Connected Autonomous Mobility in the United States: A Narrative Review of Transportation, Urban, Economic, Environmental, and Governance Implications

Hung-Yu Lin
Dept. of Computing Sciences
Texas A&M University–Corpus Christi
Corpus Christi, TX, USA
hlin5@islander.tamucc.edu

Xingran Huang
Dept. of Computer Science and Engineering
University of California, Riverside
Riverside, CA, USA
xhuan230@ucr.edu

Qiming Guo
Dept. of Computing Sciences
Texas A&M University–Corpus Christi
Corpus Christi, TX, USA
qguo2@islander.tamucc.edu

Jinwen Tang
EECS Department
University of Missouri
Columbia, MO, USA
jt4cc@umsystem.edu

***Abstract*—Connected autonomous vehicles are often evaluated as individual driving systems, yet their larger transportation effects depend on how automation interacts with connectivity, service models, freight operations, infrastructure, and governance. This narrative, trend-oriented review synthesizes U.S.-focused literature on passenger and freight automation, traffic operations, urban form, mobility, economics, energy, cybersecurity, and regulation. The reviewed evidence does not support a single expected outcome. Cooperative control can improve traffic stability and capacity under sufficient participation; shared mobility can reduce parking demand yet generate empty travel; freight automation can improve logistics efficiency while shifting infrastructure and workforce requirements; and energy benefits can be offset by induced travel. Four scenarios distinguish development paths by ownership, application, and degree of network coordination rather than by assumed adoption rates. The central conclusion is that the long-term significance of autonomous vehicles may depend less on removing the human driver than on whether passenger vehicles, freight fleets, public transit, and infrastructure become interoperable components of a coordinated mobility network. The resulting benefits and risks are therefore system-level and policy-dependent.**

***Index Terms*—autonomous vehicles, connected vehicles, V2X, intelligent transportation systems, smart mobility, urban transportation, smart cities**

I. Introduction

Autonomous driving in the United States is increasingly moving from technological development toward practical transportation applications. Tesla stated in its Q2 2026 investor update that production of its purpose-built Cybercab had begun and that production vehicles were undergoing public-road engineering tests [1]. In freight transportation, Aurora reported through a company press release that its commercial driverless trucking operations had begun and that its freight network was expanding across the southern United States [2]. These corporate disclosures are used in this paper only as evidence of company-reported commercial activity; they are not treated as independent evidence of safety, reliability, scalability, or transportation-system performance.

Tesla is also not the only relevant passenger-mobility example. Waymo provides an additional U.S. example of commercial driverless passenger service. In August 2023, the California Public Utilities Commission (CPUC) authorized Waymo to provide fared driverless passenger service in San Francisco at any time of day [3]. This regulatory authorization is used here as evidence of commercial deployment activity rather than as evidence of superior safety or transportation-system performance.

These developments illustrate that autonomous transportation is emerging in both passenger and freight applications. However, the long-term impact of autonomous vehicles may extend beyond replacing human drivers. Previous research suggests that widespread vehicle automation could affect traffic conditions, travel behavior, parking demand, urban development, energy consumption, and transportation-related economic activity [4], [5]. When automation is combined with vehicle connectivity, vehicles may also exchange information with other vehicles and infrastructure, creating the possibility of more cooperative transportation behavior [6].

A. United States Context and Motivation

The United States provides an important context for examining this transition because autonomous transportation is developing in both passenger and freight applications. Current Robotaxi programs illustrate different approaches to automated passenger mobility, while autonomous trucks are being developed for freight corridors and logistics operations. A recent review of the U.S. autonomous trucking market identifies freight transportation as a major potential application of automated driving and highlights operational efficiency, vehicle utilization, regulation, infrastructure, and workforce impacts as important factors in its development [7].

The regulatory environment is also continuing to develop. In 2026, the National Highway Traffic Safety Administration announced work on updated guidance for the safe development and deployment of automated driving systems [8]. The future of autonomous transportation in the United States will therefore depend not only on vehicle technology, but also on infrastructure, regulation, business models, public acceptance, and transportation policy.

B. Scope and Objective

This paper examines the potential long-term transformation of autonomous transportation in the United States from a qualitative, literature-based, and trend-oriented perspective. It considers both passenger mobility and freight transportation rather than focusing on a single vehicle manufacturer or autonomous driving system.

The discussion focuses on how increasing automation and connectivity could affect traffic conditions, road and urban design, vehicle ownership, shared mobility, public transportation, freight logistics, economic activity, environmental impacts, cybersecurity, and transportation governance.

The paper does not attempt to predict a specific autonomous vehicle adoption rate or deployment timeline. Current commercial developments are considered as evidence of emerging deployment pathways rather than evidence that any particular long-term transportation outcome is inevitable.

The central argument of this paper is that the long-term significance of autonomous vehicles may not come solely from automating individual vehicles. A broader transformation could occur if passenger and freight vehicles increasingly become parts of a connected and coordinated transportation network.

C. Review Methodology

This study adopts a narrative and trend-oriented review approach rather than a systematic review or meta-analysis. The literature was collected iteratively through targeted searches of Google Scholar, IEEE Xplore, ScienceDirect, and the Transportation Research International Documentation (TRID) database. Publisher databases and reference lists of relevant review and research articles were also used to identify additional studies. Technical standards and current U.S. policy information were verified, when applicable, through primary sources from organizations and government agencies including SAE International, 3GPP, ETSI, the U.S. Department of Transportation, the National Highway Traffic Safety Administration (NHTSA), the Federal Communications Commission (FCC), and the Bureau of Industry and Security (BIS).

