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REVIEW

Prospects and challenges of Metaverse application in data-driven intelligent transportation systems

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Abstract
The Metaverse is a concept used to refer to a virtual world that exists in parallel to the physical world. It has grown from a conceptual level to having real applications in virtual reality games. The applicability of the Metaverse in numerous sectors like marketing, education, social, and even advertising exists. However, there exists little or no work on Metaverse applicability to the transportation industry. Data-driven intelligent transportation systems (DDITS) aim to provide more intelligent systems based on exploiting data. This paper reviews the concepts and features of the Metaverse. Also, the review goes over three dominant DDITS challenges: vehicle fault detection and repair, testing new technologies, and anti-theft systems. In addition, it highlights prospective Metaverse solutions that apply to the DDITS. Buttressing the utility of Metaverse in DDITS, this paper presents two major case studies: the invisible to visible (I2V) and the Metaverse on Wheels (MoW) technologies. Finally, the influence, limitations, and open issues of Metaverse applications to DDITS are discussed.

1 | INTRODUCTION

The term “Metaverse” is a fusion of the prefix “meta,” which means transcending, and the suffix “universe.” It refers to a digitally simulated environment that is connected to the physical environment. The word “Metaverse” first came into existence in the year 1992, by *Neal Stephenson*, in his speculative fictional work titled *Snow Crash* [1]. In this work, Stephenson described the Metaverse as a virtual environment that exists in parallel with the physical world, with users interacting as avatars. In the year 2000, *Garner*: an information technology (IT) research firm, termed the fusion of the digital and real worlds in the era of the internet as the *Supranet* [2]. In 2011, a novel titled *Ready Player One* was published by *Ernest Cline*. This book was based on a future time in which people could escape the throes of the world through a virtual reality (VR) game cum parallel world called *OASIS*. Between 2018 and 2020, Cline’s book was adapted into a film [3]. It is evident that the concept of Metaverse is not entirely novel and has been existing for over a decade.

The Metaverse has since evolved beyond the conceptual level to a full-blown application, the most being in virtual worlds and games (see Figure 1). There is a 3D game based on a virtual world invented in the year 1998. In this game, players could interact with each other as avatars and pay for goods and services using the currency of the virtual world; *therebucks* [4]. Virtual platforms such as *Traveler*, *ActiveWorlds*, and *Croquet* were introduced [5] between the 1990s and 2000s. These platforms are either 3D virtual games *ActiveWorlds* or multi-user environments *Croquet*. *Runscape* is another very popular online role-playing game for multiple players, which was released in the year 2001. In 2003, Linden Lab launched *second life*, with the main aim of creating a user-influenced world in which users can socialize, engage in business transactions, communicate, and also play [6]. In 2006, *Roblox* was launched. This platform enables its users to build and play games with other users virtually. By the year 2011, *There* returned after a short closure in March 2010. In 2014, *Zwift*, an immersive cycling game, was launched. *Minecraft* is a virtual platform that has not only been explored for games, but extended to education, in what was named *MinecraftEdu* [7]. In 2017 *Fortnite Battle Royale*; a free-to-play online multiplayer game was released by *Epic Games*. Between 2018 and 2019, this game generated over $9billion

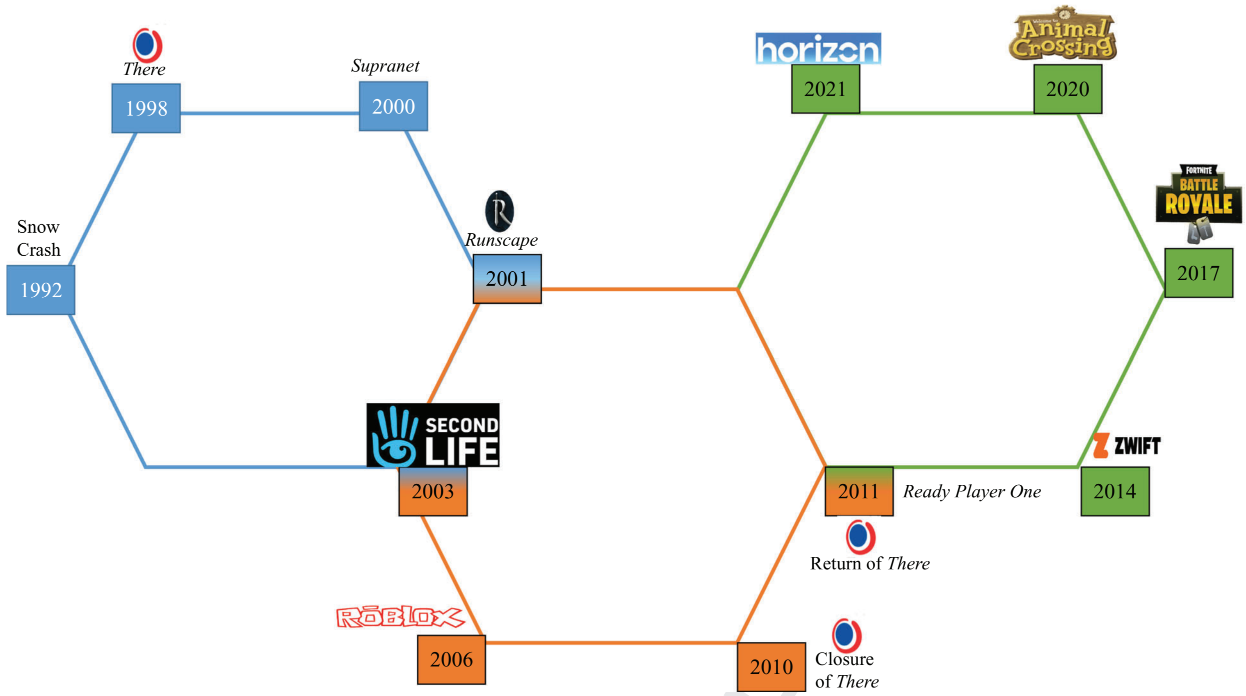

FIGURE 1 Metaverse development timeline

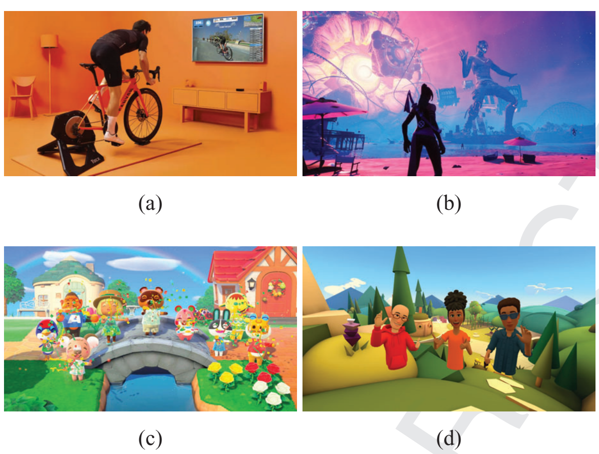

FIGURE 2 Representation of different Metaverse games: (a) Zwift cyclist games, (b) Travis Scott performing on Fortnite, (c) Animal crossing game and (d) Horizon worlds

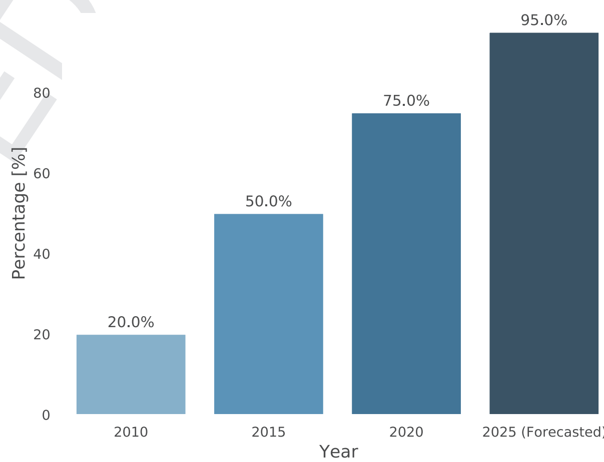

FIGURE 3 The percentage of game revenue from virtual items [12]

in revenue [8]. *Fortnite*[9] had an estimated 250 million active users as of 2019. Figure 2 shows figures of four different Metaverse games.

In 2019, it was reported that approximately 50% of *Roblox* users spent the money they earned from the platform on the purchase of customized avatars. This money remained in circulation within the economy of the *Roblox* universe [10]. In the year 2020, *Nintendo* launched *Animal Crossing: New Horizons*. This is a game that allows its users to interact with plants, animals, and villagers in a virtual world. In the same year, *Fortnite* hosted a virtual concert, featuring a famous rapper, *Travis Scott*. This concert drew over 12 million people's attention [10]. In 2021, the Republic of Korea declared that it was going to build a national augmented reality (AR) and VR platform [11]. The company *Meta* formerly known as *Facebook* also has a metaversial game called *Horizon worlds*. Although this game is currently in its beta phase, it will accept the use of VR devices and would only be accessible by invite. According to [12], and as illustrated in Figure 3, there will be a 20% growth in the revenue from virtual items, between the years 2020 and 2025.

