effects of Wasteful Spending [7]
Hershey H. Friedman, Dov Fischer, and Sholom Schochet

Poststructuralism and the Post-Marxist Critique of Knowledge Capitalism: A Personal Account [21]
Michael A. Peters

Biometric Facial Recognition Technology, Law Enforcement Algorithmic Automation, and Data-driven Predictive Policing Systems in Human Rights Protections and Abuses [38]
Filip Bacalu

Blockchain Technology Adoption in Artificial Intelligence-based Digital Financial Services, Accounting Information Systems, and Audit Quality Control [55]
Rafaela Cazazian

Biometric Sensor Technologies, Visual Imagery and Predictive Modeling Tools, and Ambient Sound Recognition Software in the Economic Infrastructure of the Metaverse [72]
Tomas Kliestik, Marek Vochozka, and Mile Vasić

Virtual Navigation and Geospatial Mapping Tools, Customer Data Analytics, and Computer Vision and Simulation Optimization Algorithms in the Blockchain-based Metaverse [89]
Susan Gordon

Haptic and Biometric Sensor Technologies, Spatio-Temporal Fusion Algorithms, and Virtual Navigation Tools in the Decentralized and Interconnected Metaverse [105]
Jana Majerová and Aurel Pera

Visual Imagery and Geospatial Mapping Tools, Virtual Simulation Algorithms, and Deep Learning-based Sensing Technologies in the Metaverse Interactive Environment [122]
Anna Zauskova, Renata Miklencicova, and Gheorghe H. Popescu

Geospatial Mapping Technologies, Predictive Modeling Algorithms, and Immersive Visualization Systems in the Virtual Economy of the Metaverse [138]
Raluca-Ștefania Balica

Virtual Retail Algorithms, Behavioral Predictive Analytics, and Geospatial Mapping Technologies in the Decentralized Metaverse [154]
Susan Beckett

Cognitive Artificial Intelligence Algorithms, Movement and Behavior Tracking Tools, and Customer Identification Technology in the Metaverse Commerce [171]
Katarina Zvarikova, Veronika Machova, and Elvira Nica

Metaverse Technologies, Behavioral Predictive Analytics, and Customer Location Tracking Tools in Blockchain-based Virtual Worlds [188]
Brian Carey

Image Processing Computational Algorithms, Sensory Data Mining Techniques, and Predictive Customer Analytics in the Metaverse Economy [205]
Marian Grupac and George Lăzăroiu

Machine Vision Algorithms, Sensory Data Mining Techniques, and Geospatial Mapping Tools in the Blockchain-based Virtual Economy [223]
Adela-Claudia Cuțitoi

Simulation Modeling and Image Recognition Tools, Spatial Computing Technology, and Behavioral Predictive Analytics in the Metaverse Economy [239]
Katarina Valaskova, Jakub Horak, and Sofia Bratu

Big Data Processing Techniques and Algorithmic Decision-Making Tools in Cloud-based Accounting Information Systems [256]
Luminița Ionescu

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The Harmful Effects of Wasteful Spending

Hershey H. Friedman[1], Dov Fischer[2], and Sholom Schochet[3]

ABSTRACT. This paper examines the significant problems that result from wasteful spending, which include fiscal irresponsibility, deferred maintenance, and excessive executive compensation. Waste in areas such as health care, defense, higher education, and municipal government are studied. The authors conclude that executives and auditors should be as concerned with wasteful spending as fraud because the former can be as devastating to an organization as the latter.

Keywords: fraud; wasteful spending; health care; higher education; transit authority; Pentagon.

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Introduction

It is of paramount importance for a leader to build a culture of integrity and ethics and set the tone at the top. Three common unethical practices involve fraud, waste, and abuse. Fraud tends to be intentional, while waste and abuse generally relate to inefficiency. Rooting out fraud, waste, and abuse have been given priority in the area of healthcare reform. Abuse in healthcare involves harmful or unnecessary medical treatments that increase costs; it is closely related to fraud. It is believed that the elimination of fraud, waste, and abuse in healthcare could provide more than a trillion dollars in savings and pay for universal coverage (Iglehart, 2009). Speer et al. (2020) conclude that excess medical care waste varies from $600 billion to more than $1.9 trillion per year, or roughly $1800 to $5700 per person per year.

Fraud, waste, and abuse are serious problems in both the corporate world as well as running government. According to one survey, 54% of Americans have been victims of corporate abuse, which includes predatory lending and debt collection practices, wage theft, and the refusal to refurbish hazardous housing (Porter and Habig, 2019).

Fraud, waste, and abuse are often collectively defined as any improper activity that involves the misconduct or misuse of an organization's resources or property. For example, the California Government Code (Section 53087.6(f)(2)) defines fraud, waste, and abuse as "any activity by a local agency or employee that is undertaken in the performance of the employee's official duties, including activities deemed to be outside the scope of his or her employment, that is in violation of any local, state, or federal law or regulation relating to corruption, malfeasance, bribery, theft of government property, fraudulent claims, fraud, coercion, conversion, malicious prosecution, misuse of government property, or willful omission to perform duty, is economically wasteful, or involves gross misconduct." However, fraud, waste, and abuse can be further distinguished by the intent to deceive and conceal (fraud), versus using resources in a manner that is contrary to the spirit of the rules or natural use (abuse), versus careless or negligent spending and inefficiencies (waste). In a sense, the three activities may be viewed as a continuum with fraud often being grounds for criminal prosecution, waste being grounds for administrative sanctions, and abuse somewhere in between. In that regard, fraud is more clearly defined, while waste and abuse are often "in the eyes of the beholder" (Feldman and Eichenthal, 2014).

As a result of the ambiguities surrounding abuse and waste, there has been much more emphasis on fraud than abuse and wasteful spending. This paper fills this gap and highlights the damage that results from profligate, reckless spending. We demonstrate the severe problems that arise from wasteful spending and argue that auditors should be as concerned with waste as much as with fraud.

Literature Review

Ethical Breakdowns and Scandals

The following are just some examples of major scandals that rocked the corporate world during the last several years: Boeing's 737 Max, Wells Fargo's account fraud, Libor's rate fixing, Takata's faulty airbags, Volkswagen's emissions rigging, General Motors' ignition switch, Toyota's sticky pedals, Toshiba's accounting, Purdue Pharma's opioid marketing, sexual harassment at Uber, and Listeria-tainted Blue Bell ice cream. Organizational leaders and boards may be paying lip service to the importance of integrity and ethics but are not practicing what they preach. Bazerman and Tenbrunsel (2011) state that a considerable amount of money is spent to ensure compliance – about one million for every billion in sales. Despite all this, unethical behavior is quite common. Approximately 23% of employees have come under pressure to engage in immoral actions. These include "rule violations (29%), lying (27%), unhealthy work environment (27%), ... sacrificing safety (9%), discrimination (3%), stealing (3%), and bullying (2%)" (Ivcevic et al., 2020).

Companies and their leaders have no qualms about price gouging, selling dangerous products, committing fraud, or using deceitful accounting as a way to make money. Amazon shut down over 500,000 products and suspended more than 6,000 vendors because of COVID-19 price gouging (Friedman and Gerstein, 2016; Morad, 2020). Top executives at Purdue Pharmacy, manufacturer of Oxycontin, were aware of the extensive abuse of their opioids in the late 1990s and purposely hid this information from the government. Over the last two decades, more than 200,000 people died from opioid overdoses (Meier, 2018).

The number of sexual harassment cases involving executives has been astronomical, with companies often paying up to cover up crimes committed by executives and making victims sign nondisclosure agreements. The Harvey Weinstein case, together with the #MeToo movement, changed everything. By 2018, more than 200 powerful men lost their positions because of sexual misconduct (Carlsen et al., 2018).

Executives at the Brazilian mining giant, Vale, are facing homicide charges for putting profits above safety and covering up information regarding the stability of its dams. There was retaliation against auditing firms that pointed out that there was a danger that some of the dams might collapse. When the Brumadinho dam burst in January 2019, at least 259 people died (Londoño and Andreoni, 2020).

According to prosecutors, the April 16, 2014 Sewol ferry disaster that resulted in the death of more than 300 people might have been averted if company executives had spent more on safety measures. Instead, money from the company that owned the ferry (Chonghaejin Marine Company) was embezzled and enriched the Yoo family members that controlled the firm (Sang-Hun and Hughes, 2020).

Having a code of ethics does not ensure that the organizational culture will change. Hamel (2009) posits that rules do not suffice to improve corporate ethics. If an organization is genuinely concerned about ethics, it has to follow what the VA (Department of Veterans Affairs) is doing and take a three-pronged, systems-focused model that considers "decisions and actions, systems and processes, and environment and culture." Leaders have a crucial role in shaping the culture of their organization. If leaders are sincere about ethics and deal with it how they treat other organizational priorities such as cost or profit, they will create an ethical environment. Ethics must be value-driven, not rule-driven.

> Rules usually define prohibited behavior or minimal standards, instead of inspiring exemplary or even good practices. A rules-based culture tends to emphasize compliance with 'the letter of the law' as opposed to fulfilling 'the spirit of the law.' From an ethics perspective, overemphasizing rules can lead to 'moral mediocrity' – or worse, unethical practices, if employees equate 'no rule' with 'no problem' or if they 'game the rules' by developing ethically problematic workarounds. While employees in rules-driven organizations tend to concentrate on what they must do, those in organizations with a healthy ethical environment and culture tend to concentrate more on what they should do – finding ethically optimal ways to interpret and act on the rules in service of the organization's mission and values (National Center for Ethics in Health Care, 2007, p. 3).

The Integrated Ethics approach used by the VA is one way of ensuring an ethical organizational climate. Organizations using this approach provide an *ethical consultation service* so employees and others know where to turn when a difficult decision must be made. These firms are also concerned with *preventive ethics*, which means that a proactive approach is taken and work processes may be restructured to preclude unethical behavior. Employees may need to be educated and even offered incentives to strengthen ethical practices. Ultimately, the key responsibility lies with leaders to create a "workplace culture based on integrity, accountability, fairness, and respect" (National Center for Ethics in Health Care, 2007).

Ho (2015) questions the belief that the way to solve common ethical problems is by learning ethical theories:

> The idea that we need ethical theories to tell us what we ought to do might strike most laypersons as awkward and artificial; e.g., consider how odd it sounds to decide whether one ought to continue a pregnancy by seeing if it maximizes utility. The fact is we frequently resolve ethical disputes in our daily lives, often paying

> little attention to ethical theories. To be sure, when challenged, many of us justify our moral choices on the basis of some ethical theories, but the appeal to theories is often a form of post hoc rationalization. Psychological studies done by Jonathan Haidt support this view (Ho, 2015, para. 8).

The COVID-19 pandemic has had a massive impact on many companies. Several firms are uncertain whether they will be able to survive (Obrenovic et al., 2020). Those that succeed will have to find ways to cut costs without compromising efficiency, service quality, and customer satisfaction. Rust et al. (1994) demonstrate the relationship between quality and efficiency.

There is no question that fraud and waste are serious problems. Dyck et al. (2021) estimate that approximately one-third of corporate fraud is uncovered. Furthermore, 11% of publicly traded companies are guilty of securities fraud annually. It is considerably more challenging to detect waste, but it is quite probable that the costs are even higher. Indeed, one may posit that squandering money may result in as much harm to an organization as an unethical business practice. Funds spent foolishly on unnecessary items mean that there will be less available for much-needed repairs and improvements.

Fiscal Recklessness

Most people do not think of fiscal recklessness as an example of unethical behavior. However, a fiscally irresponsible leader may cause more harm to an organization than one who commits fraud and takes a kickback from a supplier. Some argue that politicians engage in wasteful spending not out of negligence but instead "out of a desire to improve their chances of re-election by signaling their commitment to supplying public goods" (Dewatripont and Seabright, 2006). Further, Liebman and Mahoney (2017) find that federal government agencies are being incentivized to wastefully spend, particularly towards the end of the fiscal year, as a result of the "use-it-or-lose-it" nature of time-limited budget authority.

John V. Lindsay was the charismatic mayor of New York City from 1965 to 1973. His biggest mistakes involved financial recklessness; he did not understand that there was a limit to how much debt a city could issue. Under his watch, welfare rolls skyrocketed from 500,000 in 1965 to 1,200,000 in 1969 (one-sixth of the city's population). The mayor funded seminars on recruiting more welfare recipients, eliminating screening to determine applicants' eligibility, and eliminating time limits on benefits (Malanga, 2001). Hospital costs, education costs, and municipal labor costs also rose very steeply. The city budget was $4.6 billion in 1967 and $7.8 billion in 1971, a 41% increase. The city introduced an income tax, increased corporate taxes, and added a commuter tax as well as other taxes (Rothstein, 2010). New York City's overtaxed economy crashed at the start of Lindsay's second term; the city was virtually bankrupt in 1973. Lindsay was presumably planning on running for president and needed to pad his resume with accomplishments. The easiest way to do this was by spending vast amounts of money and issuing debt. He made it look like he was accomplishing a great deal by instituting sizeable social welfare programs, but he was bankrupting the city.

The coronavirus pandemic has reduced New York City's tax revenue by as much as $9 billion. Mayor de Blasio is talking about shrinking the municipal labor force by 22,000 workers as well as cutting infrastructure spending, especially from the transit authority, which needs $54 billion to modernize the outdated transportation system. The mayor wants the state to allow the city to take on additional debt for operating costs. The mayor has not mentioned that the city workforce grew by 30,000 during his administration to a record 326,000 by the end of 2019 (Rubinstein and Goldbaum, 2020). City Council was surprised that Mayor de Blasio's spouse, Chirlene McCray, has spent $900 million on her ThriveNYC program that was supposed to reduce homelessness and help the mentally ill. It appears that the money was wasted and was ineffective. Several elected officials have complained about the lack of transparency (McManus, 2019). There have also been complaints about the enormous cost of non-classroom bureaucracy at the Department of Education in New York City that increased from $489 million in 2014 to $734 million in 2020. Because the city is facing a huge fiscal crisis due to the pandemic, the mayor is talking about cutting the education budget by $827 million. Most likely the classroom teaching budget will be facing the draconian cuts, not the administrative bloat (Edelman, 2020).

It is imperative for leaders to make their organizations efficient and not merely expand the workforce. Hiring more workers may help mayors win elections but can wreak havoc with finances in times of a crisis. If the transit system in New York City is allowed to deteriorate again, New York City may never fully recover. Unfortunately, kicking the can down the road is a standard solution to government problems.

Deferred Maintenance: Expansion Rather than Reliability and Safety

It is not sexy to maintain buildings, so many organizational leaders spend considerable sums of money on new buildings and allow older buildings to fall apart. This is what is going on all over the country when it comes to infrastructure, such as bridges. A total of 58,495 bridges out of 609,539 (9.6%) in the United States are rated as structurally deficient (Cardno, 2016). 17% of American dams (15,498) have been recognized as high-hazard potential by the American Society of Civil Engineers ("Dams," 2017). Politicians prefer investing in something new rather than fixing old infrastructure, i.e., choosing expansion over maintenance. By doing this, they are also sacrificing safety and reliability in the name of development and growth. If you want to look good for your next job, it is more impressive to say that you built a new bridge, dam, building, and/or program than saying you maintained the existing infrastructure. Maintenance can never be as sexy as expansion.

New York City is spending billions on new subway stations but uses an antiquated signal system; much of it dates back to the 1930s. The signal system was supposed to be computerized in 1991 after a subway derailment killed five people. In 2017, more than 25 years later, only one out of 22 subway lines has automated signals. The deadline for finishing this task keeps getting pushed forward and is now estimated to be 2045 (Fitzsimmons, 2017).

The Metropolitan Transportation Authority (MTA) is an excellent example of an organization that may have to reduce service drastically because of profligate spending. Many experts have noted that "MTA operations are riddled with massive overspending and wastes of labor: a slate of operational reforms and modernization could have reduced operational expenditures enough to cover the entire current deficit" (Harris, 2020, para. 3). One example of the waste is that unlike most systems in the world that only utilize one person to run a train, a New York City subway uses a conductor and motorman. Also, it costs four times more to maintain tracks and facilities in New York City than any other subway system. Harris (2020) provides several other examples of excessive spending. If the MTA does not receive billions in emergency aid from the government, its executives threaten to make draconian cuts to service. No one is talking about looking for operational efficiencies.

Many college presidents prefer to invest in new programs and buildings that cost a great deal but bring in little revenue. Closely related to the problem of underinvesting in maintenance is the issue of administrative bloat. Administrative bloat, the hiring of too many administrators, is a national problem and has resulted in an inordinate amount of waste in higher education (Amoo and Friedman, 2020; Marcus, 2014; Ginsberg, 2014; Green et al., 2010).

A rational person might believe that it makes no sense for a college to create unneeded departments or schools when a campus is unsafe and falling apart. However, college presidents are often more concerned with padding their CVs by showing substantial, splashy accomplishments. Unfortunately, there is no auditor concerned with the examination of facility maintenance. There have been complaints regarding the crumbling infrastructure at many of the City University of New York colleges. Brooklyn College of the City University of New York was called "Brokelyn College" by students and faculty (Chen, 2016; Frangipane, 2016; Grassman and Shortell, 2016). The students were posting pictures on Instagram (https://www.instagram.com/cuny_brokelyn_college/) showing how dilapidated the facilities had become.

There are many other examples of disasters that resulted from not maintaining plant and equipment properly. On December 2, 1984, a horrific tragedy occurred when a storage tank in the Union Carbide pesticide plant in Bhopal, India, began to leak methyl isocyanate (MIC) gas into the city. Approximately

3,000 people perished immediately, and another 20,000 people died over the next 20 years from the poison gas. This disaster occurred because the company was more concerned with cutting costs than maintaining a safe workplace (Gerstein and Friedman, 2015). Gerstein and Friedman (2015) posit that the catastrophic flooding of New Orleans due to Hurricane Katrina had more to do with neglect, inadequate maintenance, and engineering flaws than with the hurricane itself. More than 1800 people died as a result of this disaster.

For years, the Pacific Gas & Electric (PG&E) company repeatedly failed to adequately maintain its aging power lines, notwithstanding that they passed through windy, forested areas. The infamous Camp Fire caused 84 deaths and billions of dollars in damages; the entire town of Paradise, California was destroyed. The company had spent billions on shareholder dividends and bonuses for executives rather than repairing equipment that was decades old. Moreover, the firm had paid fines in 2017 and 2018 for negligence that resulted in fires. The CEO of PG&E pleaded guilty to the charge of corporate wrongdoing and apologized for the disaster. Survivors of the blaze were not happy that PG&E was ordered to pay a small $3.5 million fine (Penn, 2020; Rosenblatt, 2019).

Wasteful Spending on Unnecessary Projects and Tasks

As noted above, college presidents and provosts often waste precious resources on unneeded schools and academic departments. The healthcare industry is arguably the most inefficient when it comes to spending money wisely. No country spends more than the United States on health care; costs are approximately 18% of GDP. Researchers believe that about 25% to 30% of health care spending is wasteful (Shrank et al., 2019). This waste results from misspending in six areas: "failure of care delivery, failure of care coordination, overtreatment or low-value care, pricing failure, fraud and abuse, and administrative complexity." There are many methods to reduce extravagant spending – especially when it comes to administrative waste and the high cost of drugs – but what stands in the way of progress is greed. Too many companies benefit from the inefficiency. Both Senator Charles E. Grassley, chairman of the Finance Committee, and Representative Frank Pallone Jr. are working on bills to reduce pharmaceutical costs. The house bill could save as much as $500 billion over a decade, but drug companies are fighting any legislation dealing with pricing (Weiland, 2020).

It is no secret that unnecessary medical treatments, including surgery, inflate health care costs. Frakt describes how huge savings would result from this area of inefficiency:

> With more than half of medical treatments lacking solid evidence of effectiveness, it's not surprising that these areas add up to a large total. They include things like hospital-acquired infections; use of

> high-cost services when lower-cost ones would suffice; low rates of preventive care; avoidable complications and avoidable hospital admissions and readmissions; and services that provide little to no benefit (Frakt, 2019, para. 18).

Brody (2012) asserts that the ethical debate in medicine is shifting from rationing to waste avoidance. He defines waste as "spending on interventions that do not benefit patients" (p. 1950) and amounts to more than 30% of the budget. Waste contributes significantly to rising health care costs. Moreover, in many cases, costly treatments for patients near death do not extend life but transform patients' remaining months into a nightmare. Brody concludes that the ethics of rationing and the ethics of waste avoidance are not in competition but complement each other. Weber (2011, p. 69) asserts that the "obligation to put the patient's welfare first does not mean that the professional is justified in ignoring costs." There is evidence that the way physicians and hospitals are reimbursed provides them with a financial incentive to over-diagnose and overtreat. He cites Brownlee, who claims that "Patients who went to the hospitals that spent the most – and did the most – were 2 to 6 percent more likely to die than patients who went to the hospitals that spent the least" (p. 73).

The Department of Defense

In the past, the Defense Department had to explain why it spent $436 for hammers, $117 for soap dish covers, and $999 for pliers. Recently, they purchased cups for $1,280 and 3-D printed toilet seats for $14,000. In 1990, Congress passed the Chief Financial Officers Act to require every federal agency to prepare audited financial statements. Every federal agency has been able to be reviewed annually except for the Department of Defense. It appears that the Pentagon prefers having an infrastructure consisting of hundreds of different accounting systems to make it virtually impossible to conduct a clean audit. It is difficult to know where all the money is going. The total budget is more than $700 billion.

> Enron at its core was an accounting maze that systematically hid losses and overstated gains in order to keep investor money flowing in. The Pentagon is an exponentially larger financial bureaucracy whose mark is the taxpayer. Of course, less overtly a criminal scheme, the military still churns out Enron-size losses regularly, and this is only possible because its accounting is a long-tolerated fraud. We've seen glimpses already. The infamous F-35 Joint Strike fighter program is now projected to cost the taxpayers $1.5 trillion, roughly what we spent on the entire Iraq War (Taibbi, 2019, paras. 21–22).

In 2018, an audit was conducted at the cost of $400 million but could not come up with a definitive answer. A total of 1,200 auditors were unable to offer an opinion because the numerous accounting systems – some still use the outdated computing language of COBOL – were too confusing to understand (Grassley, 2018; Taibbi, 2019). Taibbi (2019, para. 12) points out that "It's the world's largest producer of wrong numbers, an ingenious bureaucratic defense system that hides all the other rats' nests underneath."

Excessive Executive Compensation

One form of improvident spending at some organizations deals with the compensation of executives. Baker et al. (2019) maintain that the rapidly increasing compensation for CEOs – in 2017, the mean salary for CEOs at the 350 largest companies was $18.9 million – has exacerbated the problem of income inequality in the United States. The extravagant pay for CEOs affects the pay scale for upper-level managers and executives throughout the economy. Even at nonprofits, people at the higher ends of management continue to earn more while wages and salaries for employees in the middle and bottom remain stagnant. Adding insult to injury, CEOs' exorbitant salaries are not correlated with performance; instead, they are related to the strength of the relationship CEOs have with the board members who determine compensation.

Moriarty (2009) posits that the right amount of compensation for an executive is the minimum needed to "attract, retain, and motivate" the CEO to do the best possible job to maximize the firm's value. He states that CEOs have a fiduciary duty to shareholders (and stakeholders), making it immoral for them to accept any compensation greater than this minimum. In any case, excessive CEO compensation would be another example of wasteful spending. Caywood (2010) provides an exciting solution to this problem. He argues that a strengthened corporate waste doctrine and a say-on-pay resolution could be used to fight against a board of directors unconcerned about excessive executive compensation. Most of the time, Caywood notes that members of boards who are generally CEOs themselves have little incentive to do anything to speak out against disproportionate remuneration. One exception mentioned by Caywood occurred in 2009 when the board of American International Group (AIG) announced it would be paying executives a bonus of $165 million. AIG was on the brink of bankruptcy and was only saved because of a government bailout.

Conclusion

When it comes to allocating scarce resources, there is often a tradeoff between efficiency and ethics. Lee and Geelhoed (2011) posit that there are situations when it makes sense to fund a program that is not that efficient for various reasons. Typically, wasteful spending is closely related to fraud and may even encourage it. This paper demonstrates the severe problems that arise from wasteful spending, and auditors should be as concerned with waste as much as with fraud. Much damage may result when an organization's resources are misallocated to showy projects that look good on someone's CV, and simple maintenance is deferred. The long-term harm that may result from fiscal irresponsibility can be as devastating as that of fraud. While it is essential to teach about corruption in business ethics courses, it is equally important to describe the devastation resulting from wasteful spending.

Author contributions
All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Poststructuralism and the Post-Marxist Critique of Knowledge Capitalism: A Personal Account

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ABSTRACT. Motivated by readings of Lyotard, Foucault, Derrida, and Deleuze and Guattari, this paper outlines the basis for three related claims: (i) the knowledge economy is a form of neoliberal globalization; (ii) education has become a form of knowledge capitalism; (iii) poststructuralism provides a post-Marxist critique of knowledge capitalist form of neoliberal globalization. I see my own work as a working out of the exploration of these themes aided by the work of Lyotard, Foucault, Derrida and Deleuze. While these philosophers view themselves in some kind of relationship to the legacy of Marx as Marxist or post-Marxist thinkers, they also entertain ways of going beyond both Marx and the Althusser's Spinoza-inspired reading of Marx that was dominant in 1970s France. Foucault was intent on establishing a Left culture that was not Marxist, one that could engage with neoliberalism that did not simply repeat old structuralist binaries yet he remained wedded to political economy. He pursued the genealogy of the revival of *homo economicus* as the basis for the emergence of economic liberalism in the twentieth century. Deleuze and Guattari remained Marxists even after 1968 while systematically displacing Marxist concepts to introduce the concept of "desiring-production" (Marx *and* Freud), to put desire into the social realm of production as a libidinal investment that takes place without a subject and is autonomous, self-constituting, and creative. Lyotard, as a post-Marxist thinker, examined the status and development of knowledge, science and technology in advanced capitalist societies within the broader context of the sociology of postindustrial society and studies of postmodern culture. After the "fall" of communism, Derrida embraces Marx's spirit of radical critique and the prospect of the New International to formulate a philosophy of social responsibility. In recent work inspired by these thinkers I posit an alternative form of educational globalization that I call "knowledge socialism" that is based on principles of openness, the ethics of collaboration, and the rise of peer production, which together can constitute a powerful modality of transnational networked intelligence.

Keywords: poststructuralism; post-Marxist; critique; knowledge; capitalism

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Reading Derrida

I was sitting in my office in an old villa at the University of Auckland, New Zealand, slumped over my desk trying to read an early essay of his called "Punctuations: The Time of the Thesis" that was based on a speech he presented in 1980 on the occasion of Derrida finally receiving his doctorate; in effect, it was his thesis defence that took place at the Sorbonne in front of a jury chaired by Maurice de Gandillac and composed of Pierre Aubenque, Jean-Toussaint Desanti (supervisor), Henry Joly, Gilbert Lascault, and Emmanuel Levinas. Derrida describes how he submitted his thesis topic in 1957 that he called *The Ideality of the Literary Object*, a thesis that Jean Hyppolite was to supervise. Hyppolite told Derrida that he could not see where he [Derrida] was going, whereupon Derrida responded – "If I could see clearly in advance where I'm going, I don't think I would go one step further to get there," and then he remarked: "What is the point of going where we know we are going and where we know we are destined to arrive?". As Derrida indicates his thesis was an attempt to bend "the techniques of transcendental phenomenology to the needs of elaborating a new theory of literature," and especially to explore the relation between literature and philosophy (2004: 116). He was driven back to a Hegelian reading of Husserl's phenomenology and, in particular, the genesis of structure that Husserl developed in *The Origin of Geometry*, and how this problematic accounted for much of what followed:

> …of the historicity of ideal objects, of traditions, of inheritance, of filiation or of wills and testaments, of archives, libraries, of writing and living speech, of the relationships between semiotics and linguistics, of the question of truth and of undecidability, of irreducible alterity that divides the self-identity of the living present, of the necessity for new analyses concerning nonmathematical idealities, and so on (p. 118).

At the time of reading Derrida's essay I was struggling to come to terms in my doctoral studies with my own reading of Wittgenstein and I found uncanny resonances between the two philosophers, particularly in relation to the importance of style in philosophy. I distinctly remember an earlier session where I had fallen asleep with my head in my hands and dreamt how I should read him as one would read the most experimental avant-garde literature – as one learns to read Stern's *Tristam Shandy* or Joyce's *Ulysses*. Suddenly, the book fell open; there was no going back. I came to recognize why so many scholars had referred to his genius in developing *deconstruction* based on "the graphics of *différance*, of the trace, of the supplement and so on," that is, as he suggests, a critical relation to everything in relation to the French theoretical production of "structuralism" (p. 119). In essence, in "The Time of the Thesis," he was both undermining the predominant form of French theoretical production – Structuralism – (and the form of the thesis), while advancing a conception that questioned the logocentrism of the *universitas* and its embodiment in "the ontological and logocentric onto-encyclopedic system." In short, a revision of Western metaphysics and of the institutions it supported including the university and its extant models of interpretation.

Perhaps, more than any of his colleagues Derrida taught me that philosophy was a kind of literature. Derrida (1967) submitted his thesis for *Doctorat de spécialité* as *Of Grammatology: Essay on the Permanence of Platonic, Aristotelian and Scholastic Concepts of the Written Sign*. It became the handbook of deconstructive practice. As a demonstration of the history of writing as a "fall" from the full presence of speech and the oral voice, Derrida begins by updating Saussure's concept of the sign and to deconstruct Saussure's ruling assumption that "Language and writing are two distinct systems of signs; the second exists for the sole purpose of representing the first." By contrast, Derrida argues that writing is a significant signifier and should not be seen in derivative terms in relation to oral speech. In "Linguistics and Grammatology," translated by Gayatri Chakravorty Spivak, published in 1974, Derrida begins with the following quotation from Rousseau's *Fragment inedit d'un essai sur les langues* – "Writing is nothing but the representation of speech; it is bizarre that one gives more care to the determining of the image that to the object." He follows this clue with thought concerning the definition of a science:

> The concept of writing should define the field of a science. But can it be determined by scholars outside of all historico-metaphysical predeterminations that we have just situated so clinically? What can a science of writing begin to signify, if it is granted:
> 1) that the very idea of science was born in a certain epoch of writing;
> 2) that it was thought and formulated, as task, idea, projects, in a language implying a kind of structurally and axiologically determined relationship between speech and writing;
> 3) that, to that extent, it was first related to the concept and the adventure of phonetic writing, valorized as the telos of all writing, even though what was always the exemplary model of scientificity – mathematics – constantly moved away from the goal;
> 4) that the strictest notion of a *general science of writing* was born, for non-fortuitous reasons, during a certain period of the world's history (beginning around the end of the eighteenth century) and within a certain determined systems of relationships between 'living' speech and inscription (p. 127)

His "Time of the Thesis" was a spectacular example of his own self-consistent literary practice. It opened a skylight. *Of Grammatology* in my doctoral studies first gave me headaches and great anguish on the intuition that here was something path-breaking but I couldn't completely access it. In this regard to my inchoate feeling of philosophical childishness, I came across the brilliant "Introduction" of Gayatri Spivak, an internationally acclaimed *tour de force*. The basis was laid for deconstructive philosophy as radical Marxism, a form of emancipation, tied to the critique of Western of logocentrism used not only to demythologize Western metaphysics but also to analyze political discourse and ideology.

Spivak, Eurocentrism, Marx, and the Asia Century

Steve Paulson's (2016) interview with Spivak in the *Los Angeles Review of Books* explains how she came to Derrida's work and to the task of translation as a young Indian scholar who had migrated to the USA.

> When I translated it, I didn't know who Derrida was or anything about his thinking. So I did my best to introduce and translate it and the introduction really caught on, for which I'm very grateful. But now, after a lifetime of working with and through Derrida, I can say something more to my readers about this extraordinary thinker, so I added an afterword. This is a kind of tribute to a lived life rather than encountering a great new text. https://conversations.e-flux.com/t/gayatri-spivak-on-derrida-the-subaltern-and-her-life-and-work/4198

She says she "didn't notice how critical the book was of 'Eurocentrism' because the word in 1967 was not so common." Equipped with deconstruction Spivak became one of the founders of postcolonial theory, suggesting "it was an engagement with that part of deconstruction, which looked at what is excluded when we construct systems," where "theorizing is a practice." The immediate resonance for approaching and reading texts, that went beyond Eurocentrism, systems and Western metaphysics, is not lost on reading Marx, or should say on rereading Marx (after Althusser)? Immediately, the decentering of the text as the only true literary object is a shipwreck, along with all other forms of foundationalism and fundamentalism. Is there a Marxism, as the critics say, "after Marx"? Is there a nonfoundationalist, nonEurocentric Marx? And what is its interpretative future? The traditional of Western Marxism has a history of its different forms and interpretation, each succeeding the last, each with its followers, and each pushing ahead to realize a different conception. In *Spectres of Marx* Derrida (1994) in the spirit of Marx calls for a "New International," neither a party of workers' organization, but a group of global activists that can renew and radicalize Marx to tackle questions of international law in respect of employment, immigration, war, debt, the arms trade, nuclear proliferation and inter-ethnic conflicts.

With the rise of China, we must anticipate the effects of new Chinese Marxism and its possible dialogue with the tradition of Western Marxism

(Chengbing and Peters, 2021). Only by doing so we will be able to respond to the question of Chinese modernity, the Asian century, and the future shape and direction of global society. The combination of Derrida and Spivak edges us away from Eurocentric and logocentric accounts of Marx to embrace a gender and racial equality of the working subject while recognizing the transformation of labour in age of algorithmic and platform knowledge capitalism that consists in the engineering of autonomous and intelligent information systems with its privileging of digital networks and its associated forms of technological unemployment (Peters et al., 2019). Marx's "Fragments on Machines" (*The Grundrisse*, pp. 690–712) with its notion of the General Intellect provides a sketch of an account that understands how the machinery of production has become autonomous.[1] It points toward a political economy that might come to grips with the coming intersection between global cryptocurrencies and the emergence of the quantum internet.

Jean-Francois Lyotard's Abandonment of the Dialectic

> Inasmuch as there was in Marxism a discourse which claimed to be able to express without residue all opposing positions, which forgot that *differends* are embodied in incommensurable figures between which there is no logical solution it became necessary to stop speaking this idiom at all... (Lyotard, 1988: 61).

Lyotard uses the term "postmodern condition" to describe the state of knowledge and the problem of its legitimation in the most highly developed societies to designate the state of Western culture "following the transformations which, since the end of the nineteenth century, have altered the game rules for science, literature and the arts" (Lyotard, 1984: 3) which leads him to review these transformations within the context of the crisis of narratives, especially those Enlightenment metanarratives concerning meaning, truth and emancipation.[2] These are the traditional liberal metanarratives that have been used to legitimate both the rules of knowledge of the sciences and the foundations of the modern university.

Lyotard wishes to call into question the effects of the new technologies since the 1950s and their combined impact on the two principal functions of knowledge, research and the transmission of learning, maintaining that all the leading sciences and technologies based on language-related developments, including theories of linguistics, cybernetics, informatics, computer languages, telematics, theories of algebra, as well as their miniaturization and commercialization. The status of knowledge is permanently altered in this context: its availability as an international commodity becomes the basis for national and commercial advantage within the global economy and its computerized uses has become the basis for enhanced State security and "intelligence." In short, knowledge has become the principal force of production, changing the composition of the workforce in advanced economies. The commercialization of knowledge and new forms of social media circulation raise new ethical and legal issues between the nation-state and the internet multinationals, as well as widening the gap between the North and South.

In his early works, *Discours, figure* (1971) and *Economie libidinale* (1974), Lyotard shifts away from the doctrinaire praxis philosophy which characterized the non-PCF Marxism tradition of *Socialisme ou barbarie*. The former work attempts to develop a metaphysics of truth without negation; the latter attempts to substitute Freud's economy of libidinal energy (and the notion of primary process) for Marxist political economy. In this situation there is no truth arrived at through dialectics: the supposed ethical and social truths of Marxism, based upon an appeal to an historical ideal, are no better than the falsehoods it wants to overcome. Lyotard (1974) criticizes the underlying notion of the dialectic. He simply does not believe that a political, philosophical, or artistic position is to be abandoned because it is "sublated." It is not true that the experience of a position means its inevitable exhaustion and necessary development into another position where it is both conserved and suppressed.

Michel Foucault's Relation to Marx

> Marx's economic discourse comes under the rules of formation of the scientific discourses that were peculiar to the nineteenth century ... Marxist economics – through its basic concepts and the general rules of its discourse – belongs to a type of discursive formation that was defined around the time of Ricardo. (Foucault, 2001: 269).

Foucault began his academic life as a Marxist under the influence of his mentor Louis Althusser but consciously moved away from the Communist Party in 1952 even though he remained within the tradition of the French historical materialist epistemology informed by Marx. In 1966 with the publication of *The Order of Things*, he began to historicize Marx and epistemology arguing that the episteme organizes knowledge in any given epoch discursively govern the rules for the kind of statements taken to be true. This quasi-structuralism (Foucault avoided the term) eventually led him to question Marxism in relation to the development of economics as a form of nineteenth century political economy, the radical critique of political economy that Marx mounted against liberal economics. His encounter with Nietzsche deepened this historicism as a form of genealogy that raised the order of discourse to the political realm and provided an account of "power/knowledge" as a concept that inextricably links power and knowledge in terms of historically contingent discourses and disciplines: their rules of formation, principles and methodologies, the emergence and history of disciplines. Marxist political economy Foucault suggests is subject to the rules of its formation and the early rules of the discourse established by Ricardo, Smith and others. Marx's radical critique is a critique of nineteenth century political economy at the point when the disciplines of economics, politics and philosophy were separating from one another. Following Foucault's direction we can go back to Sir James Stewart (1767) whose *Inquiry into the Principles of Political Economy* articulated a form of mercantilism. Jean-Jacques Rousseau's (1755) *A Discourse on Political Economy* is also noteworthy for its defining qualities:

> The word Economy, or OEconomy, is derived from oikos, a house, and nomos, law, and meant originally only the wise and legitimate government of the house for the common good of the whole family. The meaning of the term was then extended to the government of that great family, the State.[3]

David N. Balaam argues that the field of political economy emerged in the eighteenth century in reaction to mercantilism when Adam Smith (1723–90) and David Human (1711–76) and Francois Quesnay (1694–1774) create the rules of the discourse to treat it systematically.[4] Smith's (1776) comprehensive *The Wealth of Nations* reflected the individualist bias of Thomas Hobbes (1588–1679), John Locke (1632–1704), "the Realpolitik of the Italian political theorist Niccolò Machiavelli (1469–1527), and the inductive method of scientific reasoning invented by the English philosopher Francis Bacon (1561–1626)." An interesting mix to argue individual self-interest over state theories. David Ricardo (1792–1823) sought develop Smith's ideas. This argument strand based on individual self-interest was countered by Friedrich List (1789–1842) and Marx (1818–33).

One of Foucault's (1991) most accessible texts is *Remarks on Marx: Conversations with Duccio Trombadori* which is a series of interviews and conversation with Foucault towards the end of 1978. These conversations indicate the centrality of a Hegelian-inspired phenomenology and phenomenological existentialism centered on lived experience that dominated French post-war thought that also aligned with a reading of the early Marx's concept of alienated and "Marxism as a humanism," as Sartre expressed it. Foucault indicate his debt to Nietzsche in developing a microphysics of power and the concept "power/knowledge" that helped to explain the problem of truth in relation to discourse. Trombadori suggested in *The Order of Things* Foucault "reduced Marxism to an episode definitively within the episteme of the nineteenth century" (p. 103). Foucault responds:

> I wanted to confine my observations to Marx's political economy. I never spoke of Marxism, or if I used this term, I did so in order to refer to the history of political economy. And to tell the truth, I don't consider it so absurd to sustain that Marxist economics – for its fundamental concepts and the general rules of its discourse –

> belongs to a type of discursive formation that first took shape at around the time of Ricardo. In any case it was Marx himself who affirmed that his political economy was indebted in its fundamental principles to David Ricardo (p. 104).

Foucault's suggestion is that "the rules of Marx's economic discourse…" shared "the episteme of the criteria of the formation of scientific discourse proper to the nineteenth century" (p. 104). Traditional Marxists were very bitter about Foucault's approach that historized Marx's discourse on political economy linking it firmly to the liberal economics of Ricardo, and then through his governmentality studies he broadened his engagement with the four major strands of modern neoliberal economics in *The Birth of Biopolitics* (Foucault, 2008; Peters, 2007).

It is perhaps not surprising that scholars have sought to comment on relations between Marx and Foucault. *Marx & Foucault; Readings, Uses, Confrontations*, edited by Christian Laval, Luca Paltrinieri and Fernat Taylan (2015), provides a good example of a broad interpretation that suggests that the Left cannot "grasp the meaning of our present" without their concepts and analyses and yet as they acknowledge, the "Eras, intentions, even philosophies cannot be superimposed."

In the 1970s Foucault wanted to free himself from the tight grip of the Paris Communist Party and also to move beyond the phenomenological interpretations of Marx that dominated post-war France especially the humanist and existentialist readings. He also wanted to move beyond his mentor Althusser, even though Foucault embraced many of the aspects of the French historicist tradition of epistemology and the structuralist paradigm, which he always found troubling because of its alleged scientificity, static-ness, lack of historical dimensions and universalist pretensions. His contribution to Marxism was to embrace a Nietzschean reading of power that was not a simple articulation or subsumption and contrary to Balibar probably not a "meta-theory." Yet Foucault and Marx ought not to be considered to be irreconcilable (Keucheyan, 2016) and we ought not expect an easy superimposition of concepts and theories but rather a critical tension and distance that provide new ways of understanding the twists and turns of contemporary capitalism. Reflecting on what the interpretive demands of fundamentalist readings of Marx require, a set of principles for a radical critique of capitalism that do not change as capitalism changes. This is an unrealistic set of demands.

Gilles Deleuze and Felix Guattari as Post-Marxist Thinkers

> Félix Guattari and I have remained Marxists, in our two different ways, perhaps, but both of us. You see, we think any political philosophy must turn on the analysis of capitalism and the ways it has developed. (Deleuze, 1995, p. 171)

Deleuze and Guattari remained Marxists even after 1968 while systematically renovating Marxist concepts to introduce the concept of "desiring-production" (Marx *and* Freud), to put desire into social realm of production as a libidinal investment that takes place without a subject and is autonomous, self-constituting, and creative. I will focus on two main sources here: Deleuze's (1962) reading of Nietzsche that was a critical factor in the renaissance of Nietzsche thought in Post-war France and his relationship with Foucault, and the work with Guattari published as *Anti-Oedipus* (1972) and *A Thousand Plateaus* (1980), the two volumes of *Capitalism and Schizophrenia.* Both books are major statements of a host of original concepts – schizoanalysis, desiring-machines, body-without-organs, ensemblage, line of flight, deterritorialization – that seek to analyze the family as an agent of repression and political economy of desire of social production under capitalism. This was seen as a reworking of Freudianism and Marxism as reactionary movements using Nietzsche as the source of reformist and revolutionary interpretation, although no political framework is provided.

In *Nietzsche and Philosophy,* Deleuze (1962) pursues a Nietzsche-inspired critique of dialectics to develop the possibility of a non-Hegelian universal (Krtolica, 2012). In *Poststructuralism, Politics and Education* (Peters, 1996) in the "Introduction" I begin my analysis with the heading "The Games of the Will to Power Against the Labour of the Dialectic," which describes in shorthand formula basically how Deleuze interprets Nietzsche as the interpretation of a revolutionary Marxism that he develops with Guattari by bringing together the registers of power (Marx) and Nietzsche (desire). The book, my first sole-authored book after the collection *Education and the Postmodern Condition* (Peters, 1995) that explored the relevance of Lyotard's philosophy, was essentially a poststructuralist critique of then current neoliberal philosophy and policy in education. I tried to develop a poststructuralist critique of subject-centred reason, investigating the issue against the background of the modernity versus postmodernity and information/postindustrial society debates to criticize neoliberal constructions of the subject in education that rest heavily on the revitalization of *homo economicus* with its assumptions of individuality, rationality and self-interest. It was an early attempt to pursue the question of how poststructuralism represented in the works of Lyotard, Foucault, Derrida, and Deleuze and Guattari might inform a critique of neoliberal globalization in education by examining a range of interrelated themes central to the field of education that focused on the critique of reason and the problematic nature of the subject.

I focused on Deleuze's (1992) "Societies of Control," a concept that indicates a profound shift beyond Foucault's "disciplinary societies" based on technologies of confinement to one a form of power Deleuze calls "control," after William Burroughs, that operates through constant communication (Peters, 2001). Deleuze explains how the notion of control is applied to new institutional forms defined by open, networked and flexible architectures that blur boundaries among the different institutional spaces that we inhabit. It is a foresightful paper that signals a critique of cybernetic capitalism and the pervasiveness of an open architecture that I apply to education recognizing the fundamental shift from "disciplinary pedagogy" to "perpetual training." I explore its significance for the global knowledge economy through the concept of the spatialization of knowledge which draws on Deleuze and Guattari's "geophilosophy," the principle of territory and a form of a "capitalism of communication." I have pursued Deleuze's work in a variety of papers (e.g., Peters 2014, 2020) and working with Danilo Taglietti (Peters and Taglietti, 2019) attempted to spell out how Deleuze's rhizomatic analysis of Foucault provides resources for a new sociology. Postmodern society we argued is no longer about simply the evolution of liberal capitalism as a system but much more about the decoupling of economic and political systems in the wider global sense. We argued: "The fortunes of liberal capitalism or, indeed, liberal internationalism, are in jeopardy from outside the international system of world order that has dominated the last seventy years, but also from within. State capitalism of East Asia based on forms of social authoritarianism have long been advocated by Asian theorists, such as Lee Kuan Yew, as a more efficient means of development that does not require liberal democracy." We went on to suggest that "Liberalism as a form of democracy that supports the free market seems dislocated to capitalism and politically in tatters while science and convergent technologies (nanotechnology, biotechnology, information technology, cognitive science) seem to have an independent dynamic creating a trillion-dollar capitalist techno-science." Poststructuralism is a continuation of the train of thought initiated in the sociology of post-industrialism that adopts Marxist political economy in the examination of new forms of cybernetic or algorithmic capitalism (Peters, 2017).

Poststructuralism Is neither Anti-Marxist, nor Anti-Structuralist

Poststructuralism, Marxism, and Neoliberalism (Peters, 2001) focuses on two interrelated themes: contemporary neoliberal capitalism and poststructuralism as part of the critical culture of Western Marxism that has the theoretical capacity to analyse and conceptualize developments in contemporary capitalism. As I explained to my intended audience poststructuralism is a different child from postmodernism born of European formalism whose parental guidance owed much to Roman Jacobson's linguistic circles in Moscow and St Petersburg, that issued in the moment of French structuralism with Claude Levi-Strauss, Roland Barthes, Jacques Lacan and (early) Michel Foucault. I had also attempted to explain in unambiguous terms:

> Poststructuralism is not a form of anti-Marxism; indeed, poststructural philosophers view themselves in some kind of relationship to the legacy of Marx. Either they have been Marxist or still view themselves as Marxist. In a post-Marxist era they have invented new ways of reading and writing Marx.

Poststructuralism is neither anti-Marxist, nor anti-structuralist. What I was at pains to investigate was the significance of poststructuralism, specifically how the different philosophies of Derrida, Lyotard, Foucault and Deleuze and Guattari, were among the best critical resources enabling us to understand the way that neoliberalism is committed to the revitalization of *homo economicus* and neoclassical economics as a world-historical paradigm and political project aimed at a form of capitalist globalisation. The structure of the book was an introduction to the politics of poststructuralism, focusing on the concept "poststructuralist Marxisms" by reference to Lyotard's notion of "performativity" and the "problem of capitalism," "Derrida, Neoliberalism and Democracy to Come," Foucault's understanding of neoliberal governmentality, and Deleuze's "Societies of Control." I wanted to demonstrate how poststructuralism could help us understand the massive privatization of public education in the West and its attack on all forms of the public. From this viewpoint I made the argument that poststructuralist Marxisms – poststructuralism as contemporary forms of post-Marxism – was an ideal tool box for deconstructing the prevalent and dominant neoliberal capitalist political economy with its strong ideological critique of the State, its celebration of the market, and its ideological attempt to privatise society and economy. This is the story of the neoliberal experiment now forty years old that seemingly only grew stronger after the Global Financial Crisis (GFC) in 2008 and enter a phase of advanced financialization with the almost complete automation of equity markets by the early 2000s (Peters, 2012; Peters et al., 2015). The COVID-19 crisis of 2020 and the GFC seemed based on "privatise profits, socialise losses' with massive trillion dollar spends by the State. Not only does neoliberal capitalism seem basically unable to cope with global disasters but also to have been deeply complicit in them.

I tried to make the case for reading Marx differently, after Althusser, and for a critical pedagogy that aimed at reading Marx again and again, differently every time. This is the essence of an open tradition of criticism that keeps Marxism alive and vital. Of the French philosophers I mention, Deleuze and Foucault were responsible for leading the engagement of a Nietzschean Marx. Others came to see that it was possible to examine and dislodge the Hegelian phenomenological Marx based on French readings of the significance of Hegel's (1807/2018) *Phenomenology of Mind* that took hold until Althusser and structuralists who jettisoned the humanist Marx to emphasize Marxism as a science.

Reading Marx after Althusser

"After" Althusser, reading Marx had become a favorite critical activity that had released Marx from the confines of Hegel's metaphysics and his Christian eschatology. A new generation of Continental thinkers read Marx through Nietzsche, Heidegger or Spinoza. They were non-Hegelian, non-dialectical thinkers and their work provide alternative frameworks and schemas to read Marx anew and adapt Marxism to a changing political economy. Indeed, looking back I should have also included Jean Baudrillard's (1975) *The Mirror of Production* as well as prominent forms of non-Hegelian Marxism based on jettisoning Hegel and focusing on Nietzsche, Heidegger and Spinoza as a means for updating most promising forms of radical political economy for the twenty-first century, both to question the historical teleology of idealism and to rescue Marx from a Christian eschatological vision. Marx read Spinoza and made substantial transcriptions during the period 1841–1842 before he embarked on "Critique of Hegel's Philosophy of Right' and he rejected the political dimension of Spinoza in favour of Hegel as providing the most fully developed account of liberalism (Peters, 2018).

Althusser regarded himself as influenced by Spinoza (rather than structuralism) and Marcuse (1962) explored the basis for a Heideggerian Marxism in *One Dimensional Man*. There are historical issues between Marx/Spinoza versus Marx/Hegel yet it does suggest a certain literary and historical flexibility and opens the critical ground to other attempts. In this regard we must remember that we are dealing with a period of French philosophy in the first instance, roughly from the early 1960s and the first French Nietzsche conferences to the demise of each of these philosophers – Foucault died in 1984 and Derrida in 2004, with both Lyotard and Deleuze passing away in 1998, and 1995 respectively. The first phase of poststructuralism is over. Second and third generations might be seen first in literature departments in the West and simultaneously perhaps, also by postcolonial theorists like Spivak and Edward Said. Third generation might be hypothesized as its continuation within Italian political philosophy by thinkers as diverse as Negri and Agamben, and also seen in the work of Hardt and Negri, although it would be hard to argue this as a stand-alone interpretation and development without mentioning also other post-Marxist approaches. Fourth generation may also apply differently when considering the spread across the disciplines – in political economy, economics, sociology, law, philosophy, literary studies, international relations, history and education, to name a few "migrations." This does not exhaust the spread and distribution of these "poststructuralist" ideas because within discipline we might also note the differential effects among countries and disciplines, for instance, the appropriation of Foucault and Derrida by feminist thinkers who drew on these thinkers correcting its male gender bias, ethnocentrism and empirical application. Sometimes as in educational philosophy and theory there are several of these cross-currents happening at the same time. The ongoing disciplinary uptake and effects of these thinkers must also be measured against the brief moment of French structuralism from Claude Levi-Strauss' (1958) *Anthropologie structurale* to Jean Piaget's (1968) *Le Structuralism,* and against the theoretical innovations in epistemology dating back to Russian formalism at the beginning of the twentieth century. This historical interpretation then would see "poststructuralism" as a French chapter in the book of European philosophy inspired by nuanced readings of Nietzsche and Heidegger (Peters, 1996). I was lucky to meet and publish an essay by Derrida as well as corresponding with Lyotard for a year or so to persuade him to write a brief foreword for my collection *Education in the Postmodern Condition* (1995). Foucault was dead by the date I completed my PhD thesis although I travelled to France to visit his archive centre. I focused on Deleuze's *Nietzsche and Philosophy* and his final book with Guattari *What Is Philosophy?* (Deleuze and Guattari, 1991/1996), although I did read and publish on Guattari (Peters, 2013). It is clear that poststructuralism cuts a swathe across the disciplines and genealogically has both affinities and differences with structuralism, but it also has complex links to modern twentieth century European philosophy, to post-Kantian idealism and to Hegel in particular, to Heidegger and his reading of Nietzsche, to Nietzsche himself, and as I have tried to demonstrate, to Marx and Marxism.

Knowledge Economy: Capitalist or Socialist?