Searches primarily emphasized literature published between 2015 and August 2026, while earlier foundational studies were retained when they provided important evidence on cooperative vehicle control, traffic-flow stability, or connected transportation. Keyword combinations included terms related to autonomous and connected vehicles, V2X communication, cooperative driving and CACC, Robotaxis and shared autonomous mobility, autonomous trucking and freight logistics, traffic flow and roadway capacity, urban form and parking, energy use and emissions, cybersecurity, regulation, and transportation governance.

The geographic emphasis of the review is the United States. Studies from other countries were included when they addressed technical mechanisms or transportation effects that were considered transferable to the U.S. context, such as cooperative vehicle control or traffic-flow behavior. U.S. government and regulatory sources were prioritized for claims involving domestic policy, spectrum allocation, safety reporting, and regulation.

Sources were included when they consisted of peer-reviewed research, government reports, technical standards, or other authoritative documents that directly addressed the technological, transportation, urban, economic, environmental, or governance dimensions examined in this paper. Corporate reports and press releases were used only to document company-reported commercial activity and were not treated as independent evidence of safety, performance, or societal benefit. Sources consisting primarily of unsupported forecasts, promotional claims, duplicative commentary, or component-level technical research without a clear transportation-system implication were generally excluded.

Because the literature was collected iteratively as part of a narrative review, formal screening counts were not recorded. No PRISMA-style exhaustive search, formal risk-of-bias assessment, or meta-analytic pooling was conducted. The resulting literature base should therefore be interpreted as a selective synthesis of relevant evidence rather than a comprehensive or systematic inventory of all research on autonomous transportation.

II. Autonomous Driving and Connected Transportation

The future of autonomous transportation in the United States depends on two closely related developments: vehicle automation and vehicle connectivity. Automation determines which driving tasks can be performed by the vehicle, while connectivity determines how vehicles exchange information with other vehicles, infrastructure, and transportation networks. Although these technologies are often discussed together, they represent different capabilities.

A. Autonomous Driving

SAE International classifies driving automation into six levels, from Level 0, with no sustained driving automation, to Level 5, in which an automated driving system can perform the complete driving task under all operating conditions [9].

Autonomous vehicles generally rely on onboard sensing, perception, planning, and control systems to understand their surroundings and determine how the vehicle should move. Importantly, an autonomous vehicle does not necessarily need to communicate with other vehicles in order to operate. It may make driving decisions mainly from information collected through its own sensing systems [6].

Automation therefore primarily changes *who or what performs the driving task*. This capability is relevant to both passenger transportation, such as Robotaxi services, and freight transportation, where automated driving systems may perform portions of truck operation.

B. Connected Vehicles and V2X

Vehicle connectivity introduces an additional source of information. Vehicle-to-Everything (V2X) communication allows vehicles to communicate with other vehicles, road infrastructure, communication networks, and potentially other road users [10].

The main forms of V2X include Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), Vehicle-to-Network (V2N), and Vehicle-to-Pedestrian (V2P) communication. Through these connections, vehicles may exchange information such as position, speed, traffic conditions, road hazards, or infrastructure status.

The key difference is that a connected vehicle is not limited to information that can be directly detected by its own sensors. Information from surrounding vehicles or infrastructure can provide additional awareness of conditions beyond the immediate environment. Connectivity does not replace onboard sensing; communication may be unavailable, delayed, or limited to equipped vehicles.

In the United States, V2X deployment also depends on spectrum allocation, communication standards, and supporting infrastructure. In 2020, the Federal Communications Commission (FCC) reconfigured the 5.9 GHz band (5.850–5.925 GHz), making the lower 45 MHz (5.850–5.895 GHz) available for unlicensed use while retaining the upper 30 MHz (5.895–5.925 GHz) for Intelligent Transportation System (ITS) operations [11]. The same proceeding established C-V2X as the future communication technology for ITS operations in the retained spectrum and initiated the transition away from Dedicated Short-Range Communications (DSRC) [11].

The regulatory transition continued in 2024, when the FCC finalized technical and operational rules for C-V2X use in the retained 30 MHz and established a two-year transition period for remaining DSRC operations [12]. These decisions are important because cooperative vehicle operation depends not only on whether individual vehicles possess communication capability, but also on compatible spectrum, standards, and roadside infrastructure. Vehicle-level connectivity should therefore not be interpreted as equivalent to system-wide interoperable connectivity.

C. Connected Autonomous Vehicles

When automation and connectivity are combined, a vehicle can both control itself and use information received from the wider transportation system. This forms the basis of the connected autonomous vehicle (CAV).

The two capabilities have distinct but complementary roles. Automation provides automated vehicle control, while connectivity provides shared information beyond the vehicle's onboard sensors. Their combination can support cooperative behavior among vehicles and infrastructure.

Research has shown that communication between automated vehicles can support more coordinated vehicle behavior and influence traffic-flow stability under appropriate conditions [6]. The broader transportation effects considered in this paper therefore depend not only on vehicles being able to drive themselves, but also on their ability to interact with other parts of the transportation system.

D. Passenger and Freight Applications in the United States

Connected autonomous technology can be applied differently to passenger and freight transportation.

In passenger mobility, autonomous vehicles may operate as privately owned vehicles or as shared services such as Robotaxis. These applications are particularly relevant in urban and metropolitan environments, where vehicles must interact with pedestrians, intersections, public transportation, and complex road networks.

Freight transportation presents a different operating environment. Autonomous trucks may initially be more suitable for long-distance highway corridors and structured logistics routes. Research on the U.S. autonomous trucking market identifies freight efficiency, vehicle utilization, infrastructure, regulation, and workforce effects as important factors influencing future deployment [7].

Despite these differences, passenger and freight vehicles could eventually participate in the same connected transportation environment, sharing communication infrastructure and interacting with common traffic-management systems.