The Metaverse has grown to have several definitions and representations in numerous concepts. Some of these concepts include mirror world [13], spatial Internet [14], virtual world [15–17], lifelogging [18], a continuous 3D world online [19], and an immersive world that simulates real-world objects [20]. The Metaverse enables individual users to represent their characters using avatars. In this paper, we treat the Metaverse as a

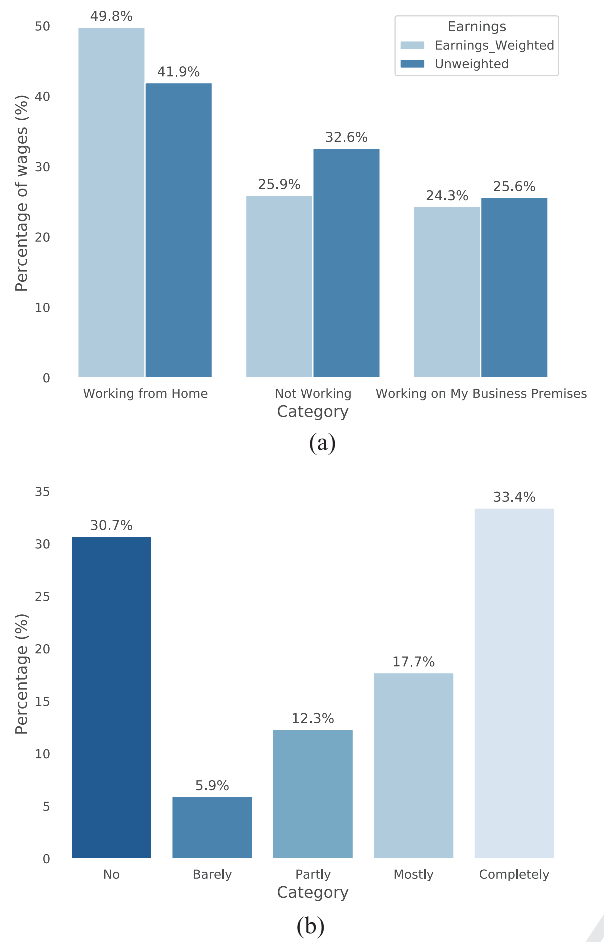

FIGURE 4 Statistics showing: (a) How WFH accounted for more than 60% of US economy activity as of May 2020, (b) Percentage of jobs that can be performed WFH [23]

digitally simulated world that exists in parallel with its real-world replica. Likewise, the Metaverse scenario depicted in Snow Crash shows the real world and a replica of a digital world. The Metaverse embodies a convergence of web technologies, the internet, VR, AR, mixed reality (MR), and extended reality (XR). According to [21], MR fuses the physical and digital worlds to some degree while combining the technologies of VR and AR into one, while XR universally refers to all these immersive technologies [22].

With the intrusion created by the novel Corona virus from the year 2019 till date, migrating most organizational activities online, it has become more imperative to encourage any Metaverse application. Working from home (WFH) has dominated the lives of many workers. According to [23], in May 2020, 42% of the US workforce was working from home full-time. 33% were not working at all, while 26% were working from their business premises. This statistic is illustrated in Figure 4a and shows how much COVID distorted the lifestyle of the workforce. Figure 4b illustrates the percentage of jobs which can actually be conducted from home. 33.4% of jobs can be carried out completely at home, 30.7% cannot be carried out at home at all.

Although, the concept of Metaverse and its applications are still under development, there have been some considerable research on the Metaverse. In [24], the authors introduced a learning system for the analysis of devices via the virtual world. This system was aimed at encouraging collaboration and interaction between members of remote organizations. In [25], the authors discussed the components and applications of Metaverse. They further analyzed all the Metaverse approaches employed, while utilizing hardware and software. Although Metaverse is being investigated for marketing [26], advertising [27], educational [28], and social purposes [29], industries should not be overlooked, as they serve the basic needs of human life. One of such industries is the transportation industry.

1.1 | Contributions

Transportation is a very crucial part of human activities, and as such, it is important to develop ways to make it more convenient, safe, and suitable for its users. Intelligent transportation systems (ITS) have been developed by exploring historical and human experiences to make performance better. Another method that has been explored is to use the data to create more ITS. This is known as data-driven intelligent transportation systems (DDITS) [30]. DDITS enables more people-centric and privacy-aware transportation systems to be created. Data are collected from a variety of sources including sensors, a global positioning system (GPS), a microphone etc., to play a key role in DDITS. This data is then used to train artificial intelligence (AI) algorithms [31–33] to solve specific challenges in DDITS. Some of these challenges include vehicle theft detection [34], fault diagnosis [35], traffic object detection [36], tracking and recognition, traffic behavior analysis [37], amongst others. Despite extensive research on ITS and existing solutions, there are still challenges that need to be addressed. This paper aims to explore how Metaverse can be applied to achieve ITS. Some elements of Metaverse have already been explored for ITS. Specifically, AR and VR have already been explored to improve ITS. In [38], VR technology was explored for intelligent traffic construction. In [39], the concept of parallel ITS, consisting of a real and an artificial ITS, was explored. Other researchers have also discussed the prospects of AR for future mobility [40]. This paper serves as the first attempt to offer a review of the potential applications of Metaverse in the transportation industry. The main contributions of this paper are four-fold.

- We discussed the basic understanding of Metaverse, its genesis, as well as previous and modern prototypes of the Metaverse application, and conducted a systematic review of the existing research on Metaverse for industrial applications.
- We discussed the seven different levels of the Metaverse, including: infrastructure, human interface, decentralization, spatial computing, creator economy, exploring, and experience. We further reviewed the elements and features that are required to realize the Metaverse.

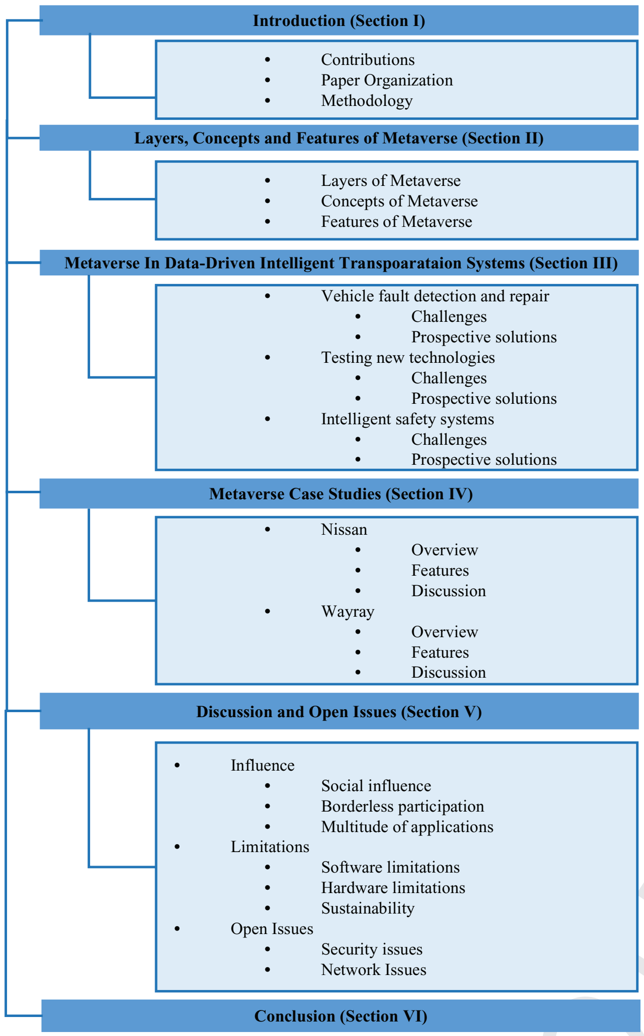

FIGURE 5 Organization of paper

- We investigated three current issues in ITS, including vehicle fault detection and repair; testing new technologies; and intelligent safety systems, highlighting current trends, challenges, and potential solutions that Metaverse technologies can offer.
- We reviewed two main case studies of Metaverse applications for DDITS: invisible-to-visible technology by *Nissan* and Metaverse on wheels by *WayRay*, highlighting the key innovations of their functions.
- Finally, we discussed the influence, limitations, and open issues that will arise from implementing a Metaverse application.

1.2 | Paper organization

This section gives a concise introduction to the Metaverse and a systematic review of previous works on the Metaverse and the industry. The remainder of this paper is organized as illustrated in Figure 5. Table 1 lists the acronyms and abbreviations used in the paper. Section 2 introduces the different factors that are considered in the development of the Metaverse, called levels. This section also discusses concepts of the Metaverse, such as avatars, VR, AR, MR, XR, and digital twin technology. Finally, it gives a brief discussion of the features that every Metaverse application possesses. In Section 3, a brief but concise introduction to the DDITS is given. Subsequently, the challenges in specific areas of DDITS are reviewed, along with the prospective solutions Metaverse can introduce. Section 4 discusses two case studies on the application of Metaverse in DDITS. Nissan's invisible-to-visible technology and WayRay's Metaverse on wheels are two case studies that highlight just how much Metaverse can make transportation comfortable and convenient.