In my work I have sought to draw on the works of these thinkers over twenty years to analyze the positioning and privileging of education in terms of a major shift in political economy – from a Keynesian welfare right of liberalism in a mixed economy to a commodity in the neoliberal marketplace – a shift symbolized by the concept "knowledge economy" and Gary Becker's (1964) work on human capital. Each paradigm dominated for forty to fifty years in each case. The neoliberal paradigm with its roots in Hayek's Mt Pelerin Society set up after WWII may be finally waning especially with the disruptions of the GFC and incursions of COVID-19. Against all neoliberal market approaches capitalist democracies have enacted strong interventionist policies that are anything but neoliberal, as they did in buying distressed assets thought to be "too big to fail." During the period of financialization Big Tech and other transnational corporations stripped out jobs, decimated and compressed the middle class, paid no tax, and virtually decoupled from democratic government. Its failure has been evident in the huge growth of inequalities and the right-wing populist backlash in the US leading ultimately to the rise of the far-right and to the politics of insurrection. In 2021 President Biden's twin infrastructure bills indicate a strong interventionist philosophy designed to "out-compete" China's BRI.

For me growing up and studying for a PhD in New Zealand on the periphery of the world system in a small democracy that functioned as a welfare state, the textual opening or opening of the text that Derrida, Foucault and others provided, allowed me to draw out a poststructuralist reading of Marx, as a form of post-Marxism. I have tried to construe education in the West as a form of knowledge capitalism that followed the neoliberal policy construction of the "knowledge economy." The knowledge economy discourse anchored in human capital theory, endogenous growth theory and intellectual property law, prevailed in the 1990s and was both formulated and endorsed by the OECD and World Bank to become the horizon of all policy debates and discussion concerning the economics of education and R&D. It is a concept that had its neoliberal trajectory from Hayek, Becker, Romer and its policy formulations by OECD and World Bank in the mid-1990s to early 2000s. There was also a post-Marxist sociological left alternative that surfaced first in the work of Alain Touraine (1971) on the postindustrial society in the 1960s that theorized the revolutionary potential of students as a new social movement. In its various readings as postindustrial society, this interpretation was directed at the shape of future global society by scholars of left radical orientation such as that embraced by interpretations and readings of post-Althusserian and poststructuralist political philosophy including the Italian autonomous movement (Negri, 1991), Laclau and Mouffe's (2001) influential *Hegemony and Socialist Strategy,* Hardt and Negri's trilogy (*Multitude, Empire, Commonwealth*), not to mention the line of thinking represented by Moulier-Butang's (2012) *Cognitive Capitalism.*

My recent work draws on poststructuralist philosophy following Lyotard's analysis of "technoscience" and Foucault's analysis of neoliberal governmentality to analyze and critique the mega-paradigm of the Chicago school and its effects in the social sciences that has encouraged market logic into all aspects of social existence (Peters, 2007). I have followed what I consider to be the progressive elements of the Italian Left political program and Foucault's biopolitics in relation to immaterial or digital labor (Peters and Bulut, 2012) and what I have called "postcolonial biopolitics in the empire of capital" (Peters, 2015). My aim in recent years has been to problematize "knowledge capitalism," my term for the "knowledge economy" under neoliberal economics, and, by contrast, to posit a conception of "knowledge socialism" focusing on the rise of peer production, collegiality, collaboration, and collective intelligence (Peters et al., 2020). Marx taught us that knowledge and the value of knowledge has its roots in social relations. Paradoxically, it is these networked social relations in an emerging algorithmic networked platform capitalism that also provides the infrastructure for the possibilities of greater knowledge sharing.

Author contributions
The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement
The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

NOTES

1. https://medium.com/@MichaelMcBride/did-karl-marx-predict-artificial-intelligence-170-years-ago-4fd7c23505ef
2. This section is based on an early paper "Lyotard, Education, and the Problem of Capitalism in the Postmodern Condition" (Peters, 1997).
3. https://www.files.ethz.ch/isn/125495/5020_Rousseau_A_Discourse_on_Political_Economy.pdf
4. https://www.britannica.com/topic/political-economy

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Biometric Facial Recognition Technology, Law Enforcement Algorithmic Automation, and Data-driven Predictive Policing Systems in Human Rights Protections and Abuses

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ABSTRACT. The aim of this systematic review is to synthesize and analyze facial recognition systems and predictive policing algorithms. With increasing evidence of biometric data processing, digital police surveillance technologies, and automated decision-making systems, there is an essential demand for comprehending whether police surveillance technologies and subjectivities enact regulatory governance. In this research, prior findings were cumulated indicating that digital police surveillance technologies and practices are pivotal in regulatory governance and environments. I carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout May 2022, with search terms including "human rights protections and abuses" + "biometric facial recognition technology," "law enforcement algorithmic automation," and "data-driven predictive policing systems." As I analyzed research published in 2022, only 142 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, I decided on 25, chiefly empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Distiller SR, ROBIS, and SRDR.

Keywords: predictive policing; facial recognition technology; human right

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1. Introduction

Accurate biometric data technologies can typify individual behavior (Lewkowich, 2022; Lăzăroiu et al., 2022; Nica, 2018; Vătămănescu et al., 2022) while violating privacy rights, and thus regulatory measures are required. The purpose of my systematic review is to examine the recently published literature on human rights protections and abuses and integrate the insights it configures on biometric facial recognition technology, law enforcement algorithmic automation, and data-driven predictive policing systems. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that digital police surveillance technologies and practices are pivotal in regulatory governance and environments. The actuality and novelty of this study are articulated by addressing facial recognition systems and predictive policing algorithms, that is an emerging topic involving much interest. My research problem is whether police surveillance technologies and subjectivities enact regulatory governance.

In this review, prior findings have been cumulated indicating that facial recognition technology leveraged by policing agencies requires legitimacy and trust, not sadness and fear. The identified gaps advance operational digital policing practices and technological policing tools. My main objective is to indicate that predictive policing systems and surveillance technologies (Balcerzak et al., 2022; Durana et al., 2022; Mihăilă et al., 2016; Nica and Stehel, 2021) can maintain safety and security by tracking and capturing criminals. This systematic review contributes to the literature on biometric data processing, mass surveillance, and predictive policing algorithms by clarifying that digital predictive policing technologies and social media intelligence (Andronie et al., 2021a, b, c; Barbu et al., 2021; Popescu, 2018) integrate digital surveillance governance mechanisms (Bowles, 2022; Nica, 2017; Peters, 2022a, b; Vătămănescu et al., 2020) in regulatory controls and regimes and crime detection and disruption. This research endeavors to elucidate whether big data and predictive policing systems together with face recognition and surveillance technologies (Kliestik et al., 2022a, b; Nica et al., 2022; Popescu et al., 2020) should be citizen-protective while processing biometric data.

2. Theoretical Overview of the Main Concepts

Social equity and public organizational arrangements in digital governance require advanced analytics in solving complex public issues, but biased enactments of computational algorithms, facial recognition technology, and automated decision-making systems amplify social inequalities and perpetuate systemic barriers instead of building public trust and preventing crimes.

The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), facial recognition systems, technological surveillance governance networks, and predictive policing algorithms (section 4), biometric data processing, digital police surveillance technologies, and automated decision-making systems (section 5), digital surveillance governance mechanisms, computational algorithms, and data-driven predictive policing technologies (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

I carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout May 2022, with search terms including "human rights protections and abuses" + "biometric facial recognition technology," "law enforcement algorithmic automation," and "data-driven predictive policing systems." The search terms were determined as being the most employed words or phrases across the analyzed literature. As I analyzed research published in 2022, only 142 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, I decided on 25, chiefly empirical, sources (Tables 1 and 2). Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Distiller SR, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
human rights protections and abuses + biometric facial recognition technology	49	9
human rights protections and abuses + law enforcement algorithmic automation	47	9
human rights protections and abuses + data-driven predictive policing systems	46	8
Type of paper		
Original research	120	25
Review	3	0
Conference proceedings	14	0
Book	2	0
Editorial	3	0

Source: Processed by the author. Some topics overlap.

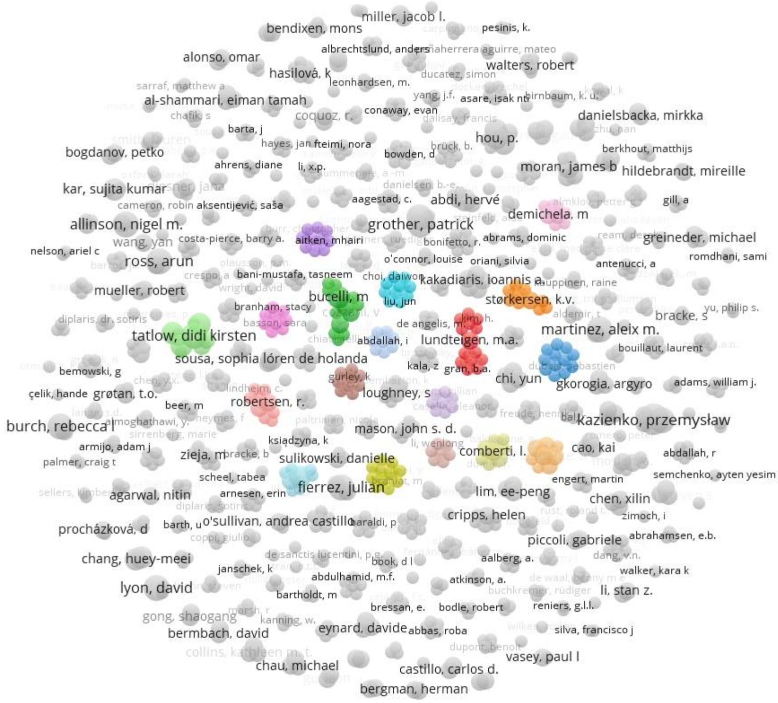

Figure 1 Co-authorship

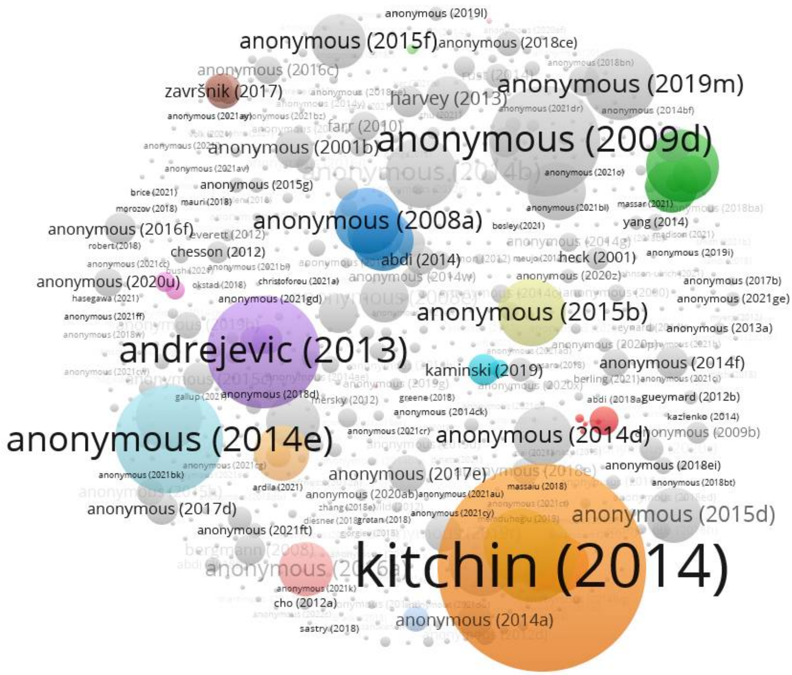

Figure 2 Citation

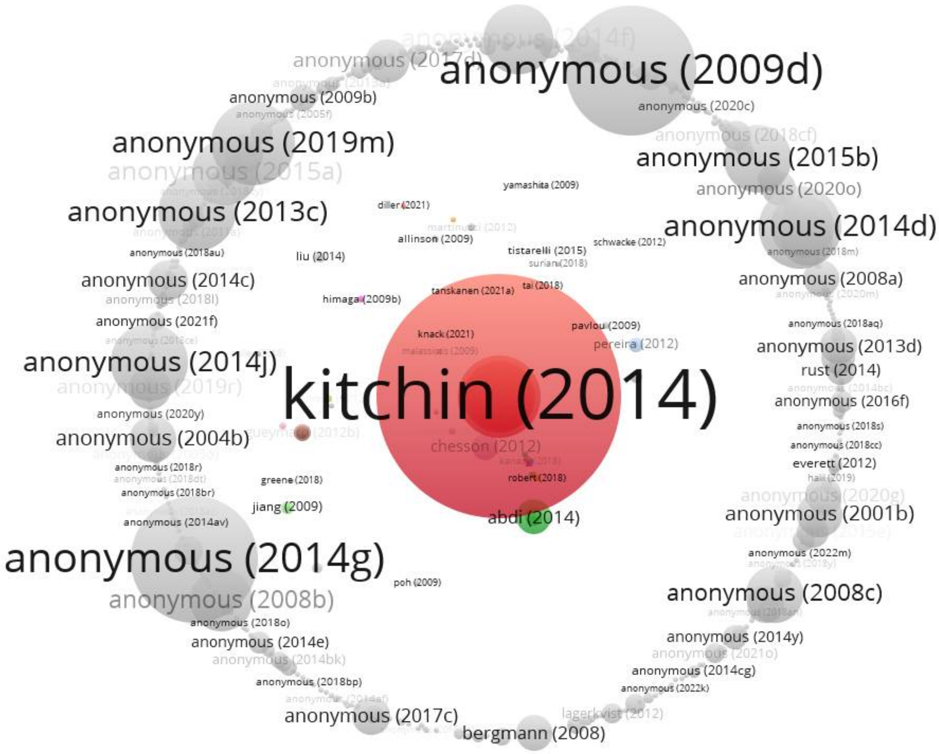

Figure 3 Bibliographic coupling

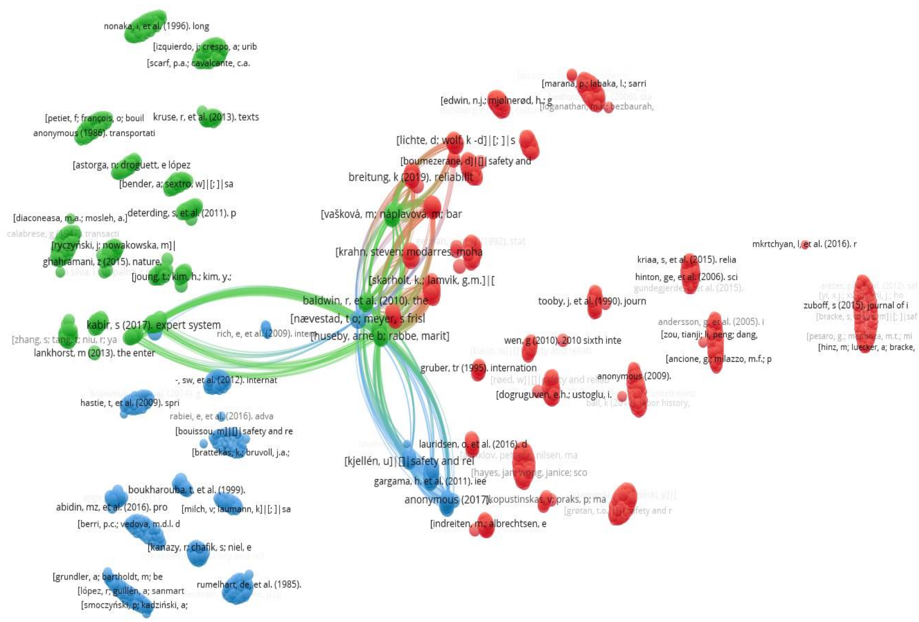

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Biometric facial recognition technology entails automated differentiation of facial features in law enforcement to solve crimes while integrating individual privacy, regulation, autonomy, security, and democratic accountability.	Sarabdeen, 2022; Smith and Miller, 2022; Urquhart and Miranda, 2022
Police legitimacy is attained by consistent lawful practices and societal expectations in relation to criminal threats, public security and order, and human rights protections and abuses.	Bonner and Dammert, 2022; Fleet and Hine, 2022; Fussey and Sandhu, 2022
Facial recognition systems and predictive policing algorithms can violate civil liberties and human rights. Predictive policing systems and surveillance technologies can maintain safety and security by tracking and capturing criminals.	Fountain, 2022; Green, 2022; Hong, 2022; Humphrey, 2022
Discretionary and opaque rules and principles of law enforcement algorithmic automation and data-driven predictive policing systems can be effective in public order measures across decision-making environments while affecting human rights of individuals as regards data protection in crime investigations.	Enarsson et al., 2022; Fountain, 2022; Fussey and Sandhu, 2022
Biometric data processing, mass surveillance, and predictive policing algorithms can affect human rights. Facial recognition and surveillance technologies deployed by law enforcement authorities can enhance public security and raise privacy concerns and legitimacy issues in relation to police accountability.	Ashraf, 2022; Eneman et al., 2022; Kosta, 2022; Raposo, 2022a, b
Law enforcement authorities deploy facial processing technologies and predictive policing systems as regards crime rate reduction while possibly perpetuating social inequalities.	Dass et al., 2022; Fussey and Sandhu, 2022; Lee and Park, 2022
Human rights and public order policing by use of surveillance technologies may disrupt the coherency of interconnected formal procedures and legitimate norms in terms of legal basis.	Lee and Park, 2022; Martin, 2022; Ricciardelli et al., 2022; Teo, 2022
Big data-driven technologies can be pivotal in law enforcement, policing, and criminal justice in terms of operational efficiency, accuracy, and control while undermining fundamental rights.	De Hert and Bouchagiar, 2022; Fountain, 2022; Sachoulidou, 2022
Biometric surveillance and data-driven predictive policing technologies and tools are instrumental in algorithmically-determined law enforcement through predicting, preventing, and reducing crime.	Davis et al., 2022; Fussey and Sandhu, 2022; Rodríguez-Gómez and Russell, 2022

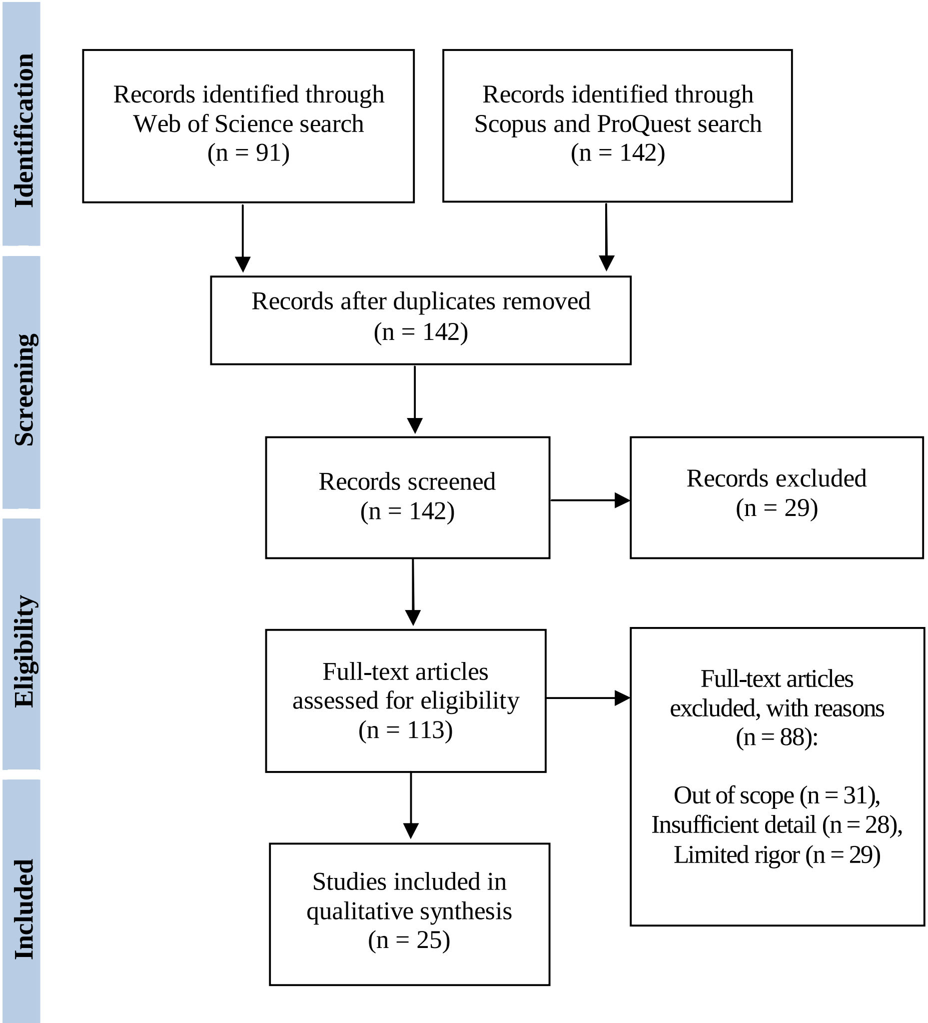

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.

To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

Distiller SR screened and extracted the collected data.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

Figure 6 Screening and quality assessment tools

4. Facial Recognition Systems, Technological Surveillance Governance Networks, and Predictive Policing Algorithms

Biometric facial recognition technology entails automated differentiation of facial features in law enforcement (Sarabdeen, 2022; Smith and Miller, 2022; Urquhart and Miranda, 2022) to solve crimes while integrating individual privacy, regulation, autonomy, security, and democratic accountability. Accurate biometric data technologies can typify individual behavior while violating privacy rights, and thus regulatory measures are required. Policing technologies harness visual surveillance mechanisms, social media intelligence, and emotion sensing systems to read facial expressions.

Police legitimacy is attained by consistent lawful practices and societal expectations (Bonner and Dammert, 2022; Fleet and Hine, 2022; Fussey and Sandhu, 2022) in relation to criminal threats, public security and order, and human rights protections and abuses. Facial recognition technology leveraged by policing agencies requires legitimacy and trust, not sadness and fear. Operational digital policing practices and technological policing tools configure technological surveillance governance networks and digital policing regulatory environment.

Facial recognition systems and predictive policing algorithms (Fountain, 2022; Green, 2022; Hong, 2022; Humphrey, 2022) can violate civil liberties and human rights. Biased enactments of computational algorithms, facial recognition technology, and automated decision-making systems can lead to discriminatory decisions, processes, and procedures that (un)intentionally disadvantage individuals, instead of improving public policy. Biometric surveillance and sensing technologies can gather data in relation to affect and behavior. Predictive policing systems and surveillance technologies can maintain safety and security by tracking and capturing criminals. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Biometric facial recognition technology entails automated differentiation of facial features in law enforcement to solve crimes while integrating individual privacy, regulation, autonomy, security, and democratic accountability.	Sarabdeen, 2022; Smith and Miller, 2022; Urquhart and Miranda, 2022
Police legitimacy is attained by consistent lawful practices and societal expectations in relation to criminal threats, public security and order, and human rights protections and abuses.	Bonner and Dammert, 2022; Fleet and Hine, 2022; Fussey and Sandhu, 2022
Facial recognition systems and predictive policing algorithms can violate civil liberties and human rights. Predictive policing systems and surveillance technologies can maintain safety and security by tracking and capturing criminals.	Fountain, 2022; Green, 2022; Hong, 2022; Humphrey, 2022

5. Biometric Data Processing, Digital Police Surveillance Technologies, and Automated Decision-Making Systems

Discretionary and opaque rules and principles of law enforcement algorithmic automation and data-driven predictive policing systems (Enarsson et al., 2022; Fountain, 2022; Fussey and Sandhu, 2022) can be effective in public order measures across decision-making environments while affecting human rights of individuals as regards data protection in crime investigations. Social equity and public organizational arrangements in digital governance require advanced analytics in solving complex public issues, but biased enactments of computational algorithms, facial recognition technology, and automated decision-making systems amplify social inequalities and perpetuate systemic barriers instead of building public trust and preventing crimes. Police surveillance technologies and subjectivities enact regulatory governance.

Biometric data processing, mass surveillance, and predictive policing algorithms (Ashraf, 2022; Eneman et al., 2022; Kosta, 2022; Raposo, 2022a, b) can affect human rights. Legal ground and security measures are needed in biometric data processing procedures by facial recognition technology and digital tools in terms of fundamental rights, norms, and values. Facial recognition and surveillance technologies deployed by law enforcement authorities can enhance public security and raise privacy concerns and legitimacy issues in relation to police accountability.

Law enforcement authorities deploy facial processing technologies and predictive policing systems (Dass et al., 2022; Fussey and Sandhu, 2022; Lee and Park, 2022) as regards crime rate reduction while possibly perpetuating social inequalities. Digital police surveillance technologies and practices are pivotal in regulatory governance and environments. Big data can fortify preventive reactions to crimes by law enforcement authorities. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Discretionary and opaque rules and principles of law enforcement algorithmic automation and data-driven predictive policing systems can be effective in public order measures across decision-making environments while affecting human rights of individuals as regards data protection in crime investigations.	Enarsson et al., 2022; Fountain, 2022; Fussey and Sandhu, 2022
Biometric data processing, mass surveillance, and predictive policing algorithms can affect human rights.	Ashraf, 2022; Eneman et al., 2022; Kosta, 2022; Raposo, 2022a, b
Law enforcement authorities deploy facial processing technologies and predictive policing systems as regards crime rate reduction while possibly perpetuating social inequalities.	Dass et al., 2022; Fussey and Sandhu, 2022; Lee and Park, 2022

6. Digital Surveillance Governance Mechanisms, Computational Algorithms, and Data-driven Predictive Policing Technologies

Human rights and public order policing by use of surveillance technologies (Lee and Park, 2022; Martin, 2022; Ricciardelli et al., 2022; Teo, 2022) may disrupt the coherency of interconnected formal procedures and legitimate norms in terms of legal basis. Law enforcement authorities leverage digital technology that has social justice implications in terms of privacy rights. Artificial intelligence pervasiveness can lead to human rights violations in relation to privacy and freedom of expression, affecting individual lives. Big data-driven policing systems and surveillance technologies can shape crime rate reduction and prevention, personal security, civil right infringement, and state power expansion.

Big data-driven technologies can be pivotal in law enforcement, policing, and criminal justice (De Hert and Bouchagiar, 2022; Fountain, 2022; Sachoulidou, 2022) in terms of operational efficiency, accuracy, and control while undermining fundamental rights. Digital government and public organizational arrangements encompassing facial recognition technologies, computational algorithms, predictive policing systems, and automated decision-making and screening tools can amplify systemic bias, instead of producing neutrally applied procedural rules. Big data and predictive policing systems together with face recognition and surveillance technologies should be citizen-protective while processing biometric data.

Biometric surveillance and data-driven predictive policing technologies and tools are instrumental in algorithmically-determined law enforcement (Davis et al., 2022; Fussey and Sandhu, 2022; Rodríguez-Gómez and Russell, 2022) through predicting, preventing, and reducing crime and violence. Digital predictive policing technologies and social media intelligence integrate digital surveillance governance mechanisms in regulatory controls and regimes and crime detection and disruption. Transformative types of knowledge are pivotal in human rights violations through structural violence. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Human rights and public order policing by use of surveillance technologies may disrupt the coherency of interconnected formal procedures and legitimate norms in terms of legal basis.	Lee and Park, 2022; Martin, 2022; Ricciardelli et al., 2022; Teo, 2022
Big data-driven technologies can be pivotal in law enforcement, policing, and criminal justice in terms of operational efficiency, accuracy, and control while undermining fundamental rights.	De Hert and Bouchagiar, 2022; Fountain, 2022; Sachoulidou, 2022
Biometric surveillance and data-driven predictive policing technologies and tools are instrumental in algorithmically-determined law enforcement through predicting, preventing, and reducing crime.	Davis et al., 2022; Fussey and Sandhu, 2022; Rodríguez-Gómez and Russell, 2022

7. Discussion

I integrate my systematic review throughout research indicating how artificial intelligence pervasiveness can lead to human rights violations in relation to privacy and freedom of expression, affecting individual lives. My research complements recent analyses clarifying how facial recognition and surveillance technologies deployed by law enforcement authorities can enhance public security and raise privacy concerns and legitimacy issues in relation to police accountability. I elucidate, by cumulative evidence, previous research demonstrating how legal ground and security measures are needed in biometric data processing procedures by facial recognition technology and digital tools in terms of fundamental rights, norms, and values.

8. Synopsis of the Main Research Outcomes

Biometric surveillance and sensing technologies can gather data in relation to affect and behavior. Digital government and public organizational arrangements encompassing facial recognition technologies, computational algorithms, predictive policing systems, and automated decision-making and screening tools can amplify systemic bias, instead of producing neutrally applied procedural rules. Law enforcement authorities leverage digital technology that has social justice implications in terms of privacy rights.

9. Conclusions

Relevant research has investigated whether big data can fortify preventive reactions to crimes by law enforcement authorities. This systematic literature review presents the published peer-reviewed sources covering how human rights and public order policing by use of surveillance technologies may disrupt the coherency of interconnected formal procedures and legitimate norms in terms of legal basis. The research outcomes drawn from the above analyses indicate that big data-driven technologies can be pivotal in law enforcement, policing, and criminal justice in terms of operational efficiency, accuracy, and control while undermining fundamental rights.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on biometric facial recognition technology, law enforcement algorithmic automation, and data-driven predictive policing systems in human rights protections and abuses may have been excluded. Limitations of this research comprise particular kinds of publications (original empirical research and review articles) discounting others (conference proceedings articles, books, and editorial materials). The scope of my study also does not move forward the inspection of technological surveillance governance networks and digital policing regulatory environment.

Subsequent analyses should develop on biometric surveillance and data-driven predictive policing technologies and tools. Future research should thus investigate how law enforcement authorities deploy facial processing technologies and predictive policing systems. Attention should be directed to algorithmically-determined law enforcement.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the author.

Data availability statement

All data generated or analyzed are included in the published article.

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Author contributions

The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record

The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement

The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Blockchain Technology Adoption in Artificial Intelligence-based Digital Financial Services, Accounting Information Systems, and Audit Quality Control

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ABSTRACT. I draw on a substantial body of theoretical and empirical research on blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures. With increasing evidence of big data- and artificial intelligence-based decentralized accounting information systems and auditing procedures, there is an essential demand for comprehending whether cloud computing and blockchain technologies articulate accounting information systems, in addition to data analytics and machine and deep learning algorithms. In this research, prior findings were cumulated indicating that data and process integrity shape blockchain and accounting adoption in business operations. I carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout May 2022, with search terms including "blockchain technology" and "artificial intelligence" + "digital financial services," "accounting information systems," and "audit quality control." As I analyzed research published in 2022, only 138 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, I decided on 31, chiefly empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, ROBIS, and SRDR.

Keywords: blockchain technology; digital financial service; accounting; audit

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1. Introduction

Blockchain technology integrates auditing, control, and management and financial accounting processes, capabilities, transactions, procedures, information processes, and techniques. The purpose of my systematic review is to examine the recently published literature on blockchain technology adoption and integrate the insights it configures on artificial intelligence-based digital financial services, accounting information systems, and audit quality control. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that blockchain technology can record accounting transactions and data, being also pivotal in audit practice. The actuality and novelty of this study are articulated by addressing blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures, that is an emerging topic involving much interest. My research problem is whether digital financial services develop on blockchain technology trust, acceptance, and adoption (Andronie et al., 2021; Ionescu, 2021; Olssen, 2021; Popescu Ljungholm, 2022; Zvarikova et al., 2021), in addition to behavioral intention, perceived usefulness, and perceived ease of use.

In this review, prior findings have been cumulated indicating that data and process integrity shape blockchain and accounting adoption in business operations. The identified gaps advance big data- and artificial intelligence-based (Barbu et al., 2021; Kliestik et al., 2020a, b; Popescu et al., 2017; Rydell, 2022) decentralized accounting information systems and auditing procedures. My main objective is to indicate that cloud computing and blockchain technologies (Burke and Zvarikova, 2021; Kliestik et al., 2022a, b; Popescu et al., 2018; Stone et al., 2022) articulate accounting information systems, in addition to data analytics and machine and deep learning algorithms. This systematic review contributes to the literature on data management, enterprise accounting information, auditing, and taxation, by clarifying that artificial intelligence adoption leads to job performance improvement (Crișan-Mitra et al., 2020; Konhäusner et al., 2021; Popescu et al., 2019; Valaskova et al., 2021) across accounting information systems, decreasing repetitive tasks and human error risk (Hackman and Reindl, 2022; Lăzăroiu et al., 2022; Popescu et al., 2022; Valaskova et al., 2022), while optimizing data management skills.

2. Theoretical Overview of the Main Concepts

Auditors assist companies in designing and carrying out blockchain-based solutions to enable transactions due to the growing automation of accounting information. Social trust, value creation, and blockchain applications can shape corporate collaborative innovation, configuring economic and financial features of blockchain technology-based corporate governance. Mobile network infrastructures and management, data traceability and interoperability, and secure and reliable transactions integrate blockchain accounting capabilities. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures (section 4), economic and financial features of blockchain technology-based corporate governance (section 5), big data- and artificial intelligence-based decentralized accounting information systems and auditing procedures (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

I carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout May 2022, with search terms including "blockchain technology" and "artificial intelligence" + "digital financial services," "accounting information systems," and "audit quality control." The search terms were determined as being the most employed words or phrases across the analyzed literature. As I analyzed research published in 2022, only 138 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, I decided on 31, chiefly empirical, sources (Tables 1 and 2). Extracting and inspecting publicly accessible files (scholarly sources) as evidence, before the research began no institutional ethics approval was required. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
blockchain technology + artificial intelligence-based digital financial services	46	10
blockchain technology + artificial intelligence-based accounting information systems	48	12
blockchain technology + artificial intelligence-based audit quality control	44	9
Type of paper		
Original research	113	29
Review	8	2
Conference proceedings	11	0
Book	3	0
Editorial	3	0

Source: Processed by the author. Some topics overlap.

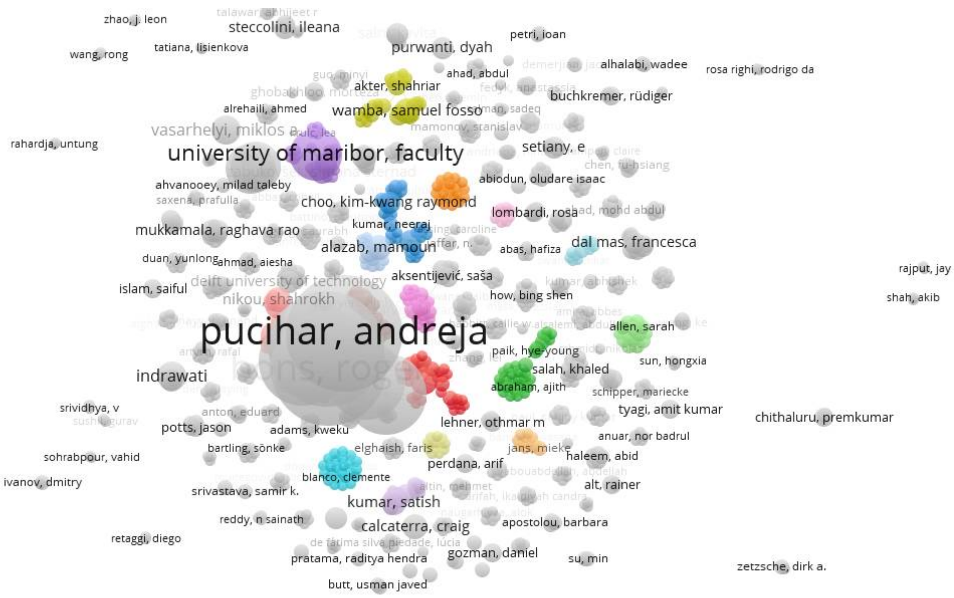

Figure 1 Co-authorship

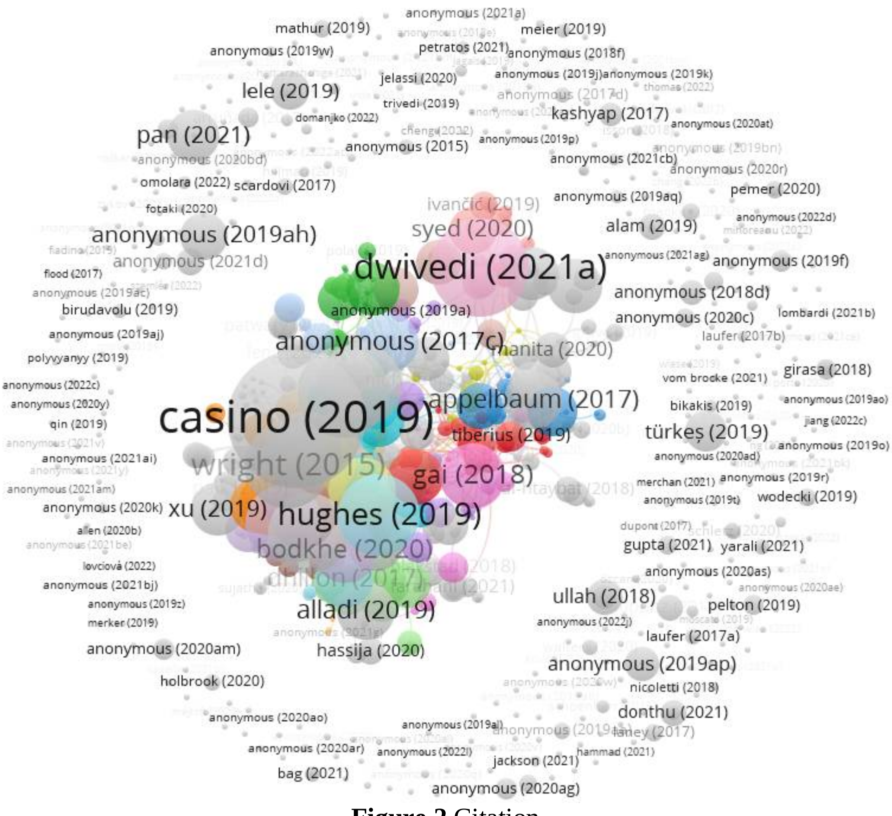

Figure 2 Citation

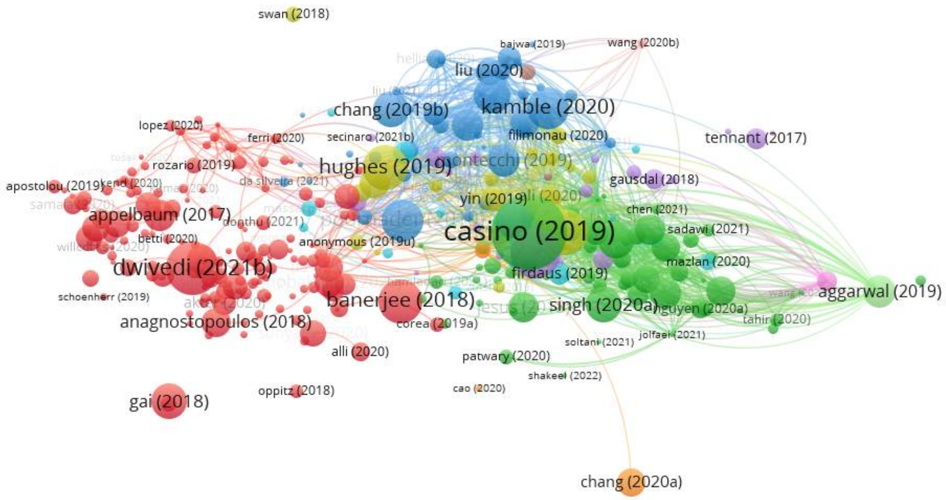

Figure 3 Bibliographic coupling

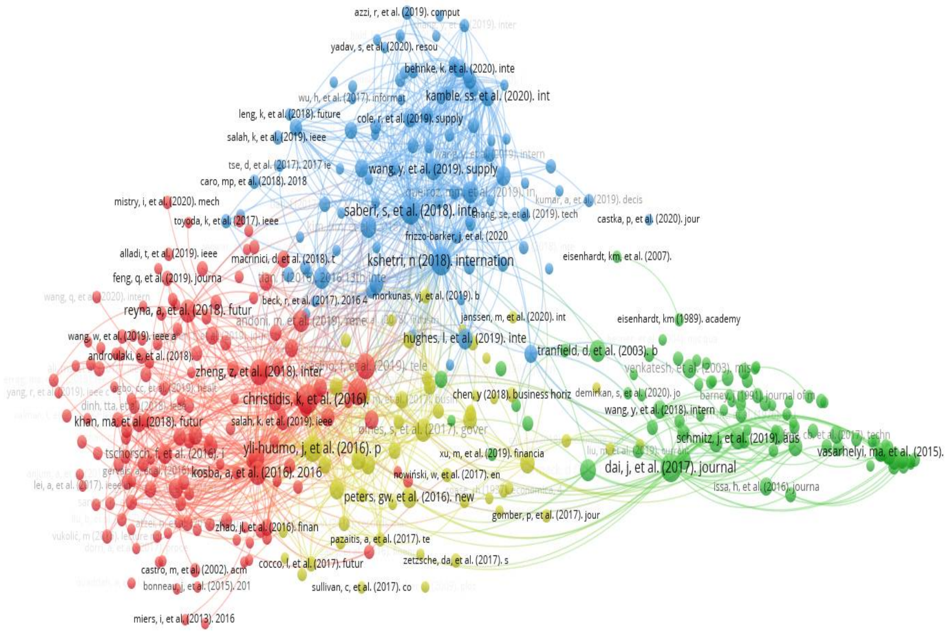

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Audit quality control optimizes the quality of accounting information and enterprise operational processes through blockchain technology integration, furthering data security.	Agustí and Orta-Pérez, 2022; Li and Juma'h, 2022; Stratopoulos et al., 2022; Wang, 2022
Blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures require streamlined data management and governance. Data and process integrity shape blockchain and accounting adoption in business operations.	Appelbaum et al., 2022; Jayasuriya and Sims, 2022; Kostić and Sedej, 2022
Blockchain-based systems and technology integrate data management, enterprise accounting information, auditing, and taxation, shaping cryptocurrency accounting standards and practices, in addition to accounting information quality.	Abu Afifa et al., 2022; Bellucci et al., 2022; Malladi, 2022; Tan et al., 2022 Wang et al., 2022
Decision support and blockchain technologies, together with machine and deep learning algorithms, enhance accounting information systems. Artificial intelligence-based accounting information systems can build organisational success.	Igou et al., 2022; Jackson et al., 2022; Moore and Felo, 2022
Blockchain-based cryptocurrencies and systems can deploy public accounting ledgers, influencing the predictive capacity of accounting transactions, information, knowledge, and techniques.	Amiram et al., 2022; Bellucci et al., 2022; Ezzi et al., 2022; Lardo et al., 2022
Blockchain-based systems can build interorganizational trust and collaboration, impacting accounting standard application and guidance as regards crypto-assets.	Chen et al., 2022; Chou et al., 2022; Di Vaio et al., 2022; Kumari and Devi, 2022; Wan et al., 2022
Machine and deep learning algorithms, blockchain technology, and cloud software services typify the accounting environment in terms of workflow and processes.	Foshee Holmes and Douglass, 2022; Kommunuri, 2022; Li et al., 2022
Blockchain-based Internet of Things architecture and sensing devices, network traffic information, and large-scale data management lead to long-term economic development and optimize the financial sector.	Fotoh and Lorentzon, 2022; Voundi Koe et al., 2022; Yu, 2022
Big data- and artificial intelligence-based decentralized accounting information systems and auditing procedures develop on transparency and efficiency in organizational cultures. Blockchain technology can record accounting transactions and data, being also pivotal in audit practice.	Dehghani et al., 2022; Jayasuriya and Sims, 2022; Li and Juma'h, 2022; Munim et al., 2022

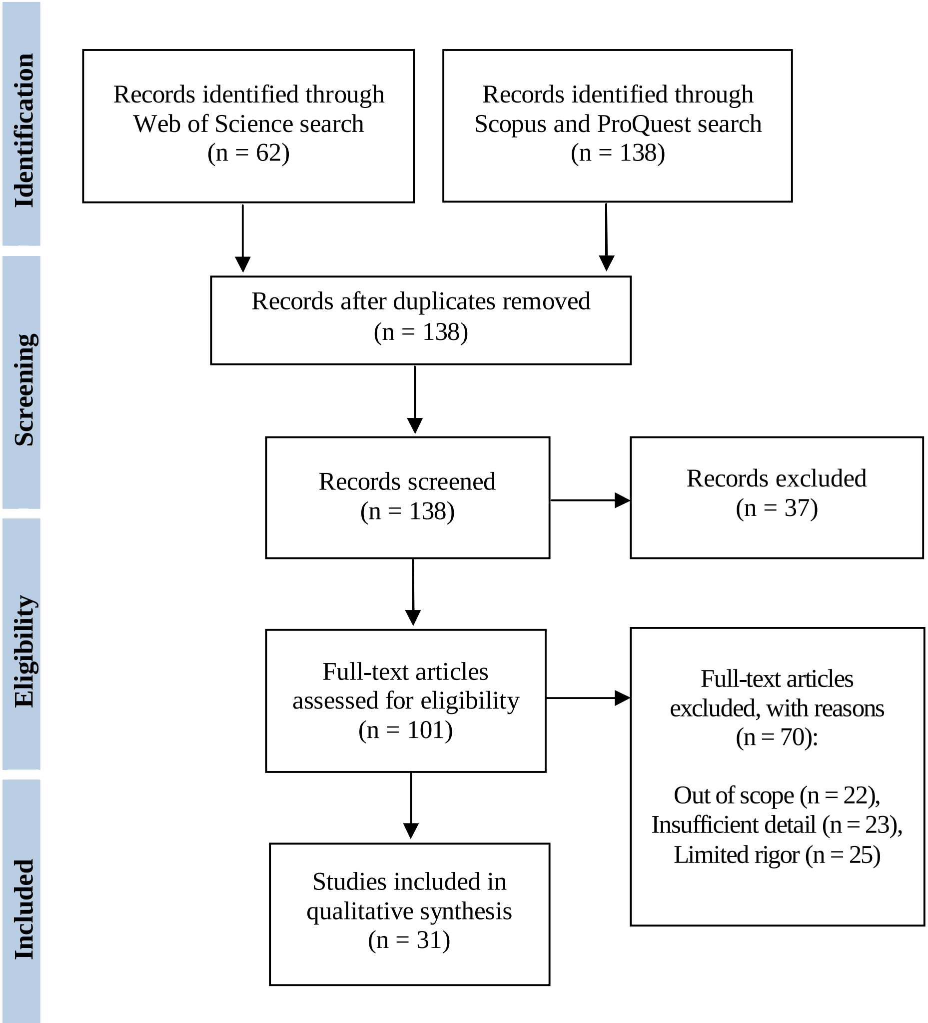

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.

To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

ROBIS assessed the risk of bias in systematic reviews.

Figure 6 Screening and quality assessment tools

4. Blockchain Adoption in Accounting Standards, Financial Reporting, Taxation, and Auditing Procedures

Audit quality control optimizes the quality of accounting information and enterprise operational processes (Agustí and Orta-Pérez, 2022; Li and Juma'h, 2022; Stratopoulos et al., 2022; Wang, 2022) through blockchain technology integration, furthering data security. Auditors assist companies in designing and carrying out blockchain-based solutions to enable transactions due to the growing automation of accounting information. Corporate disclosures indicate corporations' expectations and interests in blockchain adoption through big data- and artificial intelligence-based accounting and auditing.

Blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures (Appelbaum et al., 2022; Jayasuriya and Sims, 2022; Kostić and Sedej, 2022) require streamlined data management and governance. Blockchain technology assists management accounting practices and control mechanisms and procedures across inter-organizational relationships and collaboration in terms of information exchange. Data and process integrity shape blockchain and accounting adoption in business operations.

Blockchain-based systems and technology (Abu Afifa et al., 2022; Bellucci et al., 2022; Malladi, 2022; Tan et al., 2022; Wang et al., 2022) integrate data management, enterprise accounting information, auditing, and taxation, shaping cryptocurrency accounting standards and practices, in addition to accounting information quality. Blockchain can enhance information schedules and accounting soundness due to its decentralization and transparency. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Audit quality control optimizes the quality of accounting information and enterprise operational processes through blockchain technology integration, furthering data security.	Agustí and Orta-Pérez, 2022; Li and Juma'h, 2022; Stratopoulos et al., 2022; Wang, 2022
Blockchain adoption in accounting standards, financial reporting, taxation, and auditing procedures require streamlined data management and governance. Data and process integrity shape blockchain and accounting adoption in business operations.	Appelbaum et al., 2022; Jayasuriya and Sims, 2022; Kostić and Sedej, 2022
Blockchain-based systems and technology integrate data management, enterprise accounting information, auditing, and taxation, shaping cryptocurrency accounting standards and practices, in addition to accounting information quality. Blockchain can enhance information schedules and accounting soundness due to its decentralization and transparency.	Abu Afifa et al., 2022; Bellucci et al., 2022; Malladi, 2022; Tan et al., 2022 Wang et al., 2022

5. Economic and Financial Features of Blockchain Technology-based Corporate Governance

Decision support and blockchain technologies, together with machine and deep learning algorithms (Igou et al., 2022; Jackson et al., 2022; Moore and Felo, 2022), enhance accounting information systems. Cloud computing and blockchain technologies articulate accounting information systems, in addition to data analytics and machine and deep learning algorithms. Artificial intelligence-based accounting information systems can build organizational success.

Blockchain-based cryptocurrencies and systems (Amiram et al., 2022; Bellucci et al., 2022; Ezzi et al., 2022; Lardo et al., 2022) can deploy public accounting ledgers, influencing the predictive capacity of accounting transactions, information, knowledge, and techniques. Blockchain technologies impact accounting and auditing practices and related information systems. Blockchain technology integrates auditing, control, and management and financial accounting processes, capabilities, transactions, procedures, information processes, and techniques.

Blockchain-based systems can build interorganizational trust and collaboration (Chen et al., 2022; Chou et al., 2022; Di Vaio et al., 2022; Kumari and Devi, 2022; Wan et al., 2022), impacting accounting standard application and guidance as regards crypto-assets. Social trust, value creation, and blockchain applications can shape corporate collaborative innovation, configuring economic and financial features of blockchain technology-based corporate governance. Digital financial services develop on blockchain technology trust, acceptance, and adoption, in addition to behavioral intention, perceived usefulness, and perceived ease of use. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Decision support and blockchain technologies, together with machine and deep learning algorithms, enhance accounting information systems. Artificial intelligence-based accounting information systems can build organisational success.	Igou et al., 2022; Jackson et al., 2022; Moore and Felo, 2022
Blockchain-based cryptocurrencies and systems can deploy public accounting ledgers, influencing the predictive capacity of accounting transactions, information, knowledge, and techniques.	Amiram et al., 2022; Bellucci et al., 2022; Ezzi et al., 2022; Lardo et al., 2022
Blockchain-based systems can build interorganizational trust and collaboration, impacting accounting standard application and guidance as regards crypto-assets. Digital financial services develop on blockchain technology trust, acceptance, and adoption, in addition to behavioral intention, perceived usefulness, and perceived ease of use.	Chen et al., 2022; Chou et al., 2022; Di Vaio et al., 2022; Kumari and Devi, 2022; Wan et al., 2022

6. Big Data- and Artificial Intelligence-based Decentralized Accounting Information Systems and Auditing Procedures

Machine and deep learning algorithms, blockchain technology, and cloud software services (Foshee Holmes and Douglass, 2022; Kommunuri, 2022; Li et al., 2022) typify the accounting environment in terms of workflow and processes. Mobile network infrastructures and management, data traceability and interoperability, and secure and reliable transactions integrate blockchain accounting capabilities. Artificial intelligence adoption leads to job performance improvement across accounting information systems, decreasing repetitive tasks and human error risk, while optimizing data management skills.

Blockchain-based Internet of Things architecture and sensing devices, network traffic information, and large-scale data management (Fotoh and Lorentzon, 2022; Voundi Koe et al., 2022; Yu, 2022) lead to long-term economic development and optimize the financial sector. Financial enterprises can enhance their administrative management methods, data processing security systems, and task scheduling operations through blockchain technology. Digital technologies can optimize internal controls and audit quality, and further fraud prevention and detection.

Big data- and artificial intelligence-based decentralized accounting information systems and auditing procedures (Dehghani et al., 2022; Jayasuriya and Sims, 2022; Li and Juma'h, 2022; Munim et al., 2022) develop on transparency and efficiency in organizational cultures. Auditors would increasingly accept blockchain technologies through fortified knowledge and awareness of accounting software. Blockchain technology can record accounting transactions and data, being also pivotal in audit practice. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Machine and deep learning algorithms, blockchain technology, and cloud software services typify the accounting environment in terms of workflow and processes.	Foshee Holmes and Douglass, 2022; Kommunuri, 2022; Li et al., 2022
Blockchain-based Internet of Things architecture and sensing devices, network traffic information, and large-scale data management lead to long-term economic development and optimize the financial sector. Digital technologies can optimize internal controls and audit quality, and further fraud prevention and detection.	Fotoh and Lorentzon, 2022; Voundi Koe et al., 2022; Yu, 2022
Big data- and artificial intelligence-based decentralized accounting information systems and auditing procedures develop on transparency and efficiency in organizational cultures. Blockchain technology can record accounting transactions and data, being also pivotal in audit practice.	Dehghani et al., 2022; Jayasuriya and Sims, 2022; Li and Juma'h, 2022; Munim et al., 2022

7. Discussion

I integrate my systematic review throughout research indicating how corporate disclosures indicate corporations' expectations and interests in blockchain adoption through big data- and artificial intelligence-based accounting and auditing. My research complements recent analyses clarifying how artificial intelligence-based accounting information systems can build organizational success. I elucidate, by cumulative evidence, previous research demonstrating how financial enterprises can enhance their administrative management methods, data processing security systems, and task scheduling operations through blockchain technology. Social trust, value creation, and blockchain applications can shape corporate collaborative innovation, configuring economic and financial features of blockchain technology-based corporate governance.