III. From Individual Vehicles to a Connected Traffic System

Traditional road transportation is mainly based on independently operated vehicles. Each driver observes nearby traffic, reacts to surrounding vehicles, and selects routes according to locally available information. Passenger vehicles and freight trucks therefore share the same road network, but their driving decisions are generally made separately.

Connected autonomous vehicles introduce the possibility of changing this relationship. Through communication and automated control, vehicles may increasingly respond not only to their immediate surroundings, but also to information shared by other vehicles and transportation infrastructure.

A. From Local Decisions to Shared Information

In conventional traffic, most interactions are reactive. A driver responds after observing that another vehicle has slowed down, changed lanes, or entered the roadway. Connected vehicles can receive information about surrounding traffic before some of these changes become fully observable through local sensing.

Cooperative Adaptive Cruise Control (CACC) provides an example of this concept. Experimental studies have shown that communication between vehicles can support more stable vehicle-following behavior than conventional Adaptive Cruise Control under tested conditions [13]. Research has also shown that combining connectivity and automation can influence traffic-flow stability and throughput [6].

The important change is therefore not only faster vehicle control, but a transition from purely local decision making toward decisions supported by shared information.

B. Cooperative Passenger and Freight Traffic

Cooperation may extend beyond vehicle following to merging, lane changing, speed coordination, and other traffic interactions. Passenger vehicles and freight trucks could both participate in this type of connected environment.

For passenger transportation, cooperation may support coordinated movement in urban traffic, intersections, and congested road networks. For freight transportation, communication between trucks may support coordinated highway operation and more predictable movement along logistics corridors. Autonomous trucking research in the United States identifies highway operations, fleet efficiency, and infrastructure coordination as important areas for future development [7].

C. Toward Network-Level Coordination

Connectivity can extend coordination beyond nearby vehicles. Information about congestion, road conditions, intersections, and vehicle routes can also be exchanged with traffic-management systems and used to inform broader transportation decisions.

Research has explored frameworks that combine vehicle routing with the coordination of connected automated vehicles at intersections and merging areas [14]. These studies do not imply that future transportation must be controlled by a single centralized system. Instead, they demonstrate how local autonomous control can interact with network-level information.

Figure 1 summarizes this progression. The vertical sequence represents increasing levels of coordination, from independent vehicle operation to network-level integration. The grouped application domains at the final stage represent passenger mobility, freight transportation, public transit, and infrastructure as components of the integrated transportation network rather than as a separate development path.

D. Mixed Traffic During the Transition

A fully connected transportation network is unlikely to appear simultaneously across all vehicles and locations. Autonomous passenger vehicles and trucks will therefore interact with human-driven and unconnected vehicles during the transition.

This limits cooperative operation. Connected vehicles can exchange information with one another, but they must continue to rely on onboard sensing and prediction when interacting with unconnected road users. Field testing of CACC systems has shown that conventional vehicles entering cooperative vehicle groups can interrupt coordinated operation [15].

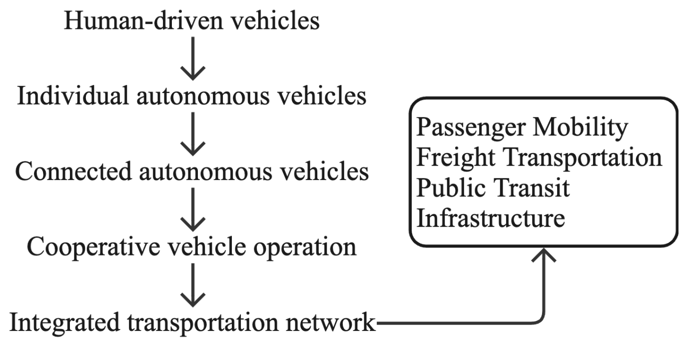

Fig. 1: Conceptual transition from independently operated vehicles to an integrated connected transportation system. The grouped application domains at the final stage represent passenger mobility, freight transportation, public transit, and infrastructure as interconnected components of the integrated network.

The transition toward connected transportation should therefore be understood as a gradual shift in the information and coordination available to vehicles rather than as an immediate replacement of conventional traffic.

IV. Changes in Traffic Conditions

The increasing use of connected autonomous vehicles could change how traffic operates on U.S. roads. Passenger vehicles and freight trucks may respond more consistently to traffic conditions, maintain more coordinated spacing, and exchange information before disturbances become visible to nearby drivers. These capabilities can affect traffic-flow stability and road utilization, although their network-level effect depends on traffic demand and the prevalence and distribution of compatible connected vehicles.

A. Traffic-Flow Stability and Capacity

Traffic congestion can develop from small changes in vehicle speed even when no physical bottleneck is present. Experimental research has shown that minor disturbances can grow into stop-and-go waves as they propagate through a traffic stream [16].

Connected vehicle control can alter this propagation mechanism. Studies comparing Adaptive Cruise Control (ACC) and Cooperative Adaptive Cruise Control (CACC) have shown that communication-enabled vehicles can maintain more stable following behavior under tested conditions [13]. Research also indicates that connectivity and automation can influence traffic-flow stability and roadway throughput [6].

Connected vehicles may also maintain shorter and more consistent following gaps. This can increase the number of vehicles that a lane can accommodate when compatible vehicles operate cooperatively. However, automation alone does not necessarily produce the same effect. Research on freeway capacity found substantially different behavior between conventional ACC and CACC, with the larger capacity effect associated with cooperative operation [17].

B. Market Penetration as a Gating Condition

Market penetration is not merely a background assumption in cooperative traffic analysis; it is a gating variable. Shladover et al. found that the capacity response to CACC penetration is nonlinear because a CACC-equipped vehicle can use its cooperative short-gap capability when it follows a compatible connected vehicle, but must revert toward conventional ACC behavior when following a non-cooperative vehicle [17]. Consequently, aggregate capacity grows slowly when compatible vehicles are sparse and more rapidly when cooperative vehicle pairings become more common.