TABLE 1 Acronyms used in the article and their meanings

Acronyms	Meaning
ADAS	Advanced Driver Assistance System
AI	Artificial Intelligence
AR	Augmented Reality
AV	Autonomous Vehicle
DDITS	Data-driven Intelligent Transportation Systems
DL	Deep Learning
DNS	Domain Name System
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HMD	Head mounted display
I2V	Invisible-to-visible
ICT	Information and Communication Technology
IP	Internet Protocol
IT	Information Technology
IoT	Internet of Things
ITS	Intelligent Transportation Systems
LIDAR	Light Detection and Ranging
MATLAB	Matrix Laboratory
ML	Machine Learning
MoW	Metaverse on wheels
MR	Mixed Reality
NFT	Non-fungible Token
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
QoS	Quality of Service
XR	Extended Reality
US	United States
V2X	Vehicle-to-Everything
VR	Virtual Reality
WFH	Work from Home
WHO	World health organization
Wi-Fi	Wireless Fidelity
2D	Two-Dimension
3D	Three-Dimension
5G	Fifth Generation

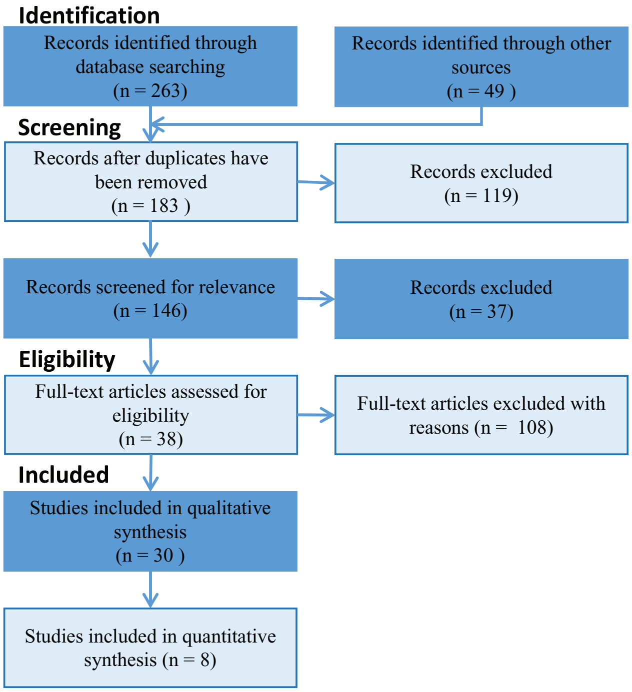

FIGURE 6 The PRISMA flowchart

Section 5 discusses the influence, challenges, and open issues with the application of Metaverse, while Section 6 concludes the paper.

1.3 | Methodology

This review adopted the preferred reporting items for systematic reviews and meta-analyses (PRISMA), which is one of the most reliable systematic review methodologies as used in [25]. The documents used for the study were taken from database and non-database sources as indicated in the Figure 6. A total of 13 databases were searched, including IEEExplore, ScienceDirect (Elsevier), Association for Computing Machinery (ACM), Semnatic Scholar, Hindawi, PubMed, Taylor and Francis, De Gruyter, Springer, MDPI, arXiv, EBSCO/ProQuest, and Google Scholar etc. All databases were searched using key search terms "Metaverse" and "intelligent transportation systems", or "Metaverse" and "ITS" , or "Metaverse" and "autonomous vehicles", or "Metaverse" and "review". Table 2 is a breakdown of the number of documents selected according to sources.

Article selection (inclusion) and exclusion criteria include the following:

1. We considered original articles published in journals, arXiv, or conference proceedings.
2. We included publications or reporting years 1992-2022 that represent the first 30 years of the Metaverse.
3. For qualitative analysis, we considered papers that addressed the issues and concerns of intelligent transportation and(or) the Metaverse (a total of 30).

TABLE 2 Sources of articles used in the study

Database source	No. of documents	% Freq
IEEE Xplore	51	35
Elsevier ScienceDirect	16	11
Semantic Scholar	6	4
ACM	3	2
Hindawi	2	1
PubMed	2	1
Taylor and Francis	3	2
De Gruyter	2	1
Springer	11	8
Hindawi	2	1
MDPI	4	3
Google Scholar/ EBSCO/Proquest	13	9
arXiv	6	4
Other sources	25	17
Total	146	100

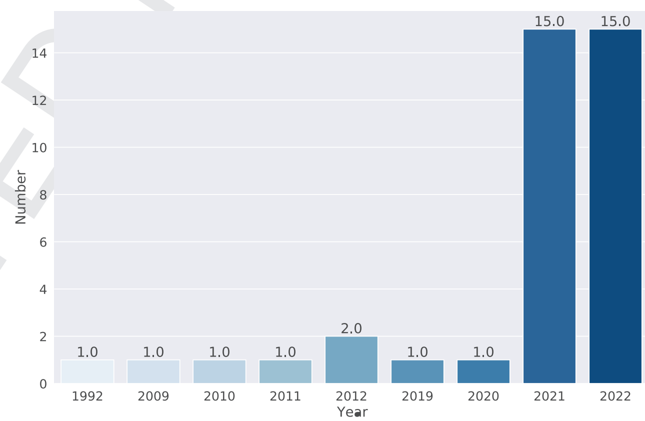

FIGURE 7 Distribution of the selected papers on Metaverse by year of publication

4. Metaverse must be central to the review publication for final selection for comparison with our review (a total of 8).
5. The papers have to be written entirely in English.
6. We excluded the papers whose databases had access restrictions, because the authors could not access them.

As shown in Figure 6, a total of 302 documents were identified by search. 119 documents were excluded due to duplication, leaving a total of 183 for screening. 37 were further excluded after screening for relevance and elimination of papers with open abstract but restricted access to full paper content. Of the 146 documents remaining, 108 were excluded using the inclusion criteria above. Thus, a total of 38 documents were used for the analyses. 30 of these were used for qualitative analysis, while the rest 8 were compared with our review as summarized in Table 3 and Figure 7, respectively.

TABLE 3 Summary of selected Metaverse review articles showing the unique contribution of this review

Authors	Database source?	Focus Area	Enabling Tech	Systematic Review	Case Studies	Year
S.M. ParK et al. [25]; H. Ning et al. [41]	✓	Multi-Domain	✓	✓	✓	2022
J. Kim [27]	×	Advertisement	×	×	×	2021
K. Bokyung et al. [28]	×	Education	✓	×	✓	2021
Y. Wang et al. [42]	×	Security	✓	×	✓	2022
T. Huynh-The et al. [43]	×	AI	✓	×	✓	2022
L. H. Lee et al. [44]	✓	Tutorial Survey	✓	✓	✓	2021
M. Damar [45]	✓	Content Analysis	×	✓	✓	2021
This Review	✓	ITS	✓	✓	✓	2022

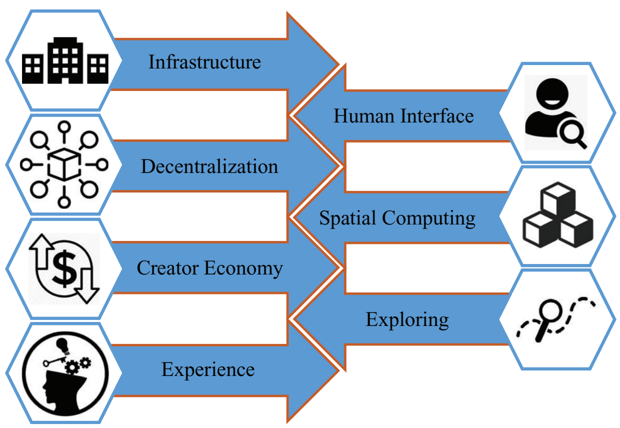

FIGURE 8 The seven layers of the Metaverse

Table 3 clearly shows that this is the first attempt to conduct a comprehensive review of Metaverse and its application to ITS. Furthermore, in addition to using a systematic review approach, our review combined the use of case studies by leveraging industry-based projects to identify the enabling technologies required to drive ITS with Metaverse.

2 | LAYERS, CONCEPTS AND FEATURES OF METAVERSE

In this section, the layers, concepts, and features of the Metaverse were discussed and summarized in Figure 8. These include the theories that constitute the Metaverse and what criteria any Metaverse system should possess.

2.1 | Layers of Metaverse

According to the chief executive of Beamable Inc., Jon Radoff, who doubles as a game designer and author, the Metaverse can be categorized into 7 layers [43, 44, 46]. These layers represent the value chain of the Metaverse space, covering the technologies needed to develop the Metaverse and the experience that people expect to have. The layers can also be used to describe the conceptual segments that constitute every Metaverse design. This subsection introduces these layers, including: (i) infrastructure; (ii) human interface; (iii) decentralization; (iv) spatial computing; (v) creator economy; (vi) exploring; and (vii) experience.

2.1.1 | Infrastructure

The first layer in the development of the Metaverse includes the technologies that empower the devices, enables them connect to a network and to eventually deliver the required content. Virtual spaces cannot be interconnected without internet technologies such as 5G and Wi-Fi [47]. Furthermore, the cloud and its computing resources are also essential infrastructural requirements for developing the Metaverse [48].