8. Synopsis of the Main Research Outcomes

Blockchain technology assists management accounting practices and control mechanisms and procedures across inter-organizational relationships and collaboration in terms of information exchange. Blockchain technologies impact accounting and auditing practices and related information systems. Auditors assist companies in designing and carrying out blockchain-based solutions to enable transactions due to the growing automation of accounting information. Mobile network infrastructures and management, data traceability and interoperability, and secure and reliable transactions integrate blockchain accounting capabilities.

9. Conclusions

Relevant research has investigated whether auditors would increasingly accept blockchain technologies through fortified knowledge and awareness of accounting software. This systematic literature review presents the published peer-reviewed sources covering how digital technologies can optimize internal controls and audit quality, and further fraud prevention and detection. The research outcomes drawn from the above analyses indicate that blockchain can enhance information schedules and accounting soundness due to its decentralization and transparency.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on blockchain technology adoption in artificial intelligence-based digital financial services, accounting information systems, and audit quality control may have been excluded. Limitations of this research comprise particular kinds of publications (original empirical research and review articles) discounting others (conference proceedings articles, books, and editorial materials). The scope of my study also does not move forward the inspection of artificial intelligence-based accounting information systems.

Subsequent analyses should develop on big data- and artificial intelligence-based accounting and auditing. Future research should thus investigate economic and financial features of blockchain technology-based corporate governance. Attention should be directed to blockchain accounting capabilities.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the author.

Data availability statement

All data generated or analyzed are included in the published article.

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Author contributions

The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record

The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement

The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Biometric Sensor Technologies, Visual Imagery and Predictive Modeling Tools, and Ambient Sound Recognition Software in the Economic Infrastructure of the Metaverse

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ABSTRACT. We draw on a substantial body of theoretical and empirical research on metaverse assets and services in interactive virtual environments. In this research, prior findings were cumulated indicating that predictive and retail analytics and data sharing technologies optimize consumer purchase behaviors. We carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout April 2022, with search terms including "the economic infrastructure of the metaverse" + "biometric sensor technologies," "visual imagery and predictive modeling tools," and "ambient sound recognition software." As we analyzed research published in 2021 and 2022, only 141 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, we decided on 25, chiefly empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, ROBIS, and SRDR.

Keywords: customer predictive analytics; geolocation data; immersive technologies; metaverse commerce; ambient sound recognition software; biometric sensor technologies

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1. Introduction

Immersive retail experiences can be attained by use of conversational artificial intelligence and image processing computational algorithms (Andronie et al., 2021a; Krizanova et al., 2019; Nica, 2021; Throne and Lăzăroiu, 2020) in extended reality environments. The purpose of our systematic review is to examine the recently published literature on the economic infrastructure of the metaverse and integrate the insights it configures on biometric sensor technologies, visual imagery and predictive modeling tools (Andronie et al., 2021b; Lewkowich, 2022; Nica and Stehel, 2021; Valaskova et al., 2021), and ambient sound recognition software. By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that retail business analytics deploys simulation modeling tools in immersive virtual shopping as regards digital assets (Andronie et al., 2021c; Mircică, 2020; Poliak et al., 2020; Vătămănescu et al., 2022), attracting and retaining customers. The actuality and novelty of this study are articulated by addressing metaverse assets and services in interactive virtual environments, that is an emerging topic involving much interest. Our research problem is whether business intelligence operations and consumer behavior and data (Balcerzak et al., 2022; Nica, 2017; Rogers and Zvarikova, 2021; Vinerean et al., 2022) develop on visual analytics, natural language processing tools, and ambient sound recognition software in 3D immersive environments. .

In this review, prior findings have been cumulated indicating that augmented reality commerce platforms and virtual retail environments integrate data visualization tools (Dabija et al., 2022; Nica et al., 2020; Rowland, 2022; Zvarikova et al., 2021), shaping consumer sentiment and behavior. The identified gaps advance sentiment analytics and metaverse interoperability assisting artificial intelligence-powered live shopping experiences across virtual marketplaces. Our main objective is to indicate that predictive and retail analytics and data sharing technologies optimize consumer purchase behaviors. This systematic review contributes to the literature on immersive decentralized networking and metaverse brand experiences by clarifying that customized data workflows and speech analytics are pivotal in personalized digital shopping experiences across interconnected virtual worlds, shaping customer preferences and buying habits.

2. Theoretical Overview of the Main Concepts

Technology-enabled live shopping requires voice and gesture recognition tools and spatial computing technology in virtual marketplaces. Immersive technologies further augmented reality-based livestream shopping in extended reality environments. Analytical artificial intelligence and haptic and biometric sensor technologies enable immersive digital experiences in virtual marketplaces. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), real-time predictive analytics, ambient sound recognition software, biometric sensor technologies and in the economic infrastructure of the metaverse (section 4), visual imagery tools, customer predictive analytics, and geolocation data in the metaverse commerce (section 5), predictive modeling tools, consumer analytics, and immersive technologies in the virtual economy of the metaverse (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

We carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout April 2022, with search terms including "the economic infrastructure of the metaverse" + "biometric sensor technologies," "visual imagery and predictive modeling tools," and "ambient sound recognition software." As we analyzed research published in 2021 and 2022, only 141 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, we decided on 25, chiefly empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the economic infrastructure of the metaverse + biometric sensor technologies	45	8
the economic infrastructure of the metaverse + visual imagery and predictive modeling tools	49	9
the economic infrastructure of the metaverse + ambient sound recognition software	47	8
Type of paper		
Original research	99	21
Review	25	4
Conference proceedings	9	0
Book	2	0
Editorial	6	0

Source: Processed by the authors. Some topics overlap.

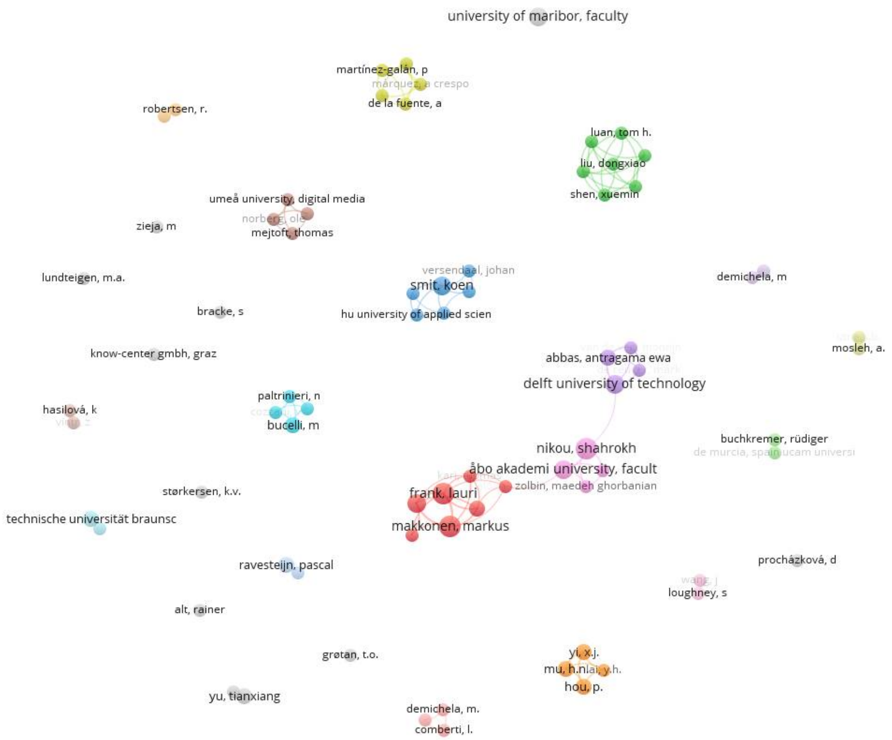

Figure 1 Co-authorship

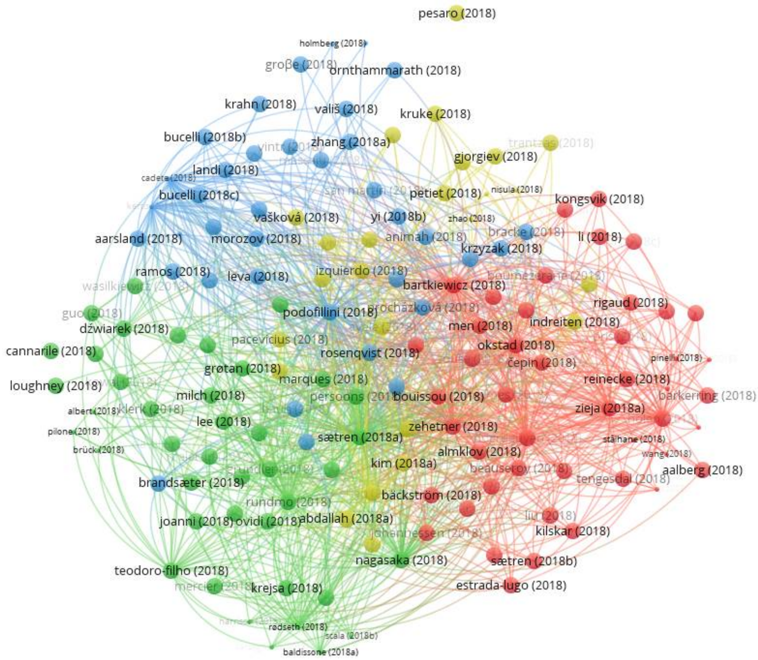

Figure 2 Citation

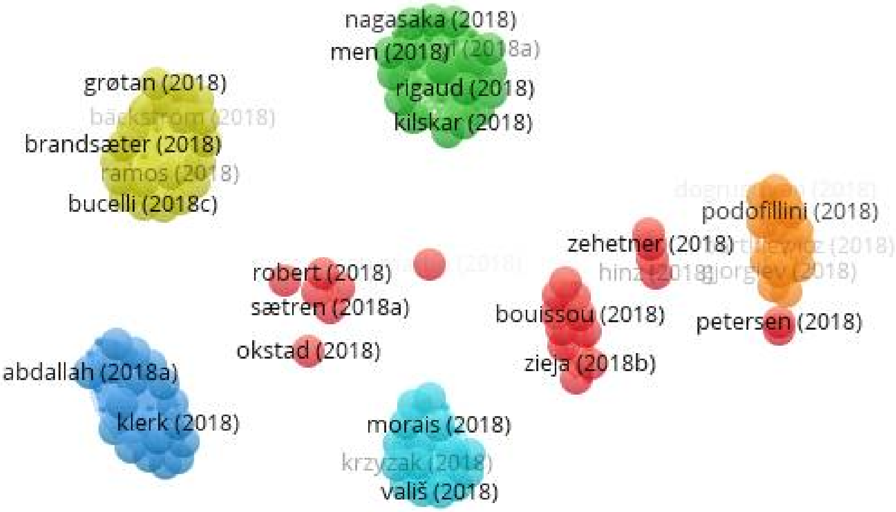

Figure 3 Bibliographic coupling

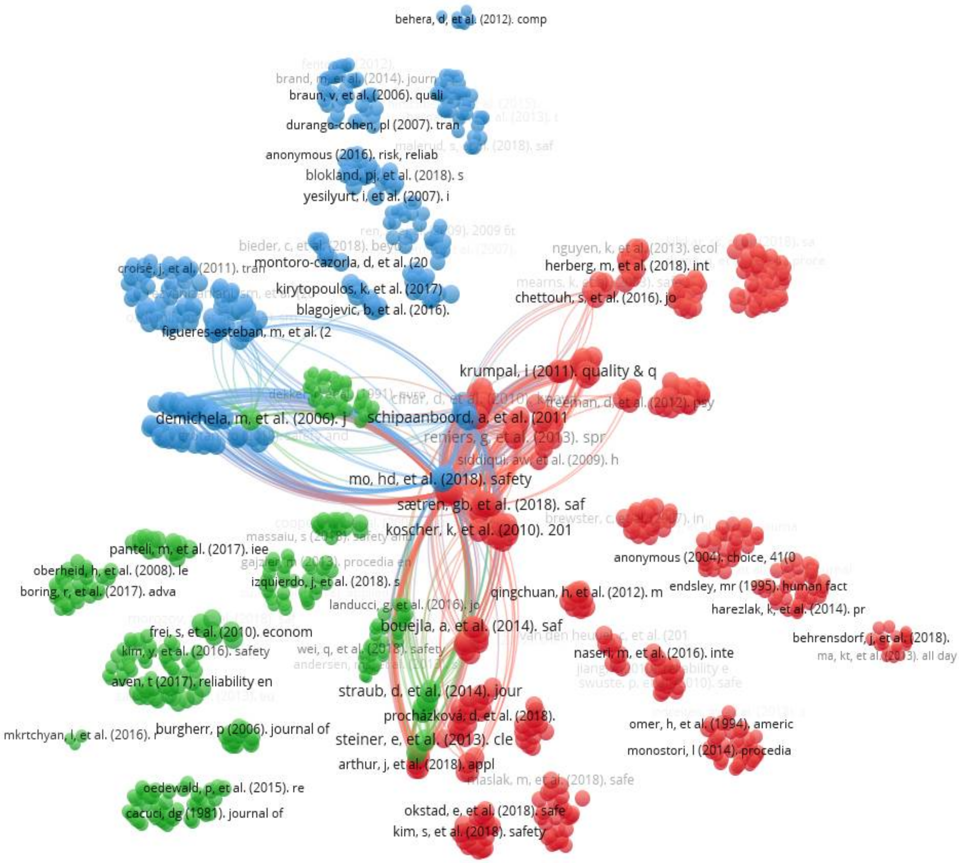

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Real-time predictive analytics and customer biometric data improve metaverse assets and services in interactive virtual environments. Spatial analytics enables hyper-realistic personalized interactive experiences and consumer digital engagement in virtual shopping malls.	Almarzouqi et al. 2022; Nica et al., 2022; Park et al., 2022
Computer vision algorithms and retail analytics are instrumental in immersive decentralized networking and metaverse brand experiences. Immersive technologies further augmented reality-based livestream shopping.	Dozio et al., 2022; Hawkins, 2022a; Reis and Ashmore, 2022
Simulation modeling tools enhance metaverse live-video shopping events and 3D immersive content in extended reality environments. Realistic virtual shopping experiences can be achieved by use of visual analytics in metaverse customer engagement.	Dawson, 2022; Hollensen et al., 2022; Liu et al., 2022
Sentiment analytics and metaverse interoperability assist artificial intelligence-powered live shopping experiences across virtual marketplaces, optimizing purchase journeys.	Hawkins, 2022b; Siyaev and Jo, 2021; Zhang et al., 2022a
Metaverse technologies develop on visual analytics and computer vision-based systems as regards virtual items. Customer predictive analytics leverages movement and behavior tracking tools in metaverse live shopping.	Guo and Gao, 2022; Laviola et al., 2022; Skalidis et al., 2022
Customer behavior analytics harnesses immersive technologies and geolocation data in live e-commerce shopping in the metaverse economy. Visual imagery tools configure lifetime customer value as regards digitized retail products in immersive hyper-connected virtual spaces.	Almarzouqi et al., 2022; Xi et al., 2022; Zyda, 2022
Predictive modeling tools and computer vision algorithms articulate immersive metaverse experiences in virtual retail stores. Natural language processing tools and digital contact tracing technologies improve consumer sentiment and behavior in live shopping events.	Han et al., 2022; Lv et al., 2022; Wang, 2022
Consumer analytics deploys business intelligence and simulation modeling tools in the virtual economy of the metaverse.	Gills and Hosseini, 2022; Kshetri, 2022; Park et al., 2022
Immersive technologies and customer personalization tools impact user experiences and behaviors across the interconnected metaverse. Predictive and retail analytics and data sharing technologies optimize consumer purchase behaviors.	Hwang and Chien, 2022; Jang et al., 2022; Zhang et al., 2022b

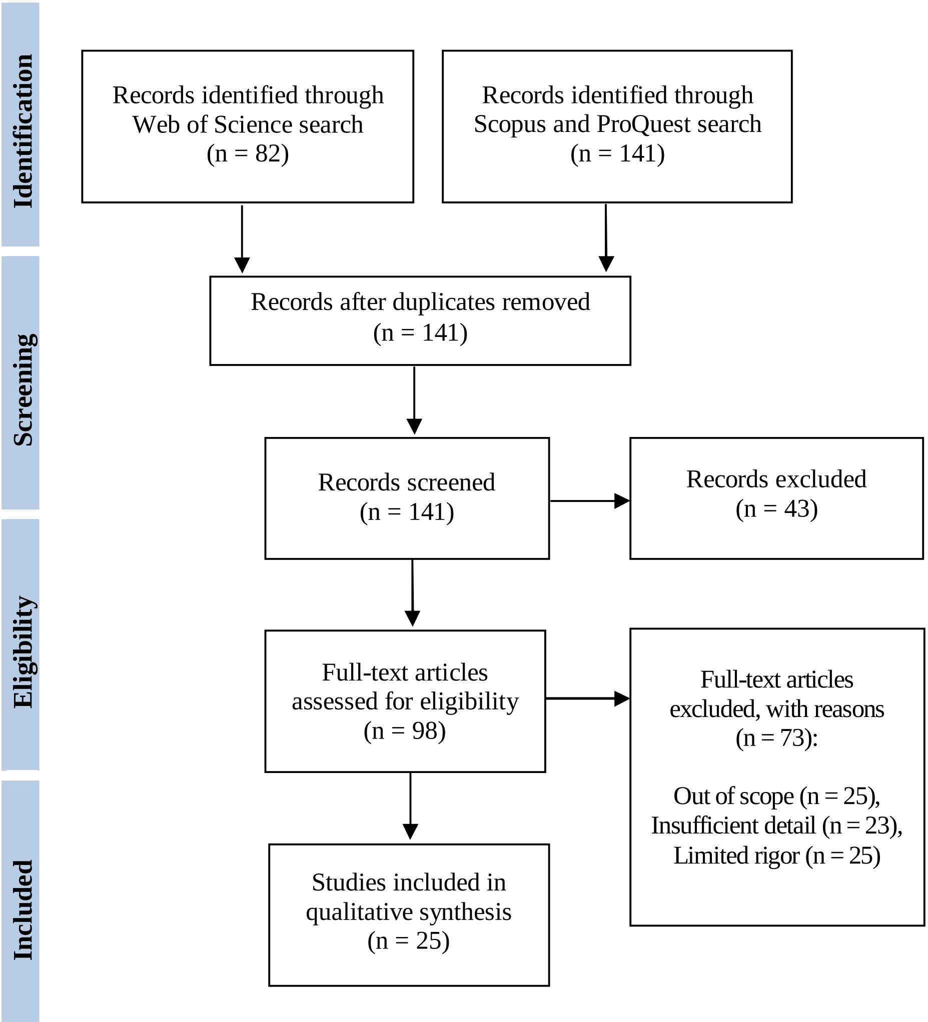

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2021–2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

ROBIS assessed the risk of bias in systematic reviews.

Figure 6 Screening and quality assessment tools

4. Real-Time Predictive Analytics, Ambient Sound Recognition Software, and Biometric Sensor Technologies in the Economic Infrastructure of the Metaverse

Real-time predictive analytics and customer biometric data (Almarzouqi et al. 2022; Nica et al., 2022; Park et al., 2022) improve metaverse assets and services in interactive virtual environments. Transaction geolocation data and biometric authentication features configure consumer behavior and expectations and virtual retail experiences in the economic infrastructure of the metaverse. Technology-enabled live shopping requires voice and gesture recognition tools and spatial computing technology in virtual marketplaces. Spatial analytics enables hyper-realistic personalized interactive experiences and consumer digital engagement in virtual shopping malls.

Computer vision algorithms and retail analytics (Dozio et al., 2022; Hawkins, 2022a; Reis and Ashmore, 2022) are instrumental in immersive decentralized networking and metaverse brand experiences. Machine learning-based image recognition tools articulate metaverse live shopping and immersive retail experiences across customer journey in the virtual commerce. Business intelligence operations and consumer behavior and data develop on visual analytics, natural language processing tools, and ambient sound recognition software in 3D immersive environments. Immersive technologies further augmented reality-based livestream shopping in extended reality environments.

Simulation modeling tools enhance metaverse live-video shopping events and 3D immersive content (Dawson, 2022; Hollensen et al., 2022; Liu et al., 2022) in extended reality environments. Immersive retail experiences can be attained by use of conversational artificial intelligence and image processing computational algorithms in extended reality environments. Social commerce capabilities and contextual consumer data optimize virtual consumer engagement in terms of buying habits and behaviors in the metaverse economy. Analytical artificial intelligence and haptic and biometric sensor technologies enable immersive digital experiences in virtual marketplaces. Realistic virtual shopping experiences can be achieved by use of visual analytics in metaverse customer engagement. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Real-time predictive analytics and customer biometric data improve metaverse assets and services in interactive virtual environments.	Almarzouqi et al. 2022; Nica et al., 2022; Park et al., 2022
Computer vision algorithms and retail analytics are instrumental in immersive decentralized networking and metaverse brand experiences.	Dozio et al., 2022; Hawkins, 2022a; Reis and Ashmore, 2022
Simulation modeling tools enhance metaverse live-video shopping events and 3D immersive content in extended reality environments.	Dawson, 2022; Hollensen et al., 2022; Liu et al., 2022

5. Visual Imagery Tools, Customer Predictive Analytics, and Geolocation Data in the Metaverse Commerce

Sentiment analytics and metaverse interoperability assist artificial intelligence-powered live shopping experiences across virtual marketplaces (Hawkins, 2022b; Siyaev and Jo, 2021; Zhang et al., 2022a), optimizing purchase journeys. Metaverse capabilities optimize live shopping events in the virtual retail market. Customer experience analytics leverages conversational artificial intelligence and predictive algorithms as regards entertaining metaverse events. Retail business analytics deploys simulation modeling tools in immersive virtual shopping as regards digital assets, attracting and retaining customers. Sentiment analytics and voice recognition software articulate consumer behavior and preferences in immersive digital worlds.

Metaverse technologies develop on visual analytics and computer vision-based systems (Guo and Gao, 2022; Laviola et al., 2022; Skalidis et al., 2022) as regards virtual items. Augmented reality commerce platforms and virtual retail environments integrate data visualization tools, shaping consumer sentiment and behavior. Behavioral and demographic analytics and customer engagement tools assist immersive 3D technologies in livestream shopping events. Customer predictive analytics leverages movement and behavior tracking tools in metaverse live shopping.

Customer behavior analytics harnesses immersive technologies and geolocation data in live e-commerce shopping (Almarzouqi et al., 2022; Xi et al., 2022; Zyda, 2022) in the metaverse economy. Multisensory customer experiences integrate spatial analytics and business intelligence tools in the metaverse commerce. Customized data workflows and speech analytics are pivotal in personalized digital shopping experiences across interconnected virtual worlds, shaping customer preferences and buying habits. Visual imagery tools configure lifetime customer value as regards digitized retail products in immersive hyper-connected virtual spaces, forecasting user preferences. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Sentiment analytics and metaverse interoperability assist artificial intelligence-powered live shopping experiences across virtual marketplaces, optimizing purchase journeys.	Hawkins, 2022b; Siyaev and Jo, 2021; Zhang et al., 2022a
Metaverse technologies develop on visual analytics and computer vision-based systems as regards virtual items.	Guo and Gao, 2022; Laviola et al., 2022; Skalidis et al., 2022
Customer behavior analytics harnesses immersive technologies and geolocation data in live e-commerce shopping in the metaverse economy.	Almarzouqi et al., 2022; Xi et al., 2022; Zyda, 2022

6. Predictive Modeling Tools, Consumer Analytics, and Immersive Technologies in the Virtual Economy of the Metaverse

Predictive modeling tools and computer vision algorithms articulate immersive metaverse experiences (Han et al., 2022; Lv et al., 2022; Wang, 2022) in virtual retail stores. Data visualization tools and biometric authentication features further immersive shopping experiences in extended reality environments. Natural language processing tools and eye-tracking technologies enhance consumer habits and expectations in virtual retail stores and augmented reality-powered immersive spaces. Natural language processing tools and digital contact tracing technologies improve consumer sentiment and behavior in live shopping events.

Consumer analytics deploys business intelligence and simulation modeling tools (Gills and Hosseini, 2022; Kshetri, 2022; Park et al., 2022) in the virtual economy of the metaverse. Interactive brand experiences can be achieved in immersive interconnected virtual worlds through data visualization tools and connected e-commerce apps. Predictive customer analytics and data-driven artificial intelligence harness augmented reality shopping tools in virtual commerce. Contextual awareness and automated speech recognition tools are pivotal in product customization services and entertaining metaverse events across virtual economy. Customer identification technology and simulation modeling tools shape live shopping events in extended reality environments.

Immersive technologies and customer personalization tools impact user experiences and behaviors (Hwang and Chien, 2022; Jang et al., 2022; Zhang et al., 2022b) across the interconnected metaverse. Personalized purchase experiences can be attained through business intelligence tools and customer data analytics across digital marketplaces, building seamless shopping experiences. Fuzzy search techniques, computer-generated images, and predictive maintenance are instrumental in data-driven customer engagements across virtual shopping malls. Predictive and retail analytics and data sharing technologies optimize consumer purchase behaviors. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Predictive modeling tools and computer vision algorithms articulate immersive metaverse experiences in virtual retail stores.	Han et al., 2022; Lv et al., 2022; Wang, 2022
Consumer analytics deploys business intelligence and simulation modeling tools in the virtual economy of the metaverse.	Gills and Hosseini, 2022; Kshetri, 2022; Park et al., 2022
Immersive technologies and customer personalization tools impact user experiences and behaviors across the interconnected metaverse.	Hwang and Chien, 2022; Jang et al., 2022; Zhang et al., 2022b

7. Discussion

We integrate our systematic review throughout research indicating how spatial analytics enables hyper-realistic personalized interactive experiences and consumer digital engagement in virtual shopping malls. Our research complements recent analyses clarifying how social commerce capabilities and contextual consumer data optimize virtual consumer engagement in terms of buying habits and behaviors in the metaverse economy. We elucidate, by cumulative evidence, previous research demonstrating how metaverse capabilities optimize live shopping events in the virtual retail market.

8. Synopsis of the Main Research Outcomes

Transaction geolocation data and biometric authentication features configure consumer behavior and expectations and virtual retail experiences in the economic infrastructure of the metaverse. Natural language processing tools and eye-tracking technologies enhance consumer habits and expectations in virtual retail stores and augmented reality-powered immersive spaces. Contextual awareness and automated speech recognition tools are pivotal in product customization services and entertaining metaverse events across virtual economy.

9. Conclusions

Relevant research has investigated whether customer predictive analytics leverages movement and behavior tracking tools in metaverse live shopping. This systematic literature review presents the published peer-reviewed sources covering how realistic virtual shopping experiences can be achieved by use of visual analytics in metaverse customer engagement. The research outcomes drawn from the above analyses indicate that machine learning-based image recognition tools articulate metaverse live shopping and immersive retail experiences across customer journey in the virtual commerce.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on biometric sensor technologies, visual imagery and predictive modeling tools, and ambient sound recognition software in the economic infrastructure of the metaverse may have been excluded. The scope of our study also does not move forward the inspection of metaverse technologies developing on visual analytics and computer vision-based systems.

Subsequent analyses should develop on simulation modeling tools enhancing metaverse live-video shopping events and 3D immersive content. Future research should thus investigate customer behavior analytics harnessing immersive technologies and geolocation data in live e-commerce shopping. Attention should be directed to predictive modeling tools and computer vision algorithms articulating immersive metaverse experiences.

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Author contributions
All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record
The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement
The authors affirm that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Virtual Navigation and Geospatial Mapping Tools, Customer Data Analytics, and Computer Vision and Simulation Optimization Algorithms in the Blockchain-based Metaverse

Susan Gordon*

ABSTRACT. The purpose of this study is to examine consumer habits and expectations in immersive interconnected virtual worlds. In this article, I cumulate previous research findings indicating that customer behavior analytics shapes immersive digital and metaverse brand experiences in virtual marketplaces. I contribute to the literature on business intelligence operations in extended reality environments and Web3-powered metaverse worlds by showing that customer data analytics is pivotal in immersive virtual experiences across interactive digital worlds. Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including “the blockchain-based metaverse” + “virtual navigation and geospatial mapping tools,” “customer data analytics,” and “computer vision and simulation optimization algorithms.” As I inspected research published in 2022, only 136 articles satisfied the eligibility criteria. By removing controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 21, generally empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, MMAT, and SRDR.

Keywords: metaverse interactive environment; shopper behavioral data; customer personalization tools; image recognition technologies; automated speech recognition tools; retail business analytics

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1. Introduction

Real-time predictive analytics optimizes purchase journeys in retail live-streaming on blockchain-based metaverse platforms (Andronie et al., 2021; Kliestik et al., 2020; Rogers and Zvarikova, 2021; Zvarikova et al., 2021) by use of immersive technologies. The purpose of my systematic review is to examine the recently published literature on the blockchain-based metaverse and integrate the insights it configures on virtual navigation and geospatial mapping tools, customer data analytics, and computer vision and simulation optimization algorithms. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that immersive retail experiences develop on the metaverse operations management, raising brand awareness and driving shopper engagement. The actuality and novelty of this study are articulated by addressing consumer habits and expectations in immersive interconnected virtual worlds, that is an emerging topic involving much interest. My research problem is whether Business intelligence analytics and visual imagery tools (Balcerzak et al., 2022; Konhäusner et al., 2021; Throne and Lăzăroiu, 2020; Valle, 2021) shape consumer behavior and data in the virtual retail market, articulating immersive retail experiences.

In this review, prior findings have been cumulated indicating that customer behavior analytics shapes immersive digital and metaverse brand experiences in virtual marketplaces. The identified gaps advance business intelligence operations (Ionescu, 2020; Lăzăroiu et al., 2020; Scott et al., 2020; Vinerean et al., 2022) in extended reality environments and Web3-powered metaverse worlds. My main objective is to indicate that customer data analytics is pivotal in immersive virtual experiences across interactive digital worlds. This systematic review contributes to the literature on business intelligence operations (Gray-Hawkins and Lăzăroiu, 2020; Krizanova et al., 2019; Poliak et al., 2020; Vătămănescu et al., 2022) across blockchain-based virtual worlds in the metaverse interactive environment by clarifying that metaverse platform engagement and immersive 3D experiences require shopper behavioral data, simulation modeling tools, and customer traffic analytics.

2. Theoretical Overview of the Main Concepts

Fuzzy search techniques, data visualization tools, and real-time sensor data optimize consumer sentiments, attitudes, and behaviors as regards metaverse assets and services in the blockchain-based virtual economy. Retail business analytics deploys geolocation data, augmented reality tools, and digital twin modeling to articulate robust immersive experiences in the blockchain-based metaverse. Customer response sentiment in augmented reality-powered immersive spaces and across interconnected virtual worlds can be articulated by use of business intelligence tools, speech analytics, and biometrics data fusion. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), shopper behavioral data, customer personalization tools, and retail business analytics in the blockchain-based metaverse (section 4), virtual navigation and automated speech recognition tools, computer vision and simulation optimization algorithms, and consumer journey analytics in Web3-powered metaverse worlds (section 5), customer data analytics, image recognition technologies, and geospatial mapping tools in the metaverse interactive environment (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "the blockchain-based metaverse" + "virtual navigation and geospatial mapping tools," "customer data analytics," and "computer vision and simulation optimization algorithms." As I inspected research published in 2022, only 136 articles satisfied the eligibility criteria. By removing controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 21, generally empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, MMAT, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the blockchain-based metaverse + virtual navigation and geospatial mapping tools	49	8
the blockchain-based metaverse + customer data analytics	43	6
the blockchain-based metaverse + computer vision and simulation optimization algorithms	44	7
Type of paper		
Original research	108	16
Review	16	5
Conference proceedings	8	0
Book	1	0
Editorial	3	0

Source: Processed by the author. Some topics overlap.

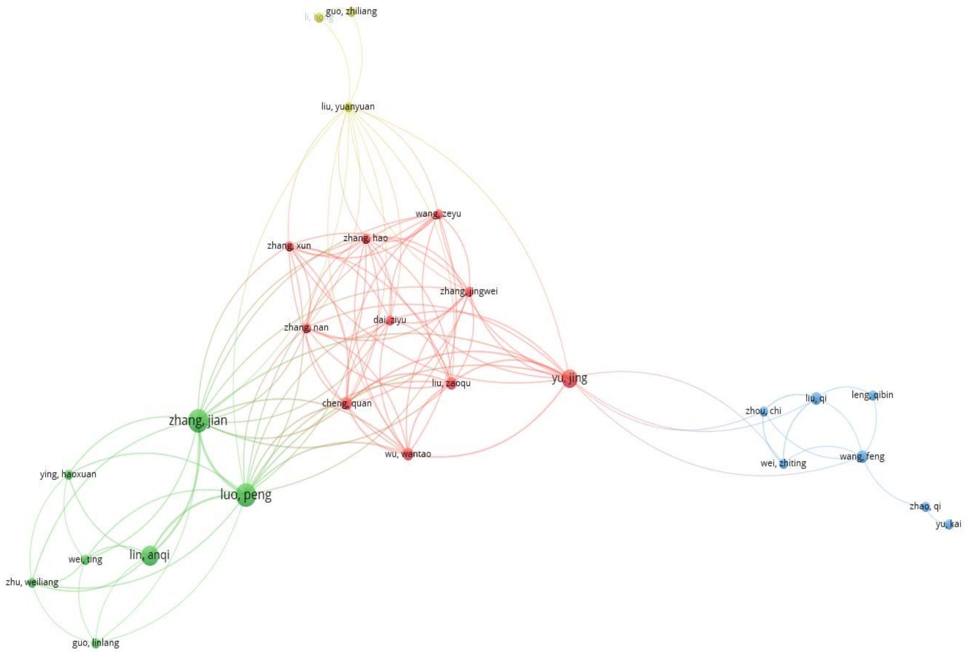
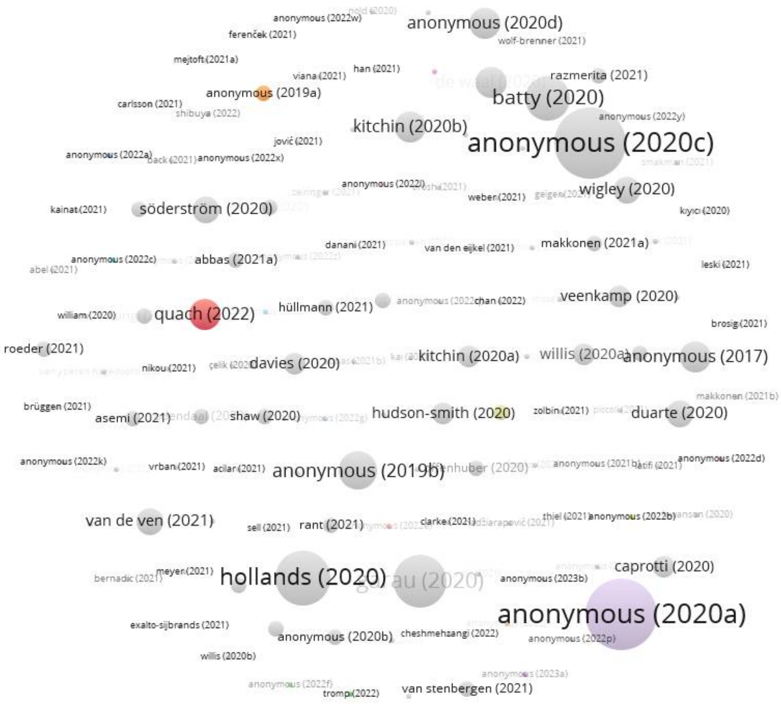


Figure 1 Co-authorship



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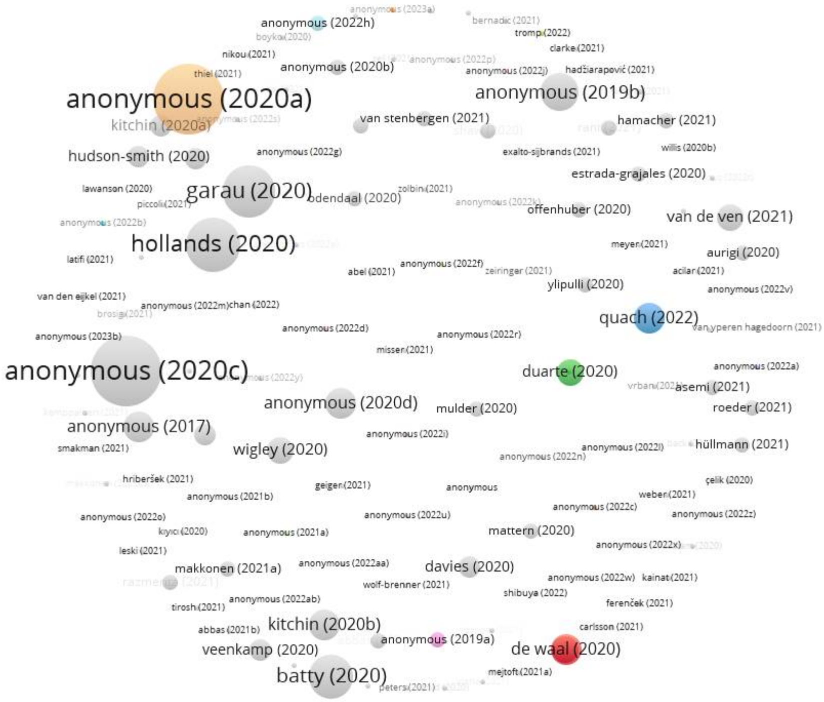

Figure 3 Bibliographic coupling

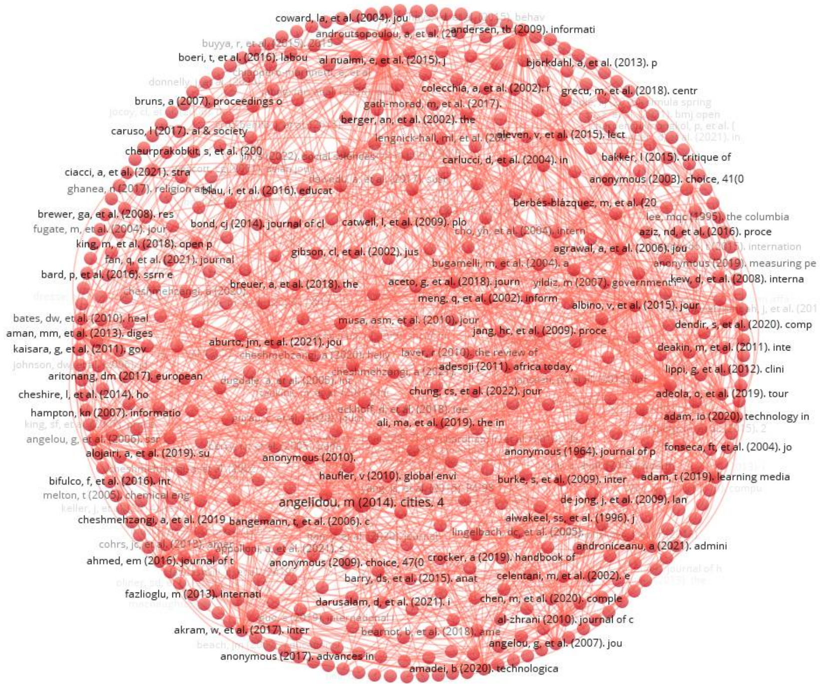

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Augmented reality shopping tools and spatial analytics shape virtual consumer engagement and immersive virtual retail experiences in the metaverse economy.	Dozio et al., 2022; Rydell, 2022; Zhang et al., 2022
Digitally extended social interactions and metaverse brand experiences can be attained in an augmented reality-based commerce landscape by use of cognitive technologies, business intelligence tools, and customer behavior analytics.	Almarzouqi et al. 2022; Guo and Gao, 2022; Hopkins, 2022
Customer personalization tools assist live shopping events across extended reality environments by leveraging business intelligence analytics in the metaverse commerce.	Gössling and Schweiggart, 2022; Hawkins, 2022; Zyda, 2022a
Customer engagement tools harness computer vision and simulation optimization algorithms, artificial intelligence-powered search capabilities, and immersive technologies across business intelligence operations in extended reality environments and Web3-powered metaverse worlds.	Hollensen et al., 2022; Hopkins, 2022; Popescu et al., 2022
Machine learning-based image recognition tools, metaverse capabilities, and cognitive enhancement technologies improve consumer habits. Customer experience analytics deploys immersive visualization systems across digital marketplaces in the virtual commerce as regards consumption patterns and spending habits.	Kozinets, 2022; Zhao et al., 2022; Zyda, 2022b
Augmented reality shopping tools, consumer journey analytics, and data mining techniques configure metaverse live-video shopping events. Immersive shopping experiences integrate business intelligence operations in terms of consumer behavior and expectations in virtual environments.	Gössling and Schweiggart, 2022; Lv et al., 2022; Yeh et al., 2022
Virtual retail algorithms and shopper engagement technologies enhance consumer behavior and preferences in the retail metaverse as regards digital assets and 3D immersive content.	Gills and Hosseini, 2022; Jang et al., 2022; Wang, 2022
Image recognition technologies and simulation modeling tools configure business intelligence operations across blockchain-based virtual worlds in the metaverse interactive environment, leading to lasting competitive advantage.	Almarzouqi et al. 2022; Dozio et al., 2022; Gibbert et al., 2022
The economic infrastructure of the metaverse develops on immersive and engaging content, typifying customer preferences and buying habits in relation to virtual retail experiences.	Guo and Gao, 2022; Park et al., 2022; Zhang et al., 2022

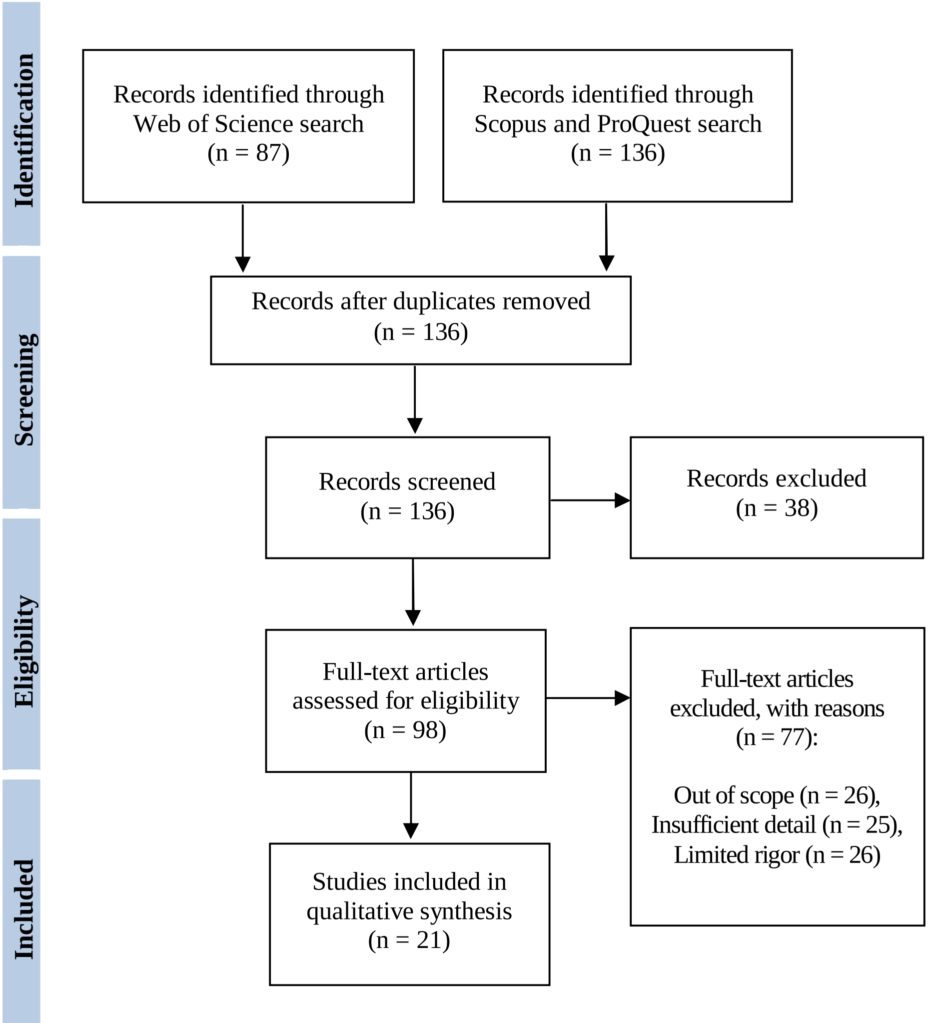

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.

To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

Dedoose analyzed qualitative and mixed methods research.

Figure 6 Screening and quality assessment tools

4. Shopper Behavioral Data, Customer Personalization Tools, and Retail Business Analytics in the Blockchain-based Metaverse

Augmented reality shopping tools and spatial analytics shape virtual consumer engagement and immersive virtual retail experiences (Dozio et al., 2022; Rydell, 2022; Zhang et al., 2022) in the metaverse economy. Digital twin simulation tools configure hyper-realistic personalized interactive experiences in user-generated digital virtual environments. Blockchain-based digital assets integrate ambient sound recognition and processing tools, metaverse technologies, and real-time Internet of Things data in extended reality environments, improving consumer purchasing habits in virtual shopping malls.

Digitally extended social interactions and metaverse brand experiences can be attained in an augmented reality-based commerce landscape (Almarzouqi et al. 2022; Guo and Gao, 2022; Hopkins, 2022) by use of cognitive technologies, business intelligence tools, and customer behavior analytics. Immersive retail experiences develop on the metaverse operations management, raising brand awareness and driving shopper engagement. Metaverse platform engagement and immersive 3D experiences require shopper behavioral data, simulation modeling tools, and customer traffic analytics.

Customer personalization tools assist live shopping events across extended reality environments (Gössling and Schweiggart, 2022; Hawkins, 2022; Zyda, 2022a) by leveraging business intelligence analytics in the metaverse commerce. Retail business analytics deploys geolocation data, augmented reality tools, and digital twin modeling to articulate robust immersive experiences in the blockchain-based metaverse. Data tracking apps and behavioral algorithms enable virtual asset purchasing, articulating shopper traffic patterns and driving customer loyalty in the metaverse economy. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Augmented reality shopping tools and spatial analytics shape virtual consumer engagement and immersive virtual retail experiences in the metaverse economy.	Dozio et al., 2022; Rydell, 2022; Zhang et al., 2022
Digitally extended social interactions and metaverse brand experiences can be attained in an augmented reality-based commerce landscape by use of cognitive technologies, business intelligence tools, and customer behavior analytics.	Almarzouqi et al. 2022; Guo and Gao, 2022; Hopkins, 2022
Customer personalization tools assist live shopping events across extended reality environments by leveraging business intelligence analytics in the metaverse commerce.	Gössling and Schweiggart, 2022; Hawkins, 2022; Zyda, 2022a

5. Virtual Navigation and Automated Speech Recognition Tools, Computer Vision and Simulation Optimization Algorithms, and Consumer Journey Analytics in Web3-powered Metaverse Worlds

Customer engagement tools harness computer vision and simulation optimization algorithms, artificial intelligence-powered search capabilities, and immersive technologies (Hollensen et al., 2022; Hopkins, 2022; Popescu et al., 2022) across business intelligence operations in extended reality environments and Web3-powered metaverse worlds. Eye-tracking technologies and data visualization tools enhance live e-commerce shopping in relation to shifting consumer behaviors and 3D immersive content across digital hyper-realistic worlds. Customer behavior analytics shapes immersive digital and metaverse brand experiences in virtual marketplaces.

Machine learning-based image recognition tools, metaverse capabilities, and cognitive enhancement technologies (Kozinets, 2022; Zhao et al., 2022; Zyda, 2022b) improve consumer habits and expectations in immersive interconnected virtual worlds. Virtual navigation and automated speech recognition tools, biometric authentication features, and natural language processing algorithms shape livestreaming e-commerce digital events. Customer experience analytics deploys immersive visualization systems across digital marketplaces in the virtual commerce as regards consumption patterns and spending habits.

Augmented reality shopping tools, consumer journey analytics, and data mining techniques (Gössling and Schweiggart, 2022; Lv et al., 2022; Yeh et al., 2022) configure metaverse live-video shopping events. Fuzzy search techniques, data visualization tools, and real-time sensor data optimize consumer sentiments, attitudes, and behaviors as regards metaverse assets and services in the blockchain-based virtual economy. Immersive shopping experiences integrate business intelligence operations in terms of consumer behavior and expectations in virtual environments. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer engagement tools harness computer vision and simulation optimization algorithms, artificial intelligence-powered search capabilities, and immersive technologies across business intelligence operations in extended reality environments and Web3-powered metaverse worlds.	Hollensen et al., 2022; Hopkins, 2022; Popescu et al., 2022
Machine learning-based image recognition tools, metaverse capabilities, and cognitive enhancement technologies improve consumer habits.	Kozinets, 2022; Zhao et al., 2022; Zyda, 2022b
Augmented reality shopping tools, consumer journey analytics, and data mining techniques configure metaverse live-video shopping events.	Gössling and Schweiggart, 2022; Lv et al., 2022; Yeh et al., 2022

6. Customer Data Analytics, Image Recognition Technologies, and Geospatial Mapping Tools in the Metaverse Interactive Environment

Virtual retail algorithms and shopper engagement technologies enhance consumer behavior and preferences in the retail metaverse (Gills and Hosseini, 2022; Jang et al., 2022; Wang, 2022) as regards digital assets and 3D immersive content. Real-time predictive analytics optimizes purchase journeys in retail livestreaming on blockchain-based metaverse platforms by use of immersive technologies. Predictive algorithms, conversational artificial intelligence, and movement and behavior tracking tools are pivotal in multi-sensory customer experiences as regards virtual items across extended reality environments, optimizing buying habits and behaviors.

Image recognition technologies and simulation modeling tools configure business intelligence operations across blockchain-based virtual worlds in the metaverse interactive environment (Almarzouqi et al. 2022; Dozio et al., 2022; Gibbert et al., 2022), leading to lasting competitive advantage. Augmented reality shopping tools and spatial computing technology are instrumental in attracting and retaining customers in 3D immersive environments. Customer data analytics is pivotal in immersive virtual experiences across interactive digital worlds.

The economic infrastructure of the metaverse develops on immersive and engaging content (Guo and Gao, 2022; Park et al., 2022; Zhang et al., 2022), typifying customer preferences and buying habits in relation to virtual retail experiences. Customer response sentiment in augmented reality-powered immersive spaces and across interconnected virtual worlds can be articulated by use of business intelligence tools, speech analytics, and biometrics data fusion. Business intelligence analytics and visual imagery tools shape consumer behavior and data in the virtual retail market, articulating immersive retail experiences. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Virtual retail algorithms and shopper engagement technologies enhance consumer behavior and preferences in the retail metaverse as regards digital assets and 3D immersive content.	Gills and Hosseini, 2022; Jang et al., 2022; Wang, 2022
Image recognition technologies and simulation modeling tools configure business intelligence operations across blockchain-based virtual worlds in the metaverse interactive environment, leading to lasting competitive advantage.	Almarzouqi et al. 2022; Dozio et al., 2022; Gibbert et al., 2022
The economic infrastructure of the metaverse develops on immersive and engaging content, typifying customer preferences and buying habits in relation to virtual retail experiences.	Guo and Gao, 2022; Park et al., 2022; Zhang et al., 2022

7. Discussion

I integrate my systematic review throughout research indicating how blockchain-based digital assets integrate ambient sound recognition and processing tools, metaverse technologies, and real-time Internet of Things data in extended reality environments, improving consumer purchasing habits in virtual shopping malls. My research complements recent analyses clarifying how eye-tracking technologies and data visualization tools enhance live e-commerce shopping in relation to shifting consumer behaviors and 3D immersive content across digital hyper-realistic worlds. I elucidate, by cumulative evidence, previous research demonstrating how immersive shopping experiences integrate business intelligence operations in terms of consumer behavior and expectations in virtual environments.

8. Synopsis of the Main Research Outcomes

Digital twin simulation tools configure hyper-realistic personalized interactive experiences in user-generated digital virtual environments. Augmented reality shopping tools and spatial computing technology are instrumental in attracting and retaining customers in 3D immersive environments. Immersive retail experiences develop on the metaverse operations management, raising brand awareness and driving shopper engagement.

9. Conclusions

Relevant research has investigated whether customer experience analytics deploys immersive visualization systems across digital marketplaces in the virtual commerce as regards consumption patterns and spending habits. This systematic literature review presents the published peer-reviewed sources covering how predictive algorithms, conversational artificial intelligence, and movement and behavior tracking tools are pivotal in multisensory customer experiences as regards virtual items across extended reality environments, optimizing buying habits and behaviors. The research outcomes drawn from the above analyses indicate that data tracking apps and behavioral algorithms enable virtual asset purchasing, articulating shopper traffic patterns and driving customer loyalty in the metaverse economy.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on virtual navigation and geospatial mapping tools, customer data analytics, and computer vision and simulation optimization algorithms in the blockchain-based metaverse may have been excluded. The scope of my study also does not move forward the inspection of customer preferences and buying habits in relation to virtual retail experiences.