This interpretation is consistent with experimental and field evidence. The string-stability advantages demonstrated by Milanés and Shladover were observed in consecutive CACC-equipped vehicles [13], while field testing showed that conventional vehicles entering cooperative formations can interrupt platoon operation [15]. The relevant variable is therefore not simply the number of connected vehicles, but whether enough compatible vehicles are present, sufficiently close to one another, to form useful cooperative interactions.

Penetration-dependent effects also appear in cooperative ramp-merging research. Liao et al. evaluated a cooperative CAV merging strategy under multiple CAV penetration rates and traffic-congestion conditions [18]. Their results show that the effectiveness of cooperative merging depends in part on the composition of mixed traffic.

Together with the nonlinear CACC capacity effects reported by Shladover et al. [17], these findings support treating market penetration as an operating condition that influences whether cooperative vehicle interactions can occur frequently enough to affect aggregate traffic performance. This paper does not infer a universal penetration threshold, since the relationship depends on the control strategy, traffic demand, roadway geometry, and application.

C. Merging and Freight Corridors

Merging areas are important sources of traffic disturbance because vehicles entering a highway must interact with vehicles already traveling on the main road. Connected autonomous vehicles can coordinate speed and position before reaching the merging point rather than relying only on individual gap selection.

Simulation studies of cooperative merging have shown that connected automated vehicles can coordinate merging sequences and improve traffic operation under modeled conditions [19]. This type of coordination is particularly relevant to U.S. highway freight corridors, where autonomous trucks and passenger vehicles may increasingly share the same road infrastructure.

For freight transportation, more coordinated highway operation can also improve the predictability of truck movement and support more efficient fleet operation. These effects nevertheless depend on infrastructure, vehicle connectivity, and safe interaction with surrounding passenger traffic [7].

D. Congestion and Mixed Traffic

Connected autonomous vehicles should not be expected to eliminate congestion. If traffic demand exceeds available roadway capacity, automation does not remove the underlying demand-capacity imbalance.

A more defensible expectation is that cooperative operation can reduce some avoidable disturbances and improve the use of available capacity. During a long transition period, however, connected autonomous vehicles will continue to share roads with human-driven and unconnected vehicles. Field testing of CACC has shown that conventional vehicles entering cooperative groups can disrupt coordinated operation [15].

Traffic benefits must therefore be interpreted as conditional on participation, compatibility, demand, infrastructure, and control strategy rather than as an inherent property of autonomous driving.

V. Transformation of Roads and Urban Design

Widespread autonomous and connected mobility could affect the physical design of roads and cities through changes in parking, curb use, transportation infrastructure, freight facilities, and travel behavior. These effects depend strongly on whether autonomous mobility develops primarily through private vehicles or shared transportation services [20], [21].

A. Parking and Urban Space

Parking is one of the most direct links between autonomous mobility and urban land use. Conventional privately owned vehicles require parking near homes, workplaces, and commercial destinations for substantial portions of the day.

Shared autonomous fleets could reduce some parking demand by allowing the same vehicle to serve multiple travelers. Reviews of the built-environment literature identify potential opportunities to convert parking and curb space to housing, commercial development, pedestrian space, or green areas [21].

The opposite effect is also possible under continued private ownership. Vehicles could travel empty to remote parking locations rather than remove parking demand altogether, adding vehicle travel while relocating where parking occurs. Parking effects should therefore be evaluated together with ownership and fleet-operating models.

B. Road and Transportation Infrastructure

Connected autonomous vehicles also change the role of road infrastructure. Precise vehicle control and V2X communication can support traffic-signal coordination, cooperative intersections, and more dynamic highway management. This adds a digital, data-driven layer to conventional physical infrastructure, and spatio-temporal models have already been applied across urban systems including traffic forecasting [22], mobility demand prediction [23], and underground water networks [24].

Freight automation creates additional infrastructure requirements. Autonomous trucks may increase the importance of highway corridors, transfer hubs, logistics terminals, and facilities designed to support automated fleet operations. U.S. autonomous-trucking research identifies infrastructure readiness and integration with existing freight networks as important deployment factors [7].

C. Urban Form and Land Use

Autonomous mobility creates two opposing land-use mechanisms. Shared mobility and lower parking requirements can reduce the amount of urban land devoted to vehicle storage, while a lower perceived burden of travel can make longer trips and more distant residential locations more attractive.

Scenario and built-environment reviews therefore do not identify either compact development or suburban expansion as an inevitable outcome [20], [21], [25]. For urban planning, the important implication is that parking policy, curb management, transit integration, infrastructure investment, and land-use regulation will mediate how autonomous mobility affects development patterns.

This uncertainty is particularly relevant in the United States because dense metropolitan centers, suburban regions, and highway-oriented freight corridors begin from substantially different transportation and land-use conditions.

VI. Changes in Vehicle Usage and Mobility

Autonomous driving can change how transportation is accessed and organized even before it changes the broader structure of cities or transportation networks. Passenger mobility involves choices among private vehicles, shared autonomous services, and public transit, while freight automation changes how driving tasks are distributed across logistics networks.

A. Private Vehicles and Shared Autonomous Mobility

Autonomous vehicles do not necessarily imply the end of private ownership. Some travelers may continue to value vehicle availability, privacy, storage, or personal control over vehicle use. Driverless operation also enables a different model in which users purchase mobility from an on-demand fleet rather than own the vehicle.

Tesla's Cybercab provides a company-reported example of a purpose-built Robotaxi development pathway [1]. It is used here only to document the direction of a commercial program, not to establish the performance or economics of that service.