2.1.2 | Human interface

The second layer asks us to tackle one particular challenge of how people can access the Metaverse. The Metaverse will be a wide empty virtual space if it is devoid of humans. For example, in [49] a glove based on a human-machine interface for AR and VR applications that can recognize gestures and provide haptic feedback to the user about virtual world events. Thus, it is important to create a human interface that is enabled by various technologies such as VR headsets, AR glasses, and haptics, amongst others.

2.1.3 | Decentralization

The *OASIS* of *Ready Player One* was overseen by a single entity [50]. That is the total opposite of the structure that is expected in the Metaverse. There should be no centralized control in the Metaverse, as there is no centralized control over the world. One simple example of decentralization is in the use of Domain Name System (DNS) [51]. DNS saves users the trouble of entering a number whenever they want to access the internet. Instead, each user is mapped to a specific IP address.

Technologies such as blockchain could aid in providing the support necessary for achieving decentralization in the Metaverse [52]. Other technologies that can help include edge computing and AI [53].

2.1.4 | Spatial computing

The Metaverse would involve the development of an alternate world in a 3D version. To achieve this, there is a need for complex 3D visualization and models that the 3D worlds can be built upon. [54] studied the different AR approaches for the visualization of spatial data. This work showed the abilities of AR in spatial computing. In [55] the authors applied AR in the health sector. Specifically, spatial AR visualization was projected onto the body of the subject. The idea of spatial computing is that the computation of real and virtual existences removes the barrier between the physical and ideal worlds. This could imply the introduction of computation into objects or space into computers.

2.1.5 | Creator economy

This is one layer that critically differentiates Metaverse from other virtual environments. This layer embodies all the technologies that creators must utilize daily in crafting experiences [56]. The Metaverse gives its users the opportunity to create assets such as non-fungible tokens (NFTs) and trade with them. Thus, the Metaverse experiences will be updated on a continuous basis. So far, some experiences in the Metaverse driven by creators have been created on platforms like *Roblox* [57], *Manticore* and even *Rec Room*. These platforms provide a full suite of tools that have allowed people to create experiences for others [58].

2.1.6 | Exploring

This is another very essential layer of the Metaverse, which is all about offering users the opportunity to discover and experience new experiences. The element of discovery defines the future of the Metaverse. Discovery systems can be largely categorized into inbound and outbound systems. In the inbound discovery system, users are actively seeking details of experiences. Such discovery systems involve real-time presence, content that is community-driven, search engines, and so on [59]. In the outbound case, unsolicited information is provided to the user, just as you have in spam, pop-up notifications, and display advertising [60].

2.1.7 | Experience

The final layer of experience is the highlight of the Metaverse future, as it includes the abundant experiences that become available [61]. These formerly rare experiences will suddenly become so accessible. Contrary to popular belief, the Metaverse does not refer to the 3D space that will surround users. It refers to the continuous dissolution of physical space, objects, and distance [62]. It could include having Zoom in virtual offices, *Roblox* on computers, *Fortnite* on game consoles, *Alexa* in kitchens, and even *Beat Saber* in VR headsets [25].

2.2 | Concepts of Metaverse

This subsection briefly introduces several concepts of a Metaverse (see Figure 9) such as (i) Metaverse, (ii) Avatar, (iii) Digital Twin, (iv) Virtual Reality (VR), (v) Augmented Reality (AR), (vi) Mixed Reality (MR), and (vii) Extended Reality (XR).

2.2.1 | Metaverse

Metaverse refers to a network of 3D virtual worlds, in which avatars connect socially [25, 63]. This concept first came into the limelight in the year 1992 in a science-fiction novel *Snow Crash* by Neal Stephenson [1]. This book introduced a digital universe into which one can only enter through VR. Some contemporary applications of the Metaverse can be found on social, VR platforms that are immersive and allow collaborative spaces using AR [5].

2.2.2 | Avatar

Avatars are generally an icon that represents the character of a person in a computer game. It could be in a 2D or 3D form, depicted in a computer game or a virtual world. In a Metaverse world, avatars are the embodied representation of the user [64] and perform their specific roles [65]. Just as the avatars in computer games get manipulated to do what the user wants, avatars in a Metaverse world replicate the users' gestures and actions. Just as illustrated in [66], avatars can also refer to non-player characters who serve other purposes, such as virtual assistance.

2.2.3 | Digital twin

A digital twin represents the digital form of real-world objects, processes, scenarios, or systems[67]. These digital forms work in a manner that is synchronized with the real world. When changes occur in the real world, they are reflected in the virtual world [68].

2.2.4 | Virtual reality

VR refers to an experience that is simulated so that it is similar to or totally different from what occurs in the real world [69]. VR projects users into a new synthetic environment which is different from reality, giving them experiences that make them feel like they are in that specific location with no limits [70].

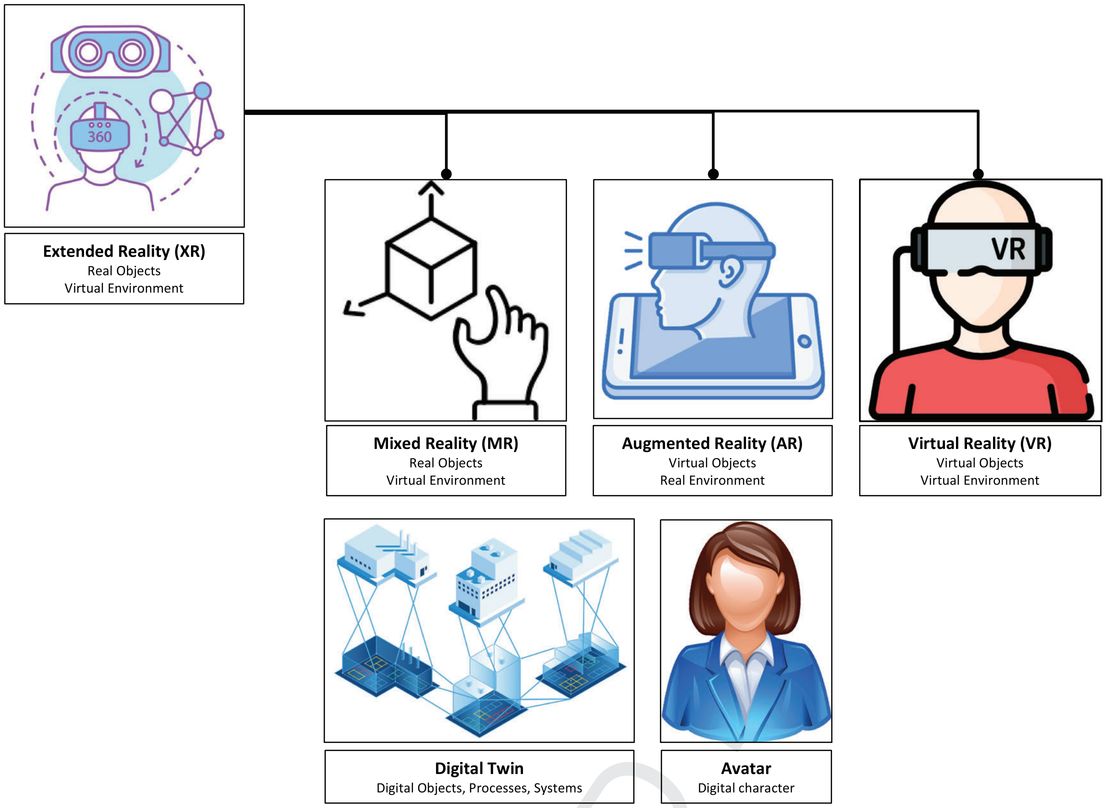

FIGURE 9 Concepts of Metaverse

2.2.5 | Augmented reality

AR refers to the overlay of virtual objects onto the real world. It is different from VR. In VR, users can interact with the virtual environment using devices, whereas, in AR, users can view virtual objects in the real environment [69].

2.2.6 | Mixed reality

MR is an integration of VR and AR. It is a concept that allows the development of digital objects that enable the users to interact with the 3D environment [71]. It refers to the fusion of the real and virtual worlds to yield a brand new world that allows the co-existence of the two worlds.

2.2.7 | Extended reality

XR refers to the integration of all previously existing realities [72]. It refers to the integration of the combined real and virtual environments, and human-machine interactions.

In a Metaverse world, all of these concepts co-exist to provide a world with buildings, objects, processes, systems, and humans, each with their features and roles.

2.3 | Features of Metaverse

There are three prominent features of a Metaverse: (i) Multi-technology, (ii) Social, and (iii) Hyper-Temporospatial [41].

2.3.1 | Multi-technology

Metaverse is an integration of various technologies such as management technologies, virtual reality object connection, virtual reality space convergence, and other fundamental technologies [5].

1. Metaverse management technologies include energy management, resource management, and session management, which enable the link between virtual and real worlds by the management of interactions between resources and their users [41, 42].
2. VR object connection enables the implementation of three things. Identity modeling for the authentication and resolution of various identities. Decentralized technologies such as blockchain. Social computing, such as swarm intelligence [41, 42].
3. VR space convergence allows the exploration of three things. XR/VR/AR/MR and holographic image technologies. Brain-computer interface for brain signal processing.