Subsequent analyses should develop on digitally extended social interactions and metaverse brand experiences in an augmented reality-based commerce landscape. Future research should thus investigate machine learning-based image recognition tools, metaverse capabilities, and cognitive enhancement technologies. Attention should be directed to augmented reality shopping tools and spatial analytics shaping virtual consumer engagement and immersive virtual retail experiences.

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Haptic and Biometric Sensor Technologies, Spatio-Temporal Fusion Algorithms, and Virtual Navigation Tools in the Decentralized and Interconnected Metaverse

Jana Majerová[1], and Aurel Pera[2]

ABSTRACT. The objective of this paper is to systematically review spatial computing algorithms, synthetic data tools, and customer behavior analytics configuring virtual retail experiences. The findings and analyses highlight that metaverse engagement metrics integrates computer vision algorithms, visual analytics, and cognitive technologies in the digital asset-based virtual economy. Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the decentralized and interconnected metaverse" + "haptic and biometric sensor technologies," "spatio-temporal fusion algorithms," and "virtual navigation tools." As research published between 2021 and 2022 was inspected, only 138 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 27 mainly empirical sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR.

Keywords: customer behavior analytics; metaverse economy; simulation modeling algorithms; virtual mapping and visual surveillance tools; natural language processing and geospatial mapping tools; sensing and computing technologies

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1. Introduction

Immersive multisensory virtual spaces integrate cyber-physical cognitive systems, real-time data tracking tools, and monitoring and sensing technologies (Blake and Frajtova Michalikova, 2021; Mircică, 2020; Valaskova et al., 2021), building seamless shopping experiences. The purpose of our systematic review is to examine the recently published literature on the decentralized and interconnected metaverse and integrate the insights it configures on haptic and biometric sensor technologies, spatio-temporal fusion algorithms, and virtual navigation tools. By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that 3D virtual space networking integrates deep learning algorithms, customer experience analytics, synthetic data tools, and spatial computing technologies. The actuality and novelty of this study are articulated by addressing metaverse technologies leveraging virtual twin modeling tools, geospatial mapping technologies (Kliestik et al., 2022; Nica, 2021; Zvarikova et al., 2021), and remote sensing systems (Andronie et al., 2021a; Konhäusner et al., 2021; Nica et al., 2021), that is an emerging topic involving much interest. Our research problem is whether metaverse engagement metrics integrates computer vision algorithms, visual analytics, and cognitive technologies (Andronie et al., 2021b; Lăzăroiu et al., 2021; Nica et al., 2022) in the digital asset-based virtual economy.

In this review, prior findings have been cumulated indicating that virtual mapping and visual surveillance tools, big geospatial data analytics (Johnson and Nica, 2021; Nica et al., 2020; Wallace and Lăzăroiu, 2021), and semantic vector search technology enhance metaverse assets and digitally extended social interactions. The identified gaps advance simulation optimization and predictive modeling algorithms assisting virtual consumer engagement. Our main objective is to indicate that digital twin simulation tools and sensor data fusion further metaverse interoperability across immersive interconnected virtual worlds. This systematic review contributes to the literature on spatial computing algorithms, synthetic data tools, and customer behavior analytics (Burke and Zvarikova, 2021; Nica, 2017; Vătămănescu et al., 2020) configuring virtual retail experiences by clarifying that metaverse consumer apps require virtual simulation algorithms, ambient sound recognition software, and remote sensing technologies (Balica, 2022; Lăzăroiu et al., 2022; Pelau et al., 2021) in 3D digital environments.

2. Theoretical Overview of the Main Concepts

Geolocation data, immersive technologies, and augmented reality shopping tools assist customer engagement tools as regards digitized retail products across shared virtual environments. Immersive visualization and cognitive computing systems, behavioral predictive analytics, and customized data workflows shape technology-enabled live shopping in 3D immersive environments. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), spatio-temporal fusion algorithms, virtual navigation tools, and customer behavior analytics in the metaverse economy (section 4), haptic and biometric sensor technologies, simulation modeling algorithms, and virtual mapping and visual surveillance tools in the metaverse interactive environment (section 5), spatial computing algorithms, natural language processing and geospatial mapping tools, and sensing and computing technologies in the decentralized and interconnected metaverse (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the decentralized and interconnected metaverse" + "haptic and biometric sensor technologies," "spatio-temporal fusion algorithms," and "virtual navigation tools." As research published between 2021 and 2022 was inspected, only 138 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 27 mainly empirical sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the decentralized and interconnected metaverse + haptic and biometric sensor technologies	43	8
the decentralized and interconnected metaverse + spatio-temporal fusion algorithms	46	9
the decentralized and interconnected metaverse + virtual navigation tools	49	10
Type of paper		
Original research	108	21
Review	18	6
Conference proceedings	9	0
Book	1	0
Editorial	2	0

Source: Processed by the authors. Some topics overlap.

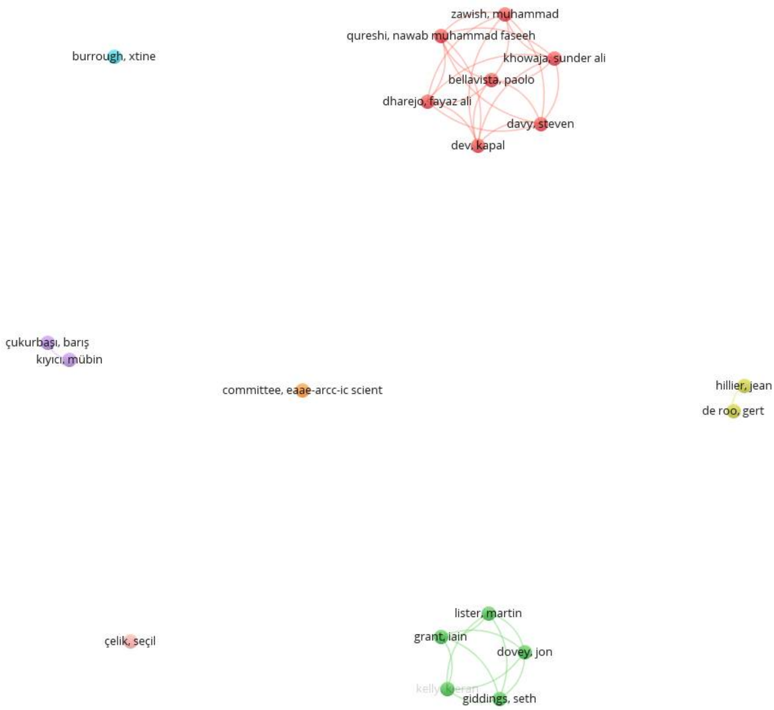

Figure 1 Co-authorship

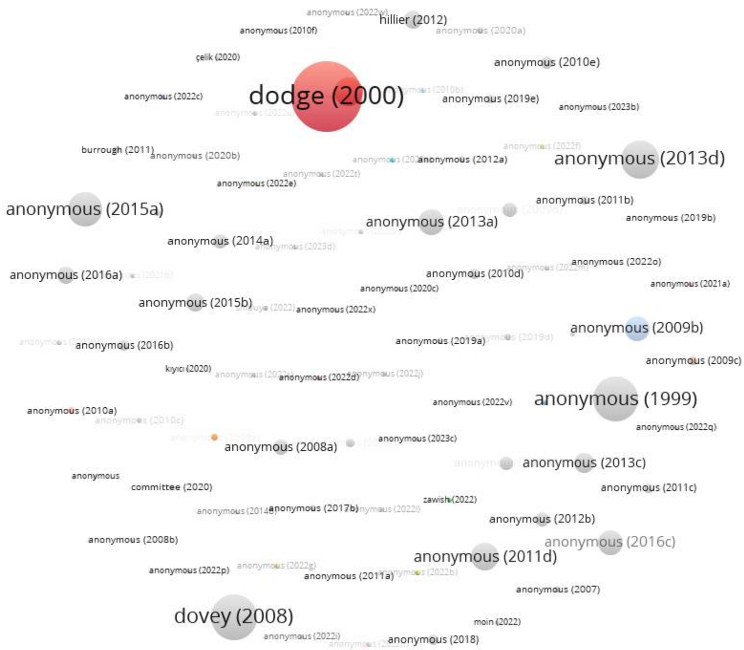

Figure 2 Citation

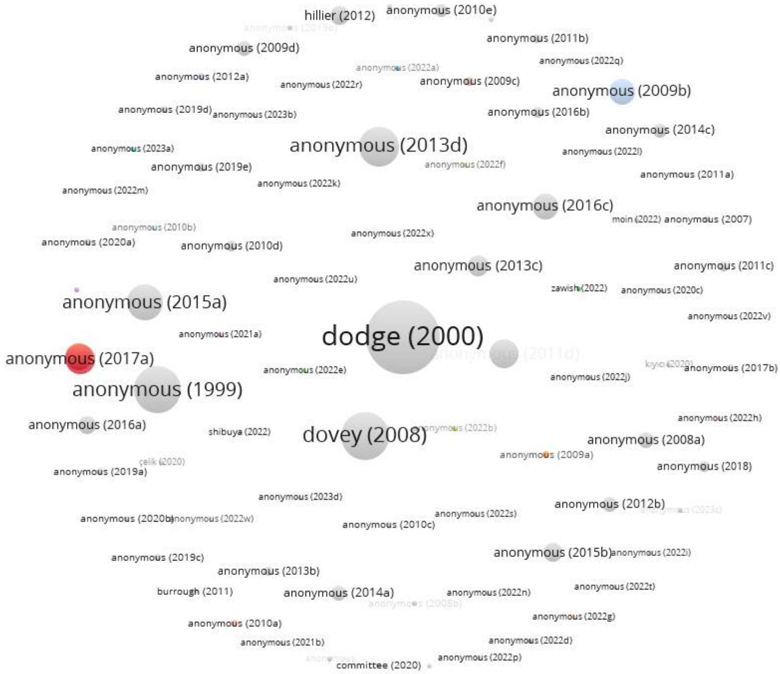

Figure 3 Bibliographic coupling

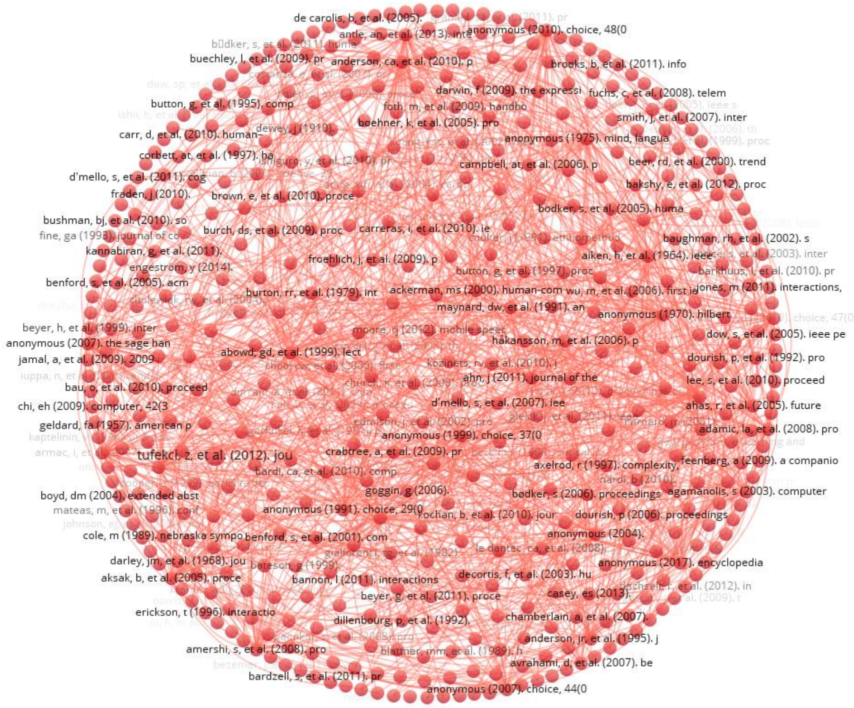

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Customer identification and cognitive enhancement technologies shape immersive shopping experiences as regards perceptual and contextual awareness in the metaverse economy.	Akyildiz et al., 2022; Jang et al., 2022; Watson, 2022
Deep learning-based sensing technologies and spatial cognition algorithms enhance metaverse live shopping in interconnected virtual worlds. Machine vision algorithms, retail business analytics, and virtual navigation tools optimize metaverse customer engagement and agile product development in virtual shopping malls.	Balica et al., 2022; Elawady et al., 2022; Wang, 2022
Simulation optimization and predictive modeling algorithms assist virtual consumer engagement in relation to entertaining metaverse events in immersive 3D environments.	Almarzouqi et al. 2022; Kovacova et al., 2022; Zhang et al., 2022
Retail business analytics harnesses behavioral algorithms and digital twin modeling tools in the blockchain-based metaverse, optimizing virtual asset purchasing.	Hamilton, 2022; Reis and Ashmore, 2022; Skalidis et al., 2022
Metaverse technologies leverage virtual twin modeling tools, geospatial mapping technologies, and remote sensing systems in immersive decentralized 3D digital worlds.	Carter, 2022; Gursoy et al., 2022; Liu et al., 2022
Internet of Things-based decision support systems, virtual navigation and data acquisition tools, and image recognition technologies are pivotal in augmented reality-based livestream shopping and immersive retail experiences in the metaverse interactive environment.	Han et al., 2022; Lukava et al., 2022; Upadhyay and Khandelwal, 2022
Spatial computing algorithms, synthetic data tools, and customer behavior analytics configure virtual retail experiences in digital hyper-realistic worlds and on blockchain-based metaverse platforms.	Kraus et al., 2022; Lin et al., 2022; Siyaev and Jo, 2021
Virtual reality-based immersive experiences integrate consumer behavior data in the decentralized and interconnected metaverse. Artificial intelligence-powered prediction tools and immersive visualization systems optimize frictionless virtual shopping experiences.	Chandra, 2022; Kshetri, 2022; Turner, 2022
Tech-based metaverse capabilities develop on data modeling and virtual navigation tools, spatial analytics, and deep neural network technology. Image recognition tools, consumer location data, and virtual retail algorithms assist personalized product recommendations.	Hwang and Chien, 2022; Solakis et al., 2022; Xi et al., 2022

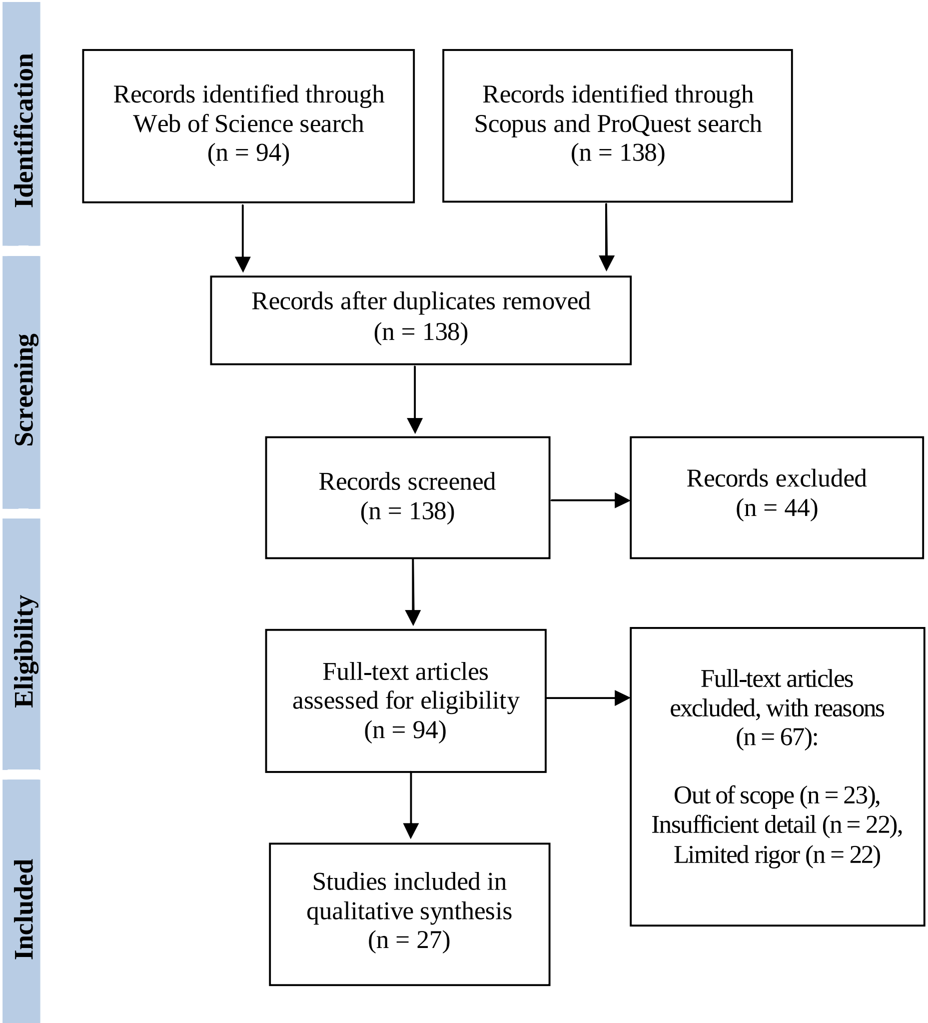

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2021 and 2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

Distiller SR screened and extracted the collected data.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

Figure 6 Screening and quality assessment tools

4. Spatio-Temporal Fusion Algorithms, Virtual Navigation Tools, and Customer Behavior Analytics in the Metaverse Economy

Customer identification and cognitive enhancement technologies shape immersive shopping experiences (Akyildiz et al., 2022; Jang et al., 2022; Watson, 2022) as regards perceptual and contextual awareness in the metaverse economy. Machine learning algorithms and blockchain technologies enable sustainable business practices and personalized digital shopping experiences, building brand awareness in interactive virtual environments. Immersive multisensory virtual spaces integrate cyber-physical cognitive systems, real-time data tracking tools, and monitoring and sensing technologies, building seamless shopping experiences.

Deep learning-based sensing technologies and spatial cognition algorithms enhance metaverse live shopping (Balica et al., 2022; Elawady et al., 2022; Wang, 2022) in interconnected virtual worlds. Geolocation data, immersive technologies, and augmented reality shopping tools assist customer engagement tools as regards digitized retail products across shared virtual environments. Machine vision algorithms, retail business analytics, and virtual navigation tools optimize metaverse customer engagement and agile product development in virtual shopping malls.

Simulation optimization and predictive modeling algorithms assist virtual consumer engagement (Almarzouqi et al. 2022; Kovacova et al., 2022; Zhang et al., 2022) in relation to entertaining metaverse events in immersive 3D environments. Spatio-temporal fusion algorithms, visual analytics, and cognitive automation technologies optimize purchase intentions and metaverse brand experiences in immersive hyper-connected virtual spaces. Metaverse engagement metrics integrates computer vision algorithms, visual analytics, and cognitive technologies in the digital asset-based virtual economy. Immersive retail experiences can be attained by use of data computing capabilities, business intelligence tools, and customer behavior analytics in a blockchain-based virtual world. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer identification and cognitive enhancement technologies shape immersive shopping experiences as regards perceptual and contextual awareness in the metaverse economy.	Akyildiz et al., 2022; Jang et al., 2022; Watson, 2022
Deep learning-based sensing technologies and spatial cognition algorithms enhance metaverse live shopping in interconnected virtual worlds.	Balica et al., 2022; Elawady et al., 2022; Wang, 2022
Simulation optimization and predictive modeling algorithms assist virtual consumer engagement in relation to entertaining metaverse events in immersive 3D environments.	Almarzouqi et al. 2022; Kovacova et al., 2022; Zhang et al., 2022

5. Haptic and Biometric Sensor Technologies, Simulation Modeling Algorithms, and Virtual Mapping and Visual Surveillance Tools in the Metaverse Interactive Environment

Retail business analytics harnesses behavioral algorithms and digital twin modeling tools (Hamilton, 2022; Reis and Ashmore, 2022; Skalidis et al., 2022) in the blockchain-based metaverse, optimizing virtual asset purchasing. Metaverse consumer apps require virtual simulation algorithms, ambient sound recognition software, and remote sensing technologies in 3D digital environments. Haptic and biometric sensor technologies, decision support tools, and retail analytics configure immersive shopping experiences in extended reality environments.

Metaverse technologies leverage virtual twin modeling tools, geospatial mapping technologies, and remote sensing systems (Carter, 2022; Gursoy et al., 2022; Liu et al., 2022) in immersive decentralized 3D digital worlds. Blockchain token-based digital assets develop on predictive and retail analytics, data visualization tools, and artificial vision systems in virtual marketplaces. Digital twin simulation tools and sensor data fusion further metaverse interoperability across immersive interconnected virtual worlds.

Internet of Things-based decision support systems, virtual navigation and data acquisition tools, and image recognition technologies (Han et al., 2022; Lukava et al., 2022; Upadhyay and Khandelwal, 2022) are pivotal in augmented reality-based livestream shopping and immersive retail experiences in the metaverse interactive environment. Voice and gesture recognition tools, analytical artificial intelligence, and sentiment analytics enable metaverse assets and services, optimizing purchase journeys in blockchain-based virtual worlds. Virtual mapping and visual surveillance tools, big geospatial data analytics, and semantic vector search technology enhance metaverse assets and digitally extended social interactions. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Retail business analytics harnesses behavioral algorithms and digital twin modeling tools in the blockchain-based metaverse, optimizing virtual asset purchasing.	Hamilton, 2022; Reis and Ashmore, 2022; Skalidis et al., 2022
Metaverse technologies leverage virtual twin modeling tools, geospatial mapping technologies, and remote sensing systems in immersive decentralized 3D digital worlds.	Carter, 2022; Gursoy et al., 2022; Liu et al., 2022
Internet of Things-based decision support systems, virtual navigation and data acquisition tools, and image recognition technologies are pivotal in augmented reality-based livestream shopping and immersive retail experiences in the metaverse interactive environment.	Han et al., 2022; Lukava et al., 2022; Upadhyay and Khandelwal, 2022

6. Spatial Computing Algorithms, Natural Language Processing and Geospatial Mapping Tools, and Sensing and Computing Technologies in the Decentralized and Interconnected Metaverse

Spatial computing algorithms, synthetic data tools, and customer behavior analytics configure virtual retail experiences (Kraus et al., 2022; Lin et al., 2022; Siyaev and Jo, 2021) in digital hyper-realistic worlds and on blockchain-based metaverse platforms. Natural language processing and geospatial mapping tools are pivotal in personalized customer shopping behavior. Immersive visualization and cognitive computing systems, behavioral predictive analytics, and customized data workflows shape technology-enabled live shopping in 3D immersive environments.

Virtual reality-based immersive experiences integrate consumer behavior data (Chandra, 2022; Kshetri, 2022; Turner, 2022) in the decentralized and interconnected metaverse. Deep learning computer vision algorithms and data mining tools shape technology-enabled live shopping in blockchain-based virtual worlds. Cognitive computing systems, consumer location data, biometric authentication features, and remote sensing data improve augmented shopping experiences as regards virtual merchandise. Artificial intelligence-powered prediction tools and immersive visualization systems optimize frictionless virtual shopping experiences.

Tech-based metaverse capabilities (Hwang and Chien, 2022; Solakis et al., 2022; Xi et al., 2022) develop on data modeling and virtual navigation tools, spatial analytics, and deep neural network technology. Natural language processing and customer engagement tools, virtual modeling technology, and interconnected sensor networks enhance machine learning-based product recognition and business intelligence operations in immersive digital worlds. 3D virtual space networking integrates deep learning algorithms, customer experience analytics, synthetic data tools, and spatial computing technologies. Image recognition tools, consumer location data, and virtual retail algorithms assist personalized product recommendations in interconnected virtual worlds. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Spatial computing algorithms, synthetic data tools, and customer behavior analytics configure virtual retail experiences in digital hyper-realistic worlds and on blockchain-based metaverse platforms.	Kraus et al., 2022; Lin et al., 2022; Siyaev and Jo, 2021
Virtual reality-based immersive experiences integrate consumer behavior data in the decentralized and interconnected metaverse.	Chandra, 2022; Kshetri, 2022; Turner, 2022
Tech-based metaverse capabilities develop on data modeling and virtual navigation tools, spatial analytics, and deep neural network technology.	Hwang and Chien, 2022; Solakis et al., 2022; Xi et al., 2022

7. Discussion

We integrate our systematic review throughout research indicating how immersive retail experiences can be attained by use of data computing capabilities, business intelligence tools, and customer behavior analytics in a blockchain-based virtual world. Our research complements recent analyses clarifying how spatio-temporal fusion algorithms, visual analytics, and cognitive automation technologies optimize purchase intentions and metaverse brand experiences in immersive hyper-connected virtual spaces. We elucidate, by cumulative evidence, previous research demonstrating how voice and gesture recognition tools, analytical artificial intelligence, and sentiment analytics enable metaverse assets and services, optimizing purchase journeys in blockchain-based virtual worlds.

8. Synopsis of the Main Research Outcomes

Machine learning algorithms and blockchain technologies enable sustainable business practices and personalized digital shopping experiences, building brand awareness in interactive virtual environments. Haptic and biometric sensor technologies, decision support tools, and retail analytics configure immersive shopping experiences in extended reality environments. Artificial intelligence-powered prediction tools and immersive visualization systems optimize frictionless virtual shopping experiences.

9. Conclusions

Relevant research has investigated whether deep learning computer vision algorithms and data mining tools shape technology-enabled live shopping in blockchain-based virtual worlds. This systematic literature review presents the published peer-reviewed sources covering how machine vision algorithms, retail business analytics, and virtual navigation tools optimize metaverse customer engagement and agile product development in virtual shopping malls. The research outcomes drawn from the above analyses indicate that blockchain token-based digital assets develop on predictive and retail analytics, data visualization tools, and artificial vision systems in virtual marketplaces.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on haptic and biometric sensor technologies, spatio-temporal fusion algorithms, and virtual navigation tools in the decentralized and interconnected metaverse may have been excluded. The scope of our study also does not move forward the inspection of perceptual and contextual awareness in the metaverse economy.

Subsequent analyses should develop on entertaining metaverse events in immersive 3D environments. Future research should thus investigate virtual reality-based immersive experiences integrating consumer behavior data. Attention should be directed to augmented reality-based livestream shopping and immersive retail experiences in the metaverse interactive environment.

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Visual Imagery and Geospatial Mapping Tools, Virtual Simulation Algorithms, and Deep Learning-based Sensing Technologies in the Metaverse Interactive Environment

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ABSTRACT. In this article, we cumulate previous research findings indicating that metaverse live shopping and 3D immersive content develop on remote sensing technologies, spatial cognition algorithms, and customer experience analytics. We contribute to the literature on virtual consumer engagement and digital shopping journeys in the metaverse economy by showing that metaverse live shopping and 3D immersive content develop on remote sensing technologies, spatial cognition algorithms, and customer experience analytics. Throughout March 2022, we performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "the metaverse interactive environment" + "visual imagery and geospatial mapping tools," "virtual simulation algorithms," and "deep learning-based sensing technologies." As we inspected research published between 2021 and 2022, only 131 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, we decided upon 23, generally empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, ROBIS, and SRDR.

Keywords: simulation modeling and cognitive artificial intelligence algorithms; sensory data mining techniques; blockchain-based virtual economy; image processing computational algorithms; customer behavior analytics; operational modeling and image recognition tools

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1. Introduction

Monitoring and sensing technologies, immersive visualization systems, and spatio-temporal fusion algorithms (Andronie et al., 2021a; Blake, 2022; Lăzăroiu et al., 2017; Poliak et al., 2020) shape blockchain-based virtual worlds. The purpose of our systematic review is to examine the recently published literature on the metaverse interactive environment and integrate the insights it configures on visual imagery and geospatial mapping tools, virtual simulation algorithms, and deep learning-based sensing technologies. By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that 3D modeling and geospatial mapping tools, deep learning algorithms, and digital twin technology shape metaverse consumer retail data across virtual delivery networks. The actuality and novelty of this study are articulated by addressing virtual consumer engagement and digital shopping journeys in the metaverse economy, that is an emerging topic involving much interest. Our research problem is whether data mining techniques, customer traffic analytics, and operational modeling and image recognition tools (Barbu et al., 2021; Krizanova et al., 2019; Peters, 2022; 2022) configure shoppable live-video events in the virtual retail market.

In this review, prior findings have been cumulated indicating that metaverse live shopping and 3D immersive content develop on remote sensing technologies, spatial cognition algorithms, and customer experience analytics. The identified gaps advance virtual asset purchasing and immersive retail experiences in the metaverse economy. Our main objective is to indicate that customer behavior analytics deploys immersive 3D technologies, biometrics data fusion, and voice recognition software (Andronie et al., 2021b; Ionescu, 2020; Lewkowich, 2022; Scott et al., 2020) across virtual marketplaces and extended reality environments. This systematic review contributes to the literature on immersive technologies, simulation modeling tools, and natural language processing algorithms (Balcerzak et al., 2022; Konhäusner et al., 2021; Nica and Stehel, 2021; Throne and Lăzăroiu, 2020) by clarifying that retail livestreaming in immersive digital worlds develops on deep learning-based ambient sound processing, behavioral algorithms, and customer data analytics.

2. Theoretical Overview of the Main Concepts

Big geospatial data analytics, virtual twin modeling tools, and interconnected sensor networks enhance shopping habits and behaviors across customer journey in immersive decentralized 3D digital worlds. Cognitive automation and geospatial mapping technologies, virtual navigation and data mining tools, and cyber-physical cognitive systems optimize immersive 3D worlds.

Virtual content optimization and digital twin modeling tools shape customer engagement behaviors in virtual retail environments. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), visual imagery and geospatial mapping tools, simulation modeling and cognitive artificial intelligence algorithms, and sensory data mining techniques in the blockchain-based virtual economy (section 4), image processing computational algorithms, deep learning-based sensing technologies, and customer behavior analytics in the metaverse interactive environment (section 5), virtual simulation algorithms, remote sensing technologies, and operational modeling and image recognition tools in the metaverse economy (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, we performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "the metaverse interactive environment" + "visual imagery and geospatial mapping tools," "virtual simulation algorithms," and "deep learning-based sensing technologies." As we inspected research published between 2021 and 2022, only 131 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, we decided upon 23, generally empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the metaverse interactive environment + visual imagery and geospatial mapping tools	46	8
the metaverse interactive environment + virtual simulation algorithms	44	8
the metaverse interactive environment + deep learning-based sensing technologies	41	7
Type of paper		
Original research	106	16
Review	15	7
Conference proceedings	7	0
Book	1	0
Editorial	2	0

Source: Processed by the authors. Some topics overlap.

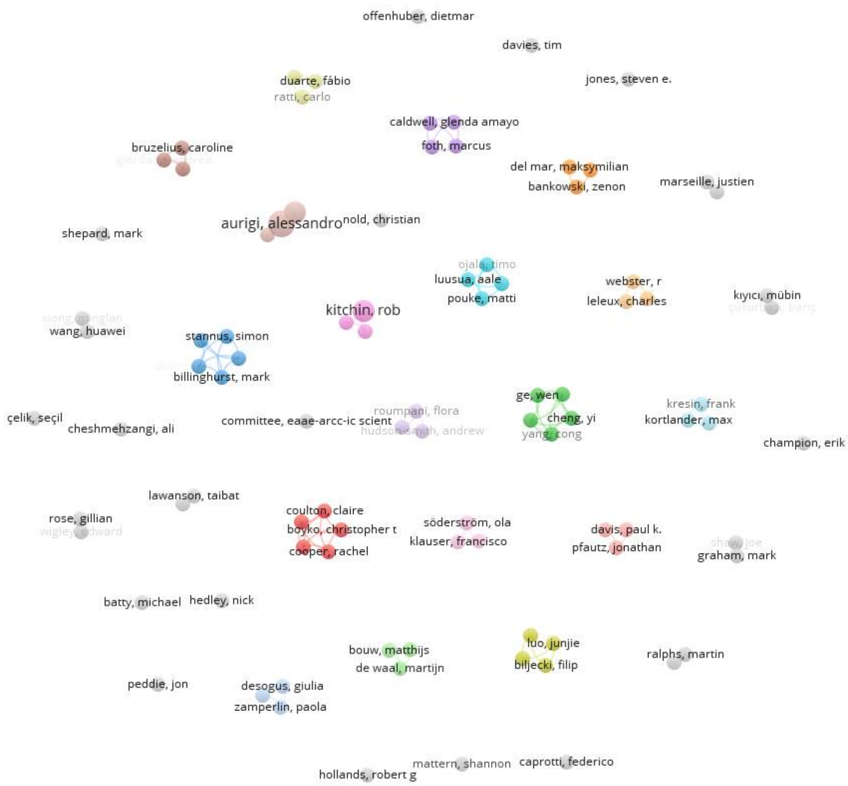

Figure 1 Co-authorship

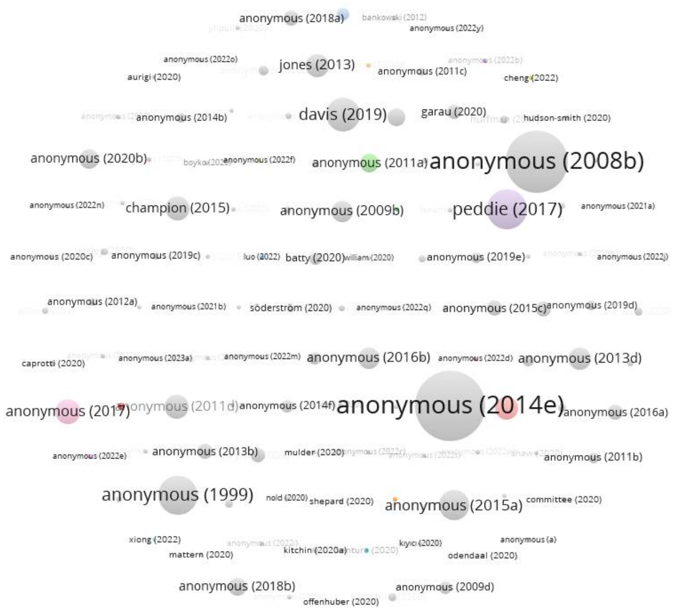

Figure 2 Citation

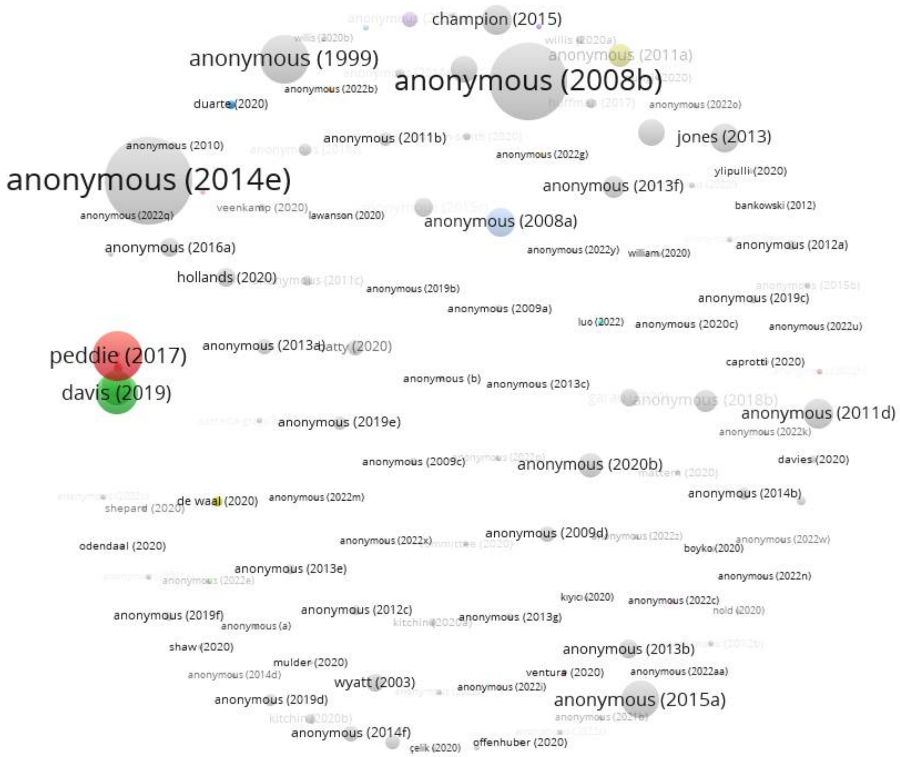

Figure 3 Bibliographic coupling

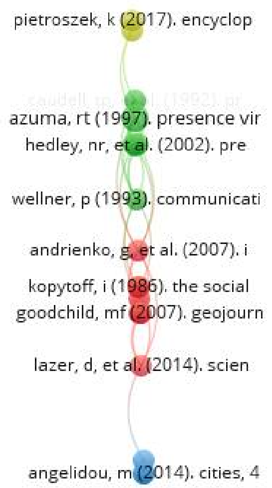

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Visual imagery tools, brand perception metrics, and digital contact tracing technologies configure 3D metaverse experiences as regards shopping and spending habits, driving consumer behavior. Retail livestreaming in immersive digital worlds develops on deep learning-based ambient sound processing, behavioral algorithms, and customer data analytics.	Gills and Hosseini, 2022; Kovacova et al., 2022a; Lukava et al., 2022
Deep learning artificial intelligence tools, real-time predictive analytics, and immersive visualization systems optimize virtual stores in a fully connected metaverse.	Dozio et al., 2022; Hudson, 2022; Park et al., 2022
Data acquisition tools, cognitive computing systems, and customer predictive analytics articulate immersive decentralized networking across the interconnected metaverse.	Guo and Gao, 2022; Kovacova et al., 2022b; Park and Kim, 2022
Granular journey and transaction geolocation data, image processing computational algorithms, and connected e-commerce apps configure immersive digital experiences and the economic infrastructure of the metaverse.	Dawson, 2022; Gibbert et al., 2022; Zhang et al., 2022
Consumer journey analytics articulates virtual retail experiences and 3D immersive content in the metaverse interactive environment by use of dynamic routing and eye-tracking technologies.	Hollensen et al., 2022; Popescu et al., 2022; Zyda, 2022
Text mining techniques, data-driven artificial intelligence, and spatial computing technology assist metaverse consumer apps in virtual mall environments.	Dozio et al., 2022; Frajtova Michalikova et al., 2022; Kozinets, 2022
Immersive technologies, simulation modeling tools, and natural language processing algorithms further user experiences and behaviors in the metaverse commerce. Virtual content optimization and digital twin modeling tools shape customer engagement behaviors in virtual retail environments.	Beniiche et al., 2022; Gibbert et al., 2022; Yeh et al., 2022
Business intelligence and simulation modeling tools, ambient sound recognition software, and sensor data fusion shape virtual consumer engagement and digital shopping journeys in the metaverse economy.	Gills and Hosseini, 2022; Laviola et al., 2022; Zhao et al., 2022
Cognitive enhancement technologies, computer vision and predictive modeling tools, and sentiment analytics assist virtual asset purchasing and immersive retail experiences in the metaverse economy.	Lv et al., 2022; Park et al., 2022; Siyaev and Jo, 2021

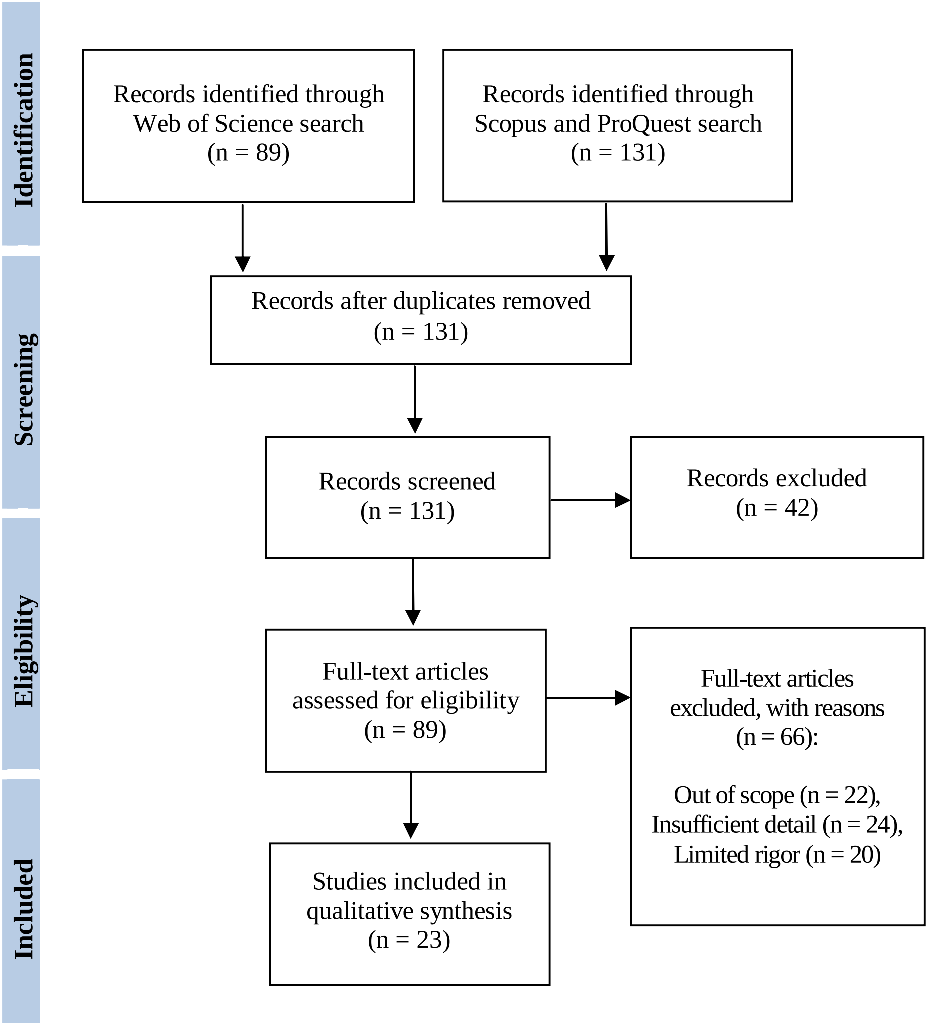

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

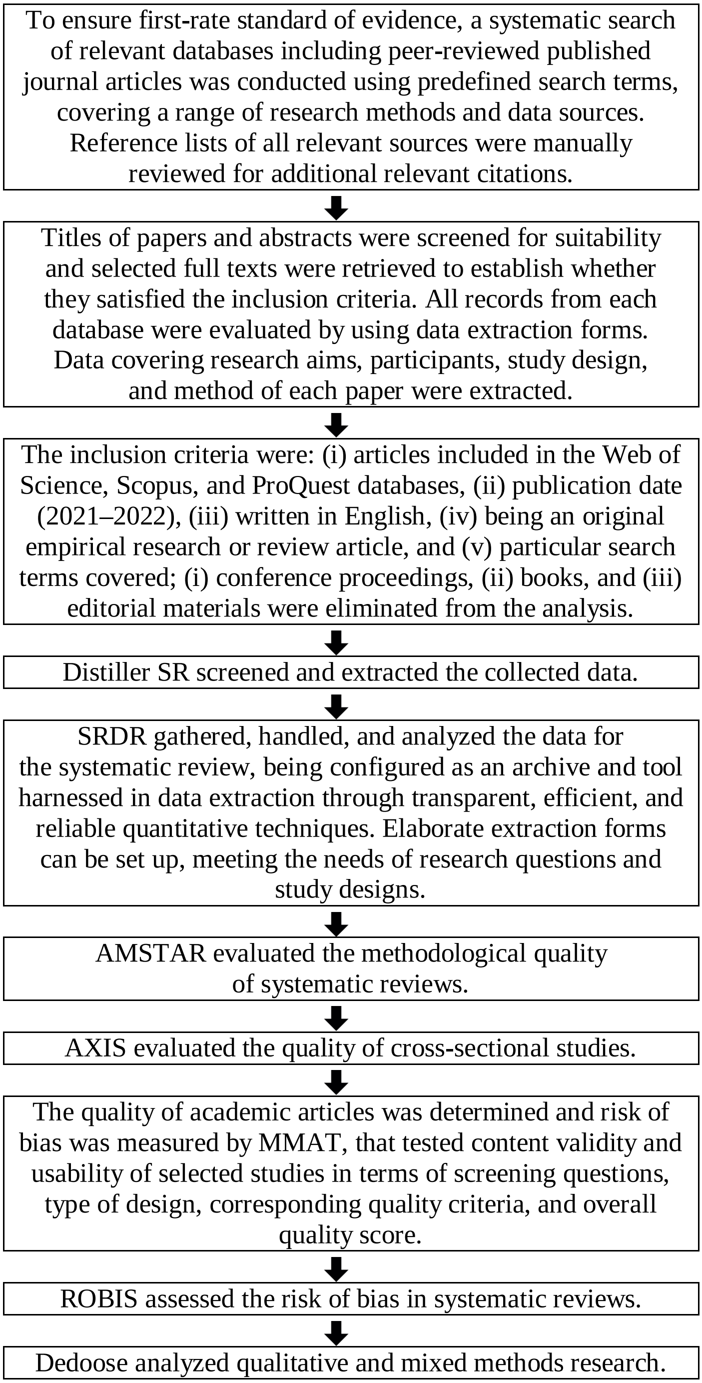

Figure 6 Screening and quality assessment tools

4. Visual Imagery and Geospatial Mapping Tools, Simulation Modeling and Cognitive Artificial Intelligence Algorithms, and Sensory Data Mining Techniques in the Blockchain-based Virtual Economy

Visual imagery tools, brand perception metrics, and digital contact tracing technologies configure 3D metaverse experiences (Gills and Hosseini, 2022; Kovacova et al., 2022a; Lukava et al., 2022) as regards shopping and spending habits, driving consumer behavior. 3D virtual space networking drives customer engagement in the blockchain-based virtual economy by integrating simulation modeling and cognitive artificial intelligence algorithms. Retail livestreaming in immersive digital worlds develops on deep learning-based ambient sound processing, behavioral algorithms, and customer data analytics.

Deep learning artificial intelligence tools, real-time predictive analytics, and immersive visualization systems (Dozio et al., 2022; Hudson, 2022; Park et al., 2022) optimize virtual stores in a fully connected metaverse. Big geospatial data analytics, virtual twin modeling tools, and interconnected sensor networks enhance shopping habits and behaviors across customer journey in immersive decentralized 3D digital worlds. Lifetime customer value can be attained across virtual marketplaces by integrating sensory data mining techniques, metaverse capabilities, and computer vision algorithms.

Data acquisition tools, cognitive computing systems, and customer predictive analytics articulate immersive decentralized networking (Guo and Gao, 2022; Kovacova et al., 2022b; Park and Kim, 2022) across the interconnected metaverse. 3D modeling and geospatial mapping tools, deep learning algorithms, and digital twin technology shape metaverse consumer retail data across virtual delivery networks. Computer-generated images, data-driven business decisions, and mobile geofencing technology configure live shopping events and virtual asset sales in the decentralized metaverse. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Visual imagery tools, brand perception metrics, and digital contact tracing technologies configure 3D metaverse experiences as regards shopping and spending habits, driving consumer behavior.	Gills and Hosseini, 2022; Kovacova et al., 2022a; Lukava et al., 2022
Deep learning artificial intelligence tools, real-time predictive analytics, and immersive visualization systems optimize virtual stores in a fully connected metaverse.	Dozio et al., 2022; Hudson, 2022; Park et al., 2022
Data acquisition tools, cognitive computing systems, and customer predictive analytics articulate immersive decentralized networking across the interconnected metaverse.	Guo and Gao, 2022; Kovacova et al., 2022b; Park and Kim, 2022

5. Image Processing Computational Algorithms, Deep Learning-based Sensing Technologies, and Customer Behavior Analytics in the Metaverse Interactive Environment

Granular journey and transaction geolocation data, image processing computational algorithms, and connected e-commerce apps (Dawson, 2022; Gibbert et al., 2022; Zhang et al., 2022) configure immersive digital experiences and the economic infrastructure of the metaverse. Monitoring and sensing technologies, immersive visualization systems, and spatio-temporal fusion algorithms shape blockchain-based virtual worlds. Immersive technologies in the virtual retail market develop on real-time data tracking tools, conversational artificial intelligence, and behavioral and demographic analytics.

Consumer journey analytics articulates virtual retail experiences and 3D immersive content in the metaverse interactive environment (Hollensen et al., 2022; Popescu et al., 2022; Zyda, 2022) by use of dynamic routing and eye-tracking technologies. Simulation optimization algorithms, deep learning-based sensing technologies, and customer biometric data improve social commerce capabilities in interactive digital worlds and immersive hyper-connected virtual spaces. Cognitive automation and geospatial mapping technologies, virtual navigation and data mining tools, and cyber-physical cognitive systems optimize immersive 3D worlds.

Text mining techniques, data-driven artificial intelligence, and spatial computing technology (Dozio et al., 2022; Frajtova Michalikova et al., 2022; Kozinets, 2022) assist metaverse consumer apps in virtual mall environments. Customer behavior analytics deploys immersive 3D technologies, biometrics data fusion, and voice recognition software across virtual marketplaces and extended reality environments. Customer engagement tools, biometric authentication features, and cognitive computing systems enable immersive virtual reality experiences. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Granular journey and transaction geolocation data, image processing computational algorithms, and connected e-commerce apps configure immersive digital experiences and the economic infrastructure of the metaverse.	Dawson, 2022; Gibbert et al., 2022; Zhang et al., 2022
Consumer journey analytics articulates virtual retail experiences and 3D immersive content in the metaverse interactive environment by use of dynamic routing and eye-tracking technologies.	Hollensen et al., 2022; Popescu et al., 2022; Zyda, 2022
Text mining techniques, data-driven artificial intelligence, and spatial computing technology assist metaverse consumer apps in virtual mall environments.	Dozio et al., 2022; Frajtova Michalikova et al., 2022; Kozinets, 2022

6. Virtual Simulation Algorithms, Remote Sensing Technologies, and Operational Modeling and Image Recognition Tools in the Metaverse Economy

Immersive technologies, simulation modeling tools, and natural language processing algorithms (Beniiche et al., 2022; Gibbert et al., 2022; Yeh et al., 2022) further user experiences and behaviors in the metaverse commerce. Retail business analytics leverages augmented reality shopping tools in immersive virtual worlds, leading to personalized digital shopping experiences. Virtual content optimization and digital twin modeling tools shape customer engagement behaviors in virtual retail environments.

Business intelligence and simulation modeling tools, ambient sound recognition software, and sensor data fusion (Gills and Hosseini, 2022; Laviola et al., 2022; Zhao et al., 2022) shape virtual consumer engagement and digital shopping journeys in the metaverse economy. Data mining techniques, customer traffic analytics, and operational modeling and image recognition tools configure shoppable live-video events in the virtual retail market. Virtual simulation algorithms, retail data optimization tools, and decision-making process automation optimize customer engagement behaviors in extended reality environments.

Cognitive enhancement technologies, computer vision and predictive modeling tools, and sentiment analytics (Lv et al., 2022; Park et al., 2022; Siyaev and Jo, 2021) assist virtual asset purchasing and immersive retail experiences in the metaverse economy. Livestream video shopping experiences require technology-enabled logistics optimization and digital twin simulation tools, shaping consumer purchase behaviors on blockchain-based metaverse platforms. Metaverse live shopping and 3D immersive content develop on remote sensing technologies, spatial cognition algorithms, and customer experience analytics. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Immersive technologies, simulation modeling tools, and natural language processing algorithms further user experiences and behaviors in the metaverse commerce.	Beniiche et al., 2022; Gibbert et al., 2022; Yeh et al., 2022
Business intelligence and simulation modeling tools, ambient sound recognition software, and sensor data fusion shape virtual consumer engagement and digital shopping journeys in the metaverse economy.	Gills and Hosseini, 2022; Laviola et al., 2022; Zhao et al., 2022
Cognitive enhancement technologies, computer vision and predictive modeling tools, and sentiment analytics assist virtual asset purchasing and immersive retail experiences in the metaverse economy.	Lv et al., 2022; Park et al., 2022; Siyaev and Jo, 2021

7. Discussion

We integrate our systematic review throughout research indicating how 3D virtual space networking drives customer engagement in the blockchain-based virtual economy by integrating simulation modeling and cognitive artificial intelligence algorithms. Our research complements recent analyses clarifying how immersive technologies in the virtual retail market develop on real-time data tracking tools, conversational artificial intelligence, and behavioral and demographic analytics. We elucidate, by cumulative evidence, previous research demonstrating how customer engagement tools, biometric authentication features, and cognitive computing systems enable immersive virtual reality experiences.

8. Synopsis of the Main Research Outcomes

Virtual simulation algorithms, retail data optimization tools, and decision-making process automation optimize customer engagement behaviors in extended reality environments. Computer-generated images, data-driven business decisions, and mobile geofencing technology configure live shopping events and virtual asset sales in the decentralized metaverse. Livestream video shopping experiences require technology-enabled logistics optimization and digital twin simulation tools, shaping consumer purchase behaviors on blockchain-based metaverse platforms.