Waymo provides an operationally distinct Robotaxi example. In 2023, the California Public Utilities Commission authorized Waymo to provide fared driverless passenger service in San Francisco [3]. Together with Tesla's company-reported Cybercab development, this example illustrates that Robotaxi deployment in the United States can follow different vehicle, fleet, and service models. These examples document commercial development pathways rather than establish comparative safety or economic performance.

Robotaxi services should therefore not be treated as one uniform business or operating model. Services can differ in vehicle design, operational design domain, fleet ownership, dispatch model, pricing, and integration with other mobility services.

User adoption also cannot be assumed. A U.S. stated-preference study found that willingness to use shared autonomous vehicles varies with income, trip purpose, sharing conditions, and travel characteristics [26]. Private autonomous vehicles and shared fleets may therefore coexist.

B. Integration with Public Transportation

Shared autonomous vehicles can also operate as first-mile and last-mile services connecting travelers with higher-capacity public transportation.

A simulation study in Austin, Texas examined shared automated vehicles providing connections to light-rail stations and found that the modeled service could support shifts from driving alone toward transit [27]. This differs structurally from using Robotaxis as a direct substitute for the entire transit trip.

The relevant mechanism is therefore service integration. Feeder operation can extend transit accessibility, whereas direct competition for existing transit trips can add road travel without strengthening the high-capacity transit network.

C. Autonomous Freight Transportation

Freight transportation uses automation differently from passenger mobility. Long-distance highways and repetitive freight routes are particularly relevant to autonomous-truck deployment in the United States [7].

One proposed operating structure is the Autonomous Transfer Hub Network (ATHN). Autonomous trucks perform highway or middle-mile transportation between transfer hubs, while human-driven vehicles can continue to handle more complex first-mile and last-mile operations. A U.S.-scale study demonstrates how this structure could integrate autonomous trucking into existing freight networks without requiring end-to-end driverless operation [28].

The immediate mechanism is therefore a redistribution of driving tasks within the freight chain rather than complete automation of every shipment.

D. Changes in Travel Behavior

Removing the driving task changes the generalized burden of travel. Passengers can use travel time for other activities, which can affect mode choice and willingness to make longer trips. U.S. survey research indicates that autonomous and shared autonomous vehicles can influence long-distance mode preferences [26].

The same mechanism can increase vehicle travel. Shared fleets accumulate unoccupied repositioning miles, while privately owned autonomous vehicles can make trips that would have been less attractive under conventional driving. Increased vehicle miles traveled is therefore an important countereffect to some expected benefits of automation [5], [29].

VII. Economic Impact

Autonomous transportation changes the cost structure of mobility and freight rather than simply removing driver labor. Vehicle acquisition, fleet utilization, maintenance, remote support, software, infrastructure, and residual human operations remain economically relevant.

A. Passenger Mobility and Robotaxi Economics

Robotaxi services alter passenger-transportation costs by removing the requirement for a driver inside every revenue-service vehicle. Cost modeling for automated and shared mobility in the United States indicates that high-utilization autonomous ride services can become competitive with conventional transportation under specified technology and operating-cost assumptions [30].

Driverless operation does not eliminate labor. Research based on U.S. Robotaxi operations identifies continuing requirements for remote assistance, fleet support, vehicle cleaning, and other operational activities [31]. Fleet utilization, maintenance, capital cost, and service operations therefore remain central to Robotaxi economics.

B. Freight and Logistics Economics

Freight transportation is sensitive to vehicle utilization, operating cost, delivery time, and labor availability. U.S. research identifies long-haul trucking as an important potential application of automated driving [7].

The U.S. Department of Transportation has concluded that higher levels of driving automation could reduce some freight-transportation costs and increase productivity, while emphasizing uncertainty regarding timing and scale [32]. Autonomous highway operation and transfer-hub models can also change how equipment and labor are allocated across long-distance and local freight segments.

Because transportation costs propagate through logistics networks, these changes can affect carriers, warehouses, distribution centers, and firms that depend on freight services.

C. Employment Transition and Cost Reallocation

Employment effects depend on both the level of automation and the operating model. Passenger Robotaxis can affect taxi and ride-hailing work, while truck automation can change demand for some long-haul driving tasks.

U.S. government studies emphasize that workforce effects are likely to vary across automation levels and deployment patterns, and that large-scale displacement should not be treated as an immediate outcome [32], [33].

Automation also reallocates rather than eliminates all operating costs and tasks. Driver labor can be partly replaced by capital, fleet supervision, remote assistance, vehicle maintenance, software, and logistics-management functions [31], [32]. The relevant economic question is therefore how transportation costs and employment functions are redistributed across the mobility and logistics system.

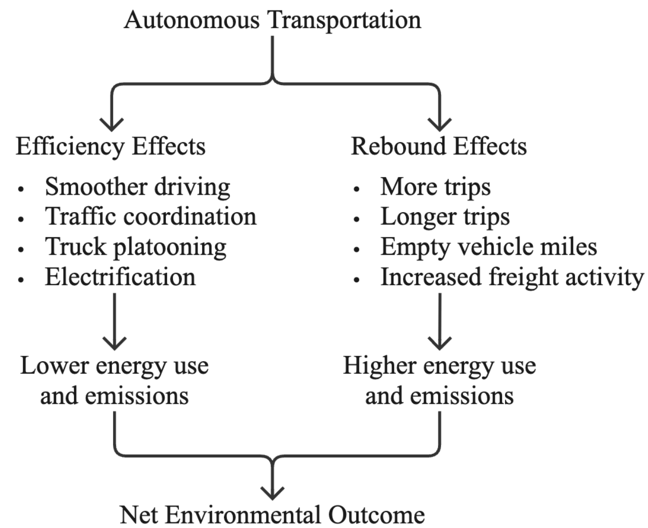

Fig. 2: Conceptual framework of the competing efficiency and rebound effects influencing the environmental impact of autonomous transportation.