Recognition and video games for real-time video rendering [41, 42].

4. Fundamental technologies of the Metaverse include Spatio-temporal consistency, privacy, security, AI, etcetera. All these play key roles in the development of the Metaverse [43, 44].

2.3.2 | Social

The Metaverse is a 3D virtual social environment that allows political, economic, legal, and cultural systems to exist just like in the real world. In this social world, users can use their avatars to navigate to different locations that are otherwise difficult for humans. There are four basic design needs for a social metaverse [29]. It must be ubiquitous, real, scalable, and interoperable.

2.3.3 | Hyper-temporospatial

The Metaverse defies the limits of space and time in the real world. By defying the limits of space, the Metaverse allows for the traversing of space within a specific period of time. By defying time, it allows for reaching into the future and returning to a past time [42].

3 | METAVERSE IN DATA-DRIVEN INTELLIGENT TRANSPORTATION SYSTEMS

The term "intelligent transportation systems" (ITS) refers to a grouping of cutting-edge automated technologies that can combine vehicles, users, and infrastructures. ITS came to the limelight in 1991 when industry professionals began to speculate about the role of electronic technologies in optimizing road transport [30]. Numerous ITS technologies provide for trip optimization through route guiding, minimizing unnecessary miles traveled, lowering traffic congestion time, and improving air quality.

ITS has recently attracted a lot of attention. This is due to the benefits provided by wireless devices, information and communication technologies (ICT) smart gadgets, and a variety of sensing technologies. These technologies have enabled numerous innovations, including the monitoring of freeway traffic, [39], the management of traffic centers, the automatic detection of incidents, vehicle screening, and autonomous driving, [73], amongst others. With the amount of data generated by transportation systems and the plethora of AI algorithms that can be used to analyze these data, DDITS was born. DDITS involves the utilization of data to solve one or more problems in transportation systems.

Most of the existing and prospective Metaverse applications target investment, marketing, and social utility. The Metaverse has immense potential that can be explored for a wider range of applications and industries. One such application is in DDITS. The aim of this section is to discuss three existing applications in DDITS and the perceived challenges they might experience. It will also highlight prospective solutions that Metaverse could provide for a more robust DDITS.

3.1 | Vehicle fault detection and repair

Numerous ITS systems, like the advanced driver assistance system (ADAS) and autonomous vehicles (AVs), have been developed [74]. While ADAS helps the driver of a vehicle to control the vehicle, AVs navigate the roads autonomously without any human control. These systems are equipped with numerous sensors, such as accelerometers, odometers, lidars, and radars, that help to obtain data about the vehicle and the environment around it. These sensors are susceptible to errors. As a result, a fault detection system is required to ensure that the ITS system operates at peak efficiency. To avoid potentially dangerous circumstances, autonomous cars require an accurate fault detection and diagnosis system.

If an undetected fault leads to the breakdown of a vehicle, the need for repair arises. In the past, and even nowadays, it is not uncommon to send vehicles for repairs and reconstruction of damaged components. Although some researchers have invested time and resources in devising novel repair mechanisms, others have focused on optimizing the profiles of vehicle components. The authors in [75] tried to analyze the rolling profile process and make recommendations for creating homogeneous plastic strain conditions during the repair of the electric motor casings and covers of vehicles. [76] explored a way to improve the economic performance of metro vehicles by optimizing the wheel repair profile.

Significant research has already been conducted on motor vehicles, rail vehicles, and aircraft [74, 77–79], with the potential to extend to watercraft, and spacecraft. The proposed applications have been extended to complex systems such as armored vehicles, intelligent connected vehicles, and amphibious vehicles [80]. Based on data, [81] investigated the prognostics and health management of armored vehicles. [82] and [77] also used AI to diagnose faults in rail vehicles. Although there are many promising solutions, some challenges need to be addressed.

3.1.1 | Challenges

Despite the volume of research on vehicle fault detection and repair, there are still some challenges that need to be better addressed. In [74], although the proposed system was very robust, the fault detection tests were carried out offline. This poses a huge research gap, as faults need to be detected early enough to be mitigated. To achieve this, the detection has to be conducted in real time, for instance, while driving. In [83], the need for such real-time detection was presented as a challenge in vehicle fault detection and repair. Such real-time fault detection could help detect faults that are caused by the present state of the vehicle. Many technological systems, such as machines and plants, require real-time decision support for emergency shutdowns in order to allow for human-machine interaction and avoid costly machine malfunctions [84]. As a result,

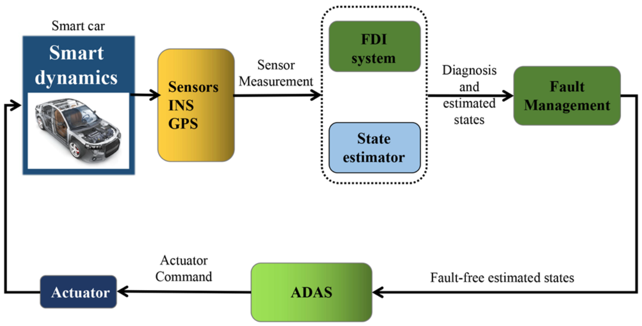

FIGURE 10 Vehicle Fault Detection and Isolation Systems [74]

abnormalities and system changes must be identified quickly and securely. Figure 10 illustrates the fault detection system proposed in [74].

3.1.2 | Prospective solutions

With Metaverse come three potentials that can be applied in ITS for fault detection and repairs: (1) near-future predictions, (2) visualize the invisible, and (3) service guide.

1. **Near future prediction:**
According to [41] and [42], the Metaverse has one distinguishing feature: *hyper spatiotemporality*. This basically means that, unlike the real world, which has a limit on having finite space and irreversible time, the Metaverse is the exact opposite. This happens because it breaks the barriers of time and space. By harnessing numerous technologies, the Metaverse can be used to access a previous time, in order to predict a future time. The concept of predicting the near future is the fundamental task of AI. This concept has been explored in [85], in which different types of behavioral data are used to predict the likely path of humans in the near future in virtual environments.
In [86], near future network traffic prediction in virtual network typologies is explored. Several studies have investigated similar concepts in the detection of vehicle faults. For example, [83] developed an expert system, which can make decisions like a human mechanic and assist drivers in real time. [87]'s car expert system was motivated by the fact that drivers can sometimes be too far from any mechanic help, and need to be able to assist themselves otherwise. These works investigated the use of past and current data to predict the near future state of vehicles, as well as troubleshoot to determine what occurrence in the past could be a trigger for the fault at hand [83, 87].
In a similar vein, Metaverse can salvage the results of past information or simulations to make predictions about the near future. This can be applied to detect and predict faults in real time. Car expert systems such as those proposed in [61] and [87] can be further enhanced by incorporating the Metaverse to visualize the internal workings of the vehicle while providing real-time assistance.
The Metaverse is made possible by so many technologies, including VR, AR, MR, XR and digital twins. While digital twins help to replicate real-world objects in the virtual world, VR, AR, MR, and XR help to visualize these items [25, 41, 42]. Thus, what is otherwise invisible becomes visible. This concept has been explored in some other applications, including academics [88], where VR is used to create a virtual learning model that makes it possible to access information that would otherwise be invisible. In [89], the same concept was used in the recovery of invisible parts of occluded vehicles that have some parts masked, using an AI algorithm. The authors of [90] focused on transforming the speed control information of an autonomous vehicle into an ecological representation, helping drivers cope with the environmental changes and unexpected driving behaviours of other drivers. Since the digital world is created by the data collected by the sensors in the real world using digital twin technology, it means that vehicles equipped with sensors at all the appropriate positions can be replicated in the digital world [91]. As a result, Metaverse has the ability to visualize the invisible. This means that it could be applied to visualize the internal workings of vehicles and inform the driver of any imminent faults.
2. **Service guide:**
According to [42], the Metaverse is social and inter-operable. This means that digital humans can freely move around different virtual environments. Since the Metaverse is also hyper spatiotemporal, these digital humans can also traverse from the real to the virtual world with ease.
With Metaverse, anyone who is authorized to can join a vehicle on a journey as an avatar. This means that professional vehicle mechanics can join trips on request and provide repair assistance in real time and from the comfort of their homes. The notion of providing a virtual guide has also been explored by [92], who discussed the Mercedes-Benz virtual remote support system. The system employs MR to allow the vehicle drivers to enjoy remote support from the brand's technical specialists across the world. VR was employed in [93] to develop an immersive service guide for home appliances. These two applications [92, 93] reinforce the fact that the Metaverse can offer a much better service guide.