9. Conclusions

Relevant research has investigated whether retail business analytics leverages augmented reality shopping tools in immersive virtual worlds, leading to personalized digital shopping experiences. This systematic literature review presents the published peer-reviewed sources covering how simulation optimization algorithms, deep learning-based sensing technologies, and customer biometric data improve social commerce capabilities in interactive digital worlds and immersive hyper-connected virtual spaces. The research outcomes drawn from the above analyses indicate that lifetime customer value can be attained across virtual marketplaces by integrating sensory data mining techniques, metaverse capabilities, and computer vision algorithms.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on visual imagery and geospatial mapping tools, virtual simulation algorithms, and deep learning-based sensing technologies in the metaverse interactive environment may have been excluded. The scope of our study also does not move forward the inspection of consumer journey analytics articulating virtual retail experiences and 3D immersive content in the metaverse interactive environment.

Subsequent analyses should develop on granular journey and transaction geolocation data, image processing computational algorithms, and connected e-commerce apps. Future research should thus investigate visual imagery tools, brand perception metrics, and digital contact tracing technologies configuring 3D metaverse experiences. Attention should be directed to data acquisition tools, cognitive computing systems, and customer predictive analytics articulating immersive decentralized networking.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the authors.

Data availability statement

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Author contributions

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record

The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement

The authors affirm that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Geospatial Mapping Technologies, Predictive Modeling Algorithms, and Immersive Visualization Systems in the Virtual Economy of the Metaverse

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ABSTRACT. This paper provides a systematic literature review of studies investigating data modeling and virtual navigation tools, dynamic routing technology, and conversational artificial intelligence in the metaverse economy. The analysis highlights that spatial awareness and tracking tools enable immersive shopping experiences, shaping customer preferences across the augmented reality-based commerce landscape. Throughout April 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "the virtual economy of the metaverse" + "geospatial mapping technologies," "predictive modeling algorithms," and "immersive visualization systems." As I inspected research published in 2022, only 124 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 18, generally empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, MMAT, and ROBIS.

Keywords: real-time data tracking tools; retail metaverse; customer identification technology; spatial cognition algorithms; data modeling and virtual navigation tools; dynamic routing technology

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1. Introduction

Metaverse purchase experiences develop on contextual consumer data, brand perception metrics, and virtual navigation tools (Andronie et al., 2021; Lăzăroiu et al., 2021; Nica, 2021; Vătămănescu et al., 2020) across interconnected digital spaces. The purpose of my systematic review is to examine the recently published literature on the virtual economy of the metaverse and integrate the insights it configures on geospatial mapping technologies, predictive modeling algorithms, and immersive visualization systems. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that metaverse brand experiences integrate virtual twin modeling and real-time data tracking tools, geospatial mapping technologies, and cognitive computing systems (Dabija et al., 2022; Lăzăroiu et al., 2022; Pelau et al., 2021; Wallace and Lăzăroiu, 2021), optimizing consumer sentiment and behavior. The actuality and novelty of this study are articulated by addressing shopper engagement technologies in the retail metaverse, that is an emerging topic involving much interest. My research problem is whether spatial awareness and tracking tools enable immersive shopping experiences, shaping customer preferences (Gray-Hawkins and Lăzăroiu, 2020; Mircică, 2020; Poliak et al., 2020) across the augmented reality-based commerce landscape.

In this review, prior findings have been cumulated indicating that data mining tools, image recognition technologies, and spatial analytics enhance consumer digital engagement, buying habits, and purchase intentions across immersive hyper-connected virtual spaces. The identified gaps advance body-tracking data metrics, virtual navigation tools, and ambient sound recognition software (Jenkins, 2022; Nica, 2017; Rogers and Zvarikova, 2021) in the blockchain-based metaverse. My main objective is to indicate that virtual retail experiences in extended reality environments develop on deep learning-based sensing technologies, predictive modeling algorithms, and digital twin simulation tools. This systematic review contributes to the literature on data modeling and virtual navigation tools, dynamic routing technology, and conversational artificial intelligence (Kliestik et al., 2020; Nica et al., 2020; Valaskova et al., 2021) in the metaverse economy by clarifying that image recognition technologies, business intelligence tools, and visual analytics assist immersive visualization systems in blockchain-based virtual worlds.

2. Theoretical Overview of the Main Concepts

Augmented reality shopping tools, picture-making neural networks, and data sharing technologies enhance virtual consumer engagement and immersive retail experiences. Remote sensing technologies, digital twin modeling tools, and Internet of Things-based decision support systems optimize consumer sentiment and behavior in virtual environments. Ambient scene detection and simulation modeling tools configure metaverse consumer retail data and data-driven customer engagements in immersive virtual environments and across digital marketplaces. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), predictive modeling and virtual simulation algorithms, real-time data tracking tools, and geospatial mapping technologies in the retail metaverse (section 4), customer identification technology, immersive visualization systems, and spatial cognition algorithms in the virtual economy of the metaverse (section 5), spatio-temporal fusion algorithms, data modeling and virtual navigation tools, and dynamic routing technology in the metaverse economy (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout April 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "the virtual economy of the metaverse" + "geospatial mapping technologies," "predictive modeling algorithms," and "immersive visualization systems." As I inspected research published in 2022, only 124 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 18, generally empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Distiller SR, MMAT, and ROBIS (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the virtual economy of the metaverse + geospatial mapping technologies	43	6
the virtual economy of the metaverse + predictive modeling algorithms	40	6
the virtual economy of the metaverse + immersive visualization systems	41	6
Type of paper		
Original research	98	13
Review	14	5
Conference proceedings	8	0
Book	1	0
Editorial	3	0

Source: Processed by the author. Some topics overlap.

Figure 1 Co-authorship

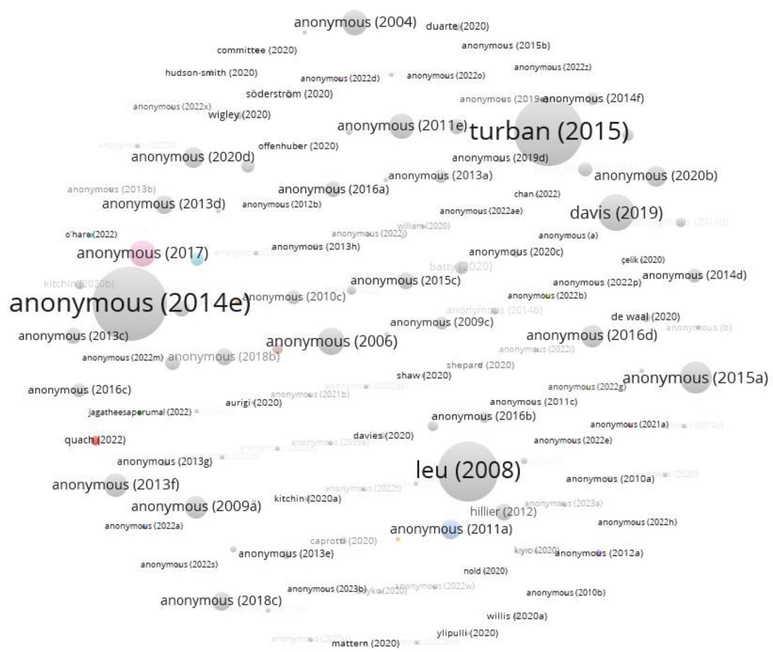

Figure 2 Citation

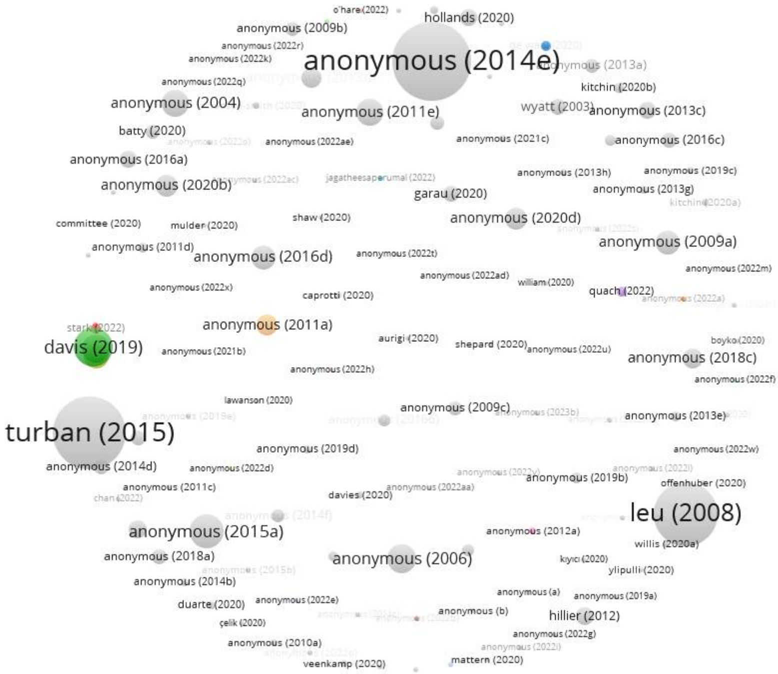

Figure 3 Bibliographic coupling

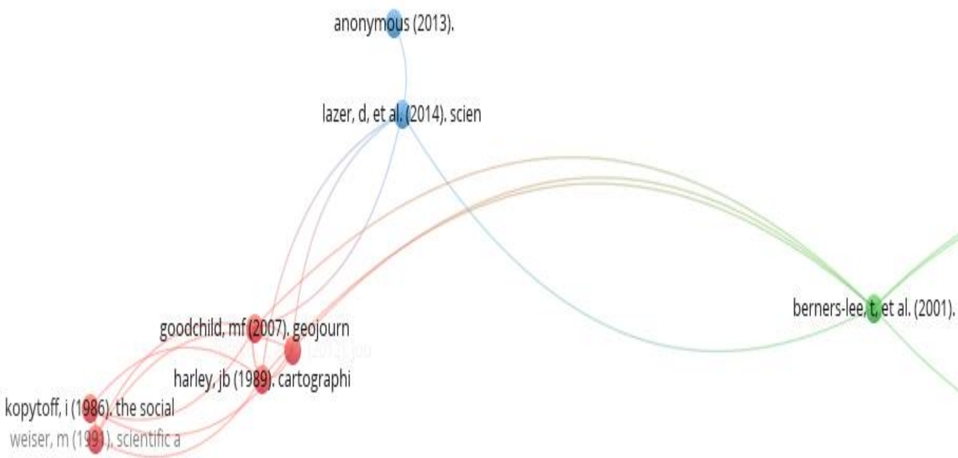

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Customer behavior analytics deploys body-tracking data metrics, virtual navigation tools, and ambient sound recognition software in the blockchain-based metaverse.	Adams, 2022; Gursoy et al., 2022; Zhang et al., 2022
Retail analytics deploys computer vision algorithms, data mining techniques, and natural language processing tools in the virtual commerce, shaping consumer sentiment and behavior during metaverse live-video shopping events.	Almarzouqi et al. 2022; Gössling and Schweiggart, 2022; Hawkins, 2022
Live shopping events as regards digital assets in the retail metaverse integrate real-time predictive analytics, automated speech recognition tools, and virtual simulation algorithms. Remote sensing technologies, digital twin modeling tools, and Internet of Things-based decision support systems optimize consumer sentiment and behavior in virtual environments.	Hamilton, 2022; Kraus et al., 2022; Reis and Ashmore, 2022
Customer identification technology, operational modeling and image recognition tools, and sentiment analytics articulate metaverse operations management and personalized purchase experiences in blockchain-based virtual worlds.	Han et al., 2022; Kshetri, 2022; Popescu Ljungholm, 2022
Consumer analytics leverages geolocation data, immersive visualization systems, and machine learning-based image recognition tools, driving spending habits in the virtual economy of the metaverse.	Gursoy et al., 2022; Jang et al., 2022; Zyda, 2022
Predictive customer analytics leverages real-time data visualization tools across entertaining metaverse events in immersive hyper-connected virtual spaces. Image recognition technologies, business intelligence tools, and visual analytics assist immersive visualization systems.	Lin et al., 2022; Kraus et al., 2022; Reis and Ashmore, 2022
Shopper engagement technologies in the retail metaverse integrate movement and behavior tracking tools, spatio-temporal fusion algorithms, and remote sensing systems.	Almarzouqi et al. 2022; Jang et al., 2022; Turner, 2022
Customer behavior analytics leverages data modeling and virtual navigation tools, dynamic routing technology, and conversational artificial intelligence in the metaverse economy.	Gössling and Schweiggart, 2022; Kshetri, 2022; Solakis et al., 2022
Blockchain-based digital assets develop on spatial and behavioral analytics, artificial intelligence-powered prediction tools, and metaverse technologies.	Akyildiz et al., 2022; Han et al., 2022; Zhang et al., 2022

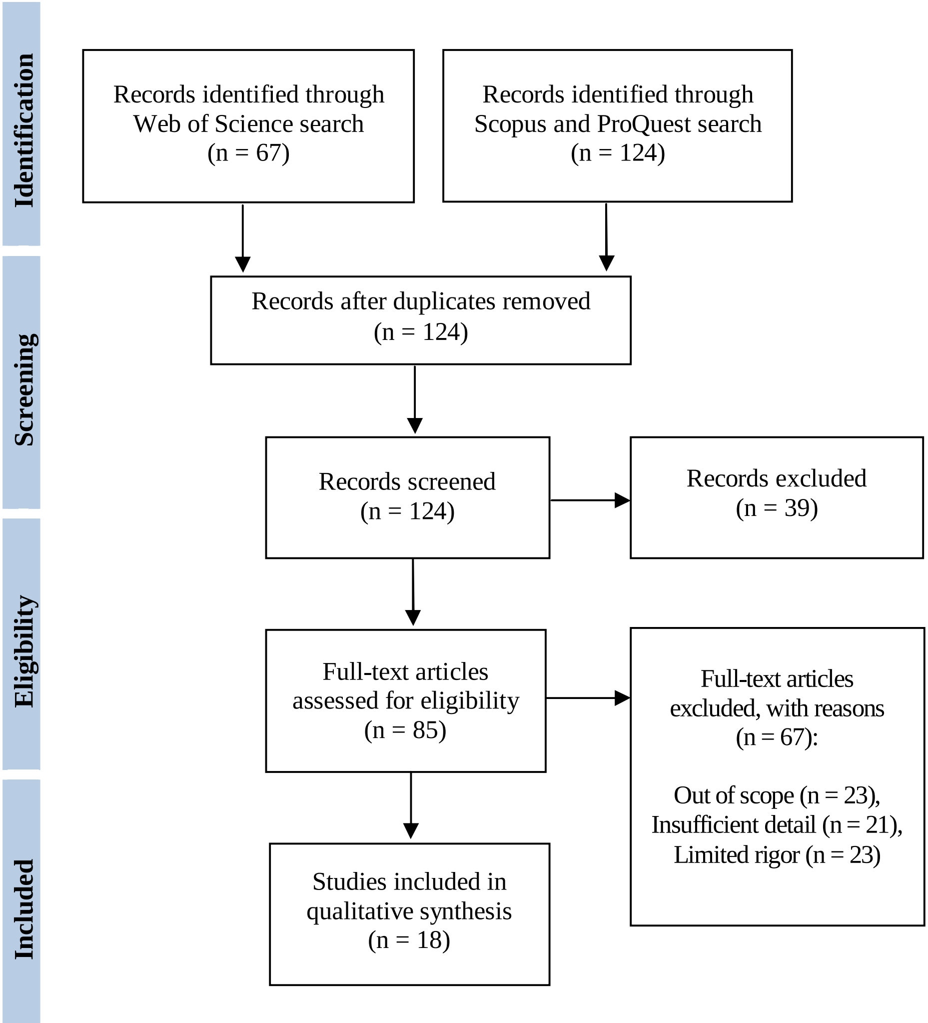

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

Figure 6 Screening and quality assessment tools

4. Predictive Modeling and Virtual Simulation Algorithms, Real-Time Data Tracking Tools, and Geospatial Mapping Technologies in the Retail Metaverse

Customer behavior analytics deploys body-tracking data metrics, virtual navigation tools, and ambient sound recognition software (Adams, 2022; Gursoy et al., 2022; Zhang et al., 2022) in the blockchain-based metaverse. Cyber-physical cognitive systems and cognitive automation technologies shape consumer habits and expectations throughout livestreaming e-commerce digital events and virtual retail stores in immersive digital worlds. Virtual retail experiences in extended reality environments develop on deep learning-based sensing technologies, predictive modeling algorithms, and digital twin simulation tools.

Retail analytics deploys computer vision algorithms, data mining techniques, and natural language processing tools in the virtual commerce (Almarzouqi et al. 2022; Gössling and Schweiggart, 2022; Hawkins, 2022), shaping consumer sentiment and behavior during metaverse live-video shopping events. Metaverse brand experiences integrate virtual twin modeling and real-time data tracking tools, geospatial mapping technologies, and cognitive computing systems, optimizing consumer sentiment and behavior.

Live shopping events as regards digital assets in the retail metaverse (Hamilton, 2022; Kraus et al., 2022; Reis and Ashmore, 2022) integrate real-time predictive analytics, automated speech recognition tools, and virtual simulation algorithms. Data mining tools, image recognition technologies, and spatial analytics enhance consumer digital engagement, buying habits, and purchase intentions across immersive hyper-connected virtual spaces. Remote sensing technologies, digital twin modeling tools, and Internet of Things-based decision support systems optimize consumer sentiment and behavior in virtual environments. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer behavior analytics deploys body-tracking data metrics, virtual navigation tools, and ambient sound recognition software in the blockchain-based metaverse.	Adams, 2022; Gursoy et al., 2022; Zhang et al., 2022
Retail analytics deploys computer vision algorithms, data mining techniques, and natural language processing tools in the virtual commerce, shaping consumer sentiment and behavior during metaverse live-video shopping events.	Almarzouqi et al. 2022; Gössling and Schweiggart, 2022; Hawkins, 2022
Live shopping events as regards digital assets in the retail metaverse integrate real-time predictive analytics, automated speech recognition tools, and virtual simulation algorithms.	Hamilton, 2022; Kraus et al., 2022; Reis and Ashmore, 2022

5. Customer Identification Technology, Immersive Visualization Systems, and Spatial Cognition Algorithms in the Virtual Economy of the Metaverse

Customer identification technology, operational modeling and image recognition tools, and sentiment analytics (Han et al., 2022; Kshetri, 2022; Popescu Ljungholm, 2022) articulate metaverse operations management and personalized purchase experiences in blockchain-based virtual worlds. Customer engagement tools enhance immersive virtual and augmented shopping experiences, attracting and retaining customers across the virtual economy. Internet of Things sensing infrastructures, digital twin simulation tools, and ambient sound recognition software articulate immersive 3D environments.

Consumer analytics leverages geolocation data, immersive visualization systems, and machine learning-based image recognition tools (Gursoy et al., 2022; Jang et al., 2022; Zyda, 2022), driving spending habits in the virtual economy of the metaverse. Fuzzy search techniques, sentiment analytics, and data visualization tools configure interactive brand experiences in immersive 3D worlds. Behavior analysis and prediction develop on biometric authentication features, computer vision-based systems, customer engagement tools, and business intelligence operations in extended reality environments.

Predictive customer analytics leverages real-time data visualization tools across entertaining metaverse events (Lin et al., 2022; Kraus et al., 2022; Reis and Ashmore, 2022) in immersive hyper-connected virtual spaces. Sensor data fusion, virtual modeling technology, and spatial cognition algorithms shape consumer behavior and expectations in virtual marketplaces. Image recognition technologies, business intelligence tools, and visual analytics assist immersive visualization systems in blockchain-based virtual worlds. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer identification technology, operational modeling and image recognition tools, and sentiment analytics articulate metaverse operations management and personalized purchase experiences in blockchain-based virtual worlds.	Han et al., 2022; Kshetri, 2022; Popescu Ljungholm, 2022
Consumer analytics leverages geolocation data, immersive visualization systems, and machine learning-based image recognition tools, driving spending habits in the virtual economy of the metaverse.	Gursoy et al., 2022; Jang et al., 2022; Zyda, 2022
Predictive customer analytics leverages real-time data visualization tools across entertaining metaverse events in immersive hyper-connected virtual spaces.	Lin et al., 2022; Kraus et al., 2022; Reis and Ashmore, 2022

6. Spatio-Temporal Fusion Algorithms, Data Modeling and Virtual Navigation Tools, and Dynamic Routing Technology in the Metaverse Economy

Shopper engagement technologies in the retail metaverse (Almarzouqi et al. 2022; Jang et al., 2022; Turner, 2022) integrate movement and behavior tracking tools, spatio-temporal fusion algorithms, and remote sensing systems. Metaverse purchase experiences develop on contextual consumer data, brand perception metrics, and virtual navigation tools across interconnected digital spaces. Movement and behavior tracking tools articulate immersive virtual retail experiences by use of consumer location data across interconnected digital realms.

Customer behavior analytics leverages data modeling and virtual navigation tools, dynamic routing technology, and conversational artificial intelligence in the metaverse economy (Gössling and Schweiggart, 2022; Kshetri, 2022; Solakis et al., 2022), shaping buying habits and behaviors. Augmented reality shopping tools, picture-making neural networks, and data sharing technologies enhance virtual consumer engagement and immersive retail experiences. Customer experience analytics harnesses business intelligence operations and data visualization tools in immersive virtual shopping, optimizing live shopping events.

Blockchain-based digital assets develop on spatial and behavioral analytics, artificial intelligence-powered prediction tools, and metaverse technologies (Akyildiz et al., 2022; Han et al., 2022; Zhang et al., 2022), raising brand awareness and optimizing product customization services across virtual delivery networks. Ambient scene detection and simulation modeling tools configure metaverse consumer retail data and data-driven customer engagements in immersive virtual environments and across digital marketplaces. Spatial awareness and tracking tools enable immersive shopping experiences, shaping customer preferences across the augmented reality-based commerce landscape. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Shopper engagement technologies in the retail metaverse integrate movement and behavior tracking tools, spatio-temporal fusion algorithms, and remote sensing systems.	Almarzouqi et al. 2022; Jang et al., 2022; Turner, 2022
Customer behavior analytics leverages data modeling and virtual navigation tools, dynamic routing technology, and conversational artificial intelligence in the metaverse economy.	Gössling and Schweiggart, 2022; Kshetri, 2022; Solakis et al., 2022
Blockchain-based digital assets develop on spatial and behavioral analytics, artificial intelligence-powered prediction tools, and metaverse technologies.	Akyildiz et al., 2022; Han et al., 2022; Zhang et al., 2022

7. Discussion

I integrate my systematic review throughout research indicating how cyber-physical cognitive systems and cognitive automation technologies shape consumer habits and expectations throughout livestreaming e-commerce digital events and virtual retail stores in immersive digital worlds. My research complements recent analyses clarifying how sensor data fusion, virtual modeling technology, and spatial cognition algorithms shape consumer behavior and expectations in virtual marketplaces. I elucidate, by cumulative evidence, previous research demonstrating how customer engagement tools enhance immersive virtual and augmented shopping experiences, attracting and retaining customers across the virtual economy.

8. Synopsis of the Main Research Outcomes

Fuzzy search techniques, sentiment analytics, and data visualization tools configure interactive brand experiences in immersive 3D worlds. Customer experience analytics harnesses business intelligence operations and data visualization tools in immersive virtual shopping, optimizing live shopping events. Metaverse purchase experiences develop on contextual consumer data, brand perception metrics, and virtual navigation tools across interconnected digital spaces.

9. Conclusions

Relevant research has investigated whether movement and behavior tracking tools articulate immersive virtual retail experiences by use of consumer location data across interconnected digital realms. This systematic literature review presents the published peer-reviewed sources covering how behavior analysis and prediction develop on biometric authentication features, computer vision-based systems, customer engagement tools, and business intelligence operations in extended reality environments. The research outcomes drawn from the above analyses indicate that Internet of Things sensing infrastructures, digital twin simulation tools, and ambient sound recognition software articulate immersive 3D environments.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on geospatial mapping technologies, predictive modeling algorithms, and immersive visualization systems in the virtual economy of the metaverse may have been excluded. The scope of my study also does not move forward the inspection of spatial and behavioral analytics, artificial intelligence-powered prediction tools, and metaverse technologies.

Subsequent analyses should develop on consumer sentiment and behavior during metaverse live-video shopping events. Future research should thus investigate predictive customer analytics leveraging real-time data visualization tools across entertaining metaverse events. Attention should be directed to metaverse operations management and personalized purchase experiences in blockchain-based virtual worlds.

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Compliance with ethical standards
This article does not contain any studies with human participants or animals performed by the author.

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The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

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The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record
The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement
The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Virtual Retail Algorithms, Behavioral Predictive Analytics, and Geospatial Mapping Technologies in the Decentralized Metaverse

Susan Beckett*

ABSTRACT. This article reviews and advances existing literature concerning immersive virtual experiences and metaverse interoperability. In this research, previous findings were cumulated showing that digitally extended social interactions and consumer behavior data articulate virtual consumer engagement in immersive 3D environments, and I contribute to the literature by indicating that natural language processing algorithms, augmented reality shopping tools, and predictive and retail analytics assist 3D metaverse experiences across virtual environments. Throughout March 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the decentralized metaverse" + "virtual retail algorithms," "behavioral predictive analytics," and "geospatial mapping technologies." As research published in 2022 was inspected, only 140 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 27 mainly empirical sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, MMAT, ROBIS, and SRDR.

Keywords: image processing computational algorithms; customer behavior analytics; data mining and virtual navigation tools; spatial cognition and simulation optimization algorithms; remote sensing systems; blockchain-based metaverse

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1. Introduction

Immersive metaverse experiences and spending habits in the virtual retail market develop on business intelligence tools, text mining techniques, and behavioral algorithms. The purpose of my systematic review is to examine the recently published literature on the decentralized metaverse and integrate the insights it configures on virtual retail algorithms, behavioral predictive analytics, and geospatial mapping technologies. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that behavioral and demographic analytics optimizes lifetime customer value (Ionescu, 2020; Nica et al., 2021; Wallace and Lăzăroiu, 2021) in virtual shopping malls across the decentralized and interconnected metaverse. The actuality and novelty of this study are articulated by addressing immersive virtual experiences and metaverse interoperability, that is an emerging topic involving much interest. My research problem is whether virtual retail algorithms and customized data workflows (Andronie et al., 2021a; Johnson and Nica, 2021; Nica and Stehel, 2021) configure augmented shopping experiences in interactive digital worlds and 3D immersive environments.

In this review, prior findings have been cumulated indicating that digitally extended social interactions and consumer behavior data (Andronie et al., 2021b; Kliestik et al., 2020; Peters, 2022) articulate virtual consumer engagement in immersive 3D environments. The identified gaps advance metaverse engagement and experiences, live e-commerce shopping, and virtual content optimization. My main objective is to indicate that natural language processing algorithms, augmented reality shopping tools, and predictive and retail analytics (Balcerzak et al., 2022; Kliestik et al., 2022; Scott et al., 2020) assist 3D metaverse experiences across virtual environments. This systematic review contributes to the literature on virtual shopping sessions in the metaverse economy by clarifying that metaverse assets in virtual marketplaces develop on Internet of Things-based decision support systems (Barbu et al., 2021; Lăzăroiu et al., 2020; Vătămănescu et al., 2022), data mining tools (Burke and Zvarikova, 2021; Lyons and Lăzăroiu, 2020; Vinerean et al., 2022), and deep neural network technology.

2. Theoretical Overview of the Main Concepts

Geospatial mapping tools, sensor data fusion, and business intelligence analytics configure virtual reality-based immersive experiences in real-time immersive 3D worlds, driving customer engagement and optimizing shopping habits and behaviors. Metaverse technologies integrate big geospatial data analytics, deep learning artificial intelligence tools, and remote sensing systems in virtual commerce, forecasting user preferences. Decision-making process automation tools and big data analytics shape metaverse operations management on augmented reality commerce platforms and in interconnected virtual worlds. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), image processing computational algorithms, geospatial mapping tools, and customer behavior analytics in the decentralized metaverse (section 4), data mining and virtual navigation tools, spatial cognition and simulation optimization algorithms, and remote sensing systems in the blockchain-based metaverse (section 5), behavioral predictive analytics, virtual retail algorithms, and geospatial mapping technologies across the decentralized and interconnected metaverse (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including “the decentralized metaverse” + “virtual retail algorithms,” “behavioral predictive analytics,” and “geospatial mapping technologies.” As research published in 2022 was inspected, only 140 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 27 mainly empirical sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, MMAT, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the decentralized metaverse + virtual retail algorithms	49	10
the decentralized metaverse + behavioral predictive analytics	43	8
the decentralized metaverse + geospatial mapping technologies	48	9
Type of paper		
Original research	113	23
Review	15	4
Conference proceedings	9	0
Book	1	0
Editorial	2	0

Source: Processed by the author. Some topics overlap.

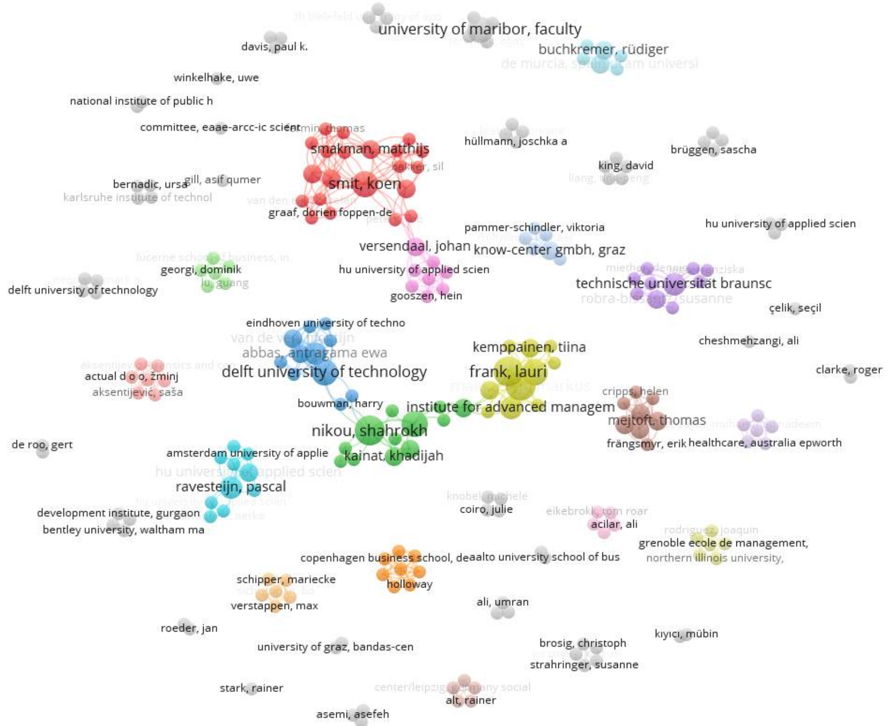

Figure 1 Co-authorship

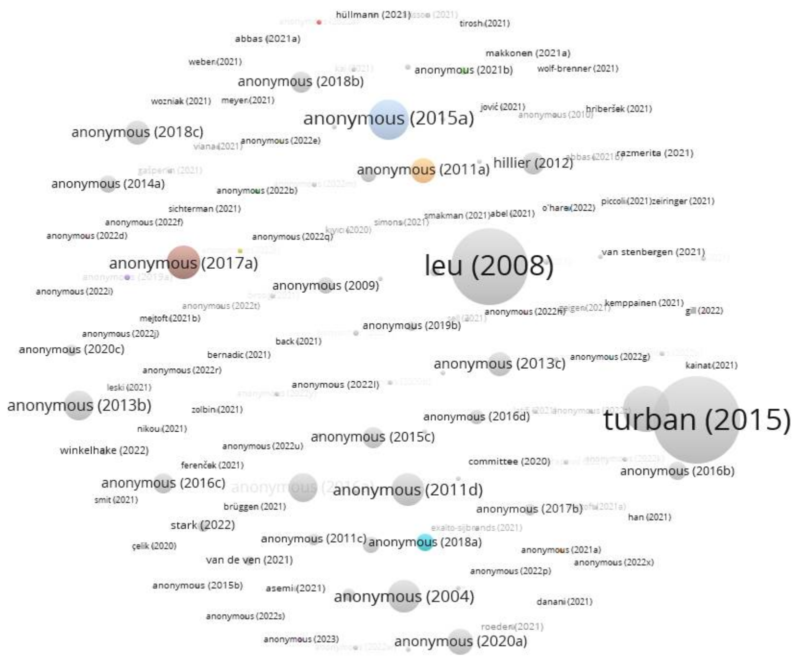

Figure 2 Citation

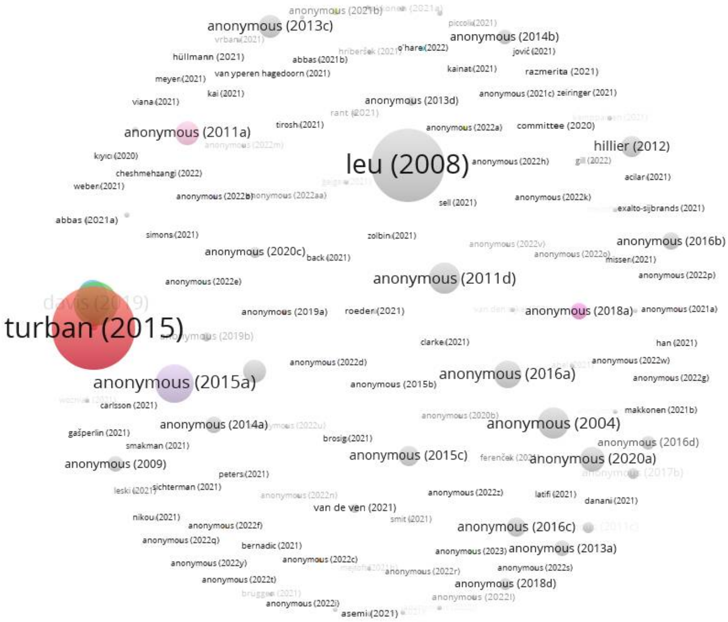

Figure 3 Bibliographic coupling

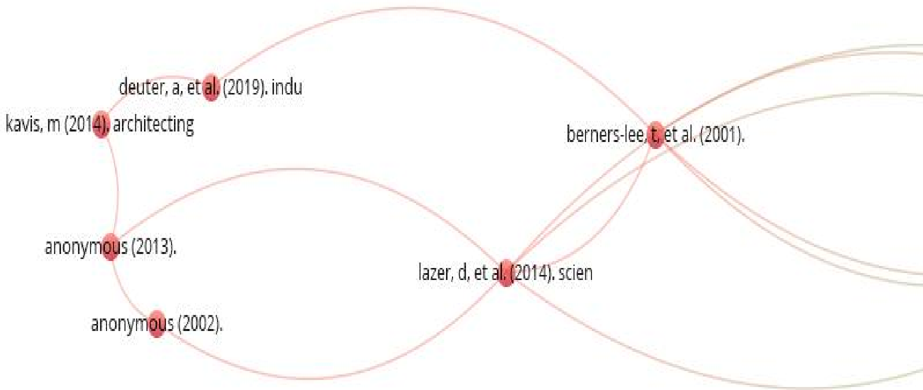

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Customer personalization tools, immersive technologies, and business intelligence operations optimize metaverse live shopping, creating engaging brand awareness.	Mircică, 2022; Park et al., 2022; Yeh et al., 2022
Cognitive computing systems, data-driven business decisions, and connected e-commerce apps articulate metaverse live shopping, agile product development, and immersive digital experiences.	Dawson, 2022; Elawady et al., 2022; Zhao et al., 2022
Immersive decentralized networking, predictive algorithms, and cyber-physical cognitive systems enhance metaverse purchase experiences across interconnected virtual worlds.	Bennett, 2022; Dozio et al., 2022; Park and Kim, 2022
Computer-generated images, mobile geofencing technology, and data visualization tools optimize metaverse assets and services in virtual mall environments. Retail analytics in immersive 3D worlds harnesses virtual navigation tools, voice recognition software, and cognitive enhancement technologies.	Gössling and Schweiggart, 2022; Upadhyay and Khandelwal, 2022; Zhang et al., 2022a
Real-time data tracking tools, business intelligence analytics, and cognitive automation technologies enable immersive virtual experiences and metaverse interoperability.	Beniiche et al., 2022; Gibbert et al., 2022; Skalidis et al., 2022
Simulation optimization algorithms, ambient sound recognition software, and immersive 3D experiences are instrumental in metaverse engagement and experiences, live e-commerce shopping, and virtual content optimization.	Chandra, 2022; Laviola et al., 2022; Zhang et al., 2022b
Metaverse engagement metrics configure immersive retail experiences, virtual asset purchasing, and personalized customer shopping behavior. Virtual retail algorithms and customized data workflows configure augmented shopping experiences in interactive digital worlds and 3D immersive environments.	Hwang and Chien, 2022; Lv et al., 2022; Xi et al., 2022
Retail business analytics optimizes virtual shopping sessions in the metaverse economy by deploying data acquisition tools, predictive modeling algorithms, and geospatial mapping technologies.	Guo and Gao, 2022; Kozinets, 2022; Wang, 2022
Virtual simulation algorithms and biometrics data fusion shape metaverse brand experiences across customer journey in digital hyper-realistic worlds, driving shopper engagement and consumer purchasing habits.	Hollensen et al., 2022; Liu et al., 2022; Reis and Ashmore, 2022

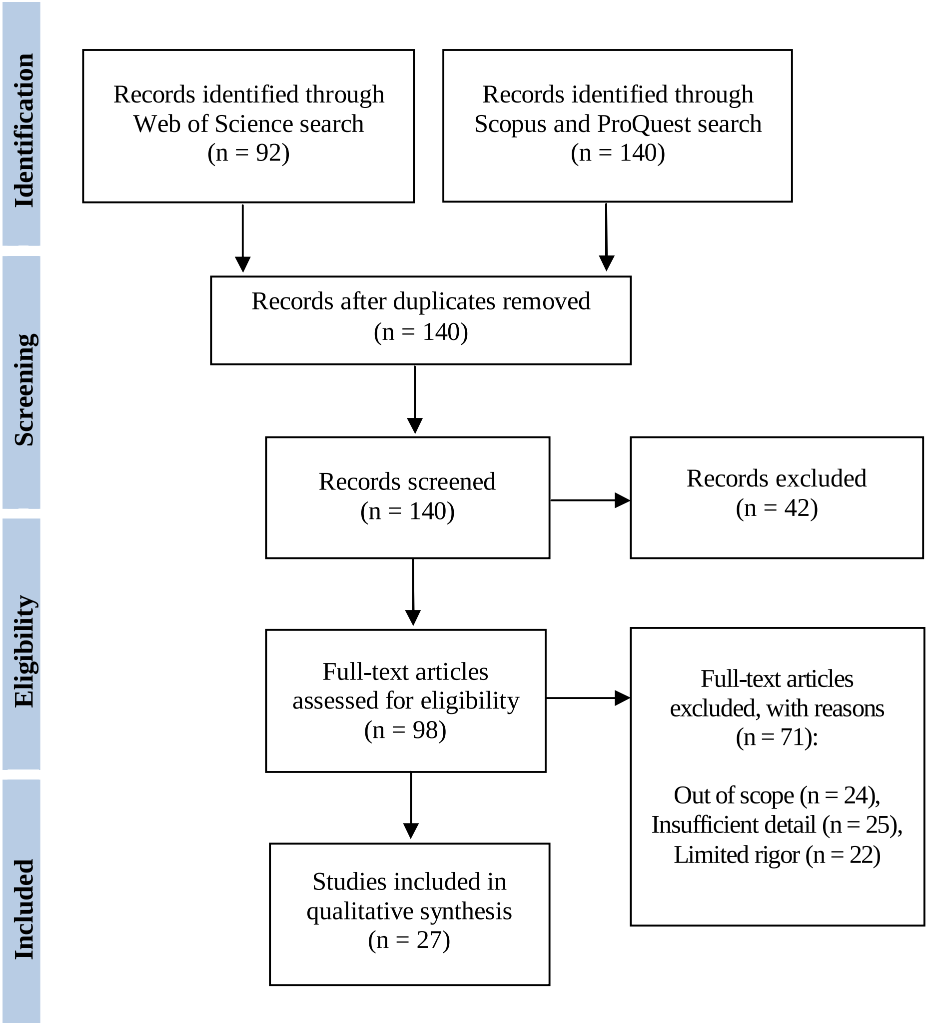

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

Distiller SR screened and extracted the collected data.

AMSTAR evaluated the methodological quality of systematic reviews.

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

Dedoose analyzed qualitative and mixed methods research.

AXIS evaluated the quality of cross-sectional studies.

ROBIS assessed the risk of bias in systematic reviews.

Figure 6 Screening and quality assessment tools

4. Image Processing Computational Algorithms, Geospatial Mapping Tools, and Customer Behavior Analytics in the Decentralized Metaverse

Customer personalization tools, immersive technologies, and business intelligence operations (Mircică, 2022; Park et al., 2022; Yeh et al., 2022) optimize metaverse live shopping, creating engaging brand awareness. Customer engagement tools, immersive technologies, and image processing computational algorithms configure behavior analysis and prediction during metaverse live-video shopping events across shared virtual environments, building brand awareness. Natural language processing algorithms, augmented reality shopping tools, and predictive and retail analytics assist 3D metaverse experiences across virtual environments.

Cognitive computing systems, data-driven business decisions, and connected e-commerce apps (Dawson, 2022; Elawady et al., 2022; Zhao et al., 2022) articulate metaverse live shopping, agile product development, and immersive digital experiences in the blockchain-based virtual economy. Geospatial mapping tools, sensor data fusion, and business intelligence analytics configure virtual reality-based immersive experiences in real-time immersive 3D worlds, driving customer engagement and optimizing shopping habits and behaviors. Customer behavior analytics leverages immersive technologies, spatio-temporal fusion algorithms, and data computing capabilities across extended reality environments.

Immersive decentralized networking, predictive algorithms, and cyber-physical cognitive systems (Bennett, 2022; Dozio et al., 2022; Park and Kim, 2022) enhance metaverse purchase experiences across interconnected virtual worlds, shaping consumer behavior and preferences. Machine learning-based product recognition and virtual twin modeling tools shape shopper traffic patterns and 3D immersive content. Realistic virtual shopping experiences develop on computer vision tools, immersive technologies, and predictive customer analytics in immersive digital worlds. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer personalization tools, immersive technologies, and business intelligence operations optimize metaverse live shopping, creating engaging brand awareness.	Mircică, 2022; Park et al., 2022; Yeh et al., 2022
Cognitive computing systems, data-driven business decisions, and connected e-commerce apps articulate metaverse live shopping, agile product development, and immersive digital experiences.	Dawson, 2022; Elawady et al., 2022; Zhao et al., 2022
Immersive decentralized networking, predictive algorithms, and cyber-physical cognitive systems enhance metaverse purchase experiences across interconnected virtual worlds.	Bennett, 2022; Dozio et al., 2022; Park and Kim, 2022

5. Data Mining and Virtual Navigation Tools, Spatial Cognition and Simulation Optimization Algorithms, and Remote Sensing Systems in the Blockchain-based Metaverse

Computer-generated images, mobile geofencing technology, and data visualization tools (Gössling and Schweiggart, 2022; Upadhyay and Khandelwal, 2022; Zhang et al., 2022a) optimize metaverse assets and services in virtual mall environments. Metaverse assets in virtual marketplaces develop on Internet of Things-based decision support systems, data mining tools, and deep neural network technology. Retail analytics in immersive 3D worlds harnesses virtual navigation tools, voice recognition software, and cognitive enhancement technologies.

Real-time data tracking tools, business intelligence analytics, and cognitive automation technologies (Beniiche et al., 2022; Gibbert et al., 2022; Skalidis et al., 2022) enable immersive virtual experiences and metaverse interoperability. Customer monitoring systems, image recognition technologies, and visual analytics are instrumental in technology-enabled live shopping in blockchain-based virtual worlds. Immersive metaverse experiences and spending habits in the virtual retail market develop on business intelligence tools, text mining techniques, and behavioral algorithms.

Simulation optimization algorithms, ambient sound recognition software, and immersive 3D experiences (Chandra, 2022; Laviola et al., 2022; Zhang et al., 2022b) are instrumental in metaverse engagement and experiences, live e-commerce shopping, and virtual content optimization. Metaverse technologies integrate big geospatial data analytics, deep learning artificial intelligence tools, and remote sensing systems in virtual commerce, forecasting user preferences. Customer mobility data and deep learning computer vision algorithms enhance personalized product recommendations in virtual marketplaces and the blockchain-based metaverse. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Computer-generated images, mobile geofencing technology, and data visualization tools optimize metaverse assets and services in virtual mall environments.	Gössling and Schweiggart, 2022; Upadhyay and Khandelwal, 2022; Zhang et al., 2022a
Real-time data tracking tools, business intelligence analytics, and cognitive automation technologies enable immersive virtual experiences and metaverse interoperability.	Beniiche et al., 2022; Gibbert et al., 2022; Skalidis et al., 2022
Simulation optimization algorithms, ambient sound recognition software, and immersive 3D experiences are instrumental in metaverse engagement and experiences, live e-commerce shopping, and virtual content optimization.	Chandra, 2022; Laviola et al., 2022; Zhang et al., 2022b

6. Behavioral Predictive Analytics, Virtual Retail Algorithms, and Geospatial Mapping Technologies across the Decentralized and Interconnected Metaverse

Metaverse engagement metrics (Hwang and Chien, 2022; Lv et al., 2022; Xi et al., 2022) configure immersive retail experiences, virtual asset purchasing, and personalized customer shopping behavior. Augmented reality shopping tools, deep learning algorithms, and digital twin technology drive brand awareness in extended reality environments, optimizing shopping and spending habits. Virtual retail algorithms and customized data workflows configure augmented shopping experiences in interactive digital worlds and 3D immersive environments.

Retail business analytics optimizes virtual shopping sessions in the metaverse economy (Guo and Gao, 2022; Kozinets, 2022; Wang, 2022) by deploying data acquisition tools, predictive modeling algorithms, and geospatial mapping technologies. Decision-making process automation tools and big data analytics shape metaverse operations management on augmented reality commerce platforms and in interconnected virtual worlds. Digitally extended social interactions and consumer behavior data articulate virtual consumer engagement in immersive 3D environments.

Virtual simulation algorithms and biometrics data fusion shape metaverse brand experiences across customer journey in digital hyper-realistic worlds (Hollensen et al., 2022; Liu et al., 2022; Reis and Ashmore, 2022), driving shopper engagement and consumer purchasing habits. Blockchain token-based digital assets develop on Internet of Things sensing infrastructures, virtual modeling technology, and immersive visualization systems. Live e-commerce shopping in the digital asset-based virtual economy integrates consumer behavior and data. Behavioral and demographic analytics optimizes lifetime customer value in virtual shopping malls across the decentralized and interconnected metaverse. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Metaverse engagement metrics configure immersive retail experiences, virtual asset purchasing, and personalized customer shopping behavior.	Hwang and Chien, 2022; Lv et al., 2022; Xi et al., 2022
Retail business analytics optimizes virtual shopping sessions in the metaverse economy by deploying data acquisition tools, predictive modeling algorithms, and geospatial mapping technologies.	Guo and Gao, 2022; Kozinets, 2022; Wang, 2022
Virtual simulation algorithms and biometrics data fusion shape metaverse brand experiences across customer journey in digital hyper-realistic worlds, driving shopper engagement and consumer purchasing habits.	Hollensen et al., 2022; Liu et al., 2022; Reis and Ashmore, 2022

7. Discussion

I integrate my systematic review throughout research indicating how customer behavior analytics leverages immersive technologies, spatio-temporal fusion algorithms, and data computing capabilities across extended reality environments. My research complements recent analyses clarifying how customer monitoring systems, image recognition technologies, and visual analytics are instrumental in technology-enabled live shopping in blockchain-based virtual worlds. I elucidate, by cumulative evidence, previous research demonstrating how retail analytics in immersive 3D worlds harnesses virtual navigation tools, voice recognition software, and cognitive enhancement technologies.

8. Synopsis of the Main Research Outcomes

Realistic virtual shopping experiences develop on computer vision tools, immersive technologies, and predictive customer analytics in immersive digital worlds. Augmented reality shopping tools, deep learning algorithms, and digital twin technology drive brand awareness in extended reality environments, optimizing shopping and spending habits. Blockchain token-based digital assets develop on Internet of Things sensing infrastructures, virtual modeling technology, and immersive visualization systems.

9. Conclusions

Relevant research has investigated whether customer engagement tools, immersive technologies, and image processing computational algorithms configure behavior analysis and prediction during metaverse live-video shopping events across shared virtual environments, building brand awareness. This systematic literature review presents the published peer-reviewed sources covering how customer mobility data and deep learning computer vision algorithms enhance personalized product recommendations in virtual marketplaces and the blockchain-based metaverse. The research outcomes drawn from the above analyses indicate that machine learning-based product recognition and virtual twin modeling tools shape shopper traffic patterns and 3D immersive content.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on virtual retail algorithms, behavioral predictive analytics, and geospatial mapping technologies in the decentralized metaverse may have been excluded. The scope of my study also does not move forward the inspection of metaverse purchase experiences across interconnected virtual worlds, shaping consumer behavior and preferences.

Subsequent analyses should develop on metaverse live shopping, agile product development, and immersive digital experiences in the blockchain-based virtual economy. Future research should thus investigate virtual simulation algorithms and biometrics data fusion shaping metaverse brand experiences across customer journey in digital hyper-realistic worlds. Attention should be directed to metaverse assets and services in virtual mall environments.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the author.

Data availability statement

All data generated or analyzed are included in the published article.

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Author contributions

The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record

The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement

The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Cognitive Artificial Intelligence Algorithms, Movement and Behavior Tracking Tools, and Customer Identification Technology in the Metaverse Commerce

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ABSTRACT. The aim of this systematic review is to synthesize and analyze biometric authentication features, metaverse capabilities, and real-time predictive analytics. With increasing evidence of digital assets in the metaverse commerce, there is an essential demand for comprehending whether augmented reality shopping tools and deep learning algorithms shape consumer sentiment and behavior and personalized purchase experiences in user-generated digital virtual environments. In this research, prior findings were cumulated indicating that transaction geolocation data, machine learning-based image recognition tools, and artificial vision systems configure consumer behavior and expectations, optimizing purchase journeys in virtual marketplaces. We carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout April 2022, with search terms including "the metaverse commerce" + "cognitive artificial intelligence algorithms," "movement and behavior tracking tools," and "customer identification technology." As we analyzed research published between 2021 and 2022, only 148 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, we decided on 29, chiefly empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Distiller SR, ROBIS, and SRDR.

Keywords: immersive visualization systems; shopper engagement technologies; metaverse interactive environment; machine learning-based product recognition tools; spatial computing technology; ambient sound recognition software

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1. Introduction

Biometric authentication features, customer identification technology, and virtual navigation tools (Andronie et al., 2021; Mircică, 2020; Rogers and Zvarikova, 2021) are instrumental in robust immersive experiences as regards metaverse assets. The purpose of our systematic review is to examine the recently published literature on the metaverse commerce and integrate the insights it configures on cognitive artificial intelligence algorithms, movement and behavior tracking tools, and customer identification technology (Barbu et al., 2021; Nica, 2017; Scott et al., 2020). By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that spatial computing technology, voice and gesture recognition tools, and data computing capabilities configure 3D immersive content and metaverse engagement metrics. The actuality and novelty of this study are articulated by addressing biometric authentication features, metaverse capabilities, and real-time predictive analytics (Blazek et al., 2022; Nica et al., 2020; Throne and Lăzăroiu, 2020), that is an emerging topic involving much interest. Our research problem is whether transaction geolocation data, machine learning-based image recognition tools, and artificial vision systems (Gray-Hawkins and Lăzăroiu, 2020; Nica, 2021; Valle, 2021) configure consumer behavior and expectations, optimizing purchase journeys in virtual marketplaces.

In this review, prior findings have been cumulated indicating that customer behavior analytics leverages data mining techniques, simulation modeling tools, and cognitive enhancement technologies (Kliestik et al., 2022; Nica and Stehel, 2021; Vătămănescu et al., 2020) in blockchain-based virtual worlds. The identified gaps advance frictionless metaverse purchase experiences. Our main objective is to indicate that metaverse technologies require natural language processing tools, sentiment analytics, and data-driven customer engagements (Konhäusner et al., 2021; Poliak et al., 2020; Wallace and Lăzăroiu, 2021) across virtual marketplaces, raising brand awareness. This systematic review contributes to the literature on digital assets in the metaverse commerce by clarifying that augmented reality shopping tools and deep learning algorithms (Lăzăroiu et al., 2021; Popescu et al., 2022; Zvarikova et al., 2021) shape consumer sentiment and behavior and personalized purchase experiences in user-generated digital virtual environments.

2. Theoretical Overview of the Main Concepts

Computer vision algorithms, simulation modeling tools, and business intelligence operations improve 3D immersive content in the virtual retail market. Visual analytics improve customer response sentiment and augmented shopping experiences in immersive virtual worlds. Business intelligence analytics deploys data visualization tools, intuitive personal shopping assistant bots, and voice recognition software in extended reality environments. Customer behavior analytics leverages visual imagery tools in immersive virtual environments. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), immersive visualization systems, cognitive artificial intelligence algorithms, and shopper engagement technologies in the virtual economy of the metaverse (section 4), machine learning-based product recognition tools, visual analytics, and customer identification technology in the metaverse commerce (section 5), movement and behavior tracking tools, spatial computing technology, and ambient sound recognition software in the metaverse interactive environment (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

We carried out a quantitative literature review of ProQuest, Scopus, and the Web of Science throughout April 2022, with search terms including "the metaverse commerce" + "cognitive artificial intelligence algorithms," "movement and behavior tracking tools," and "customer identification technology." As we analyzed research published between 2021 and 2022, only 148 papers met the eligibility criteria. By removing controversial or unclear findings (scanty/unimportant data), results unsupported by replication, undetailed content, or papers having quite similar titles, we decided on 29, chiefly empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Distiller SR, ROBIS, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the metaverse commerce + cognitive artificial intelligence algorithms	48	9
the metaverse commerce + movement and behavior tracking tools	49	10
the metaverse commerce + customer identification technology	51	10
Type of paper		
Original research	120	24
Review	17	5
Conference proceedings	7	0
Book	1	0
Editorial	3	0

Source: Processed by the authors. Some topics overlap.