VIII. Environmental Impact

The environmental effect of autonomous transportation is determined by competing changes in vehicle efficiency and total travel demand rather than by automation alone. The range identified in existing research is wide. Under illustrative scenarios premised on near-complete automation, Wadud et al. found that road-transport energy use and greenhouse-gas emissions could range from a reduction approaching 50% to an increase approaching 100%, depending on which mechanisms dominate [29]. These values are scenario bounds rather than predictions, but they demonstrate why per-mile efficiency cannot by itself determine the system-level environmental outcome.

Figure 2 summarizes the two opposing mechanisms considered in this section.

A. Passenger Mobility and Induced Travel

Automation can reduce the perceived cost of travel by lowering both vehicle operating costs and the opportunity cost associated with driving. Taiebat et al. estimated a combined fuel- and time-inclusive price elasticity of vehicle miles traveled of approximately -0.39 using U.S. household travel data. Their preferred estimates were approximately -0.1 for fuel cost and -0.4 for travel-time cost, indicating that modeled travel demand was substantially more responsive to changes in time cost than to fuel cost [34].

Under simulations of full private CAV adoption and alternative assumptions about reductions in fuel and time costs, the same study estimated a 2–47% increase in travel demand for an average household [34]. The range is not an adoption forecast; it quantifies the sensitivity of travel demand to assumptions about how automation changes the generalized cost of travel.

Shared fleets introduce an additional mechanism because vehicles can travel without passengers while repositioning between trips. The environmental performance of passenger automation therefore depends on both per-mile efficiency and the amount of occupied and unoccupied travel generated by the service model.

B. Autonomous Freight and Platooning

Freight automation provides a more specific efficiency mechanism through coordinated highway platooning. Muratori et al. estimated that approximately 65.6% of miles driven by U.S. combination trucks in their dataset were technically suitable for platoon formation [35]. Using an assumed energy saving of approximately 6.4% for vehicles operating in platoons, the study estimated an approximately 4.2% reduction in total combination-truck fuel consumption under widespread platooning [35].

These values represent technical potential rather than expected real-world savings. The estimate depends on route suitability, formation of compatible platoons, operational participation, and realization of the assumed per-platoon efficiency improvement. The study therefore provides an upper bound on one freight-efficiency mechanism rather than evidence that all autonomous trucking will produce equivalent fuel savings.

C. Electrification and Shared Mobility

Automation does not determine a vehicle's energy source, but autonomous mobility and electrification can interact through fleet utilization, charging strategy, and vehicle operation.

A U.S.-wide simulation comparing private electric vehicles with shared automated electric vehicles found that greenhouse-gas outcomes depend on the combination of automation, sharing, electrification, managed charging, fleet size, vehicle utilization, and electricity generation [36]. Electrification therefore changes the emissions intensity of vehicle travel but does not remove the importance of total vehicle miles traveled.

Across the reviewed studies, the consistent system-level implication is that efficiency and demand must be evaluated together. Smoother operation, platooning, and electrification can reduce energy use per unit of travel, while induced passenger travel, empty repositioning, and additional freight activity can increase the amount of travel over which those efficiencies are applied [29], [34], [35].

IX. Social, Regulatory, and Security Challenges

The development of connected autonomous transportation creates challenges that extend beyond vehicle performance. In the United States, increasing dependence on software, communication networks, and transportation data raises questions regarding observed safety performance, cybersecurity, privacy, regulation, liability, accessibility, and system governance. These issues apply to both passenger mobility and autonomous freight transportation.

As summarized in Table I, increasing connectivity can expand several risks from the level of an individual vehicle to the broader transportation system.

TABLE I: From Individual-Vehicle Risks to Connected-System Risks

Issue	**Individual Vehicle**	**Connected Transportation System**
Cybersecurity	Localized vehicle compromise	Potential disruption across vehicles, infrastructure, or services
Privacy	Vehicle or user data exposure	Large-scale mobility and location data exposure
System failure	Local vehicle malfunction	Network or service-level disruption
Liability	Primarily driver-centered	Shared among manufacturers, operators, and service providers
Routing and control	Individual driving decisions	Algorithmic coordination with network-wide effects

The comparison does not imply that every connected failure will become system-wide. It shows instead that connectivity can increase both the potential scale of transportation coordination and the possible consequences of failures affecting shared infrastructure or services.

A. Observed Safety Evidence and Its Limits

Real-world automated-driving activity has produced an increasing amount of safety data, but the available evidence does not support simple comparisons across developers or between automated and human driving.

California has historically provided one important source of operational data through the Department of Motor Vehicles' Autonomous Vehicle Disengagement Reports. The DMV states that these reports contain public-road testing mileage and disengagement information, but are intended to describe the operational activity of individual permit holders rather than support comparative analysis across companies [37]. The reporting framework also excluded testing outside California, private-road and simulation activity, and did not require disengagement reporting for operations conducted under deployment permits [37].

California's reporting framework is also evolving. In April 2026, the DMV adopted updated autonomous-vehicle regulations that expand safety and data reporting requirements, including information on system failures, vehicle immobilizations, hard-braking events, collisions, and vehicle miles traveled [38]. Changes in reporting requirements should therefore be considered when comparing data across time.

At the federal level, NHTSA's Third Amended Standing General Order 2021-01, effective June 16, 2025, requires specified manufacturers and operators to report qualifying crashes involving Automated Driving Systems (ADS) and Level 2 Advanced Driver Assistance Systems on publicly accessible roads [39]. These reports provide an important source of real-world incident information, but NHTSA explicitly identifies several limitations. Its current data dictionary states that access to crash data can affect reporting, incident information may be incomplete or unverified, the same crash may generate multiple reports, and summary incident data are not normalized [40].