3.2 | Testing new technologies

Numerous new technologies have been introduced and will continue to be introduced in the transportation industry. AV and self-driving cars are two examples of such technologies [94]. AVs will change the way people get transported using vehicles. However, to verify the quality of these AVs, it is important to have an effective testing technique in place. This will provide sufficient feedback for system adjustment before deployment. In [73], AVs were modeled using MATLAB/Simulink, and a set of quality of service (QoS) criteria were applied in testing the AV models. There has been a great deal of research on the subject. [95] reviewed all the publicly available datasets for driving and the virtual testing environments. [96] analyzed the

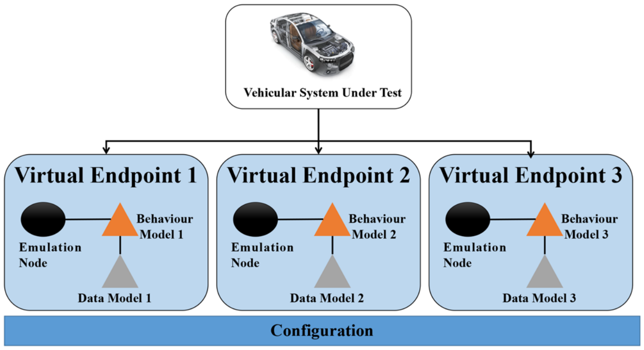

FIGURE 11 Testing new technologies [99]

mathematics behind the simulations randomly generated for testing. [97] proposed a framework that utilizes signal temporal logic formulae and evaluates test cases against it for AV systems. In [98], the researchers applied a fuzzy testing method for AV systems that was aimed at testing the most vulnerable components. Essentially, the vehicle industry faces a host of safety challenges which can be prevented by adequate testing procedures. Service virtualization refers to the use of virtualized environments for automatic testing of products. In [99], a virtual testbed was proposed for Internet of Things (IoT) devices to help accelerate IoT application development by allowing virtual testing without the need to continuously connect to the physical device. As illustrated in Figure 11, the system under test can be subjected to testing using a virtual testing environment. The authors in [100] developed a method to test military vehicles and developed well-defined standards based on the results. For their method to be realized, they had to introduce a layer that allows for interoperability, with sensors and systems connected. In [101] a testing system that combined both virtual and real environments into one was explored. Although the concept was applied to the testing of vehicle-to-everything (V2X) systems, it still portrayed the need to verify the functionalities of vehicle systems.

3.2.1 | Challenges

Despite the amount of research on the topic, there is still a lack of adequate testing methods that can accommodate all possible situations an AV may face [73, 95–98]. According to [102], it is challenging to test AVs in a very comprehensive and safe manner. Furthermore, there is no globally accepted method of testing AV systems. One major reason for this challenge is that the recent AV system models use machine learning (ML) and deep learning (DL), which utilize lots of data that needs to undergo various processing stages, making testing and verification cumbersome [97].

3.2.2 | Prospective solutions

One interesting concept which can help circumvent this challenge is the use of remote driving [103–105] and remote testing [102] procedures. Remote driving can be seen as an augmentation of autonomous driving. With remote driving and control, AVs can be tested without being physically present. In [103], the authors show that there is room to improve the latency situation while driving remotely. [104] was concerned with increasing the efficiency of remote controllers in remote driving schemes.

Metaverse allows remote access to and from a virtual environment [25]. As a result, users can test new technologies, such as AVs, from a distance. In a real-time scenario, different modified versions of AVs can be tested and verified by relying on the potential of Metaverse. Metaverse allows the replication of existing real entities from the real world to the virtual world [42]. As a result, existing AV systems can be replicated in the virtual world, including all necessary components and features, as well as the QoS experience of users. Real users can access the virtual AVs for testing and verification. In this way, there will be minimal damage. Furthermore, all the necessary changes can be made to the virtual AVs and replicated to the real AVs, once the final version is selected [44].

3.3 | Intelligent safety systems

Safety is critical to every transportation system. There are two different scenarios in which safety is very important: (i) safety while driving and (ii) safety while not driving.

1. **Safety when driving:** According to the World Health Organization (WHO), road accidents constitute one of the public and social health concerns [106]. Safety measures help prevent traffic accidents while driving. Such measures could include the monitoring of surrounding vehicles and infrastructure when driving [107] or the prediction of human behavior on the road [106]. Some researchers have focused on developing systems for AVs that are human-centered, can detect driving errors, and activate autonomous driving to prevent accidents [108]. Other researchers have focused on developing systems that issue safety warnings in real time [109, 110]. [109] reviewed the state of research on safety warnings for vehicle environments that are under connected. In [110], a real-time system for the detection of obstacles was proposed. Upon obstacle detection, a collision warning is issued to the driver.
2. **Safety when not driving:** When a vehicle is not in use, there is still a need for safety. In this scenario, there is the risk of intrusion into the vehicle or even theft. Anti-theft security monitoring systems are a very critical necessity in many applications, including street lamps [111], human interaction [112, 113] and even vehicles [114]. Today, vehicles employ a tracking system that utilizes electronic devices installed in them. They are used for tracking the location of the vehicle to prevent theft of the vehicle. There has been a lot of research on the problem of vehicle anti-theft systems [112, 113, 115–119]. Some of the works used GPS to track vehicle location and a global system for mobile communications (GSM) system to notify the owner when vehicle location changes [115] (see Figure 12). Some researchers proposed

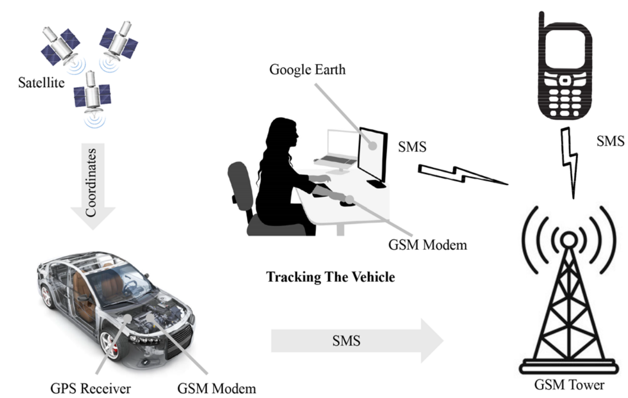

FIGURE 12 Existing anti-theft systems

an anti-theft system that employed user and vehicle authentication solutions [116]. The system was aimed at further reducing the vulnerabilities of the entire vehicle. In [117], the anti-theft vehicle tracking system uses GPS and GSM technologies. These help to track, lock the vehicle, and alert the nearest police station to take action. In [114], a remote car anti-theft system was proposed based on ZigBee wireless communication was proposed. Information about the car can be detected by the system with onboard infrared, vibration, and pyroelectric sensors.

3.3.1 | Challenges

Despite the volume of research into the development of intelligent safety systems, there is still room for improvement. This is because the different devices and technologies employed each come with their own drawbacks. For instance, it is expensive to employ high-resolution video devices. As a result, low-resolution video devices are augmented with enhanced data analysis processes [30]. Moreover, criminals are getting smarter and can disconnect the associated devices and prevent the anti-theft system from working. Thus, it is necessary to employ a system that encompasses and transcends all previous solutions [120].

3.3.2 | Prospective solutions

To create a more intelligent safety system for AVs, Metaverse technology can help to provide a smart windshield that provides the necessary information in real time. This can be made possible with AR, since it enables the overlaying of virtual objects on real objects [121, 122]. The information to be displayed on the windshield could include speed level, fuel level, unsafe situations, or even warnings that the driver must adhere to [123]. As mentioned above, Metaverse allows users to access a real or virtual location. This means that authorized users of any vehicle can access the vehicle at any given location and time. A new anti-theft system can be created by employing all previously existing technologies such as GPS, GSM [118, 119], and user and vehicle authentication alongside Metaverse [42]. This new system will enable users to determine the location of their vehicles at any time. They will also be able to access the vehicle to ascertain if it has been stolen or not [114].

4 | METAVERSE CASE STUDIES

The application of Metaverse in DDITS and in the transportation industry is gradually becoming a reality. The Invisible-to-Visible (I2V) technology by Nissan Corporation Ltd. and the Holograktor (Metaverse on wheels) by WayRay, are proofs of the realization of the Metaverse.

The goal of this section is to highlight how some of the solutions highlighted above have been applied in the transportation industry. It also aims to shed some light on what the transportation industry is doing with Metaverse. To that end, we will do a case study about these two innovations, the Metaverse elements and features they employ, and the results they achieve.

4.1 | NISSAN - invisible-to-visible (I2V) technology

4.1.1 | Overview

The I2V is a technology innovated by Nissan Corporation Ltd. It employs VR and AR to merge the virtual and real worlds in such a way that drivers can see information that is otherwise impossible to see. The goal is to introduce a more exciting, convenient, and comfortable driving experience. Although it is not yet a reality, I2V offers unique advantages brought about by the introduction of the Metaverse [124].

4.1.2 | Features

The I2V technology enables visual representation and communication of information gathered by vehicle and cloud technology. The representation of this technology is illustrated in Figure 13. Four main features make up the I2V technology:

1. Omni-sensing technology: This is a virtual hub that enables the collection of data in real time. Such data includes traffic environmental data and information pertaining to the exterior and interior surroundings of the vehicle. Interior information could include the emotion or facial expression of the driver or virtual avatar, the level of attentiveness, and body tracking information.
2. Seamless autonomous mobility: This is a system that performs real-time traffic analysis. It enables the entire system to predict traffic conditions and suggest alternative routes to the driver.
3. ProPILOT: This is a system that allows for the identification of the external conditions of the vehicle while the interior environment is identified using sensors.