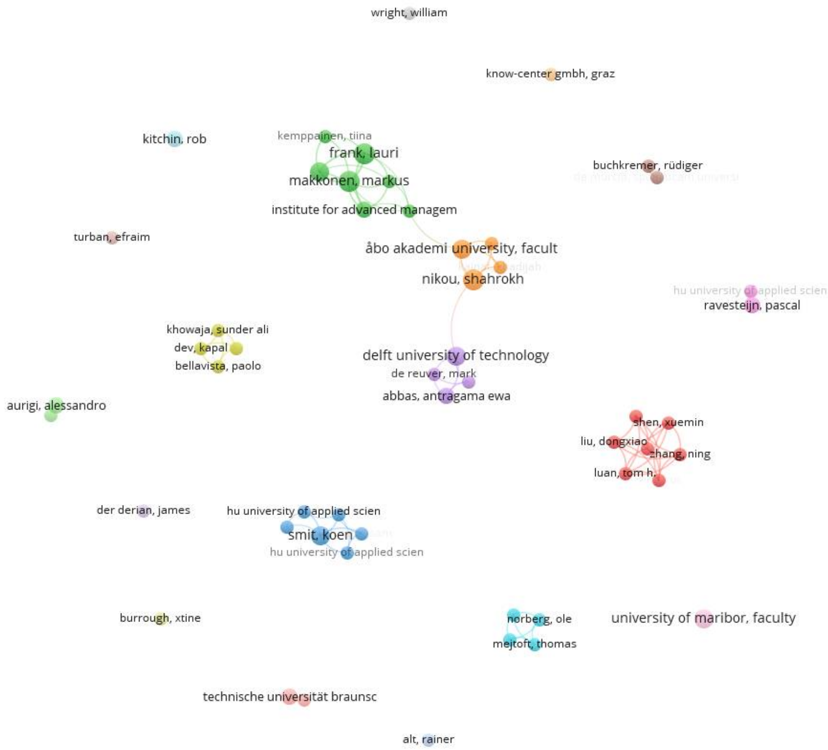

Figure 1 Co-authorship

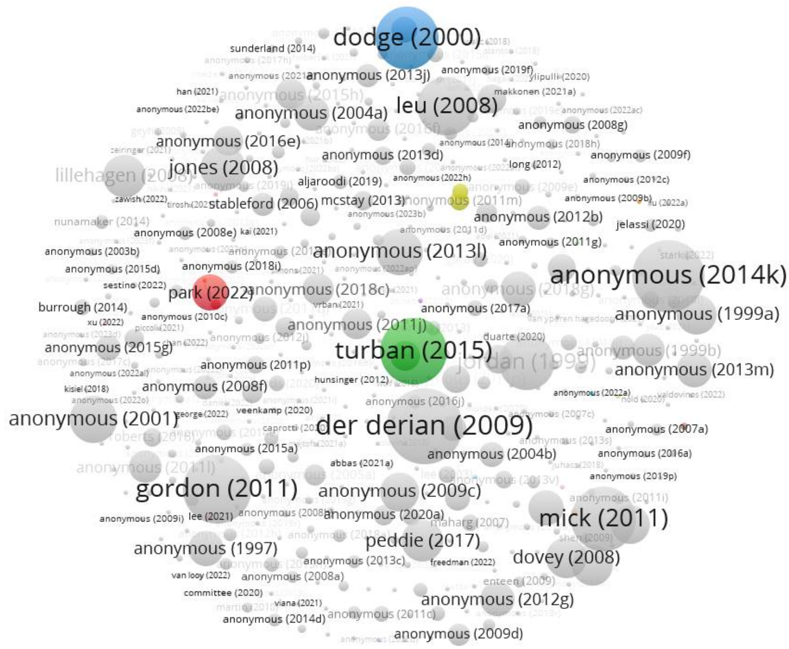

Figure 2 Citation

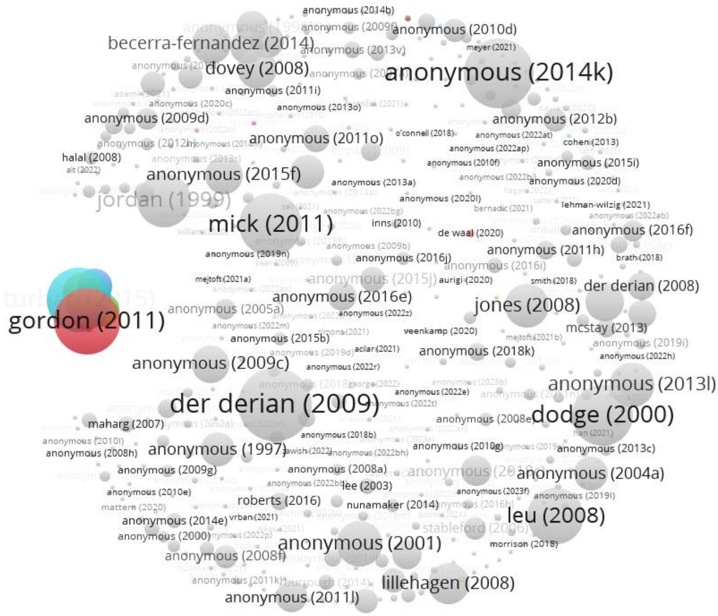

Figure 3 Bibliographic coupling

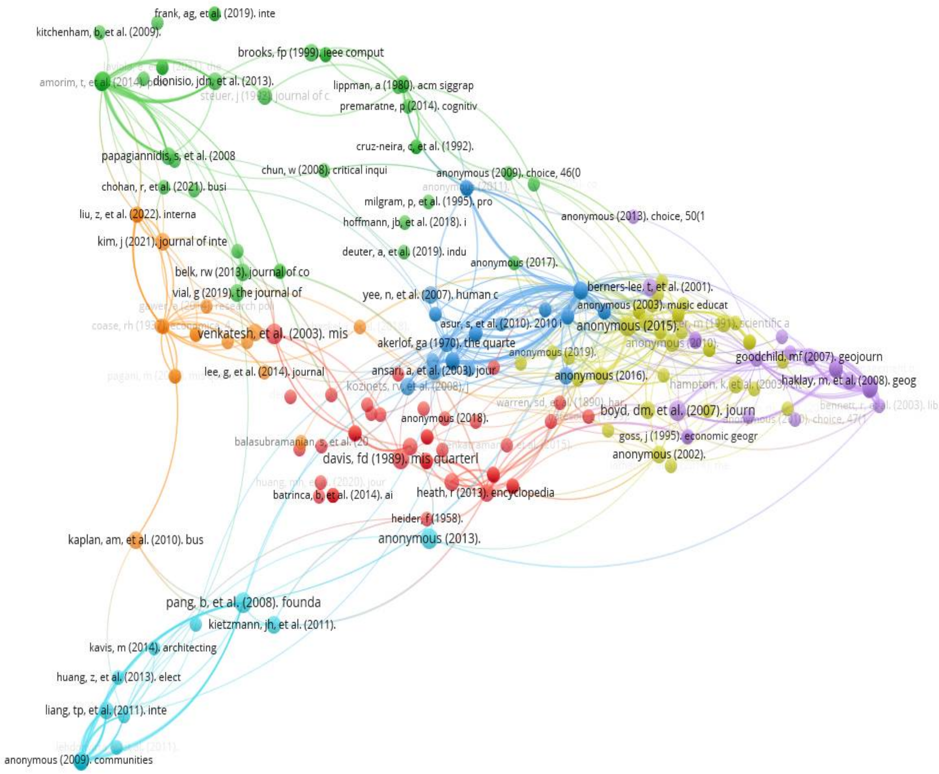

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Visual analytics, predictive modeling tools, and consumer location data articulate business intelligence operations in the virtual economy of the metaverse. Immersive visualization systems, data visualization tools, and conversational artificial intelligence enable live shopping events as regards digitized retail products in extended reality environments.	Kozinets, 2022; Turner, 2022; Valaskova et al., 2022
Biometric authentication features, metaverse capabilities, and real-time predictive analytics optimize immersive retail experiences in virtual environments.	Akyildiz et al., 2022; Kral et al., 2022; Lukava et al., 2022; Zyda, 2022a
Spatial awareness and tracking tools optimize immersive retail experiences, live shopping events, and buying habits and behaviors in the metaverse economy.	Almarzouqi et al., 2022; Dozio et al., 2022; Hawkins, 2022
Computer vision algorithms, immersive virtual shopping, and spatial analytics enhance consumer sentiment and behavior in relation to digital assets in the metaverse commerce.	Han et al., 2022; Kraus et al., 2022; Popescu et al., 2022b
Immersive retail experiences, text mining and analytics, biometric authentication features, and data-driven artificial intelligence shape the economic infrastructure of the metaverse.	Hwang and Chien, 2022; Kshetri, 2022; Upadhyay and Khandelwal, 2022
Frictionless metaverse purchase experiences develop on deep learning-based ambient sound processing, immersive 3D technologies, and customer engagement tools.	Gibbert et al., 2022; Hollensen et al., 2022; Zyda, 2022b
Analytical artificial intelligence, data mining techniques, and immersive technologies further user experiences and behaviors on blockchain-based metaverse platforms.	Chandra, 2022; Gursoy et al., 2022; Lv et al., 2022; Wang, 2022
Predictive algorithms, eye-tracking technologies, and spatial analytics further livestream video shopping experiences and entertaining metaverse events across interconnected virtual worlds. Immersive virtual experiences integrate simulation modeling tools in a decentralized 3D digital world.	Elawady et al., 2022; Gills and Hosseini, 2022; Siyaev and Jo, 2021
Behavioral and demographic analytics, conversational artificial intelligence, and customer identification technology are pivotal in digitally-enhanced personalized experiences across the interconnected metaverse.	Lin et al., 2022; Solakis et al., 2022; Zhang et al., 2022

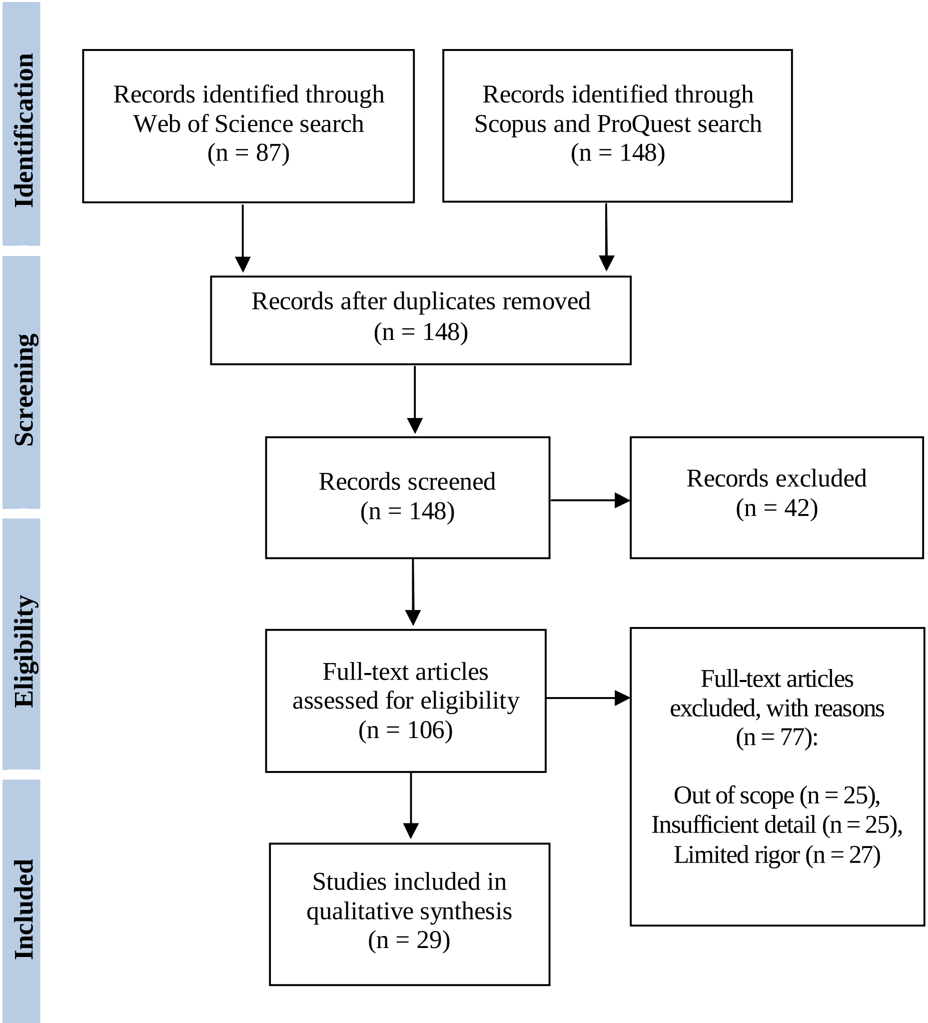

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2021–2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

ROBIS assessed the risk of bias in systematic reviews.

Figure 6 Screening and quality assessment tools

4. Immersive Visualization Systems, Cognitive Artificial Intelligence Algorithms, and Shopper Engagement Technologies in the Virtual Economy of the Metaverse

Visual analytics, predictive modeling tools, and consumer location data (Kozinets, 2022; Turner, 2022; Valaskova et al., 2022) articulate business intelligence operations in the virtual economy of the metaverse. Customer behavior analytics leverages data mining techniques, simulation modeling tools, and cognitive enhancement technologies in blockchain-based virtual worlds. Immersive visualization systems, data visualization tools, and conversational artificial intelligence enable live shopping events as regards digitized retail products in extended reality environments.

Biometric authentication features, metaverse capabilities, and real-time predictive analytics (Akyildiz et al., 2022; Kral et al., 2022; Lukava et al., 2022; Zyda, 2022a) optimize immersive retail experiences in virtual environments. Cognitive artificial intelligence algorithms harness sentiment analytics, virtual navigation and automated speech recognition tools, and customer biometric data across virtual marketplaces. Transaction geolocation data, machine learning-based image recognition tools, and artificial vision systems configure consumer behavior and expectations, optimizing purchase journeys in virtual marketplaces.

Spatial awareness and tracking tools optimize immersive retail experiences, live shopping events, and buying habits and behaviors (Almarzouqi et al., 2022; Dozio et al., 2022; Hawkins, 2022) in the metaverse economy. Customer behavior analytics leverages visual imagery tools in immersive virtual environments. Computer vision algorithms, data tracking apps, and social commerce tools enable livestream shopping events and shifting consumer behaviors in a blockchain-based virtual world. Augmented reality shopping tools and deep learning algorithms shape consumer sentiment and behavior and personalized purchase experiences in user-generated digital virtual environments. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Visual analytics, predictive modeling tools, and consumer location data articulate business intelligence operations in the virtual economy of the metaverse.	Kozinets, 2022; Turner, 2022; Valaskova et al., 2022
Biometric authentication features, metaverse capabilities, and real-time predictive analytics optimize immersive retail experiences in virtual environments.	Akyildiz et al., 2022; Kral et al., 2022; Lukava et al., 2022; Zyda, 2022a
Spatial awareness and tracking tools optimize immersive retail experiences, live shopping events, and buying habits and behaviors in the metaverse economy.	Almarzouqi et al., 2022; Dozio et al., 2022; Hawkins, 2022

5. Machine Learning-based Product Recognition Tools, Visual Analytics, and Customer Identification Technology in the Metaverse Commerce

Computer vision algorithms, immersive virtual shopping, and spatial analytics enhance consumer sentiment and behavior (Han et al., 2022; Kraus et al., 2022; Popescu et al., 2022b) in relation to digital assets in the metaverse commerce. Haptic and biometric sensor technologies, retail analytics, and computer vision algorithms articulate live shopping events in the virtual commerce through customer personalization tools. Business intelligence analytics deploys data visualization tools, intuitive personal shopping assistant bots, and voice recognition software in extended reality environments.

Immersive retail experiences, text mining and analytics, biometric authentication features, and data-driven artificial intelligence (Hwang and Chien, 2022; Kshetri, 2022; Upadhyay and Khandelwal, 2022) shape the economic infrastructure of the metaverse. 3D metaverse experiences as regards blockchain-based digital assets integrate consumer analytics, ambient scene detection and digital twin modeling tools, and shopper behavioral data. Machine learning-based product recognition tools enhance consumer sentiment and behavior in 3D immersive environments.

Frictionless metaverse purchase experiences (Gibbert et al., 2022; Hollensen et al., 2022; Zyda, 2022b) develop on deep learning-based ambient sound processing, immersive 3D technologies, and customer engagement tools. Visual analytics improve customer response sentiment and augmented shopping experiences in immersive virtual worlds. Immersive shopping experiences can be achieved through contextual consumer data, contextual awareness tools, and predictive analytics across virtual retail stores. Biometric authentication features, customer identification technology, and virtual navigation tools are instrumental in robust immersive experiences as regards metaverse assets. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Computer vision algorithms, immersive virtual shopping, and spatial analytics enhance consumer sentiment and behavior in relation to digital assets in the metaverse commerce.	Han et al., 2022; Kraus et al., 2022; Popescu et al., 2022b
Immersive retail experiences, text mining and analytics, biometric authentication features, and data-driven artificial intelligence shape the economic infrastructure of the metaverse.	Hwang and Chien, 2022; Kshetri, 2022; Upadhyay and Khandelwal, 2022
Frictionless metaverse purchase experiences develop on deep learning-based ambient sound processing, immersive 3D technologies, and customer engagement tools.	Gibbert et al., 2022; Hollensen et al., 2022; Zyda, 2022b

6. Movement and Behavior Tracking Tools, Spatial Computing Technology, and Ambient Sound Recognition Software in the Metaverse Interactive Environment

Analytical artificial intelligence, data mining techniques, and immersive technologies further user experiences and behaviors (Chandra, 2022; Gursoy et al., 2022; Lv et al., 2022; Wang, 2022) on blockchain-based metaverse platforms. Computer vision algorithms, simulation modeling tools, and business intelligence operations improve 3D immersive content in the virtual retail market. Personalized digital shopping experiences can be attained by use of customer predictive analytics, real-time data visualization tools, and image recognition technologies across digital marketplaces and in immersive virtual spaces.

Predictive algorithms, eye-tracking technologies, and spatial analytics further livestream video shopping experiences and entertaining metaverse events (Elawady et al., 2022; Gills and Hosseini, 2022; Siyaev and Jo, 2021) across interconnected virtual worlds. Metaverse technologies require natural language processing tools, sentiment analytics, and data-driven customer engagements across virtual marketplaces, raising brand awareness. Immersive virtual experiences integrate simulation modeling tools in a decentralized 3D digital world.

Behavioral and demographic analytics, conversational artificial intelligence, and customer identification technology are pivotal in digitally-enhanced personalized experiences (Lin et al., 2022; Solakis et al., 2022; Zhang et al., 2022) across the interconnected metaverse. Spatial computing technology, voice and gesture recognition tools, and data computing capabilities configure 3D immersive content and metaverse engagement metrics. Customer data analytics harnesses ambient sound recognition software in immersive interconnected virtual worlds. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Analytical artificial intelligence, data mining techniques, and immersive technologies further user experiences and behaviors on blockchain-based metaverse platforms.	Chandra, 2022; Gursoy et al., 2022; Lv et al., 2022; Wang, 2022
Predictive algorithms, eye-tracking technologies, and spatial analytics further livestream video shopping experiences and entertaining metaverse events across interconnected virtual worlds.	Elawady et al., 2022; Gills and Hosseini, 2022; Siyaev and Jo, 2021
Behavioral and demographic analytics, conversational artificial intelligence, and customer identification technology are pivotal in digitally-enhanced personalized experiences across the interconnected metaverse.	Lin et al., 2022; Solakis et al., 2022; Zhang et al., 2022

7. Discussion

We integrate our systematic review throughout research indicating how immersive visualization systems, data visualization tools, and conversational artificial intelligence enable live shopping events as regards digitized retail products in extended reality environments. Our research complements recent analyses clarifying how haptic and biometric sensor technologies, retail analytics, and computer vision algorithms articulate live shopping events in the virtual commerce through customer personalization tools. We elucidate, by cumulative evidence, previous research demonstrating how immersive shopping experiences can be achieved through contextual consumer data, contextual awareness tools, and predictive analytics across virtual retail stores.

8. Synopsis of the Main Research Outcomes

Computer vision algorithms, data tracking apps, and social commerce tools enable livestream shopping events and shifting consumer behaviors in a blockchain-based virtual world. 3D metaverse experiences as regards blockchain-based digital assets integrate consumer analytics, ambient scene detection and digital twin modeling tools, and shopper behavioral data. Immersive virtual experiences integrate simulation modeling tools in a decentralized 3D digital world.

9. Conclusions

Relevant research has investigated whether personalized digital shopping experiences can be attained by use of customer predictive analytics, real-time data visualization tools, and image recognition technologies across digital marketplaces and in immersive virtual spaces. This systematic literature review presents the published peer-reviewed sources covering how machine learning-based product recognition tools enhance consumer sentiment and behavior in 3D immersive environments. The research outcomes drawn from the above analyses indicate that cognitive artificial intelligence algorithms harness sentiment analytics, virtual navigation and automated speech recognition tools, and customer biometric data across virtual marketplaces.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on cognitive artificial intelligence algorithms, movement and behavior tracking tools, and customer identification technology in the metaverse commerce may have been excluded. The scope of our study also does not move forward the inspection of business intelligence operations in the virtual economy of the metaverse.

Subsequent analyses should develop on immersive retail experiences in virtual environments. Future research should thus investigate spatial awareness and tracking tools optimizing immersive retail experiences, live shopping events, and buying habits and behaviors. Attention should be directed to Immersive retail experiences, text mining and analytics, biometric authentication features, and data-driven artificial intelligence.

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Author contributions
All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record
The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement
The authors affirm that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Metaverse Technologies, Behavioral Predictive Analytics, and Customer Location Tracking Tools in Blockchain-based Virtual Worlds

Brian Carey*

ABSTRACT. Despite the relevance of virtual items, blockchain token-based digital assets, and 3D immersive content, only limited research has been conducted on this topic. In this article, I cumulate previous research findings indicating that data modeling tools optimize customer engagement behaviors and purchasing habits in immersive virtual worlds. I contribute to the literature on shopping habits and behaviors in metaverse live shopping across immersive 3D worlds by showing that personalized digital shopping experiences can be attained by use of customer engagement tools in immersive virtual spaces. Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "blockchain-based virtual worlds" + "metaverse technologies," "behavioral predictive analytics," and "customer location tracking tools." As I inspected research published between 2021 and 2022, only 152 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 30, generally empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, Distiller SR, and MMAT.

Keywords: spatial computing technology; virtual retail algorithms; decentralized metaverse; immersive 3D virtual environments; geospatial mapping tools; data modeling tools

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1. Introduction

Data mining techniques, consumer journey analytics, and computer vision algorithms (Andronie et al., 2021; Ionescu, 2020; Lăzăroiu et al., 2022; Throne and Lăzăroiu, 2020) assist data-driven business decisions in virtual environments. The purpose of my systematic review is to examine the recently published literature on blockchain-based virtual worlds and integrate the insights it configures on metaverse technologies, behavioral predictive analytics (Gray-Hawkins and Lăzăroiu, 2020; Lăzăroiu et al., 2017; Stone et al., 2022), and customer location tracking tools. By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that natural language processing tools and computer vision algorithms (Blake and Frajtova Michalikova, 2021; Johnson and Nica, 2021; Nica et al., 2021; Valaskova et al., 2021) are instrumental in immersive metaverse experiences. The actuality and novelty of this study are articulated by addressing virtual items, blockchain token-based digital assets, and 3D immersive content, that is an emerging topic involving much interest. My research problem is whether data modeling tools optimize customer engagement behaviors and purchasing habits in immersive virtual worlds.

In this review, prior findings have been cumulated indicating that personalized digital shopping experiences can be attained by use of customer engagement tools in immersive virtual spaces. The identified gaps advance metaverse technologies integrating consumer retail data. My main objective is to indicate that computer vision tools enable immersive shopping experiences across interconnected digital realms and extended reality environments (Burke and Zvarikova, 2021; Kliestik et al., 2020; Nica et al., 2022; Vătămănescu et al., 2022), driving purchase intentions and customer engagement. This systematic review contributes to the literature on shopping habits and behaviors in metaverse live shopping across immersive 3D worlds by clarifying that metaverse interoperability, fuzzy search techniques, and decision support tools (Dabija et al., 2022; Kliestik et al., 2022; Scott et al., 2020; Vătămănescu et al., 2020) articulate virtual retail experiences across customer journey.

2. Theoretical Overview of the Main Concepts

Geolocation data, cognitive enhancement technologies, and predictive maintenance optimize shopping and spending habits and immersive retail experiences in the blockchain-based virtual economy. Real-time sensor data, predictive customer analytics, and biometrics data fusion improve virtual asset sales and 3D immersive content in retail livestreaming and shoppable live-video events. Business intelligence analytics deploys customer monitoring systems in blockchain-based virtual worlds, driving shopper engagement. Interactive brand experiences can be attained in virtual retail environments by use of data mining techniques, customer engagement tools, and immersive visualization systems. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), spatial computing technology, virtual retail algorithms, and customer location tracking tools in immersive 3D virtual environments and on blockchain-based metaverse platforms (section 4), geospatial mapping tools, text mining and analytics, and immersive technologies in the decentralized metaverse (section 5), metaverse technologies, behavioral predictive analytics, and data modeling tools in blockchain-based virtual worlds (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "blockchain-based virtual worlds" + "metaverse technologies," "behavioral predictive analytics," and "customer location tracking tools." As I inspected research published between 2021 and 2022, only 152 articles satisfied the eligibility criteria. By eliminating controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 30, generally empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, Distiller SR, and MMAT R (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	Identified	Selected
blockchain-based virtual worlds + metaverse technologies	54	12
blockchain-based virtual worlds + behavioral predictive analytics	46	8
blockchain-based virtual worlds + customer location tracking tools	52	10
Type of paper		
Original research	124	25
Review	17	5
Conference proceedings	8	0
Book	1	0
Editorial	2	0

Source: Processed by the author. Some topics overlap.

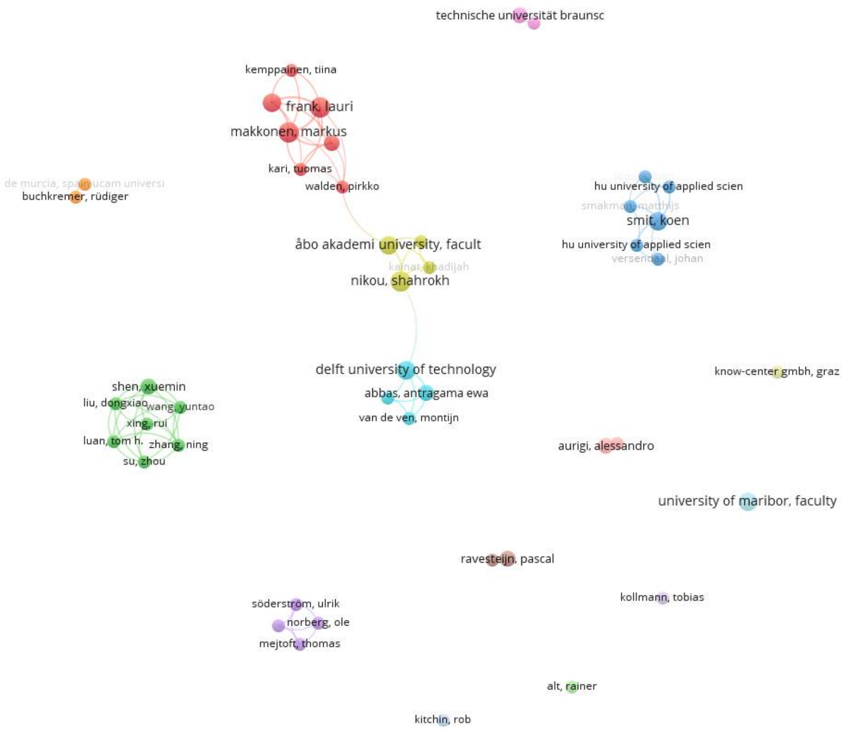

Figure 1 Co-authorship

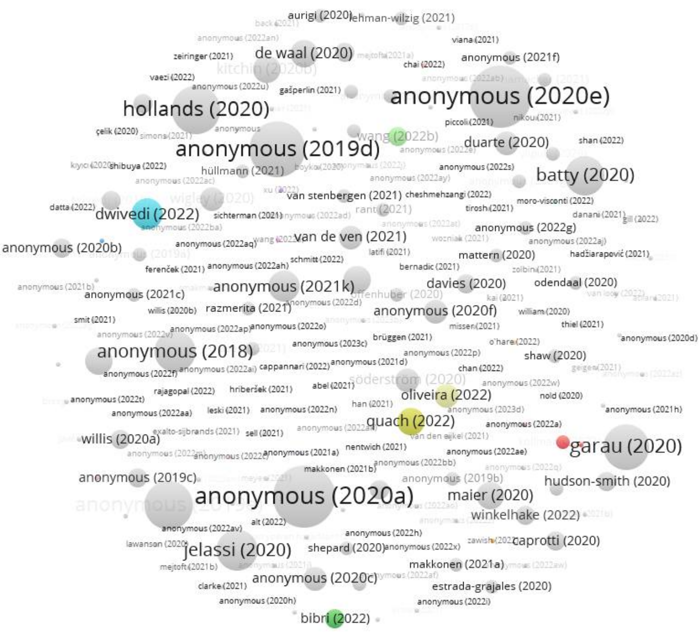

Figure 2 Citation

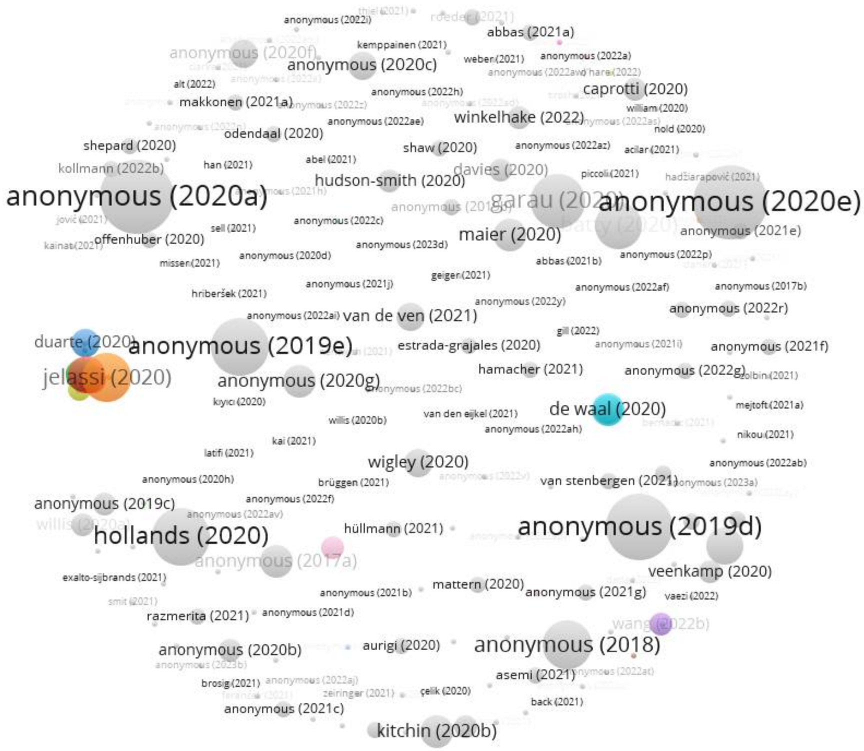

Figure 3 Bibliographic coupling

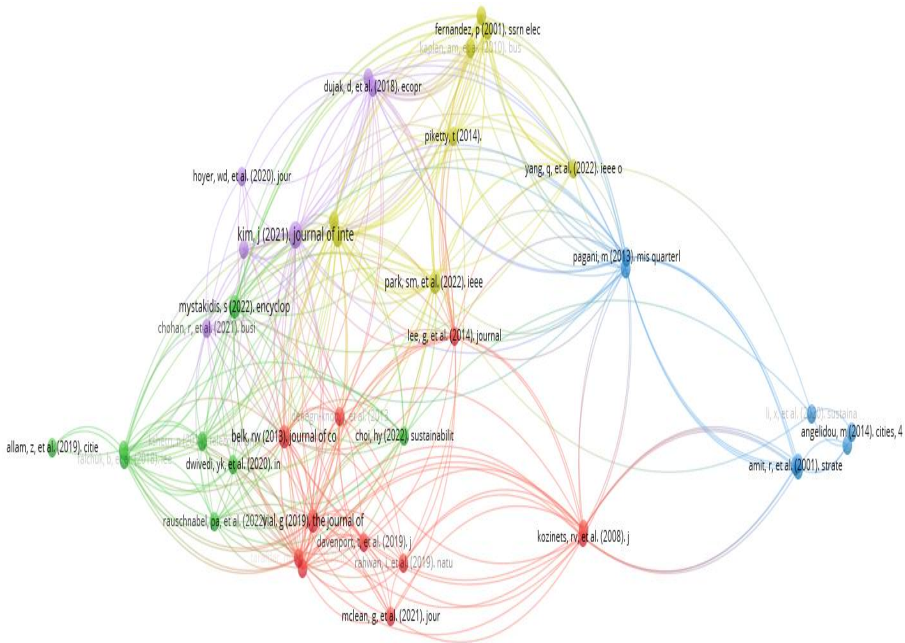

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Spatial computing technology, data visualization and simulation modeling tools, and artificial intelligence chatbot customer services shape shopping habits and behaviors in metaverse live shopping across immersive 3D worlds.	Akyildiz et al., 2022; Crowell, 2022; Zhang et al., 2022a
Business intelligence analytics drive customer engagement and agile product development in immersive 3D virtual environments and on blockchain-based metaverse platforms.	Kovacova et al., 2022; Siyaev and Jo, 2021; Xi et al., 2022
Metaverse technologies integrate consumer retail data as regards virtual items, blockchain token-based digital assets, and 3D immersive content. Immersive retail experiences and virtual content optimization can be achieved by use of picture-making neural networks, driving spending habits and attracting and retaining customers.	Hamilton, 2022; Kozinets, 2022; Laviola et al., 2022; Zhao et al., 2022
Metaverse operations management develops on social commerce capabilities and data visualization tools across the virtual economy, raising brand awareness and shaping consumer behavior and preferences.	Gursoy et al., 2022; Kral et al., 2022; Zhang et al., 2022b
Immersive technologies, natural language processing and contextual awareness tools, and biometric authentication features enhance behavior analysis and prediction in the retail metaverse.	Jang et al., 2022; Park et al., 2022; Upadhyay and Khandelwal, 2022
Natural language processing tools and computer vision algorithms are instrumental in immersive metaverse experiences, driving customer loyalty as regards blockchain-based digital assets.	Chandra, 2022; Lukava et al., 2022; Solakis et al., 2022; Yeh et al., 2022
Text mining techniques, augmented reality shopping tools, and customer traffic analytics further immersive virtual reality experiences and livestreaming e-commerce digital events in the metaverse economy.	Elawady et al., 2022; Guo and Gao, 2022; Skalidis et al., 2022
Data modeling tools further frictionless customer engagement processes and shopper traffic patterns in virtual shopping malls and across Web3-powered metaverse worlds.	Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022c
Metaverse technologies enhance immersive decentralized networking and personalized customer shopping behavior in virtual mall environments and retail stores. Customer engagement tools assist frictionless virtual shopping experiences in immersive 3D worlds, driving consumer behavior as regards virtual merchandise.	Gössling and Schweiggart, 2022; Liu et al., 2022; Park and Kim, 2022; Zyda, 2022

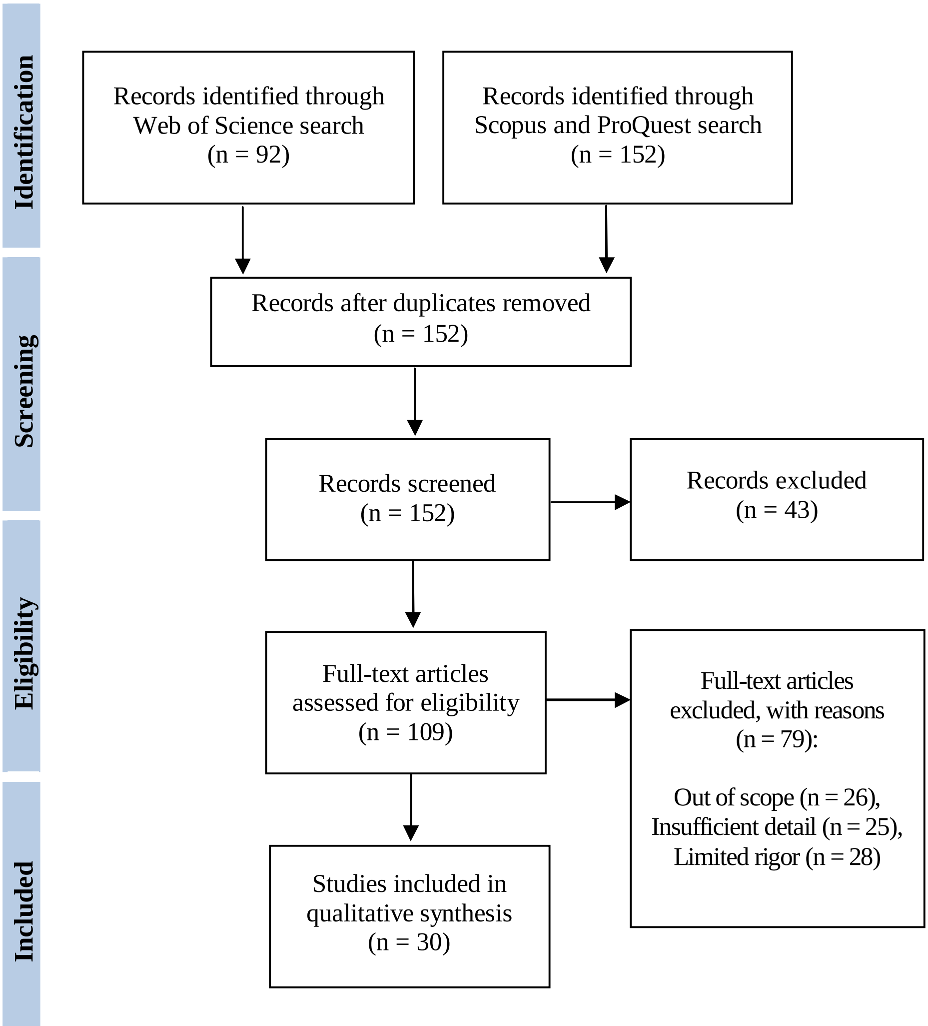

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.

To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2021–2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

Distiller SR screened and extracted the collected data.

AMSTAR evaluated the methodological quality of systematic reviews.

Dedoose analyzed qualitative and mixed methods research.

ROBIS assessed the risk of bias in systematic reviews.

AXIS evaluated the quality of cross-sectional studies.

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

Figure 6 Screening and quality assessment tools

4. Spatial Computing Technology, Virtual Retail Algorithms, and Customer Location Tracking Tools in Immersive 3D Virtual Environments and on Blockchain-based Metaverse Platforms

Spatial computing technology, data visualization and simulation modeling tools, and artificial intelligence chatbot customer services (Akyildiz et al., 2022; Crowell, 2022; Zhang et al., 2022a) shape shopping habits and behaviors in metaverse live shopping across immersive 3D worlds. Real-time sensor data, predictive customer analytics, and biometrics data fusion improve virtual asset sales and 3D immersive content in retail livestreaming and shoppable live-video events. Metaverse interoperability, fuzzy search techniques, and decision support tools articulate virtual retail experiences across customer journey.

Business intelligence analytics drive customer engagement and agile product development (Kovacova et al., 2022; Siyaev and Jo, 2021; Xi et al., 2022) in immersive 3D virtual environments and on blockchain-based metaverse platforms. Metaverse purchase experiences and lifetime customer value can be attained through behavioral and demographic analytics in immersive virtual environments. Customer location tracking tools articulate immersive virtual retail experiences and customer engagement behaviors in live e-commerce shopping.

Metaverse technologies integrate consumer retail data (Hamilton, 2022; Kozinets, 2022; Laviola et al., 2022; Zhao et al., 2022) as regards virtual items, blockchain token-based digital assets, and 3D immersive content. Interactive brand experiences can be attained in virtual retail environments by use of data mining techniques, customer engagement tools, and immersive visualization systems. Immersive retail experiences and virtual content optimization can be achieved by use of picture-making neural networks, driving spending habits and attracting and retaining customers. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Spatial computing technology, data visualization and simulation modeling tools, and artificial intelligence chatbot customer services shape shopping habits and behaviors in metaverse live shopping across immersive 3D worlds.	Akyildiz et al., 2022; Crowell, 2022; Zhang et al., 2022a
Business intelligence analytics drive customer engagement and agile product development in immersive 3D virtual environments and on blockchain-based metaverse platforms.	Kovacova et al., 2022; Siyaev and Jo, 2021; Xi et al., 2022
Metaverse technologies integrate consumer retail data as regards virtual items, blockchain token-based digital assets, and 3D immersive content.	Hamilton, 2022; Kozinets, 2022; Laviola et al., 2022; Zhao et al., 2022

5. Geospatial Mapping Tools, Text Mining and Analytics, and Immersive Technologies in the Decentralized Metaverse

Metaverse operations management develops on social commerce capabilities and data visualization tools across the virtual economy (Gursoy et al., 2022; Kral et al., 2022; Zhang et al., 2022b), raising brand awareness and shaping consumer behavior and preferences. Geolocation data, cognitive enhancement technologies, and predictive maintenance optimize shopping and spending habits and immersive retail experiences in the blockchain-based virtual economy. Movement and behavior tracking tools further immersive virtual experiences and customer preferences.

Immersive technologies, natural language processing and contextual awareness tools, and biometric authentication features (Jang et al., 2022; Park et al., 2022; Upadhyay and Khandelwal, 2022) enhance behavior analysis and prediction in the retail metaverse. Data mining techniques, consumer journey analytics, and computer vision algorithms assist data-driven business decisions in virtual environments. Mobile geofencing technology, metaverse consumer apps, and natural language processing algorithms enable immersive retail experiences in interconnected virtual worlds, building brand awareness. Personalized digital shopping experiences can be attained by use of customer engagement tools in immersive virtual spaces.

Natural language processing tools and computer vision algorithms are instrumental in immersive metaverse experiences (Chandra, 2022; Lukava et al., 2022; Solakis et al., 2022; Yeh et al., 2022), driving customer loyalty as regards blockchain-based digital assets. Business-driven data analytics harnesses geospatial mapping tools and immersive technologies in virtual marketplaces and across the economic infrastructure of the metaverse. Spatial computing technology configures shifting consumer behaviors in immersive 3D virtual environments. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Metaverse operations management develops on social commerce capabilities and data visualization tools across the virtual economy, raising brand awareness and shaping consumer behavior and preferences.	Gursoy et al., 2022; Kral et al., 2022; Zhang et al., 2022b
Immersive technologies, natural language processing and contextual awareness tools, and biometric authentication features enhance behavior analysis and prediction in the retail metaverse.	Jang et al., 2022; Park et al., 2022; Upadhyay and Khandelwal, 2022
Natural language processing tools and computer vision algorithms are instrumental in immersive metaverse experiences, driving customer loyalty as regards blockchain-based digital assets.	Chandra, 2022; Lukava et al., 2022; Solakis et al., 2022; Yeh et al., 2022

6. Metaverse Technologies, Behavioral Predictive Analytics, and Data Modeling Tools in Blockchain-based Virtual Worlds

Text mining techniques, augmented reality shopping tools, and customer traffic analytics (Elawady et al., 2022; Guo and Gao, 2022; Skalidis et al., 2022) further immersive virtual reality experiences and livestreaming e-commerce digital events in the metaverse economy. Entertaining metaverse events require augmented reality tools across virtual marketplaces in terms of consumer habits and expectations. Data modeling tools optimize customer engagement behaviors and purchasing habits in immersive virtual worlds. Customer mobility data shape buying habits in 3D immersive environments.

Data modeling tools further frictionless customer engagement processes and shopper traffic patterns (Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022c) in virtual shopping malls and across Web3-powered metaverse worlds. Customer behavior analytics leverages immersive 3D technologies in extended reality environments and interconnected digital spaces. Augmented reality shopping tools and image recognition technologies configure product customization services and data-driven customer engagements in 3D immersive environments.

Metaverse technologies enhance immersive decentralized networking and personalized customer shopping behavior (Gössling and Schweiggart, 2022; Liu et al., 2022; Park and Kim, 2022; Zyda, 2022) in virtual mall environments and retail stores. Business intelligence analytics deploys customer monitoring systems in blockchain-based virtual worlds, driving shopper engagement. Computer vision tools enable immersive shopping experiences across interconnected digital realms and extended reality environments, driving purchase intentions and customer engagement. Customer engagement tools assist frictionless virtual shopping experiences in immersive 3D worlds, driving consumer behavior as regards virtual merchandise. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Text mining techniques, augmented reality shopping tools, and customer traffic analytics further immersive virtual reality experiences and livestreaming e-commerce digital events in the metaverse economy.	Elawady et al., 2022; Guo and Gao, 2022; Skalidis et al., 2022
Data modeling tools further frictionless customer engagement processes and shopper traffic patterns in virtual shopping malls and across Web3-powered metaverse worlds.	Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022c
Metaverse technologies enhance immersive decentralized networking and personalized customer shopping behavior in virtual mall environments and retail stores.	Gössling and Schweiggart, 2022; Liu et al., 2022; Park and Kim, 2022; Zyda, 2022

7. Discussion

I integrate my systematic review throughout research indicating how metaverse purchase experiences and lifetime customer value can be attained through behavioral and demographic analytics in immersive virtual environments. My research complements recent analyses clarifying how movement and behavior tracking tools further immersive virtual experiences and customer preferences. I elucidate, by cumulative evidence, previous research demonstrating how business-driven data analytics harnesses geospatial mapping tools and immersive technologies in virtual marketplaces and across the economic infrastructure of the metaverse.

8. Synopsis of the Main Research Outcomes

Immersive retail experiences and virtual content optimization can be achieved by use of picture-making neural networks, driving spending habits and attracting and retaining customers. Entertaining metaverse events require augmented reality tools across virtual marketplaces in terms of consumer habits and expectations. Augmented reality shopping tools and image recognition technologies configure product customization services and data-driven customer engagements in 3D immersive environments. Customer engagement tools assist frictionless virtual shopping experiences in immersive 3D worlds, driving consumer behavior as regards virtual merchandise.

9. Conclusions

Relevant research has investigated whether mobile geofencing technology, metaverse consumer apps, and natural language processing algorithms enable immersive retail experiences in interconnected virtual worlds, building brand awareness. This systematic literature review presents the published peer-reviewed sources covering how spatial computing technology configures shifting consumer behaviors in immersive 3D virtual environments. The research outcomes drawn from the above analyses indicate that customer location tracking tools articulate immersive virtual retail experiences and customer engagement behaviors in live e-commerce shopping. Customer mobility data shape buying habits in 3D immersive environments.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on metaverse technologies, behavioral predictive analytics, and customer location tracking tools in blockchain-based virtual worlds may have been excluded. The scope of my study also does not move forward the inspection of metaverse operations management developing on social commerce capabilities and data visualization tools across the virtual economy.

Subsequent analyses should develop on behavior analysis and prediction in the retail metaverse. Future research should thus investigate immersive virtual reality experiences and livestreaming e-commerce digital events in the metaverse economy. Attention should be directed to metaverse technologies enhancing immersive decentralized networking and personalized customer shopping behavior.

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Compliance with ethical standards

This article does not contain any studies with human participants or animals performed by the author.

Data availability statement

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Author contributions

The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record

The editors declare no conflict of interest in the review and publication decision regarding this article.

Transparency statement

The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Image Processing Computational Algorithms, Sensory Data Mining Techniques, and Predictive Customer Analytics in the Metaverse Economy

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ABSTRACT. Based on an in-depth survey of the literature, the purpose of the paper is to explore consumer behavior across the interconnected metaverse. In this research, previous findings were cumulated showing that real-time predictive analytics, simulation modeling tools, and computer vision algorithms shape immersive retail experiences across customer journey, and we contribute to the literature by indicating that virtual content optimization as regards entertaining metaverse events can be attained by deploying retail business analytics, social commerce capabilities, and deep learning-based ambient sound processing in immersive 3D virtual environments. Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the metaverse economy" + "image processing computational algorithms," "sensory data mining techniques," and "predictive customer analytics." As research published in 2022 was inspected, only 144 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 32 mainly empirical sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR.

Keywords: immersive decentralized networking; customer engagement tools; spatial computing technology; predictive customer analytics; interconnected metaverse; cognitive artificial intelligence algorithms

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1. Introduction

Transaction geolocation data, natural language processing and simulation modeling tools, and machine vision algorithms (Andronie et al., 2021a; Johnson and Nica, 2021; Nica et al., 2021) improve consumer sentiment and behavior in the virtual retail market and throughout immersive digital worlds. The purpose of our systematic review is to examine the recently published literature on the metaverse economy and integrate the insights it configures on image processing computational algorithms, sensory data mining techniques, and predictive customer analytics (Andronie et al., 2021b; Kliestik et al., 2022a; Nica, 2021). By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that customer engagement tools, sentiment analytics, and cognitive enhancement technologies enable live shopping events and augmented shopping experiences across virtual economy. The actuality and novelty of this study are articulated by addressing consumer behavior across the interconnected metaverse, that is an emerging topic involving much interest. Our research problem is whether artificial intelligence chatbot customer services, real-time data visualization tools (Andronie et al., 2021c; Lăzăroiu et al., 2017; Nica and Stehel, 2021), and frictionless metaverse purchase experiences drive brand awareness in virtual retail stores and across immersive 3D worlds (Crowell et al., 2022; Nica, 2017; Watson, 2022).

In this review, prior findings have been cumulated indicating that lifetime customer value develops on business intelligence tools (Balcerzak et al., 2022; Lăzăroiu et al., 2022; Peters, 2022) through smart customer targeting in immersive virtual environments and decentralized 3D digital worlds. The identified gaps advance technology-enabled logistics optimization (Barbu et al., 2021; Lewkowich, 2022; Valaskova et al., 2021) across virtual retail stores. Our main objective is to indicate that real-time predictive analytics, simulation modeling tools, and computer vision algorithms (Burke and Zvarikova, 2021; Mircică, 2020; Vinerean et al., 2022) shape immersive retail experiences across customer journey. This systematic review contributes to the literature on personalized digital shopping experiences in the decentralized metaverse by clarifying that virtual content optimization as regards entertaining metaverse events can be attained by deploying retail business analytics, social commerce capabilities, and deep learning-based ambient sound processing (Dabija et al., 2022; Nica et al., 2020; Zvarikova et al., 2021) in immersive 3D virtual environments.

2. Theoretical Overview of the Main Concepts

Computer-generated images, customer engagement tools, and data visualization tools articulate behavior analysis and prediction throughout extended reality environments. Visual analytics, intuitive personal shopping assistant bots, and data sharing technologies enhance virtual consumer engagement during shoppable live-video events throughout immersive hyper-connected virtual spaces. Business-driven data analytics and customer identification technology enable immersive shopping experiences in virtual retail environments and interconnected digital spaces. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), immersive decentralized networking, image processing computational algorithms, and customer engagement tools in the metaverse economy (section 4), sensory data mining techniques, spatial computing technology, and predictive modeling tools across the interconnected metaverse (section 5), predictive customer analytics, cognitive artificial intelligence algorithms, and machine learning-based product recognition tools across the virtual economy of the metaverse (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the metaverse economy" + "image processing computational algorithms," "sensory data mining techniques," and "predictive customer analytics." As research published in 2022 was inspected, only 144 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 32 mainly empirical sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the metaverse economy + image processing computational algorithms	50	12
the metaverse economy + sensory data mining techniques	48	10
the metaverse economy + predictive customer analytics	46	10
Type of paper		
Original research	114	25
Review	18	7
Conference proceedings	9	0
Book	1	0
Editorial	2	0

Source: Processed by the authors. Some topics overlap.