Consequently, raw incident counts should not be interpreted directly as exposure-adjusted crash rates.

Exposure-adjusted analyses provide stronger evidence but still require careful interpretation. Kusano et al. compared crash experience from 7.14 million miles of Waymo rider-only operation in Phoenix, San Francisco, and Los Angeles with constructed human-driver benchmarks [41]. The study reported lower police-reported and injury-reported crashed-vehicle rates for the automated system in the combined analysis, while some lower-severity property-damage comparisons were less conclusive. Because all authors were affiliated with Waymo, the study should be treated as operator-affiliated evidence rather than an independent evaluation.

Methodological guidance further emphasizes that such comparisons require alignment between automated-driving and human benchmark data. The RAVE checklist recommends matching crash and exposure data and accounting for factors such as geographic area, road type, operating conditions, and Operational Design Domain (ODD) when evaluating retrospective ADS safety performance [42]. It also cautions against extending results beyond the deployment conditions and outcome measures actually studied.

Available real-world evidence should therefore be interpreted at the level of a specific automated-driving system, operating environment, and ODD. Observed results from one fleet or region should not be generalized to autonomous vehicles as a homogeneous class.

B. Cybersecurity and Data Privacy

Connected vehicles continuously exchange information with other vehicles, infrastructure, and network services. This connectivity improves situational awareness but also creates additional points that may be targeted by cyberattacks. Security research on V2X systems identifies authentication, message integrity, communication availability, and protection against malicious data as important requirements [10]. Because automated vehicles also depend on on-board machine-learning models, model-level threats such as extraction of on-device models [43] and supply-chain compromise of pretrained models [44] extend the attack surface beyond communication channels.

Cybersecurity has therefore become a transportation-safety issue. NHTSA recommends a layered and risk-based approach to vehicle cybersecurity, including protection of safety-critical systems, incident detection, system resilience, and information sharing [45].

Connected vehicles also generate information related to location, vehicle operation, and travel patterns. Such data can support traffic management and mobility services but create privacy concerns when information can be associated with individual travelers [46]. Because such data may also be trained into spatio-temporal traffic models, meeting data-deletion requirements can additionally involve machine unlearning at the model level [47].

C. Safety, Liability, and Regulation

Autonomous transportation changes the allocation of responsibility for vehicle operation. With higher levels of automation, responsibility can involve vehicle manufacturers, automated-driving-system developers, fleet operators, and service providers in addition to vehicle users [46].

Regulation in the United States is also adapting to vehicles that may operate without conventional human controls. In 2026, NHTSA opened a federal docket for updated guidance on the safe development and deployment of automated driving systems [8].

Vehicle operation also involves both federal and state responsibilities. Federal authorities address vehicle safety and performance standards, while states traditionally regulate areas such as registration, traffic law, licensing, insurance, and liability [48]. Autonomous deployment across state boundaries therefore raises continuing questions about regulatory consistency.

D. Accessibility and Social Equity

Autonomous mobility could improve transportation access for people who cannot easily drive, including older adults and people with disabilities. However, the distribution of these benefits depends on service design, affordability, and geographic availability.

Research examining autonomous-vehicle policies in the United States has found that deployment may improve or worsen transportation equity depending on these conditions and on public policy [49]. Robotaxi services concentrated in profitable markets, for example, need not provide equivalent access in rural or lower-income communities.

Accessibility and affordability should therefore be considered alongside traffic performance when evaluating autonomous mobility.

E. Governance and System Resilience

A highly connected transportation system creates dependence on digital infrastructure. Passenger vehicles, freight fleets, traffic-management systems, and roadside infrastructure may increasingly rely on communication networks and software platforms for coordination.

Communication outages, software failures, incorrect data, or cyberattacks can interrupt cooperative operation. Connected autonomous vehicles must therefore retain safe fallback behavior when communication is degraded or unavailable [10].

Spectrum policy represents another structural dependency for connected transportation. The FCC's 2020 reconfiguration of the 5.9 GHz band reduced the spectrum dedicated to ITS operations from 75 MHz to 30 MHz and initiated the transition from DSRC toward C-V2X [11]. The FCC subsequently finalized C-V2X technical and operational rules and the phase-out process for remaining DSRC operations in 2024 [12].

This transition illustrates that transportation connectivity depends partly on regulatory decisions concerning spectrum allocation, interoperability, and infrastructure deployment rather than on vehicle technology alone. The FCC has also noted that

DSRC and C-V2X are not interoperable, making technology transition and equipment compatibility relevant considerations for connected-vehicle deployment [12]. Consequently, a future transportation system that relies extensively on V2X coordination would also depend on the continued availability and compatibility of its communication infrastructure.

The United States has also begun treating connected-vehicle supply chains as a national-security issue. In 2025, the Bureau of Industry and Security issued restrictions addressing specified connected-vehicle hardware and software with links to designated foreign-adversary jurisdictions [50].

Governance extends beyond system security. Network-level routing can reduce total travel time while shifting traffic burdens toward particular neighborhoods, and freight optimization can prioritize logistics efficiency while increasing local traffic or environmental exposure. Defining an "optimal" connected transportation system therefore requires objectives beyond aggregate network efficiency.

Overall, the challenges of autonomous transportation extend beyond individual vehicle safety to the operation and governance of the broader transportation system.

X. Future Scenarios

The future of autonomous transportation in the United States is unlikely to follow a single development path. The effects discussed in previous sections depend strongly on vehicle ownership, shared mobility, freight applications, public transportation, infrastructure, connectivity, and the number and distribution of compatible connected vehicles.