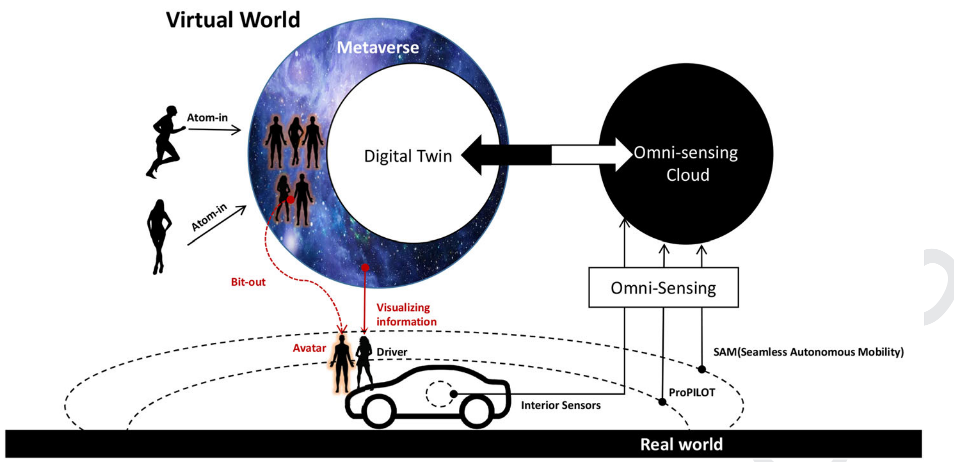

FIGURE 13 Representation of the invisible-to-visible (I2V) technology [124]

4. Digital twin: The I2V technology employs this component of the Metaverse in a lot of applications. The physical world is created digitally through the enormous amount of data amassed by Omni-Sensing technology (see Figure 13).

All of these technologies work together to enable the visualization of the invisible. The driver can receive information about potential hazards or hidden obstacles. These all lead to a very confident driving experience.

4.1.3 | Discussion

This case study employs some of the previously highlighted prospective solutions, including: near future prediction, visualizing the invisible, and overlaying of information using AR. I2V technology is very useful in five different scenarios: (i) driving; (ii) traffic congestion; (iii) mountain driving; (iv) autonomous driving; and (v) parking.

In a typical driving scenario, the system provides information about hidden potential hazards or pedestrians and gives real-time analysis of road conditions. In a traffic congestion scenario, the system provides information about future traffic situations and their causes to enable the driver to take an alternative route. In a mountain driving scenario, the driver sees images of hidden obstacles or oncoming vehicles. In an autonomous driving scenario during poor weather conditions, the driving experience is improved by projecting clear scenery onto the vehicle windows. In parking scenarios, the driver sees information about available parking spaces. Although I2V technology is expected to materialize in 2055, it is a groundbreaking idea [124]. The driver and passengers are connected to the Metaverse. This allows friends, family, and distant acquaintances to appear inside the vehicle in the form of a 3D avatar and accompany passengers, leading to a more comfortable and enjoyable time in the vehicle. The I2V technology employs all previously discussed concepts of the Metaverse, such as AR, VR, MR, and XR [25]. In this Metaverse implementation, buildings, vehicles, and environments in the physical world are created in real-time in the digital world using data. Since the digital and real worlds are connected, digital twin technology enables the sharing of information and the utilization of virtual, augmented, and mixed reality interfaces in the real world.

4.2 | WAYRAY - Metaverse on wheels

4.2.1 | Overview

One innovation at the forefront of WayRay's technology is the concept of Metaverse on wheels (MoW) [125]. WayRay's Holograktor will be the first car that has been designed based on the elements of the Metaverse. Different views of the MoW are represented in Figure 14. With the ultimate goal of connecting the real and virtual worlds to provide enhanced safety, comfort, and premium entertainment, this three-seater vehicle offers ride-hailing services like Uber. It can be driven remotely using VR control or conventionally.

4.2.2 | Features

MoW enables passengers and drivers to enjoy WayRay's holographic Deep Reality Display technology. It provides a novel way of commuting from one location to another. With MoW,

(a) (b)

FIGURE 14 Different views of the Holograktor metaverse on wheels [125]

(a) (b)

FIGURE 15 Figures showing the interior of the Holograktor [125]

(a) (b)

FIGURE 16 Figures showing the remote work station for MoW [125]

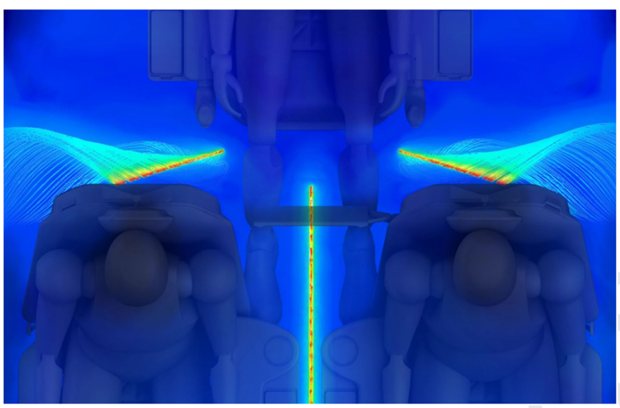

FIGURE 17 Representation of the Airknife safety system in the Holograktor[125]

a journey by car can never be uninteresting. The following features enable Metaverse on wheels to offer all its prospects:

1. AR glazing: MoW provides a safe and comfortable experience through WayRay's Deep Reality Display technology. As a result of the flawless link between the real and virtual worlds, users can get a real driving experience when they look through the windshield. The Deep Reality Display technology provides a great AR immersion in which virtual images are superimposed to blend flawlessly with the real world at an infinite distance range.
2. Remote control: Qualified drivers can remotely control the MoW using a VR remote control. This way, drivers can stay in a specific driving station and take turns driving different cars based on ride-hailing requests. The interior of the MoW Holograktor is shown in Figure 15. Figure 16 shows the remote working station of drivers.
3. AirKnife: To establish safety, this MoW implements an internal innovation called AirKnife, as illustrated in Figure 17. AirKnife is a system that helps to segregate the airflow of passengers, preventing particles from being introduced into the air by sneezing or talking. It essentially ensures that the cabin is kept clean and that the ride is comfortable.
4. Passenger oriented: One main idea behind Holograktor is that it can learn the preferences of passengers, including their regular and favorite routes, using ML. Thus, it can predict preferred routes, ambiance, and destinations. It can be inferred that the Holograktor car can adapt to its passengers.
5. Safe remote ride-hailing: Through MoW, passengers can request rides using the Holograktor application. Qualified drivers can use VR remotes to control cars and pick up passengers, who in turn can enjoy a personalized trip.

The Holograktor has eight different cameras onboard, which oversee all sectors. These cameras provide video streams that are processed and fused into a panorama in a 360-degree spherical view. Holograktor employs a remote sensing method that is based on Lidar. It employs pulsed laser-formed light to determine ranges. It is employed in the fore and rear and allows for adaptive cruise control systems. On-board Holograktors have eight ultrasonic sonars, which also monitor the front and back and are built into the front and rear bumpers of the car.

4.2.3 | Discussion

The Holograktor is indeed a Metaverse on wheels, as it embodies all the features of the Metaverse, providing a different experience much more advanced than what is available in games. The concept of ride-hailing has already been extensively explored in the real world. However, this version is very novel, as the identities of both the driver and passenger can remain hidden during the journey while providing a safe and comfortable driving experience.

5 | DISCUSSION AND OPEN ISSUES

The Metaverse aims to change the way people connect on the internet, allowing them to communicate in ways that were previously only imagined in science fiction. XR, as we know it now, might be used in the Metaverse to immerse users in an alternate world. Although the technology is still being refined, businesses such as *Meta* claim to be developing and upgrading the required gadgets. It is only a matter of time before the Metaverse becomes a reality, given the speed with which technologies and businesses are developing creative ideas around immersive reality. Notwithstanding all this, it is important to analyze the effect of the Metaverse on the day-to-day lives of people [45].

5.1 | Influence

In many aspects, the Metaverse mimics the real world and can represent alternate fictitious worlds. The fact that it is inhabited by humans is the most crucial thing. Citizens are the humans who live in this virtual world in the same way that we live in the real world. They, like us, have jobs, attend school, and participate in other regular activities. The fact that a citizen's life expectancy in the Metaverse is substantially longer than a human's life expectancy on Earth distinguishes it from the real world. Citizens can live for years, if not centuries, whereas earthlings die at the age of 100 on average. Investing in a virtual reality avatar, on the other hand, will last considerably longer than investing in a real person [126]. This is one influence the Metaverse can have over human decisions. This subsection explores other such influences. The influence of the Metaverse in the world can be summarized into three: social influence [127], borderless participation, and a multitude of applications.

5.1.1 | Social influence

It is common for people to feel less worthy after visiting social media because they compare their achievements with others. This problem could be worsened by the Metaverse. The freedom to represent one's avatar as one wishes could lead to a gross dissatisfaction with one's actual version.