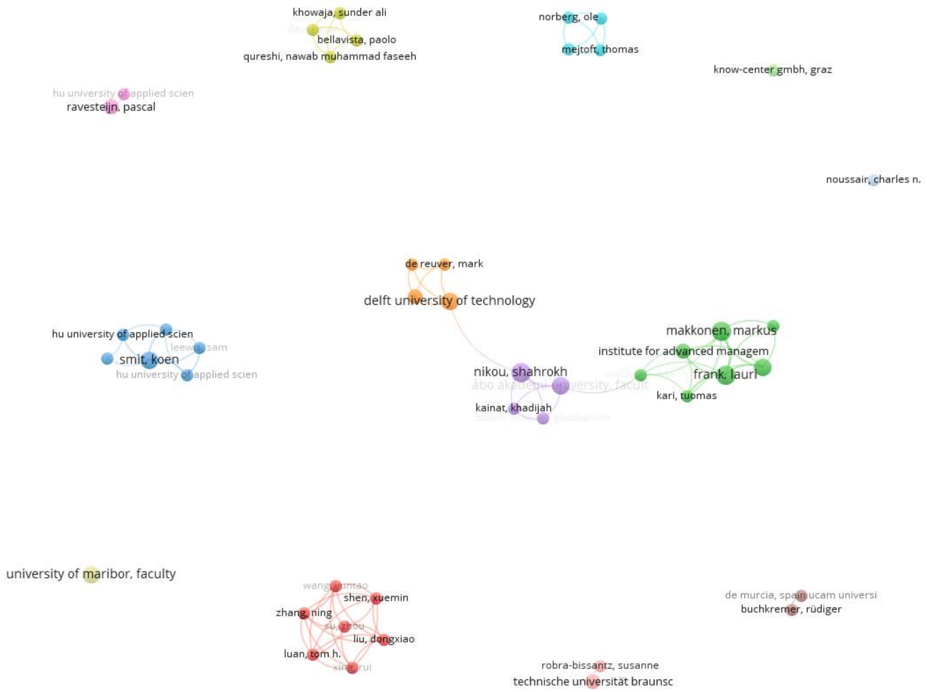

Figure 1 Co-authorship

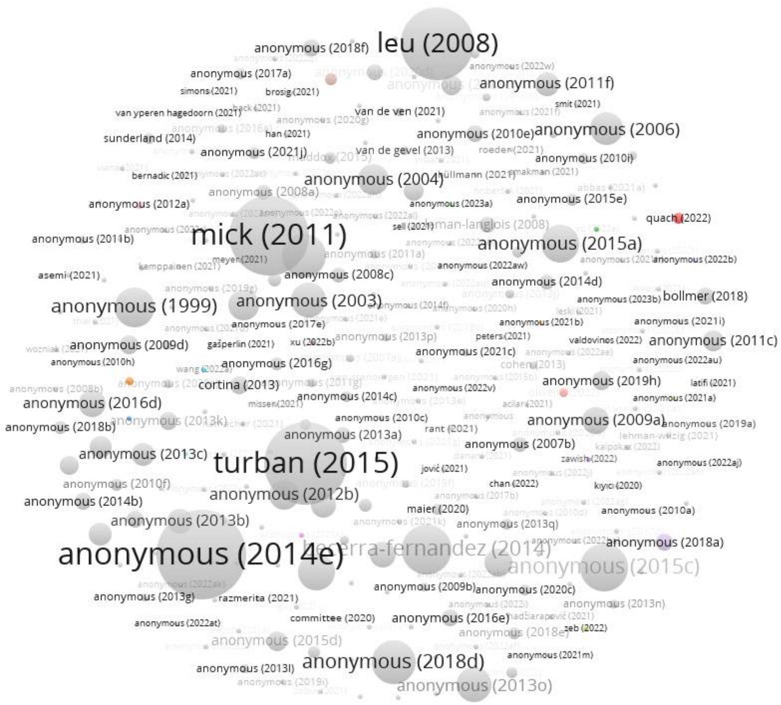

Figure 2 Citation

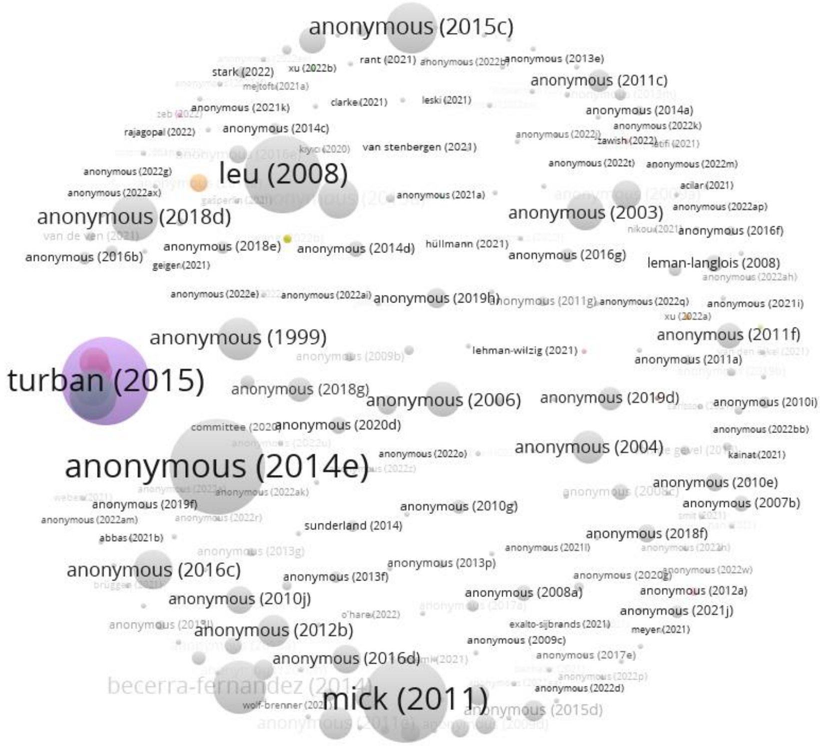

Figure 3 Bibliographic coupling

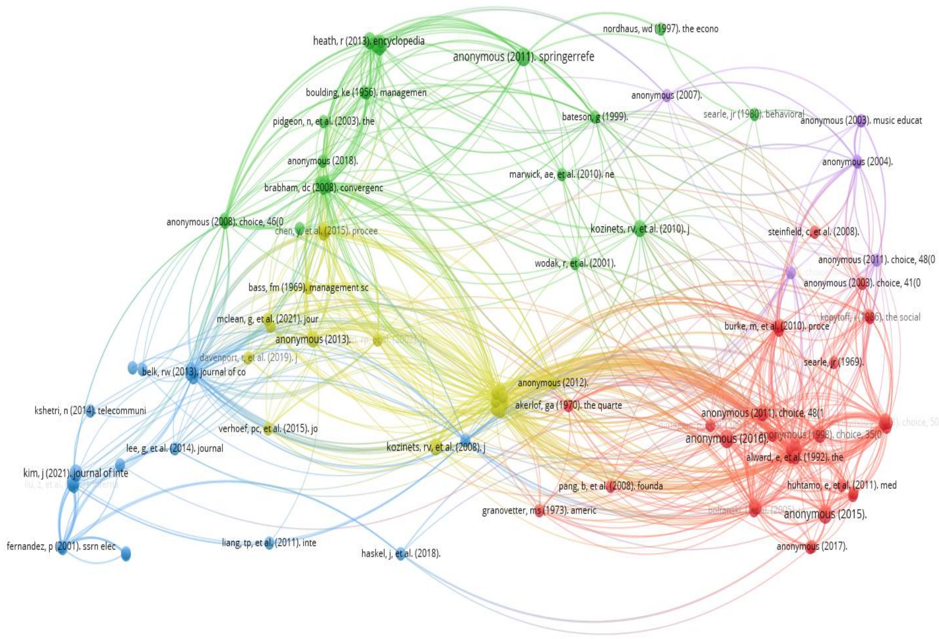

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Immersive virtual shopping integrates biometric authentication features, voice and gesture recognition tools, and data-driven business decisions in the metaverse economy.	Elawady et al., 2022; Kovacova et al., 2022; Upadhyay and Khandelwal, 2022;
The economic infrastructure of the metaverse develops on data-driven artificial intelligence, computer vision algorithms, and immersive decentralized networking.	Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022a; Zvarikova et al., 2022a
Image processing computational algorithms, business intelligence analytics, and augmented reality shopping tools are pivotal in 3D metaverse experiences and data-driven customer engagements.	Hwang and Chien, 2022; Kliestik et al., 2022; Laviola et al., 2022; Xi et al., 2022
Sensory data mining techniques, decision support tools, and 3D immersive content enable personalized digital shopping experiences in the decentralized metaverse.	Dawson, 2022; Gursoy et al., 2022; Lv et al., 2022; Reis and Ashmore, 2022
Data visualization tools, analytical artificial intelligence, and immersive technologies optimize shopping and spending habits. Customer engagement tools harness mobile geofencing technology, voice recognition software, predictive maintenance, and spatial analytics in virtual marketplaces, optimizing immersive retail experiences.	Hamilton, 2022; Kshetri, 2022; Lin et al., 2022; Popescu et al., 2022
Predictive modeling tools are pivotal during virtual shopping sessions and livestream shopping events in the retail metaverse. Visual analytics, intuitive personal shopping assistant bots, and data sharing technologies enhance virtual consumer engagement during shoppable live-video events throughout immersive hyper-connected virtual spaces.	Gössling and Schweiggart, 2022; Turner, 2022; Zhang et al., 2022b
Computer vision tools, retail and sentiment analytics, and customer monitoring systems assist metaverse live shopping and improve personalized purchase experiences in extended reality environments.	Chandra, 2022; Solakis et al., 2022; Zvarikova et al., 2022b
Eye-tracking technologies, spatial awareness and tracking tools, and body-tracking data metrics configure user experiences and behaviors across interactive virtual environments.	Gibbert et al., 2022; Han et al., 2022; Liu et al., 2022; Skalidis et al., 2022
Customer biometric data and identification technology typify immersive virtual shopping and retail experiences through virtual navigation tools and behavioral and demographic analytics.	Akyildiz et al., 2022; Park and Kim, 2022; Zhang et al., 2022c

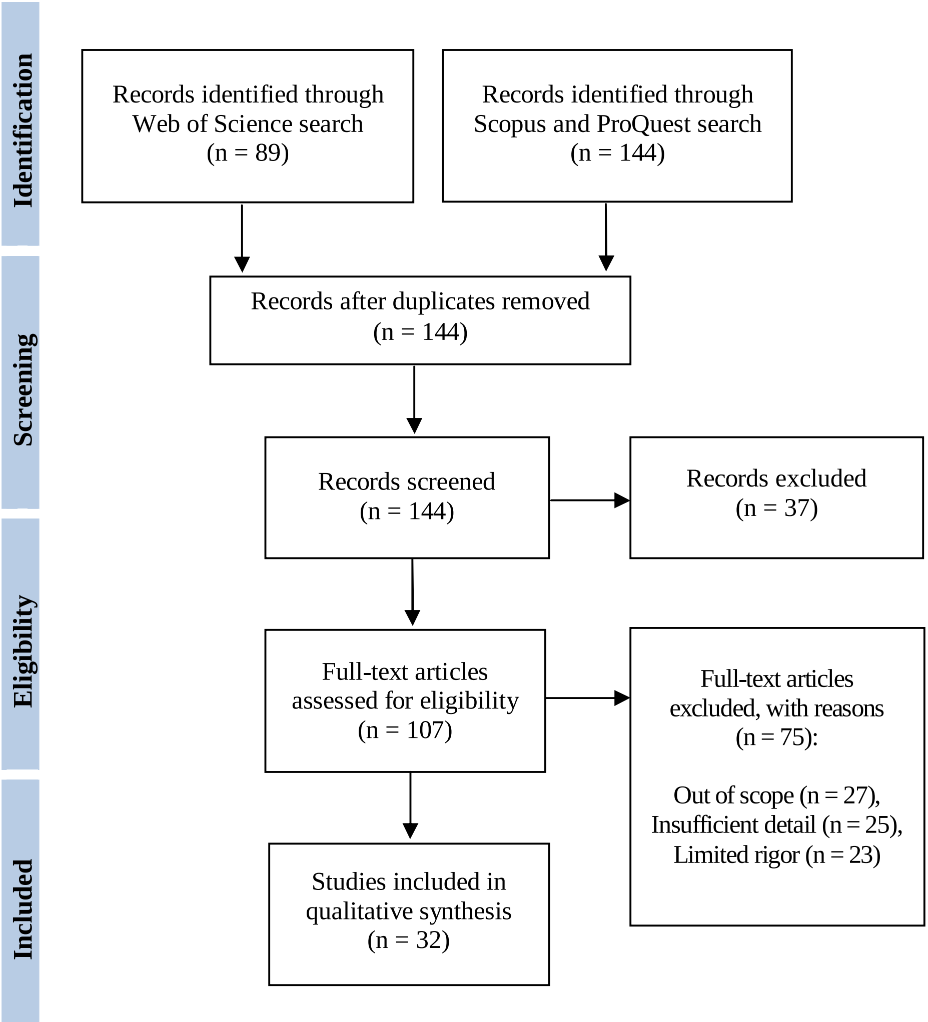

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

Distiller SR screened and extracted the collected data.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

Dedoose analyzed qualitative and mixed methods research.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

Figure 6 Screening and quality assessment tools

4. Immersive Decentralized Networking, Image Processing Computational Algorithms, and Customer Engagement Tools in the Metaverse Economy

Immersive virtual shopping integrates biometric authentication features, voice and gesture recognition tools, and data-driven business decisions (Elawady et al., 2022; Kovacova et al., 2022; Upadhyay and Khandelwal, 2022) in the metaverse economy. Connected e-commerce apps, immersive technologies, and granular journey data configure artificial intelligence-powered live shopping experiences and agile product development across virtual mall environments. Immersive virtual reality experiences and personalized customer shopping behavior can be improved by use of consumer behavior data, metaverse engagement metrics, and predictive and retail analytics.

The economic infrastructure of the metaverse develops on data-driven artificial intelligence, computer vision algorithms, and immersive decentralized networking (Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022a; Zvarikova et al., 2022a), resulting in technology-enabled logistics optimization across virtual retail stores. Real-time predictive analytics, simulation modeling tools, and computer vision algorithms shape immersive retail experiences across customer journey. Business-driven data analytics and customer identification technology enable immersive shopping experiences in virtual retail environments and interconnected digital spaces.

Image processing computational algorithms, business intelligence analytics, and augmented reality shopping tools (Hwang and Chien, 2022; Kliestik et al., 2022b; Laviola et al., 2022; Xi et al., 2022) are pivotal in 3D metaverse experiences and data-driven customer engagements across shared virtual environments. Computer-generated images, customer engagement tools, and data visualization tools articulate behavior analysis and prediction throughout extended reality environments. Lifetime customer value develops on business intelligence tools through smart customer targeting in immersive virtual environments and decentralized 3D digital worlds. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Immersive virtual shopping integrates biometric authentication features, voice and gesture recognition tools, and data-driven business decisions in the metaverse economy.	Elawady et al., 2022; Kovacova et al., 2022; Upadhyay and Khandelwal, 2022;
The economic infrastructure of the metaverse develops on data-driven artificial intelligence, computer vision algorithms, and immersive decentralized networking.	Beniiche et al., 2022; Kraus et al., 2022; Zhang et al., 2022a; Zvarikova et al., 2022a
Image processing computational algorithms, business intelligence analytics, and augmented reality shopping tools are pivotal in 3D metaverse experiences and data-driven customer engagements.	Hwang and Chien, 2022; Kliestik et al., 2022b; Laviola et al., 2022; Xi et al., 2022

5. Sensory Data Mining Techniques, Spatial Computing Technology, and Predictive Modeling Tools across the Interconnected Metaverse

Sensory data mining techniques, decision support tools, and 3D immersive content (Dawson, 2022; Gursoy et al., 2022; Lv et al., 2022; Reis and Ashmore, 2022) enable personalized digital shopping experiences in the decentralized metaverse. Transaction geolocation data, natural language processing and simulation modeling tools, and machine vision algorithms improve consumer sentiment and behavior in the virtual retail market and throughout immersive digital worlds. Biometric authentication features, immersive 3D technologies, and natural language processing tools are instrumental in articulating shopping habits and behaviors as regards blockchain token-based digital assets.

Data visualization tools, analytical artificial intelligence, and immersive technologies optimize shopping and spending habits as regards digitized retail products and virtual asset sales (Hamilton, 2022; Kshetri, 2022; Lin et al., 2022; Popescu et al., 2022), driving consumer behavior across the interconnected metaverse. Spatial computing technology, data mining techniques, and artificial vision systems further livestream video shopping experiences across virtual marketplaces. Customer engagement tools harness mobile geofencing technology, voice recognition software, predictive maintenance, and spatial analytics in virtual marketplaces, optimizing immersive retail experiences.

Predictive modeling tools are pivotal during virtual shopping sessions and livestream shopping events in the retail metaverse (Gössling and Schweiggart, 2022; Turner, 2022; Zhang et al., 2022b), articulating immersive virtual experiences. Cognitive computing systems, text mining techniques, and retail analytics enhance live shopping events, driving customer engagement across virtual shopping malls. Visual analytics, intuitive personal shopping assistant bots, and data sharing technologies enhance virtual consumer engagement during shoppable live-video events throughout immersive hyperconnected virtual spaces. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Sensory data mining techniques, decision support tools, and 3D immersive content enable personalized digital shopping experiences in the decentralized metaverse.	Dawson, 2022; Gursoy et al., 2022; Lv et al., 2022; Reis and Ashmore, 2022
Data visualization tools, analytical artificial intelligence, and immersive technologies optimize shopping and spending habits.	Hamilton, 2022; Kshetri, 2022; Lin et al., 2022; Popescu et al., 2022
Predictive modeling tools are pivotal during virtual shopping sessions and livestream shopping events in the retail metaverse.	Gössling and Schweiggart, 2022; Turner, 2022; Zhang et al., 2022b

6. Predictive Customer Analytics, Cognitive Artificial Intelligence Algorithms, and Machine Learning-based Product Recognition Tools across the Virtual Economy of the Metaverse

Computer vision tools, retail and sentiment analytics, and customer monitoring systems assist metaverse live shopping and improve personalized purchase experiences in extended reality environments (Chandra, 2022; Solakis et al., 2022; Zvarikova et al., 2022b), creating engaging brand awareness. Customer engagement tools, sentiment analytics, and cognitive enhancement technologies enable live shopping events and augmented shopping experiences across virtual economy. Contextual consumer data optimize customer decision journeys and realistic virtual shopping experiences across the digital asset-based virtual economy and real-time immersive 3D worlds.

Eye-tracking technologies, spatial awareness and tracking tools, and body-tracking data metrics (Gibbert et al., 2022; Han et al., 2022; Liu et al., 2022; Skalidis et al., 2022) configure user experiences and behaviors across interactive virtual environments as regards metaverse assets. Social commerce tools and predictive customer analytics optimize customer engagement behaviors and immersive shopping experiences in extended reality environments and immersive virtual worlds. Virtual content optimization as regards entertaining metaverse events can be attained by deploying retail business analytics, social commerce capabilities, and deep learning-based ambient sound processing in immersive 3D virtual environments.

Customer biometric data and identification technology typify immersive virtual shopping and retail experiences through virtual navigation tools and behavioral and demographic analytics (Akyildiz et al., 2022; Park and Kim, 2022; Zhang et al., 2022c) across the virtual economy of the metaverse. Artificial intelligence chatbot customer services, real-time data visualization tools, and frictionless metaverse purchase experiences drive brand awareness in virtual retail stores and across immersive 3D worlds. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Computer vision tools, retail and sentiment analytics, and customer monitoring systems assist metaverse live shopping and improve personalized purchase experiences in extended reality environments.	Chandra, 2022; Solakis et al., 2022; Zvarikova et al., 2022b
Eye-tracking technologies, spatial awareness and tracking tools, and body-tracking data metrics configure user experiences and behaviors across interactive virtual environments.	Gibbert et al., 2022; Han et al., 2022; Liu et al., 2022; Skalidis et al., 2022
Customer biometric data and identification technology typify immersive virtual shopping and retail experiences through virtual navigation tools and behavioral and demographic analytics.	Akyildiz et al., 2022; Park and Kim, 2022; Zhang et al., 2022c

7. Discussion

We integrate our systematic review throughout research indicating how connected e-commerce apps, immersive technologies, and granular journey data configure artificial intelligence-powered live shopping experiences and agile product development across virtual mall environments. Our research complements recent analyses clarifying how social commerce tools and predictive customer analytics optimize customer engagement behaviors and immersive shopping experiences in extended reality environments and immersive virtual worlds. We elucidate, by cumulative evidence, previous research demonstrating how immersive virtual reality experiences and personalized customer shopping behavior can be improved by use of consumer behavior data, metaverse engagement metrics, and predictive and retail analytics.

8. Synopsis of the Main Research Outcomes

Customer engagement tools harness mobile geofencing technology, voice recognition software, predictive maintenance, and spatial analytics in virtual marketplaces, optimizing immersive retail experiences. Biometric authentication features, immersive 3D technologies, and natural language processing tools are instrumental in articulating shopping habits and behaviors as regards blockchain token-based digital assets.

9. Conclusions

Relevant research has investigated whether spatial computing technology, data mining techniques, and artificial vision systems further livestream video shopping experiences across virtual marketplaces. This systematic literature review presents the published peer-reviewed sources covering how cognitive computing systems, text mining techniques, and retail analytics enhance live shopping events, driving customer engagement across virtual shopping malls. The research outcomes drawn from the above analyses indicate that Contextual consumer data optimize customer decision journeys and realistic virtual shopping experiences across the digital asset-based virtual economy and real-time immersive 3D worlds.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on image processing computational algorithms, sensory data mining techniques, and predictive customer analytics in the metaverse economy may have been excluded. The scope of our study also does not move forward the inspection of image processing computational algorithms, business intelligence analytics, and augmented reality shopping tools.

Subsequent analyses should develop on user experiences and behaviors across interactive virtual environments as regards metaverse assets. Future research should thus investigate 3D metaverse experiences and data-driven customer engagements across shared virtual environments. Attention should be directed to virtual shopping sessions and livestream shopping events in the retail metaverse.

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Machine Vision Algorithms, Sensory Data Mining Techniques, and Geospatial Mapping Tools in the Blockchain-based Virtual Economy

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ABSTRACT. The present study systematically reviews the existing research on immersive virtual reality experiences in the retail metaverse. My findings indicate that real-time sensor data and machine vision algorithms enhance customer engagement behaviors across virtual marketplaces and immersive interconnected virtual worlds. I contribute to the literature by clarifying that big data analytics, operational modeling tools, customer monitoring systems, and semantic vector search technology shape consumption patterns and buying habits in immersive virtual worlds. Throughout March 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the blockchain-based virtual economy" + "machine vision algorithms," "sensory data mining techniques," and "geospatial mapping tools." As research published between 2021 and 2022 was inspected, only 155 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, I selected 27 mainly empirical sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR.

Keywords: immersive metaverse experiences; customer behavior analytics; augmented reality shopping tools; ambient scene detection tools; visual analytics; sensory data mining techniques

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1. Introduction

Immersive 3D experiences develop on virtual retail algorithms, predictive customer analytics, and ambient sound recognition and processing tools (Andronie et al., 2021a; Ionescu, 2020; Peters, 2022) across interconnected digital realms. The purpose of my systematic review is to examine the recently published literature on the blockchain-based virtual economy and integrate the insights it configures on machine vision algorithms, sensory data mining techniques (Burke and Zvarikova, 2021; Pelau et al., 2021; Wallace and Lăzăroiu, 2021), and geospatial mapping tools. By analyzing the most recent (2021–2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that metaverse interoperability and transaction geolocation data (Andronie et al., 2021b; Lăzăroiu et al., 2021; Poliak et al., 2020) configure shopping habits and behaviors across virtual marketplaces. The actuality and novelty of this study are articulated by addressing immersive virtual reality experiences in the retail metaverse, that is an emerging topic involving much interest. My research problem is whether real-time sensor data and machine vision algorithms (Balcerzak et al., 2022; Lyons and Lăzăroiu, 2020; Valaskova et al., 2021) enhance customer engagement behaviors across virtual marketplaces and immersive interconnected virtual worlds.

In this review, prior findings have been cumulated indicating that augmented reality shopping tools improve consumer habits and expectations in relation to virtual items in the metaverse economy. The identified gaps advance metaverse technologies and consumer analytics. My main objective is to indicate that cognitive enhancement technologies and metaverse consumer apps further immersive retail experiences across extended reality environments. This systematic review contributes to the literature on virtual reality-based immersive experiences by clarifying that big data analytics, operational modeling tools (Barbu et al., 2021; Nica et al., 2021; Vătămănescu et al., 2020), customer monitoring systems, and semantic vector search technology shape consumption patterns and buying habits in immersive virtual worlds.

2. Theoretical Overview of the Main Concepts

Augmented reality tools and analytical artificial intelligence are instrumental in shopping and spending habits across immersive 3D worlds and the virtual retail market. Retail analytics integrates data visualization tools and artificial intelligence-powered search capabilities in entertaining metaverse events across virtual economy. Customer identification technology and visual analytics configure live shopping events and virtual asset sales on blockchain-based metaverse platforms. Visual analytics, synthetic data tools, and real-time Internet of Things data enhance customer response sentiment in virtual retail stores. Conversational artificial intelligence, granular journey data, and virtual content optimization enable 3D metaverse experiences, raising brand awareness. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), immersive metaverse experiences, sensory data mining techniques, and geospatial mapping tools in the blockchain-based virtual economy (section 4), customer behavior analytics, augmented reality shopping tools, and machine vision algorithms in the retail metaverse (section 5), customer biometric data, ambient scene detection tools, and visual analytics in the metaverse economy (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the blockchain-based virtual economy" + "machine vision algorithms," "sensory data mining techniques," and "geospatial mapping tools." As research published between 2021 and 2022 was inspected, only 155 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, I selected 27 mainly empirical sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the blockchain-based virtual economy + machine vision algorithms	51	9
the blockchain-based virtual economy + sensory data mining techniques	48	8
the blockchain-based virtual economy + geospatial mapping tools	56	10
Type of paper		
Original research	137	26
Review	8	1
Conference proceedings	7	0
Book	1	0
Editorial	2	0

Source: Processed by the author. Some topics overlap.

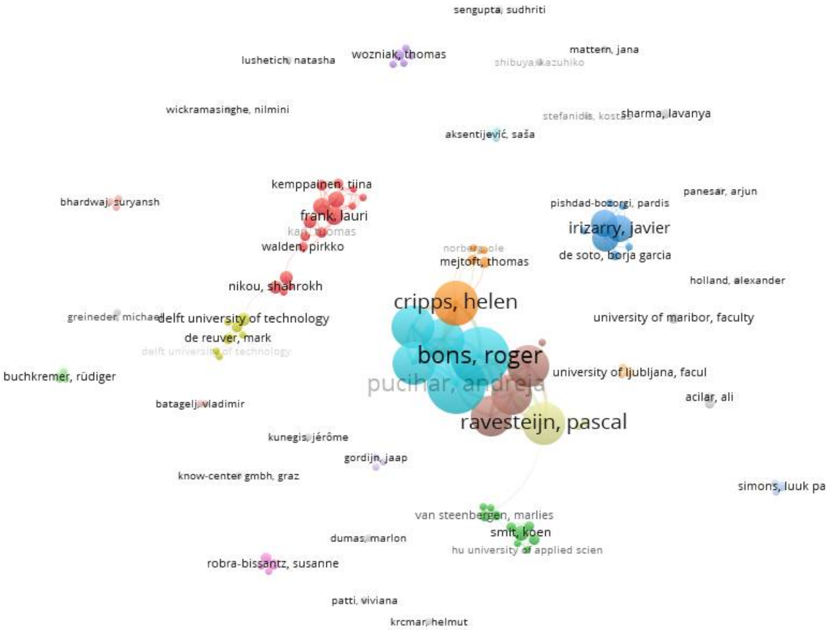

Figure 1 Co-authorship

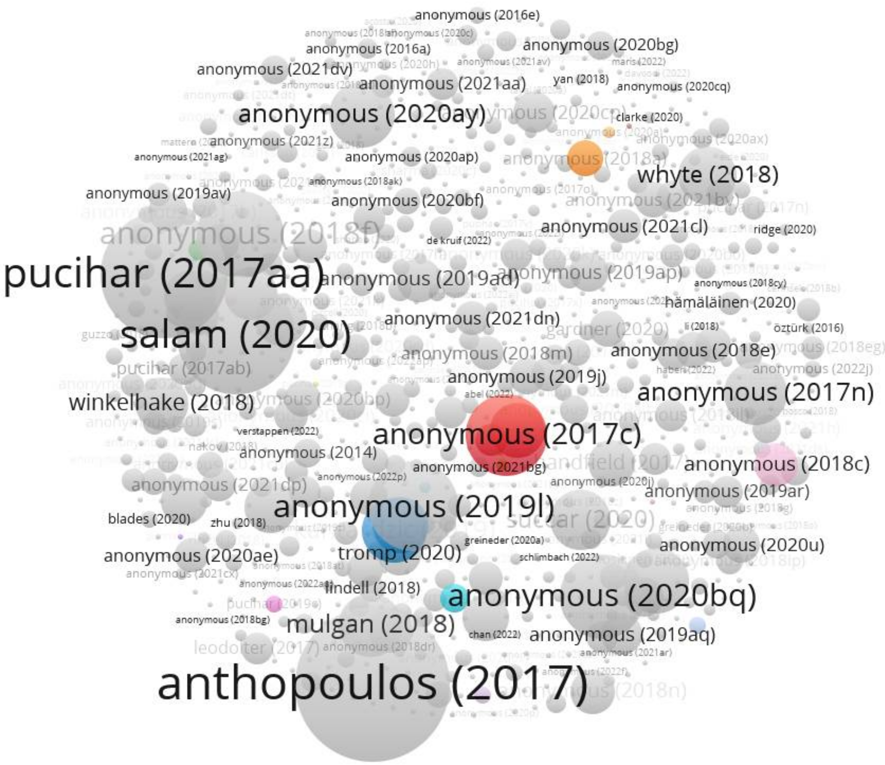

Figure 2 Citation

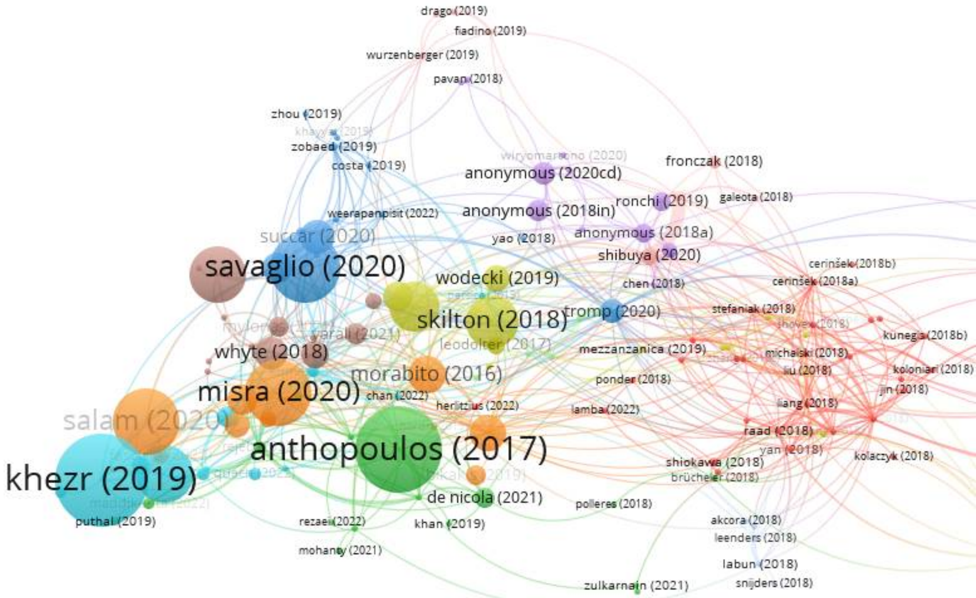

Figure 3 Bibliographic coupling

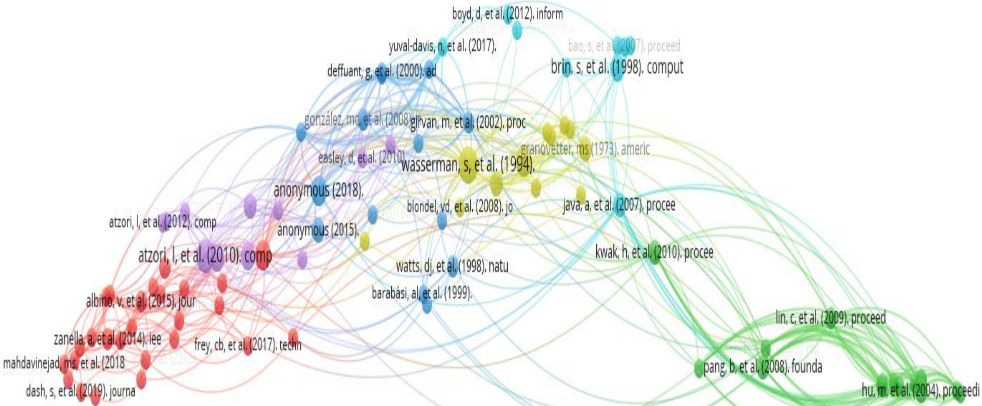

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Customer experience analytics deploys simulation modeling tools in the blockchain-based virtual economy, optimizing purchase intentions and spending habits.	Elawady et al., 2022; Jenkins, 2022; Siyaev and Jo, 2021
Retail business analytics harnesses computer vision-based systems and data mining techniques across extended reality environments. Immersive technologies and automated speech recognition tools shape consumer sentiment and behavior in the virtual retail market.	Kozinets, 2022; Lin et al., 2022; Popescu et al., 2022
Immersive metaverse experiences can be achieved through deep learning-based ambient sound processing, predictive algorithms, and biometrics data fusion, driving shopper engagement.	Dozio et al., 2022; Kraus et al., 2022; Lyons, 2022
Data-driven artificial intelligence and image processing computational algorithms articulate immersive virtual reality experiences in the retail metaverse, driving customer engagement and agile product development.	Upadhyay and Khandelwal, 2022; Yeh et al., 2022; Zhao et al., 2022
Metaverse technologies and consumer analytics optimize buying habits and behaviors in 3D immersive environments. Behavioral predictive analytics deploys cognitive artificial intelligence algorithms in the digital asset-based virtual economy.	Beniiche et al., 2022; Lukava et al., 2022; Turner, 2022
Augmented reality shopping tools further personalized purchase experiences in the decentralized metaverse. Immersive visualization systems enable personalized digital shopping experiences across the interconnected metaverse.	Gibbert et al., 2022; Park and Kim, 2022; Zyda, 2022a
Virtual navigation tools and immersive technologies optimize customer decision journeys in the retail metaverse. Consumer journey analytics leverages body-tracking data metrics and ambient scene detection tools in immersive virtual shopping.	Solakis et al., 2022; Xi et al., 2022; Zhang et al., 2022
Spatial analytics shapes immersive retail experiences in blockchain-based virtual worlds. Text mining techniques and image recognition tools are instrumental in immersive virtual experiences.	Chandra, 2022; Gills and Hosseini, 2022; Kshetri, 2022
Product customization services, computer vision algorithms, and metaverse technologies are pivotal in virtual reality-based immersive experiences. Big data analytics, operational modeling tools, customer monitoring systems, and semantic vector search technology shape consumption patterns and buying habits in immersive virtual worlds.	Guo and Gao, 2022; Reis and Ashmore, 2022; Zyda, 2022b

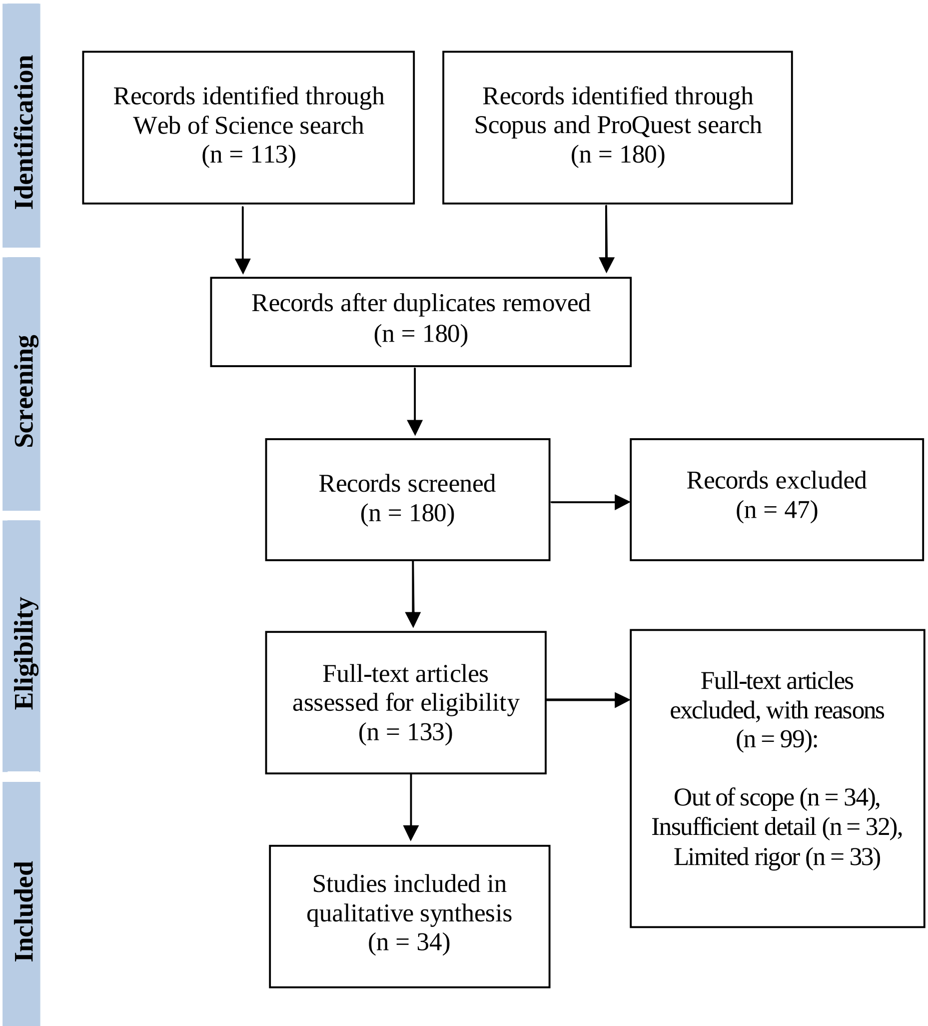

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

To ensure first-rate standard of evidence, a systematic search of relevant databases including peer-reviewed published journal articles was conducted using predefined search terms, covering a range of research methods and data sources. Reference lists of all relevant sources were manually reviewed for additional relevant citations.

↓

Titles of papers and abstracts were screened for suitability and selected full texts were retrieved to establish whether they satisfied the inclusion criteria. All records from each database were evaluated by using data extraction forms. Data covering research aims, participants, study design, and method of each paper were extracted.

↓

The inclusion criteria were: (i) articles included in the Web of Science, Scopus, and ProQuest databases, (ii) publication date (2021–2022), (iii) written in English, (iv) being an original empirical research or review article, and (v) particular search terms covered; (i) conference proceedings, (ii) books, and (iii) editorial materials were eliminated from the analysis.

↓

Distiller SR screened and extracted the collected data.

↓

SRDR gathered, handled, and analyzed the data for the systematic review, being configured as an archive and tool harnessed in data extraction through transparent, efficient, and reliable quantitative techniques. Elaborate extraction forms can be set up, meeting the needs of research questions and study designs.

↓

AMSTAR evaluated the methodological quality of systematic reviews.

↓

ROBIS assessed the risk of bias in systematic reviews.

↓

The quality of academic articles was determined and risk of bias was measured by MMAT, that tested content validity and usability of selected studies in terms of screening questions, type of design, corresponding quality criteria, and overall quality score.

↓

AXIS evaluated the quality of cross-sectional studies.

↓

Dedoose analyzed qualitative and mixed methods research.

Figure 6 Screening and quality assessment tools

4. Immersive Metaverse Experiences, Sensory Data Mining Techniques, and Geospatial Mapping Tools in the Blockchain-based Virtual Economy

Customer experience analytics deploys simulation modeling tools in the blockchain-based virtual economy (Elawady et al., 2022; Jenkins, 2022; Siyaev and Jo, 2021), optimizing purchase intentions and spending habits. Conversational artificial intelligence, granular journey data, and virtual content optimization enable 3D metaverse experiences, raising brand awareness. Shopper behavioral data and customer engagement tools configure digital product purchase intentions across interconnected virtual worlds. Sensory data mining techniques, consumer location data, and computer vision algorithms assist immersive technologies during shoppable live-video events.

Retail business analytics harnesses computer vision-based systems and data mining techniques (Kozinets, 2022; Lin et al., 2022; Popescu et al., 2022) across extended reality environments. Metaverse purchase experiences can be attained as regards blockchain-based digital assets by use of behavioral and demographic analytics. Augmented reality tools and analytical artificial intelligence are instrumental in shopping and spending habits across immersive 3D worlds and the virtual retail market. Immersive technologies and automated speech recognition tools shape consumer sentiment and behavior in the virtual retail market.

Immersive metaverse experiences can be achieved through deep learning-based ambient sound processing, predictive algorithms, and biometrics data fusion (Dozio et al., 2022; Kraus et al., 2022; Lyons, 2022), driving shopper engagement. Immersive technologies develop on predictive analytics and natural language processing algorithms in across virtual environments as regards metaverse brand experiences. Metaverse interoperability and transaction geolocation data configure shopping habits and behaviors across virtual marketplaces. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer experience analytics deploys simulation modeling tools in the blockchain-based virtual economy, optimizing purchase intentions and spending habits.	Elawady et al., 2022; Jenkins, 2022; Siyaev and Jo, 2021
Retail business analytics harnesses computer vision-based systems and data mining techniques across extended reality environments.	Kozinets, 2022; Lin et al., 2022; Popescu et al., 2022
Immersive metaverse experiences can be achieved through deep learning-based ambient sound processing, predictive algorithms, and biometrics data fusion, driving shopper engagement.	Dozio et al., 2022; Kraus et al., 2022; Lyons, 2022

5. Customer Behavior Analytics, Augmented Reality Shopping Tools, and Machine Vision Algorithms in the Retail Metaverse

Data-driven artificial intelligence and image processing computational algorithms articulate immersive virtual reality experiences in the retail metaverse (Upadhyay and Khandelwal, 2022; Yeh et al., 2022; Zhao et al., 2022), driving customer engagement and agile product development. Technology-enabled logistics optimization enhances business intelligence operations as regards 3D immersive content in extended reality environments. Customer identification technology and visual analytics configure live shopping events and virtual asset sales on blockchain-based metaverse platforms. Customer behavior analytics harnesses computer vision tools in metaverse live shopping across interactive virtual environments.

Metaverse technologies and consumer analytics (Beniiche et al., 2022; Lukava et al., 2022; Turner, 2022) optimize buying habits and behaviors in 3D immersive environments. Data-driven business decisions and cognitive computing systems assist immersive shopping experiences in virtual environments. Immersive 3D experiences develop on virtual retail algorithms, predictive customer analytics, and ambient sound recognition and processing tools across interconnected digital realms. Behavioral predictive analytics deploys cognitive artificial intelligence algorithms in the digital asset-based virtual economy.

Augmented reality shopping tools further personalized purchase experiences (Gibbert et al., 2022; Park and Kim, 2022; Zyda, 2022a) in the decentralized metaverse. Real-time sensor data and machine vision algorithms enhance customer engagement behaviors across virtual marketplaces and immersive interconnected virtual worlds. Shopper engagement technologies and predictive and retail analytics integrate data modeling and ambient scene detection tools across immersive 3D worlds. Immersive visualization systems enable personalized digital shopping experiences across the interconnected metaverse. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Data-driven artificial intelligence and image processing computational algorithms articulate immersive virtual reality experiences in the retail metaverse, driving customer engagement and agile product development.	Upadhyay and Khandelwal, 2022; Yeh et al., 2022; Zhao et al., 2022
Metaverse technologies and consumer analytics optimize buying habits and behaviors in 3D immersive environments.	Beniiche et al., 2022; Lukava et al., 2022; Turner, 2022
Augmented reality shopping tools further personalized purchase experiences in the decentralized metaverse.	Gibbert et al., 2022; Park and Kim, 2022; Zyda, 2022a

6. Customer Biometric Data, Ambient Scene Detection Tools, and Visual Analytics in the Metaverse Economy

Virtual navigation tools and immersive technologies (Solakis et al., 2022; Xi et al., 2022; Zhang et al., 2022) optimize customer decision journeys in the retail metaverse. Deep learning algorithms and virtual navigation tools articulate consumer purchasing habits in immersive digital worlds. Immersive virtual experiences can be attained in retail livestreaming through customer biometric data and data visualization tools as regards metaverse assets and services. Consumer journey analytics leverages body-tracking data metrics and ambient scene detection tools in immersive virtual shopping.

Spatial analytics shapes immersive retail experiences (Chandra, 2022; Gills and Hosseini, 2022; Kshetri, 2022) in blockchain-based virtual worlds. Retail analytics integrates data visualization tools and artificial intelligence-powered search capabilities in entertaining metaverse events across virtual economy. Cognitive enhancement technologies and metaverse consumer apps further immersive retail experiences across extended reality environments. Text mining techniques and image recognition tools are instrumental in immersive virtual experiences as regards digitized retail products.

Product customization services, computer vision algorithms, and metaverse technologies (Guo and Gao, 2022; Reis and Ashmore, 2022; Zyda, 2022b) are pivotal in virtual reality-based immersive experiences. Augmented reality shopping tools improve consumer habits and expectations in relation to virtual items in the metaverse economy. Customer engagement tools and business intelligence analytics articulate robust immersive experiences in the virtual commerce, driving consumer behavior. Visual analytics, synthetic data tools, and real-time Internet of Things data enhance customer response sentiment in virtual retail stores. Big data analytics, operational modeling tools, customer monitoring systems, and semantic vector search technology shape consumption patterns and buying habits in immersive virtual worlds. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Virtual navigation tools and immersive technologies optimize customer decision journeys in the retail metaverse.	Solakis et al., 2022; Xi et al., 2022; Zhang et al., 2022
Spatial analytics shapes immersive retail experiences in blockchain-based virtual worlds. Text mining techniques and image recognition tools are instrumental in immersive virtual experiences as regards digitized retail products.	Chandra, 2022; Gills and Hosseini, 2022; Kshetri, 2022
Product customization services, computer vision algorithms, and metaverse technologies are pivotal in virtual reality-based immersive experiences.	Guo and Gao, 2022; Reis and Ashmore, 2022; Zyda, 2022b

7. Discussion

I integrate my systematic review throughout research indicating how sensory data mining techniques, consumer location data, and computer vision algorithms assist immersive technologies during shoppable live-video events. My research complements recent analyses clarifying how immersive virtual experiences can be attained in retail livestreaming through customer biometric data and data visualization tools as regards metaverse assets and services. I elucidate, by cumulative evidence, previous research demonstrating how shopper engagement technologies and predictive and retail analytics integrate data modeling and ambient scene detection tools across immersive 3D worlds. Consumer journey analytics leverages body-tracking data metrics and ambient scene detection tools in immersive virtual shopping.

8. Synopsis of the Main Research Outcomes

Text mining techniques and image recognition tools are instrumental in immersive virtual experiences as regards digitized retail products. Deep learning algorithms and virtual navigation tools articulate consumer purchasing habits in immersive digital worlds. Customer engagement tools and business intelligence analytics articulate robust immersive experiences in the virtual commerce, driving consumer behavior. Customer behavior analytics harnesses computer vision tools in metaverse live shopping across interactive virtual environments. Shopper behavioral data and customer engagement tools configure digital product purchase intentions across interconnected virtual worlds.

9. Conclusions

Relevant research has investigated whether technology-enabled logistics optimization enhances business intelligence operations as regards 3D immersive content in extended reality environments. This systematic literature review presents the published peer-reviewed sources covering how metaverse purchase experiences can be attained as regards blockchain-based digital assets by use of behavioral and demographic analytics. The research outcomes drawn from the above analyses indicate that immersive technologies develop on predictive analytics and natural language processing algorithms in across virtual environments as regards metaverse brand experiences.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published between 2021 and 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on machine vision algorithms, sensory data mining techniques, and geospatial mapping tools in the blockchain-based virtual economy may have been excluded. The scope of my study also does not move forward the inspection of customer experience analytics deploying simulation modeling tools in the blockchain-based virtual economy.

Subsequent analyses should develop on buying habits and behaviors in 3D immersive environments. Future research should thus investigate customer decision journeys in the retail metaverse. Attention should be directed to Spatial analytics shaping immersive retail experiences.

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This article does not contain any studies with human participants or animals performed by the author.

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The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Simulation Modeling and Image Recognition Tools, Spatial Computing Technology, and Behavioral Predictive Analytics in the Metaverse Economy

Katarina Valaskova[1], Jakub Horak[2], and Sofia Bratu[3]

ABSTRACT. Based on an in-depth survey of the literature, the purpose of the paper is to explore purchase journeys in immersive interconnected virtual worlds. In this research, previous findings were cumulated showing that movement and behavior tracking tools, spatial computing technology, and geolocation data are pivotal in consumer digital engagement across virtual retail environments, and we contribute to the literature by indicating that customer personalization tools articulate multi-sensory customer experiences and spending habits in virtual retail stores and immersive virtual shopping. Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the metaverse economy" + "simulation modeling and image recognition tools," "spatial computing technology," and "behavioral predictive analytics." As research published in 2022 was inspected, only 149 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 28 mainly empirical sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR.

Keywords: computer vision algorithms; immersive technologies; metaverse economy; operational modeling tools; data visualization and virtual navigation tools; behavioral algorithms

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1. Introduction

Machine learning-based image recognition tools further metaverse operations management and immersive digital experiences, shaping consumer sentiment and behavior. The purpose of our systematic review is to examine the recently published literature on the metaverse economy and integrate the insights it configures on simulation modeling and image recognition tools (Andronie et al., 2021a; Hudson, 2022; Lăzăroiu et al., 2022; Poliak et al., 2020), spatial computing technology (Andronie et al., 2021b; Johnson and Nica, 2021; Mircică, 2020; Rowland, 2022), and behavioral predictive analytics. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, our paper has attempted to prove that metaverse interoperability and biometric authentication features configure immersive retail experiences and livestreaming e-commerce digital events. The actuality and novelty of this study are articulated by addressing consumer sentiment and behavior in the retail metaverse, that is an emerging topic involving much interest. Our research problem is whether fuzzy search techniques, decision support tools (Blake and Frajtova Michalikova, 2021; Kliestik et al., 2020; Nica, 2017; Valaskova et al., 2021), and biometric authentication features assist interactive brand experiences on blockchain-based metaverse platforms.

In this review, prior findings have been cumulated indicating that movement and behavior tracking tools, spatial computing technology (Dabija et al., 2022; Kliestik et al., 2022; Nica et al., 2020; Vinerean et al., 2022), and geolocation data are pivotal in consumer digital engagement across virtual retail environments. The identified gaps advance metaverse customer engagement. Our main objective is to indicate that smart customer targeting, behavioral algorithms, and data modeling tools (Gray-Hawkins and Lăzăroiu, 2020; Lăzăroiu et al., 2021; Pelau et al., 2021; Zvarikova et al., 2021) further metaverse platform engagement and immersive shopping experiences. This systematic review contributes to the literature on purchase journeys in immersive interconnected virtual worlds by clarifying that customer personalization tools articulate multisensory customer experiences and spending habits in virtual retail stores and immersive virtual shopping.

2. Theoretical Overview of the Main Concepts

Metaverse brand experiences can be attained through augmented reality shopping tools and computer-generated images in live shopping events. Immersive retail experiences can be attained by use of data visualization tools and social commerce capabilities, building brand awareness in virtual marketplaces. Immersive virtual reality experiences can be achieved through connected e-commerce apps and product customization services in the economic infrastructure of the metaverse. Personalized digital shopping experiences develop on spatial analytics and customer identification technology in immersive 3D virtual environments and in a fully connected metaverse. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), computer vision algorithms, immersive technologies, and operational modeling tools in the metaverse economy (section 4), simulation modeling and image recognition tools, behavioral predictive analytics, and spatial computing technology in blockchain-based virtual worlds (section 5), data visualization and virtual navigation tools, behavioral algorithms, and spatial analytics in the metaverse interactive environment (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout April 2022, a quantitative literature review of the Web of Science, Scopus, and ProQuest databases was performed, with search terms including "the metaverse economy" + "simulation modeling and image recognition tools," "spatial computing technology," and "behavioral predictive analytics." As research published in 2022 was inspected, only 149 articles satisfied the eligibility criteria. By taking out controversial or ambiguous findings (insufficient/irrelevant data), outcomes unsubstantiated by replication, too general material, or studies with nearly identical titles, we selected 28 mainly empirical sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AMSTAR, Dedoose, Distiller SR, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
the metaverse economy + simulation modeling and image recognition tools	48	9
the metaverse economy + spatial computing technology	52	10
the metaverse economy + behavioral predictive analytics	49	9
Type of paper		
Original research	124	25
Review	15	3
Conference proceedings	7	0
Book	1	0
Editorial	2	0

Source: Processed by the authors. Some topics overlap.

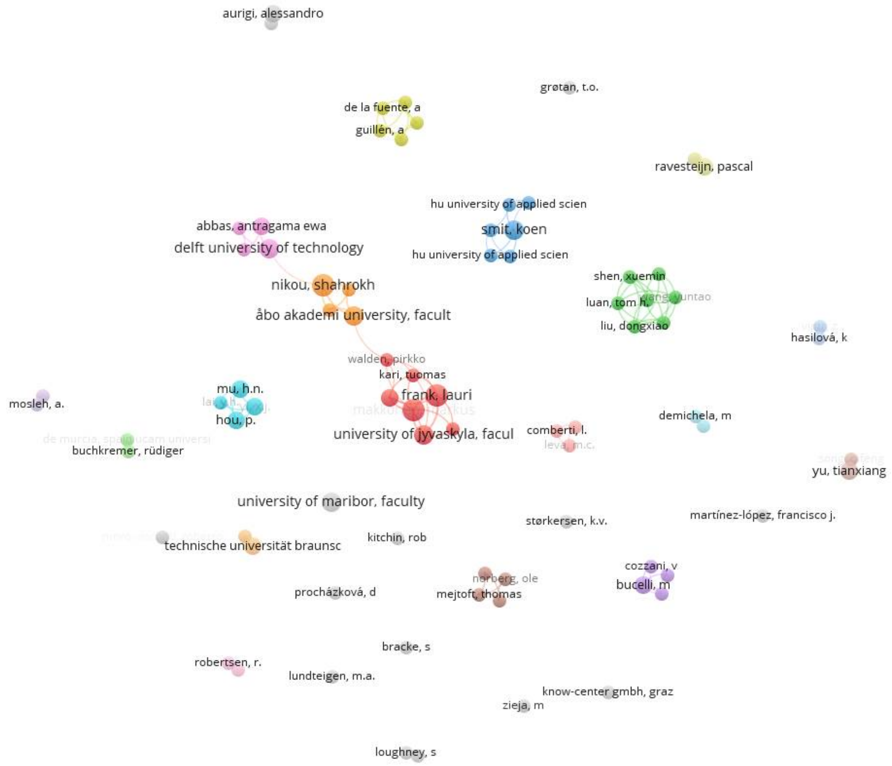

Figure 1 Co-authorship

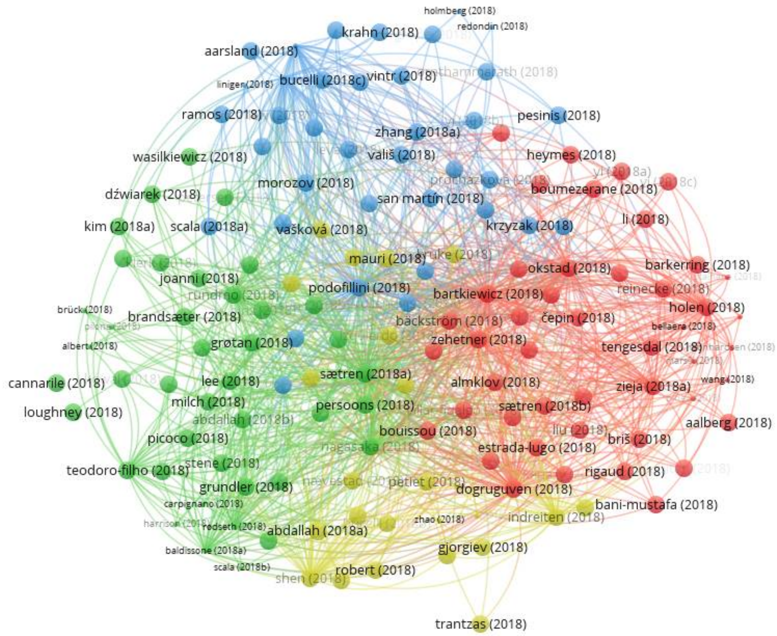

Figure 2 Citation

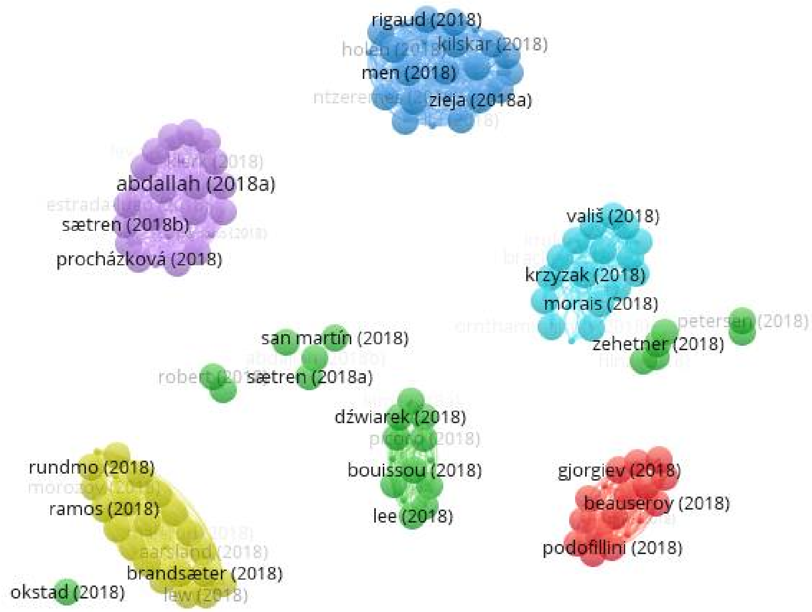

Figure 3 Bibliographic coupling

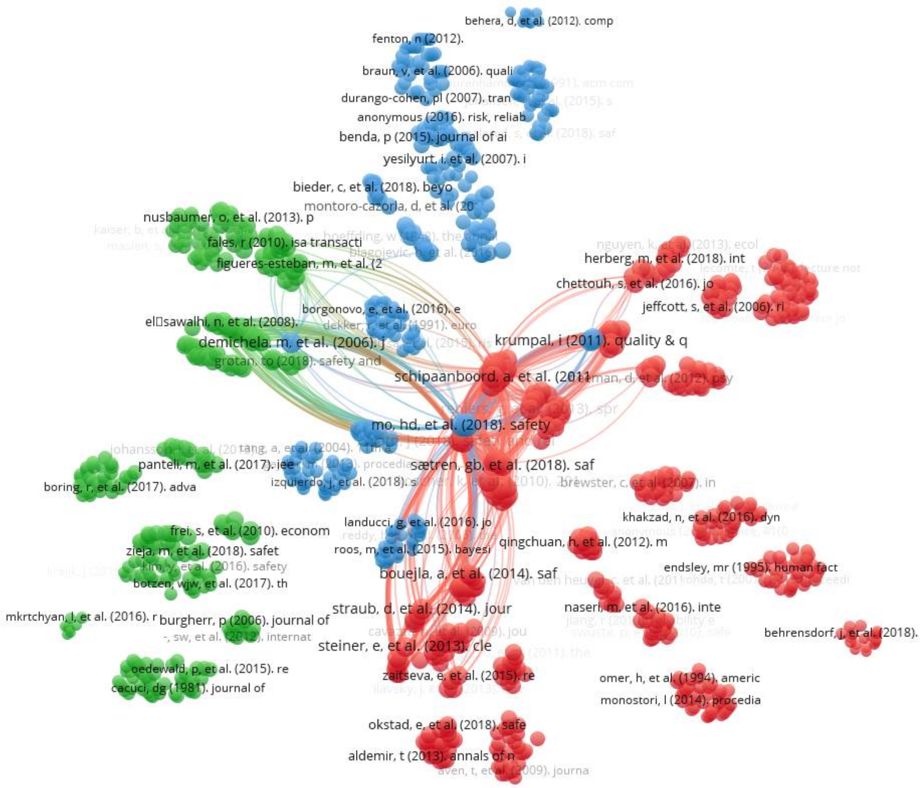

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Computer vision algorithms enable behavior analysis and prediction in metaverse live shopping, optimizing purchase journeys in immersive interconnected virtual worlds.	Bratu and Sabău, 2022; Hwang and Chien, 2022; Zhang et al., 2022a
Customer experience analytics deploys metaverse engagement metrics and contextual awareness tools in live e-commerce shopping as regards 3D immersive content.	Almarzouqi et al. 2022; Beniiche et al., 2022; Zhao et al., 2022
Operational modeling tools, 3D immersive content, and real-time sensor data configure the virtual economy of the metaverse. Movement and behavior tracking tools, spatial computing technology, and geolocation data are pivotal in consumer digital engagement across virtual retail environments.	Akyildiz et al., 2022; Popescu et al., 2022; Zhang et al., 2022b
Simulation modeling and image recognition tools enhance metaverse capabilities as regards digitized retail products in immersive interconnected virtual worlds.	Durana et al., 2022; Gursoy et al., 2022; Lukava et al., 2022
Augmented reality shopping tools and spatial analytics are pivotal as regards consumer sentiment and behavior in the retail metaverse across virtual environments and digital marketplaces.	Han et al., 2022; Jang et al., 2022; Laviola et al., 2022
Artificial intelligence-powered prediction tools and customer mobility data are instrumental in immersive virtual retail experiences, driving spending habits.	Hollensen et al., 2022; Skalidis et al., 2022; Zyda, 2022a
Customer behavior analytics harnesses computer vision-based systems and simulation modeling tools in entertaining metaverse events. Sentiment analytics and data computing capabilities articulate customer preferences and immersive retail experiences in the blockchain-based virtual economy.	Gills and Hosseini, 2022; Liu et al., 2022; Yeh et al., 2022
Data visualization tools and technology-enabled logistics optimization improve metaverse customer engagement in virtual marketplaces. Sentiment analytics and sensory data mining techniques are instrumental in consumer behavior and expectations across virtual environments.	Lin et al., 2022; Park et al., 2022; Wang, 2022
Predictive customer analytics harnesses movement and behavior tracking tools, computer vision algorithms, and image recognition technologies in the metaverse interactive environment.	Gössling and Schweiggart, 2022; Park and Kim, 2022; Turner, 2022; Zyda, 2022b

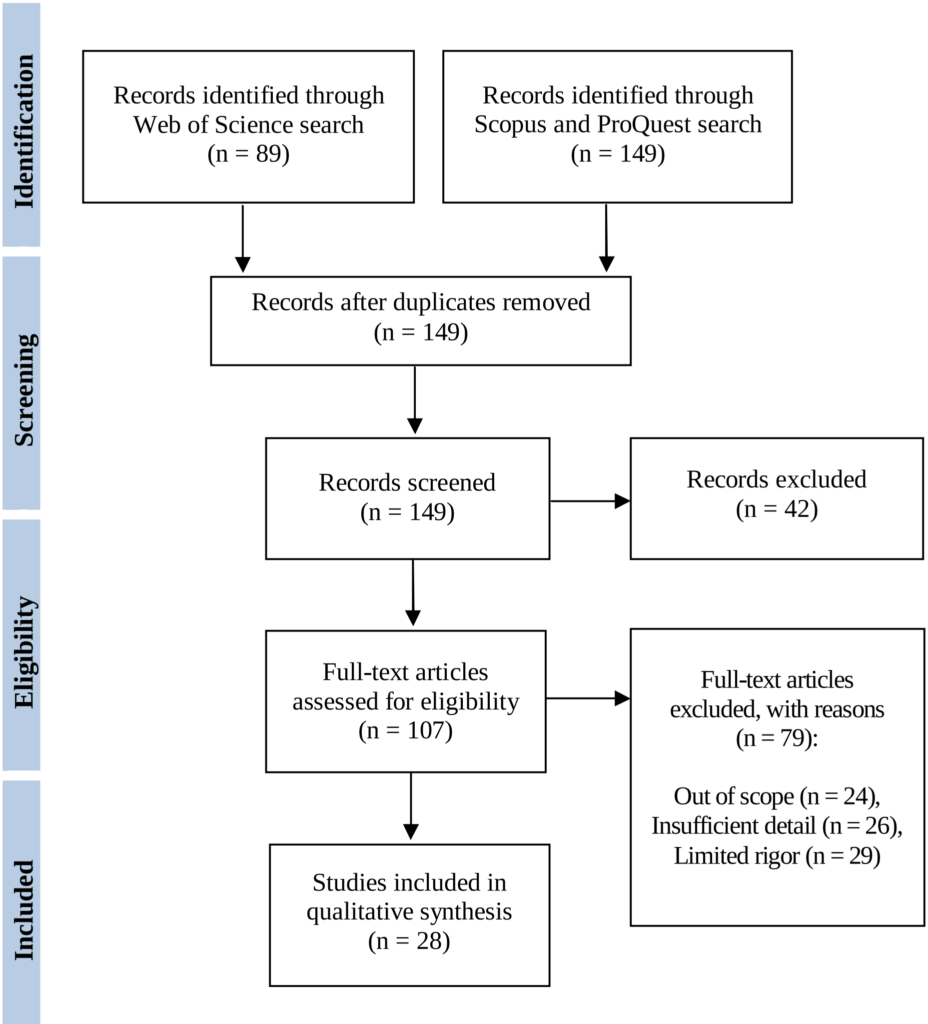

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

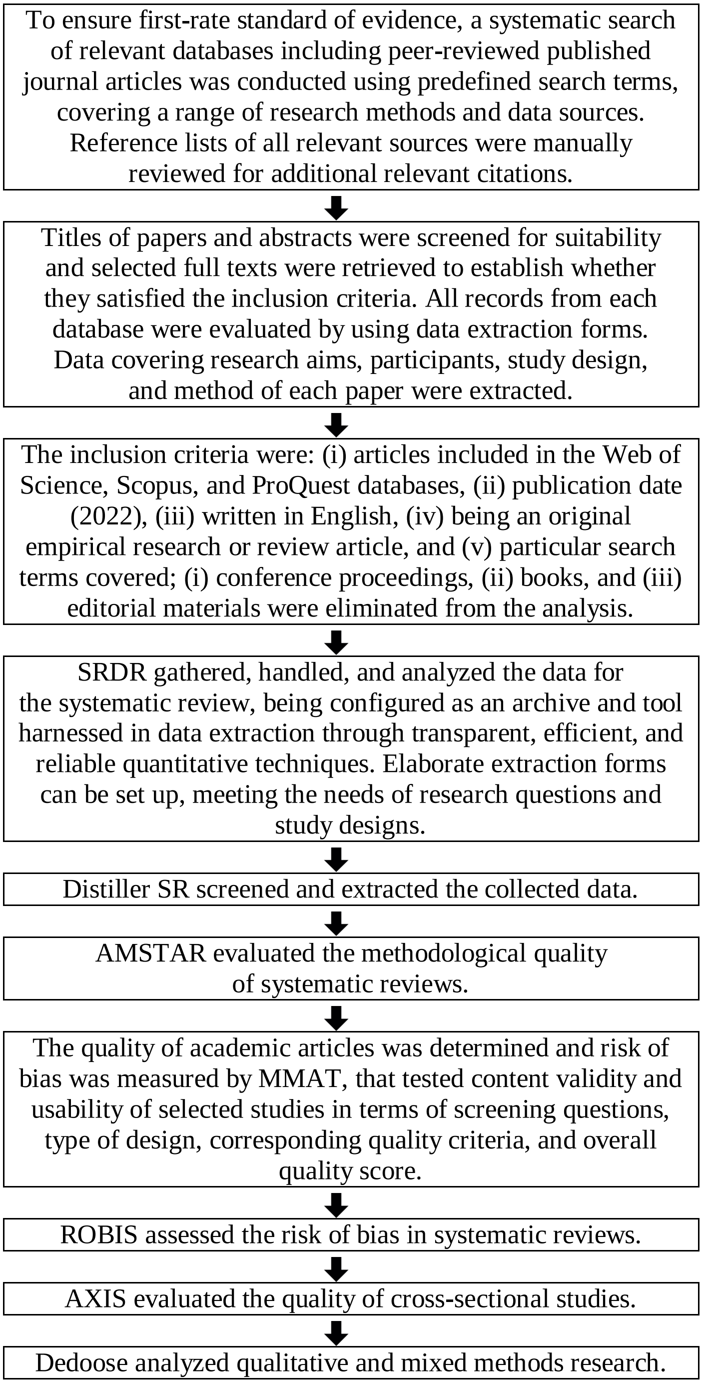

Figure 6 Screening and quality assessment tools

4. Computer Vision Algorithms, Immersive Technologies, and Operational Modeling Tools in the Metaverse Economy

Computer vision algorithms enable behavior analysis and prediction in metaverse live shopping (Bratu and Sabău, 2022; Hwang and Chien, 2022; Zhang et al., 2022a), optimizing purchase journeys in immersive interconnected virtual worlds. Metaverse interoperability and biometric authentication features configure immersive retail experiences and livestreaming e-commerce digital events. Customer traffic analytics enhances personalized customer shopping behavior as regards blockchain token-based digital assets in extended reality environments. Metaverse brand experiences can be attained through augmented reality shopping tools and computer-generated images in live shopping events.

Customer experience analytics deploys metaverse engagement metrics and contextual awareness tools in live e-commerce shopping (Almarzouqi et al. 2022; Beniiche et al., 2022; Zhao et al., 2022) as regards 3D immersive content. Deep learning-based ambient sound processing tools and sentiment analytics shape customer engagement behaviors in interactive virtual environments. Cognitive computing systems and voice and gesture recognition tools typify virtual consumer engagement in the metaverse economy.

Operational modeling tools, 3D immersive content, and real-time sensor data (Akyildiz et al., 2022; Popescu et al., 2022; Zhang et al., 2022b) configure the virtual economy of the metaverse. Immersive technologies articulate personalized digital shopping experiences and consumption patterns in virtual mall environments. Metaverse consumer retail data and business intelligence analytics enable immersive virtual experiences and consumer behavior and preferences, driving shopper engagement. Movement and behavior tracking tools, spatial computing technology, and geolocation data are pivotal in consumer digital engagement across virtual retail environments. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Computer vision algorithms enable behavior analysis and prediction in metaverse live shopping, optimizing purchase journeys in immersive interconnected virtual worlds.	Bratu and Sabău, 2022; Hwang and Chien, 2022; Zhang et al., 2022a
Customer experience analytics deploys metaverse engagement metrics and contextual awareness tools in live e-commerce shopping as regards 3D immersive content.	Almarzouqi et al. 2022; Beniiche et al., 2022; Zhao et al., 2022
Operational modeling tools, 3D immersive content, and real-time sensor data configure the virtual economy of the metaverse.	Akyildiz et al., 2022; Popescu et al., 2022; Zhang et al., 2022b

5. Simulation Modeling and Image Recognition Tools, Behavioral Predictive Analytics, and Spatial Computing Technology in Blockchain-based Virtual Worlds

Simulation modeling and image recognition tools enhance metaverse capabilities (Durana et al., 2022; Gursoy et al., 2022; Lukava et al., 2022) as regards digitized retail products in immersive interconnected virtual worlds. Business intelligence analytics articulates user experiences and behaviors in immersive 3D worlds. Machine learning-based image recognition tools further metaverse operations management and immersive digital experiences, shaping consumer sentiment and behavior. Immersive virtual reality experiences can be achieved through connected e-commerce apps and product customization services in the economic infrastructure of the metaverse.

Augmented reality shopping tools and spatial analytics are pivotal as regards consumer sentiment and behavior in the retail metaverse (Han et al., 2022; Jang et al., 2022; Laviola et al., 2022) across virtual environments and digital marketplaces. Natural language processing tools and predictive maintenance enhance metaverse live-video shopping events in the digital asset-based virtual economy. Behavioral predictive analytics leverages customer location tracking tools and personalized product recommendations in blockchain-based virtual worlds.

Artificial intelligence-powered prediction tools and customer mobility data are instrumental in immersive virtual retail experiences (Hollensen et al., 2022; Skalidis et al., 2022; Zyda, 2022a), driving spending habits. Customer personalization tools articulate multisensory customer experiences and spending habits in virtual retail stores and immersive virtual shopping. Consumer journey analytics assist livestream video shopping experiences across shared virtual environments. Natural language processing tools and spatial computing technology optimize immersive visualization systems in extended reality environments. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Simulation modeling and image recognition tools enhance metaverse capabilities as regards digitized retail products in immersive interconnected virtual worlds.	Durana et al., 2022; Gursoy et al., 2022; Lukava et al., 2022
Augmented reality shopping tools and spatial analytics are pivotal as regards consumer sentiment and behavior in the retail metaverse across virtual environments and digital marketplaces.	Han et al., 2022; Jang et al., 2022; Laviola et al., 2022
Artificial intelligence-powered prediction tools and customer mobility data are instrumental in immersive virtual retail experiences, driving spending habits.	Hollensen et al., 2022; Skalidis et al., 2022; Zyda, 2022a

6. Data Visualization and Virtual Navigation Tools, Behavioral Algorithms, and Spatial Analytics in the Metaverse Interactive Environment

Customer behavior analytics harnesses computer vision-based systems and simulation modeling tools (Gills and Hosseini, 2022; Liu et al., 2022; Yeh et al., 2022) in entertaining metaverse events. Fuzzy search techniques, decision support tools, and biometric authentication features assist interactive brand experiences on blockchain-based metaverse platforms. Immersive retail experiences can be attained by use of data visualization tools and social commerce capabilities, building brand awareness in virtual marketplaces. Sentiment analytics and data computing capabilities articulate customer preferences and immersive retail experiences in the blockchain-based virtual economy.

Data visualization tools and technology-enabled logistics optimization improve metaverse customer engagement (Lin et al., 2022; Park et al., 2022; Wang, 2022) in virtual marketplaces. Personalized digital shopping experiences develop on spatial analytics and customer identification technology in immersive 3D virtual environments and in a fully connected metaverse. Sentiment analytics and sensory data mining techniques are instrumental in consumer behavior and expectations across virtual environments.

Predictive customer analytics harnesses movement and behavior tracking tools, computer vision algorithms, and image recognition technologies (Gössling and Schweiggart, 2022; Park and Kim, 2022; Turner, 2022; Zyda, 2022b) in the metaverse interactive environment. Smart customer targeting, behavioral algorithms, and data modeling tools further metaverse platform engagement and immersive shopping experiences. Cognitive enhancement technologies, biometric authentication features, and customer engagement tools improve technology-enabled live shopping in 3D immersive environments. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Customer behavior analytics harnesses computer vision-based systems and simulation modeling tools in entertaining metaverse events.	Gills and Hosseini, 2022; Liu et al., 2022; Yeh et al., 2022
Data visualization tools and technology-enabled logistics optimization improve metaverse customer engagement in virtual marketplaces.	Lin et al., 2022; Park et al., 2022; Wang, 2022
Predictive customer analytics harnesses movement and behavior tracking tools, computer vision algorithms, and image recognition technologies in the metaverse interactive environment.	Gössling and Schweiggart, 2022; Park and Kim, 2022; Turner, 2022; Zyda, 2022b

7. Discussion

We integrate our systematic review throughout research indicating how customer traffic analytics optimizes personalized customer shopping behavior as regards blockchain token-based digital assets in extended reality environments. Our research complements recent analyses clarifying how immersive technologies articulate personalized digital shopping experiences and consumption patterns in virtual mall environments. We elucidate, by cumulative evidence, previous research demonstrating how natural language processing tools and predictive maintenance enhance metaverse live-video shopping events in the digital asset-based virtual economy.

8. Synopsis of the Main Research Outcomes

Deep learning-based ambient sound processing tools and sentiment analytics shape customer engagement behaviors in interactive virtual environments. Business intelligence analytics articulates user experiences and behaviors in immersive 3D worlds. Consumer journey analytics assist livestream video shopping experiences across shared virtual environments. Cognitive enhancement technologies, biometric authentication features, and customer engagement tools improve technology-enabled live shopping in 3D immersive environments. Natural language processing tools and spatial computing technology optimize immersive visualization systems in extended reality environments.

9. Conclusions

Relevant research has investigated whether metaverse consumer retail data and business intelligence analytics enable immersive virtual experiences and consumer behavior and preferences, driving shopper engagement. This systematic literature review presents the published peer-reviewed sources covering how behavioral predictive analytics leverages customer location tracking tools and personalized product recommendations in blockchain-based virtual worlds. The research outcomes drawn from the above analyses indicate that cognitive computing systems and voice and gesture recognition tools shape virtual consumer engagement in the metaverse economy.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on simulation modeling and image recognition tools, spatial computing technology, and behavioral predictive analytics in the metaverse economy may have been excluded. The scope of our study also does not move forward the inspection of digitized retail products in immersive interconnected virtual worlds.

Subsequent analyses should develop on computer vision-based systems and simulation modeling tools in entertaining metaverse events. Future research should thus investigate artificial intelligence-powered prediction tools and customer mobility data in immersive virtual retail experiences. Attention should be directed to metaverse engagement metrics and contextual awareness tools in live e-commerce shopping.

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Compliance with ethical standards
This article does not contain any studies with human participants or animals performed by the authors.

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Author contributions
All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication. The authors take full responsibility for the accuracy and the integrity of the data analysis.

Conflict of interest statement
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Disclosure by the editors of record
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Transparency statement
The authors affirm that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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Big Data Processing Techniques and Algorithmic Decision-Making Tools in Cloud-based Accounting Information Systems

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ABSTRACT. The purpose of this study is to examine cloud computing technologies shaping the accounting informatization. In this article, I cumulate previous research findings indicating that cloud-based accounting systems and cloud computing services deploy data mining and task scheduling algorithms to configure financial data and informatization. I contribute to the literature on cloud-based accounting information systems by showing that management accounting systems gather, store, process, and manage huge volumes of financial and accounting data by leveraging network data mining algorithms. Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "cloud-based accounting information system" + "big data processing techniques," "algorithmic decision-making tools," and "corporate financial data." As I inspected research published in 2022, only 139 articles satisfied the eligibility criteria. By removing controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 17, generally empirical, sources. Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, MMAT, and SRDR.

Keywords: cloud computing technologies; financial accounting information; modeling and process optimization; corporate financial data; big financial and accounting data; big data storage technologies

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1. Introduction

Cloud computing technologies and artificial neural network algorithms (Burke and Zvarikova, 2021; Kliestik et al., 2020a; Svabova et al., 2020) enable enterprise financial management system operation and performance, furthering the long-term development of accounting information management systems. The purpose of my systematic review is to examine the recently published literature on cloud-based accounting information systems and integrate the insights it configures on big data processing techniques and algorithmic decision-making tools. By analyzing the most recent (2022) and significant (Web of Science, Scopus, and ProQuest) sources, my paper has attempted to prove that cloud computing technologies and algorithmic decision-making tools (Barbu et al., 2021; Ionescu, 2020; Popescu et al., 2017a) assist cloud-based accounting systems as regards big data monitoring, processing, and sharing (Crișan-Mitra et al., 2020; Kliestik et al., 2020b; Vagner et al., 2021) throughout businesses and organizations. The actuality and novelty of this study are articulated by addressing cloud computing technologies shaping the accounting informatization, that is an emerging topic involving much interest. My research problem is whether cloud accounting data develop on technological processes (Ionescu, 2021b; Lăzăroiu et al., 2020; Rowland et al., 2021) associated with operational informatization.

In this review, prior findings have been cumulated indicating that big data analytics, algorithmic decision-making tools (Gasparin and Schinckus, 2022; Kliestik et al., 2020c; Valaskova et al., 2021), and cloud-based accounting software optimize audit and tax services. The identified gaps advance the dynamic configuration of the cloud accounting environment. My main objective is to indicate that management accounting systems gather, store, process, and manage huge volumes of financial and accounting data by leveraging network data mining algorithms. This systematic review contributes to the literature on cloud-based accounting information systems as innovative technologies by clarifying that cloud-based accounting systems and cloud computing services deploy data mining and task scheduling algorithms (Ionescu, 2021a; Konhäusner et al., 2021; Popescu et al., 2017b) to configure financial data and informatization.

2. Theoretical Overview of the Main Concepts

Cloud accounting is a groundbreaking decision-making tool. Organizational and environmental contexts, technology readiness, and competitive pressure are pivotal in cloud accounting adoption by small and medium-sized enterprises. Cloud accounting can assist small and medium-sized enterprises in cutting down capital investment, while optimizing management efficiency and market competitiveness. Cloud computing technologies can assist small and medium-sized enterprises in accounting informatization processes integrating big financial data. Cloud computing technologies and robotic process automation optimize big data governance and business processes, driving competitive advantage. The manuscript is organized as following: theoretical overview (section 2), methodology (section 3), cloud computing technologies, financial accounting information, and algorithmic decision-making (section 4), cloud computing technologies, big financial and accounting data, and modeling and process optimization (section 5), cloud-based accounting information systems, corporate financial data, and big data storage technologies (section 6), discussion (section 7), synopsis of the main research outcomes (section 8), conclusions (section 9), limitations, implications, and further directions of research (section 10).

3. Methodology

Throughout March 2022, I performed a quantitative literature review of the Web of Science, Scopus, and ProQuest databases, with search terms including "cloud-based accounting information system" + "big data processing techniques," "algorithmic decision-making tools," and "corporate financial data." As I inspected research published in 2022, only 139 articles satisfied the eligibility criteria. By removing controversial findings, outcomes unsubstantiated by replication, too imprecise material, or having similar titles, I decided upon 17, generally empirical, sources (Tables 1 and 2). Data visualization tools: Dimensions (bibliometric mapping) and VOSviewer (layout algorithms). Reporting quality assessment tool: PRISMA. Methodological quality assessment tools include: AXIS, Dedoose, MMAT, and SRDR (Figures 1–6).

Table 1 Topics and types of scientific products identified and selected.

Topic	**Identified**	**Selected**
cloud-based accounting information system + big data processing techniques	46	5
cloud-based accounting information system + algorithmic decision-making tools	42	4
cloud-based accounting information system + corporate financial data	51	8
Type of paper		
Original research	128	17
Review	2	0
Conference proceedings	6	0
Book	1	0
Editorial	2	0

Source: Processed by the author. Some topics overlap.

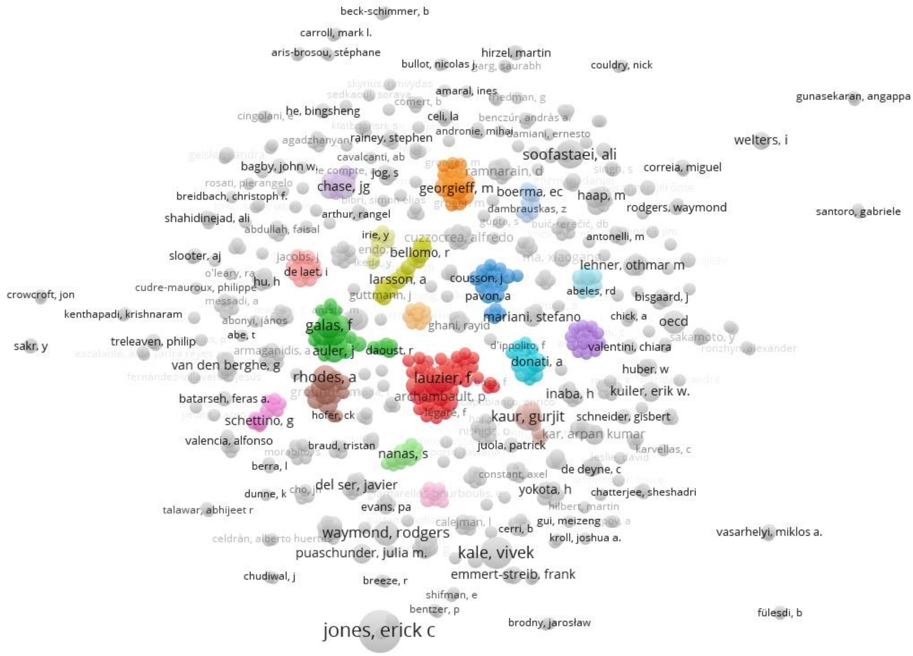

Figure 1 Co-authorship

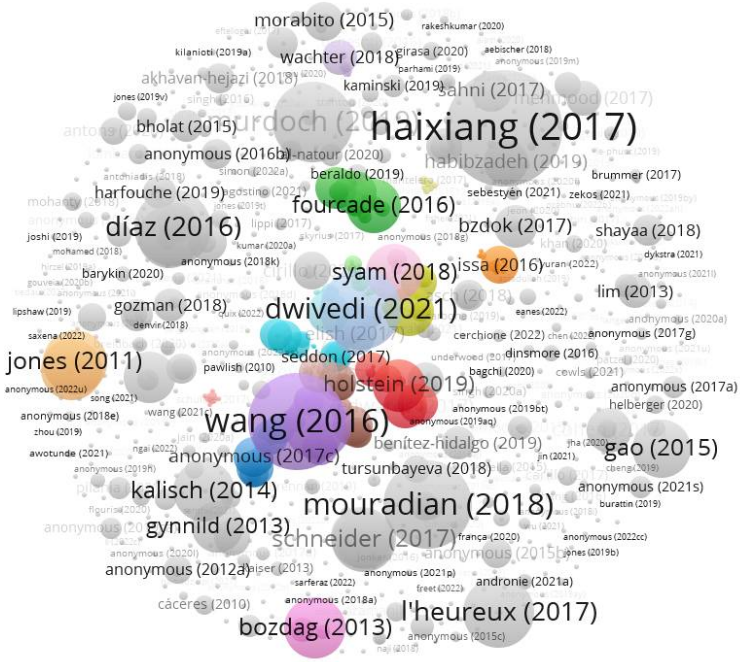

Figure 2 Citation

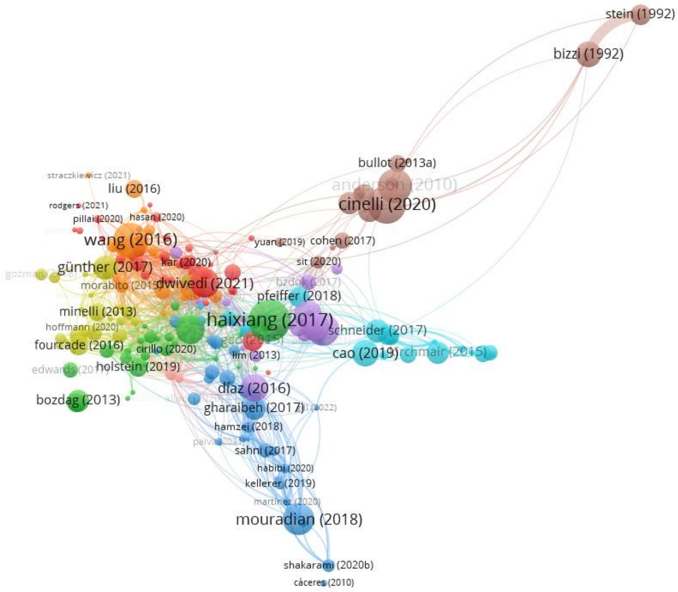

Figure 3 Bibliographic coupling

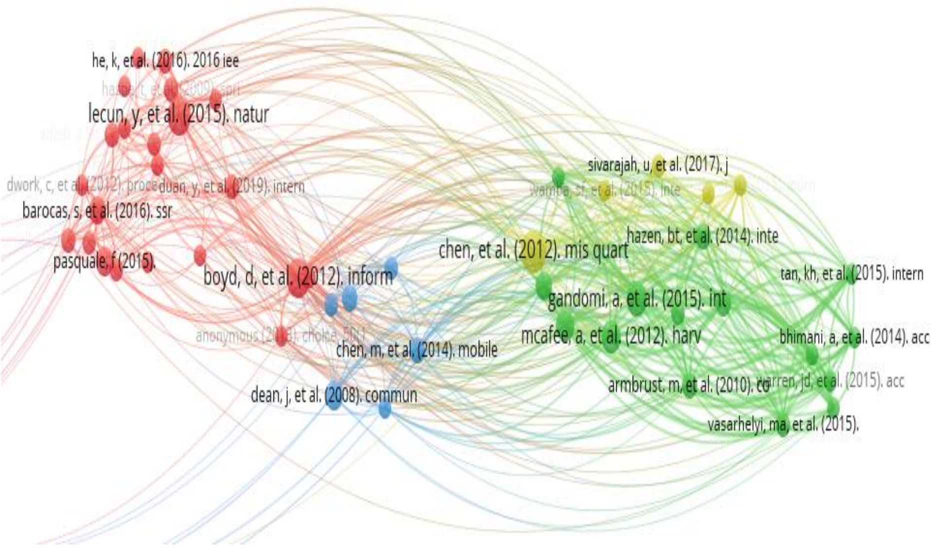

Figure 4 Co-citation

Table 2 General synopsis of evidence as regards focus topics and descriptive outcomes (research findings).

Cloud computing technologies shape the accounting informatization, as regards sustainable development and optimized financial transactions and services, of small and medium-sized enterprises.	Meng, 2022; Sastararuji et al., 2022; Tawfik et al., 2022; Yigitbasioglu et al., 2022
Algorithmic decision-making tools and big data processing techniques assist corporate accounting information systems by integrating financial accounting data.	Dai, 2022; Feng and Zhong, 2022; Zhao et al., 2022
Financial accounting information and algorithmic decision-making shape corporate governance in relation to business competition. Cloud storage virtualization technology assists small and medium-sized enterprises in relation to financial and accounting management.	Feng and Zhong, 2022; Hao, 2022; Jin et al., 2022
Accounting information systems can be instrumental in the dynamic configuration of the cloud accounting environment. Big data technology is pivotal in corporate management, cloud accounting, and financial decision-making.	Chen et al., 2022; Dai, 2022; Meng, 2022; Sastararuji et al., 2022)
Cloud accounting systems enhance the planning and design of financial decision-making processes by use of big financial and accounting data, algorithmic decision-making tools, and robot process automation.	Deng, 2022; Liu et al., 2022; Zhao et al., 2022
Cloud computing technologies, algorithmic decision-making tools, and big data processing techniques improve efficiency in storing and transmitting financial accounting data.	Feng and Zhong, 2022; Qi et al., 2022; Shyla and Sujatha, 2022
Cloud-based accounting information systems as innovative technologies can optimize financial transactions and services, leading to efficient administrative practices.	Al-Okaily et al., 2022; Dai, 2022; Sugahara et al., 2022
Cloud accounting integrates big data and blockchain technologies, computational data mining algorithms, and enterprise accounting information systems. Cloud computing technologies and big data processing techniques shape the organizational structure and performance of financial data management in competitive business environments.	Hao, 2022; Jin et al., 2022; Liu et al., 2022; Wang et al., 2022
Big data storage technologies and cost-effective cloud accounting services improve corporate and organizational management by integrating cloud accounting systems data.	Feng and Zhong, 2022; Qi et al., 2022; Yigitbasioglu et al., 2022

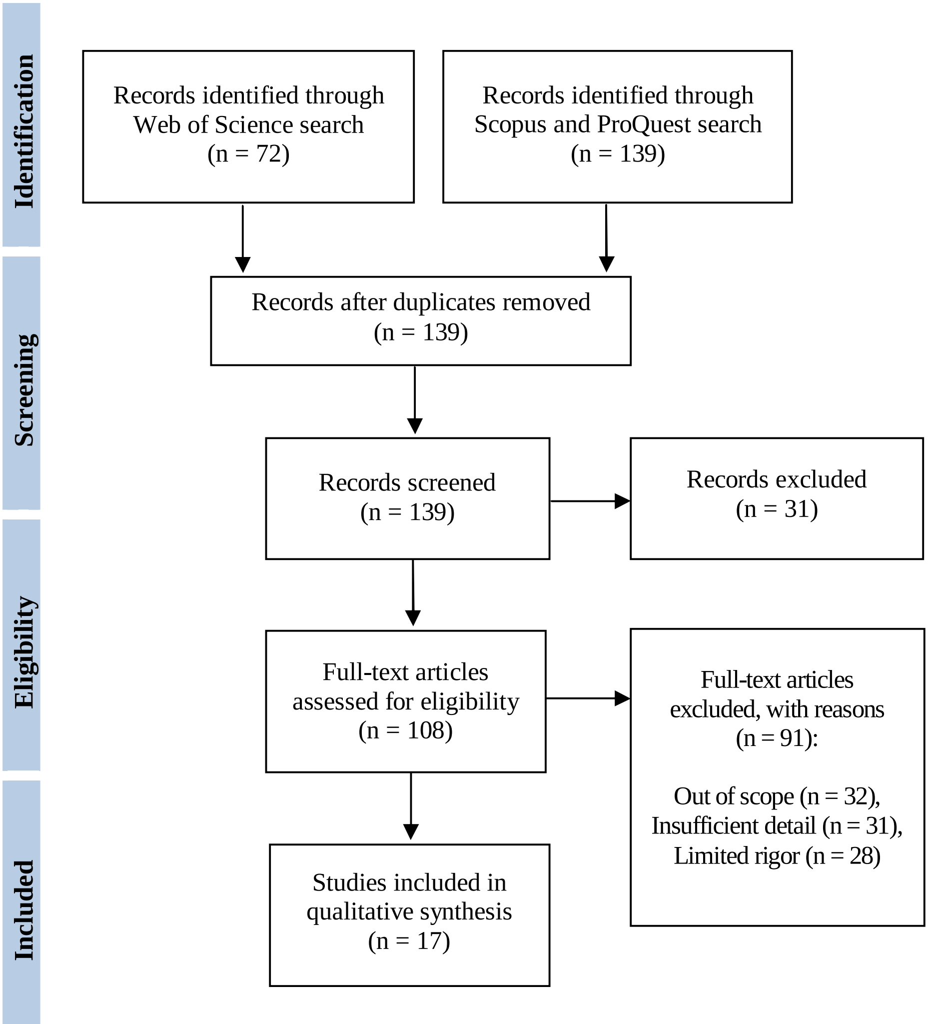

Figure 5 PRISMA flow diagram describing the search results and screening.

Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines were used that ensure the literature review is comprehensive, transparent, and replicable. The flow diagram, produced by employing a Shiny app, presents the stream of evidence-based collected and processed data through the various steps of a systematic review, designing the amount of identified, included, and removed records, and the justifications for exclusions.
To ensure compliance with PRISMA guidelines, a citation software was used, and at each stage the inclusion or exclusion of articles was tracked by use of custom spreadsheet. Justification for the removal of ineligible articles was specified during the full-text screening and final selection.

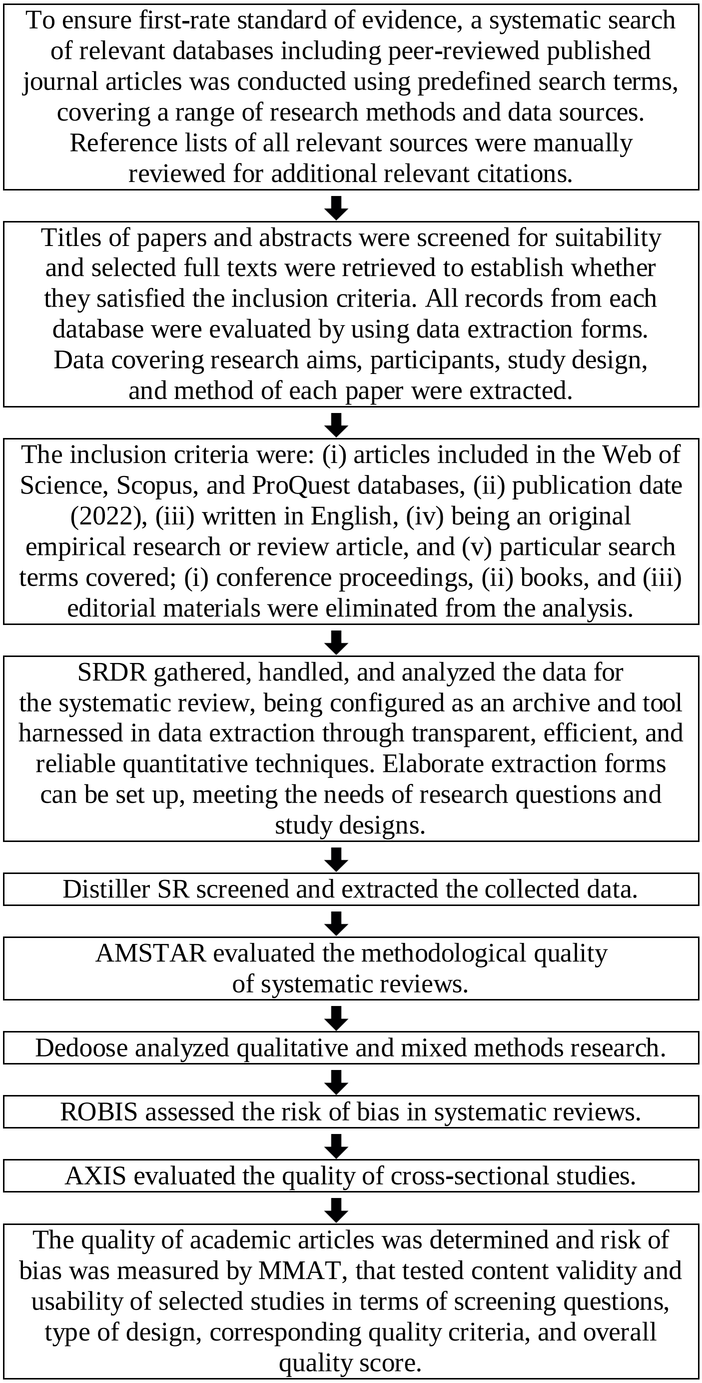

Figure 6 Screening and quality assessment tools

4. Cloud Computing Technologies, Financial Accounting Information, and Algorithmic Decision-Making

Cloud computing technologies shape the accounting informatization, as regards sustainable development and optimized financial transactions and services, of small and medium-sized enterprises (Meng, 2022; Sastararuji et al., 2022; Tawfik et al., 2022; Yigitbasioglu et al., 2022), improving management efficiency and promoting economic development. Cloud accounting constitutes a cutting-edge business operating tool for small and medium-sized enterprises. Organizational and environmental contexts, technology readiness, and competitive pressure are pivotal in cloud accounting adoption by small and medium-sized enterprises. Cloud computing technologies and robotic process automation optimize big data governance and business processes, driving competitive advantage.

Algorithmic decision-making tools and big data processing techniques assist corporate accounting information systems (Dai, 2022; Feng and Zhong, 2022; Zhao et al., 2022) by integrating financial accounting data. Big data processing techniques develop on financial information systems, assessing financial and accounting data and business operations, while decreasing operational and administrative costs. Cloud computing technologies can assist small and medium-sized enterprises in accounting informatization processes integrating big financial data.

Financial accounting information and algorithmic decision-making shape corporate governance (Feng and Zhong, 2022; Hao, 2022; Jin et al., 2022) in relation to business competition and organizational big data management. Cloud computing technologies and artificial neural network algorithms enable enterprise financial management system operation and performance, furthering the long-term development of accounting information management systems. Cloud storage virtualization technology assists small and medium-sized enterprises in relation to financial and accounting management. (Table 3)

Table 3 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Cloud computing technologies shape the accounting informatization, as regards sustainable development and optimized financial transactions and services, of small and medium-sized enterprises.	Meng, 2022; Sastararuji et al., 2022; Tawfik et al., 2022; Yigitbasioglu et al., 2022
Algorithmic decision-making tools and big data processing techniques assist corporate accounting information systems by integrating financial accounting data.	Dai, 2022; Feng and Zhong, 2022; Zhao et al., 2022
Financial accounting information and algorithmic decision-making shape corporate governance in relation to business competition.	Feng and Zhong, 2022; Hao, 2022; Jin et al., 2022

5. Cloud Computing Technologies, Big Financial and Accounting Data, and Modeling and Process Optimization

Accounting information systems can be instrumental (Chen et al., 2022; Dai, 2022; Meng, 2022; Sastararuji et al., 2022) in the dynamic configuration of the cloud accounting environment. Small and medium-sized enterprises can be more financially organized by implementing cloud-based accounting in cash flow management. Cloud accounting can assist small and medium-sized enterprises in cutting down capital investment, while optimizing management efficiency and market competitiveness. Big data technology is pivotal in corporate management, cloud accounting, and financial decision-making.

Cloud accounting systems enhance the planning and design of financial decision-making processes (Deng, 2022; Liu et al., 2022; Zhao et al., 2022) by use of big financial and accounting data, algorithmic decision-making tools, and robot process automation. Cloud-based accounting systems and cloud computing services deploy data mining and task scheduling algorithms to configure financial data and informatization. Cloud computing processing and sensor monitoring capabilities, wireless sensor network systems, and enterprise cloud services articulate financial management processes in terms of data monitoring accuracy and processing efficiency.

Cloud computing technologies, algorithmic decision-making tools, and big data processing techniques (Feng and Zhong, 2022; Qi et al., 2022; Shyla and Sujatha, 2022) improve efficiency in storing and transmitting financial accounting data. Cloud computing technologies and algorithmic decision-making tools assist cloud-based accounting systems as regards big data monitoring, processing, and sharing throughout businesses and organizations. Modeling and process optimization of enterprise accounting information systems enable long-term development of business operations by use of cloud computing technologies, algorithmic decision-making tools, and big data processing techniques. (Table 4)

Table 4 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Accounting information systems can be instrumental in the dynamic configuration of the cloud accounting environment.	Chen et al., 2022; Dai, 2022; Meng, 2022; Sastararuji et al., 2022)
Cloud accounting systems enhance the planning and design of financial decision-making processes by use of big financial and accounting data, algorithmic decision-making tools, and robot process automation.	Deng, 2022; Liu et al., 2022; Zhao et al., 2022
Cloud computing technologies, algorithmic decision-making tools, and big data processing techniques improve efficiency in storing and transmitting financial accounting data.	Feng and Zhong, 2022; Qi et al., 2022; Shyla and Sujatha, 2022

6. Cloud-based Accounting Information Systems, Corporate Financial Data, and Big Data Storage Technologies

Cloud-based accounting information systems as innovative technologies can optimize financial transactions and services (Al-Okaily et al., 2022; Dai, 2022; Sugahara et al., 2022), leading to efficient administrative practices. Cloud accounting is a groundbreaking decision-making tool. Cloud computing technologies optimize enterprise information management systems in terms of task execution, financial planning process, operational efficiency, and enterprise financial management by integrating corporate financial data.

Cloud accounting (Hao, 2022; Jin et al., 2022; Liu et al., 2022; Wang et al., 2022) integrates big data and blockchain technologies, computational data mining algorithms, and enterprise accounting information systems. Cloud accounting data develop on technological processes associated with operational informatization. Management accounting systems gather, store, process, and manage huge volumes of financial and accounting data by leveraging network data mining algorithms. Cloud computing technologies and big data processing techniques shape the organizational structure and performance of financial data management in competitive business environments.

Big data storage technologies and cost-effective cloud accounting services (Feng and Zhong, 2022; Qi et al., 2022; Yigitbasioglu et al., 2022) improve corporate and organizational management by integrating cloud accounting systems data. Cloud computing technologies are decisive in the technological development and dynamic organizational structure of accounting management systems. Big data analytics, algorithmic decision-making tools, and cloud-based accounting software optimize audit and tax services. (Table 5)

Table 5 Synopsis of evidence as regards focus topics and descriptive outcomes (research findings)

Cloud-based accounting information systems as innovative technologies can optimize financial transactions and services, leading to efficient administrative practices.	Al-Okaily et al., 2022; Dai, 2022; Sugahara et al., 2022
Cloud accounting integrates big data and blockchain technologies, computational data mining algorithms, and enterprise accounting information systems. Cloud computing technologies and big data processing techniques shape the organizational structure and performance of financial data management in competitive business environments.	Hao, 2022; Jin et al., 2022; Liu et al., 2022; Wang et al., 2022
Big data storage technologies and cost-effective cloud accounting services improve corporate and organizational management by integrating cloud accounting systems data.	Feng and Zhong, 2022; Qi et al., 2022; Yigitbasioglu et al., 2022

7. Discussion

I integrate my systematic review throughout research indicating how cloud accounting constitutes a cutting-edge business operating tool for small and medium-sized enterprises. My research complements recent analyses clarifying how small and medium-sized enterprises can be more financially organized by implementing cloud-based accounting in cash flow management. I elucidate, by cumulative evidence, previous research demonstrating how cloud computing processing and sensor monitoring capabilities, wireless sensor network systems, and enterprise cloud services articulate financial management processes in terms of data monitoring accuracy and processing efficiency.

8. Synopsis of the Main Research Outcomes

Big data processing techniques develop on financial information systems, assessing financial and accounting data and business operations, while decreasing operational and administrative costs. Cloud computing technologies and big data processing techniques shape the organizational structure and performance of financial data management in competitive business environments. Cloud computing technologies are decisive in the technological development and dynamic organizational structure of accounting management systems. Cloud computing technologies optimize enterprise information management systems in terms of task execution, financial planning process, operational efficiency, and enterprise financial management by integrating corporate financial data.

9. Conclusions

Relevant research has investigated whether modeling and process optimization of enterprise accounting information systems enable long-term development of business operations by use of cloud computing technologies, algorithmic decision-making tools, and big data processing techniques. This systematic literature review presents the published peer-reviewed sources covering how big data technology is pivotal in corporate management, cloud accounting, and financial decision-making. The research outcomes drawn from the above analyses indicate that cloud storage virtualization technology assists small and medium-sized enterprises in relation to financial and accounting management.

10. Limitations, Implications, and Further Directions of Research

By analyzing only articles published in 2022 in journals indexed in the Web of Science, Scopus, and ProQuest databases, relevant sources on big data processing techniques and algorithmic decision-making tools in cloud-based accounting information systems may have been excluded. The scope of my study also does not move forward the inspection of algorithmic decision-making tools and big data processing techniques assisting corporate accounting information systems.

Subsequent analyses should develop on sustainable development and optimized financial transactions and services. Future research should thus investigate financial accounting information and algorithmic decision-making. Attention should be directed to cloud accounting systems enhancing the planning and design of financial decision-making processes.

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The author confirms being the sole contributor of this work and approved it for publication. The author takes full responsibility for the accuracy and the integrity of the data analysis.

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Transparency statement
The author affirms that the manuscript represents an honest, accurate, and transparent account of the research being reported, that no relevant aspects of the study have been left out, and that any inconsistencies from the research as planned (and, if significant, registered) have been clarified.

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