Furthermore, as a result of the unlimited immersive experience that Metaverse offers, it is very easy to become addicted [128]. Users will avoid returning to the bland and unsatisfying realities of life. Considering the fact that numerous companies employ algorithms that try to keep users on the platform for prolonged intervals, with the ultimate goal of engaging them through advertisements, it is expected that the Metaverse will adopt the same model for operation. This could lead to addiction worse than any other platform ever caused. Worse, the probability of cyberbullying [128] increases and the experience becomes much more distressing and threatening [127].

There are also ethical concerns about what content and conduct are allowed in the Metaverse [129]. For instance, if the avatars can touch each other, is it acceptable to get touched by other avatars indiscriminately? Can there be inappropriate content in the Metaverse? if so, will the offender be punished? [130] Will there be a need for authorization before accessing any virtual location? Is there the risk of a random person joining someone on a ride in their vehicle in the Metaverse? Will murder be possible in the Metaverse? These are a couple of questions that seek to address the ethics of the Metaverse [41].

5.1.2 | Borderless participation

The Metaverse allows for borderless participation. This means that there is no restriction that defines who may and may not access the Metaverse due to the dilemma of distributed governance [131]. For instance, students from underdeveloped countries may access information and training by joining a training session conducted at a location that is otherwise impossible for them to travel to. In this way, the Metaverse bridges the knowledge gap. Furthermore, people with visual, tactile, and hearing impairments have the opportunity to experience experiences that are otherwise impossible in the real world. Essentially, Metaverse creates an opportunity for a completely different learning experience [132, 133]. People with disabilities will be able to live normal lives while in the Metaverse [133].

This comes as a great development for the transportation industry as there will be little or no restrictions on who can drive what vehicle. With the ride hailing service made possible by WayRays MoW, drivers can participate from anywhere in the world. A driver could be in one country and drive users of the Metaverse in another. In addition, people can learn to drive a car long before they even own one [125].

5.1.3 | Multitude of applications

Metaverse can be applied to a host of applications, in addition to games and social networks. It can simplify daily living for the elderly, invalids and disabled. Metaverse applications can significantly reduce the need for physical objects by providing information overlays using virtual displays. Traditional teaching methods in the educational sector will suffer a decline in usage, as educating people using the Metaverse promises to be much more effective. Since the Metaverse could create experiences that are otherwise impossible in the real world, there could be numerous applications for the educational industry [134]. Other industries, such as health care, the military, real estate, manufacturing, and even transportation, also have immense potential when Metaverse ideas are introduced. When there are more Metaverse applications, people can work smarter.

5.2 | Limitations

To build Metaverse applications, there is a need for numerous sensors attached to physical objects. These sensors sense the environment and help project a replica of it into the Metaverse. Although the Metaverse is a replica of the real world, certain signals are better sensed in the real world, such as smells, wind, sunlight etc. This subsection will give a detailed review of the limitations that the union of Metaverse and DDITS will experience.

5.2.1 | Software limitations

Humans exhibit different kinds of persona, which are expressed in different scenarios and times. It is necessary to study the process of modeling such complex personas while considering the situations. As lifelong learning becomes part of the Metaverse, there is bound to be a new persona that is yet to be documented [44]. Furthermore, most of the software programs used for Metaverse do not depend on coding [25, 44]. However, as the application becomes more complex, it becomes difficult to keep up with sophistication. With the transportation industry comes a more complicated system, as there are numerous elements to be modeled, ranging from the vehicle's exterior to its internal parts [135]. How well can the digital twin replicate these complex systems in the Metaverse? In addition, certain unexpected events happen in reality, leading to equally unexpected outcomes. How can the Metaverse predict the ideal outcome for such an unexpected event?

5.2.2 | Hardware limitations

For the Metaverse to be fully realized, augmented reality systems will overlay the virtual objects/Metaverse onto the physical world, while virtual reality will fully immerse you in the Metaverse. One major piece of hardware required for Metaverse is the head mounted display (HMD) [136], which many users usually find quite hot, heavy, and understandably uncomfortable [25]. The version of Metaverse to be used determines the device to be used. While HMDs such as *Oculus Quest*[137], *VIVE Pro 2*[138], and *HP Reverb G2*[139] can be used to display images and play sounds from the virtual environment, while ensuring full immersion in the Metaverse, they tend to feel very heavy after a substantial period of time. Alternative display devices like optical-see through glasses and video-see through glasses like the *Microsoft HoloLens*[140], *Espon Moverio*[141] and *Magic Leap*[142] do not provide the full immersion which the typical non-see through HMD provides. Moreover, they are much more expensive than HMDs. Thus, the HMD is much more preferable to save money. Remote drivers of the MoW will have to access the Metaverse using the headset, and users who want to use ride hailing services in the Metaverse will also need to use the video-see through glasses. Although the passenger might not experience much discomfort, the driver will be quite uncomfortable after prolonged use of the HMD. This means that trips to the Metaverse will have to be brief to prevent the adverse effects of these devices on the body, unless there is an improvement in hardware requirements [143].

5.2.3 | Sustainability limitation

Just as is applicable in real-life relationships, sustainability is the key to successful interactions. Similarly, to have continuous interactions in the Metaverse, sustainability is key. Users must recognize the benefit and convenience of staying in the Metaverse for extended periods [144]; otherwise, their visits will be brief. Moreover, if the level of visits and the number of users decrease, the propensity for growth reduces. Also, to participate in the Metaverse, users need to have access to a rocket-speed internet connection [143, 145]. It will be difficult because a large portion of the world does not have access to such fast internet access. How sustainable can the Metaverse be when half of the world suddenly gets cut off? What happens if a remote driver, who is currently navigating a vehicle in the real world or the Metaverse, suddenly loses access to the Internet? This can only turn out to be disastrous, leading to fatalities, especially in the real world [45].

5.3 | Open issues

5.3.1 | Security issues

As the buzz surrounding the Metaverse increases, there are concerns about the risks that could arise in a place where the physical and digital worlds unite without restrictions. The potential risks in the digital world are already numerous, so safety risks will be a research concern in the Metaverse [42]. These concerns can be summarized into three: (i) Credential and identity theft, (ii) Social engineering attacks, and (iii) ransomware.

1. Credential and identity theft: The fate of the Metaverse could hang on the level of security it provides. Seeing as the existing social media platforms can be riddled with numerous fictitious accounts, chances are that the Metaverse will not escape such an incident. In the Metaverse, users with criminal intent could assume the identity of anyone they wanted with relative ease [29, 42]. This will be one of the biggest challenges of the Metaverse, because it means that users can have their financial and personal details compromised. Moreover, hackers that are well equipped can generate digital duplicates of a Metaverse character by leveraging the data from the XR devices and can overlap another user's experience, thereby conducting a social engineering attack [42].
2. Social Engineering: Unlike in the real world, where there are documents to prove identification, users of Metaverse must identify themselves using video footage, voice recordings, and facial feature extracts with the help of digital humans [29]. These digital representations are the means by which users can relate to each other through XR devices. Unfortunately, hackers can deceive users into unveiling their personal details by using techniques and tricks that people have been known to fall victim to in real life [25, 41, 42].
3. Ransomware: This is another security concern that can be attributed to the VR component of the Metaverse. Hackers can integrate certain features and functionalities into VR platforms and devices, which could entice the user into unveiling their personal details and exploring vulnerabilities to carry out a ransomware attack [29]. In the end, not only will the personal and financial details be compromised, but also the user experience.

Although the level of security issues that will arise in the Metaverse is unknown, there will certainly be a need for research on security challenges and their prospective solutions [42] in the Metaverse ahead of time.

5.3.2 | Network issues

Considering all the plethora of applications that are prospected for the Metaverse, there is a need to wonder if the existing internet facilities can handle them [143]. Imagine the volume of vehicles that will either need to be accessed remotely using the Metaverse or controlled in the Metaverse. For vehicle drivers, VR headsets, remote controllers, and steering wheels will need to transmit all the necessary data brought about by physically controlling the device. These data will be used to replicate the movement of the avatar in real time [145]. Consider a virtual event to be attended by thousands of people. Motion tracking needs to be carried out in real time using the information from the necessary gadgets. Data from the tracking process must be forwarded to event servers and used to provide a more realistic view of participants, which must be replicated for the virtual avatar in real time [144]. With the numerous low-latency and bandwidth-hungry applications that are envisioned for the internet verse, can the existing internet infrastructure handle all these [146]?

6 | CONCLUSION

In this study, we conducted a systematic review of the current research on the Metaverse. We also discussed the seven layers and concepts of the Metaverse. Furthermore, the features of the Metaverse were discussed, including its utilization of multi-technology, its social characteristics, and its ability to traverse space and time (i.e. Hyer-temporospatial). We then reviewed three current issues in data-driven intelligent transportation systems: vehicle fault detection and repairs, testing new technologies, and intelligent safety systems. We further analyzed the current challenges with the existing solutions and how Metaverse could be employed to solve these challenges. We analyzed two case studies of Metaverse in Nissan's invisible-to-visible technology and WayRay's Metaverse on Wheels (Holograktor). Finally, we discuss the influence of the Metaverse on the real world, its limitations, and open issues. We expect that this study will shed some light on the prospects of Metaverse in ITS and provide motivation for further research in this area.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this document.

DATA AVAILABILITY STATEMENT

Data sharing not applicable - no new data generated, or the article describes entirely theoretical research

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