Existing reviews have already synthesized autonomous-vehicle scenario studies and examined potential effects on urban form and the built environment [20], [21]. The contribution of the present paper is therefore not the introduction of scenario analysis itself. Instead, this review makes two narrower distinctions. First, freight automation is treated as an independent development trajectory rather than as a secondary consequence of passenger-vehicle automation. Second, the scenarios are differentiated partly by the degree of connectivity and coordination among vehicles, infrastructure, public transportation, and freight operations rather than by an assumed vehicle-adoption rate or a predetermined urban-form outcome. The scenarios are analytical constructs rather than forecasts.

A. Scenario 1: Private Autonomous Mobility

In the first scenario, autonomous vehicles become widely available while private vehicle ownership remains dominant. The basic structure of transportation would remain similar to the current U.S. system, but passengers would no longer need to perform the driving task.

This model could improve convenience and provide some traffic benefits through automated vehicle control. However, parking demand and dependence on private vehicles may remain relatively high. Greater travel convenience could also encourage longer trips and make locations farther from urban centers more attractive, potentially contributing to increased vehicle travel and suburban development [20], [29].

In this scenario, autonomous driving would primarily change the experience of using a private vehicle rather than fundamentally changing the transportation system.

B. Scenario 2: Urban Robotaxi and Shared Mobility

A second scenario involves greater use of Robotaxis and shared autonomous vehicles in U.S. metropolitan areas. Instead of owning a vehicle, some travelers could access autonomous transportation as an on-demand service.

Shared autonomous mobility could reduce the need for some private vehicles and parking spaces, particularly if vehicles serve multiple passengers throughout the day [21], [51]. Robotaxis could also provide first-mile and last-mile connections to public transportation. Research in Austin, Texas has demonstrated the potential for shared automated vehicles to support access to rail transit under modeled conditions [27].

However, this scenario does not automatically reduce road traffic. If Robotaxis mainly replace public-transit trips, operate with low passenger occupancy, or travel significant distances without passengers, total vehicle miles traveled could increase. The outcome depends strongly on pricing, ride sharing, public-transit integration, and transportation policy.

C. Scenario 3: Autonomous Freight Corridors

A third scenario is centered on freight transportation. Autonomous trucks may initially become more common on major interstate highways and structured freight corridors rather than operating fully autonomously across every part of the road network.

One possible model is the use of autonomous transfer hubs. Human-driven trucks could transport freight between warehouses and transfer facilities, while autonomous trucks perform long-distance highway segments between hubs [28].

For the United States, such a model could affect major logistics corridors, distribution centers, fleet operations, and the trucking workforce. Research on the U.S. autonomous trucking market identifies logistics efficiency, infrastructure readiness, regulation, and labor impacts as important factors in future deployment [7].

This scenario could develop independently from urban Robotaxi services. Autonomous freight could therefore become economically significant even if passenger automation develops along a different trajectory.

D. Scenario 4: Highly Connected Integrated Transportation

The most extensive scenario involves the integration of passenger vehicles, autonomous freight, public transportation, infrastructure, and traffic-management systems into a highly connected transportation network.

Under this scenario, autonomous vehicles would not operate only as independent machines. Passenger vehicles and trucks could exchange information with infrastructure and other vehicles, while network-level systems could use traffic and routing information to coordinate movement.

This scenario has an important participation constraint. The cooperative benefits reviewed in Section IV require a sufficient presence and spatial concentration of compatible connected vehicles for repeated cooperative interactions to occur [13], [15], [17]. A highly connected scenario therefore cannot be defined solely by the technical capability of individual vehicles; it also depends on the scale and interoperability of participating vehicles and infrastructure. This review does not infer a specific penetration threshold.

At this level of integration, passenger vehicles, freight vehicles, public transportation, infrastructure, and traffic-management systems could operate as interconnected components of the same transportation network.

Such integration could support cooperative traffic management, coordinated freight movement, and multimodal passenger transportation. It would also create greater dependence on communication networks, software, and transportation data. Cybersecurity, privacy, system resilience, and governance would consequently become increasingly important [10], [46].

Table II summarizes the major differences among the four development paths discussed above.

As summarized in Table II, autonomous driving technology alone does not determine the future structure of transportation. Private autonomous vehicles may preserve many characteristics of the current U.S. transportation system, whereas shared mobility and autonomous freight could produce broader changes in vehicle use, transportation services, and logistics. Among the scenarios considered here, highly connected integrated transportation represents the broadest system-level transformation while also imposing the strongest requirements for interoperability, participation, communication, and digital infrastructure.

In practice, these scenarios are likely to overlap rather than develop independently. Different regions of the United States may follow different paths depending on population density, highway dependence, public transportation, freight activity, regulation, and infrastructure investment.

XI. Discussion and Conclusion

The reviewed literature indicates that autonomous transportation should be evaluated as a transportation-system transition rather than only as a change in vehicle control. Passenger mobility and freight automation can develop through different operating models, but their broader effects increasingly depend on shared infrastructure, connectivity, service design, and governance.

A. System-Level Implications

Three conclusions follow from the synthesis. First, the effects of automation are conditional on deployment structure. Private ownership, shared fleets, transit integration, and freight-corridor operation create different traffic, land-use, economic, and environmental mechanisms.

Second, connectivity changes both the potential benefits and the scale of dependency. Cooperative control can improve traffic operation when compatible participation is sufficient, but network-level coordination also creates dependence on communication infrastructure, interoperability, cybersecurity, and system resilience.

Third, improvements at the vehicle level do not necessarily translate into equivalent improvements at the transportation-system level. Additional travel, empty vehicle movement, changes in modal choice, infrastructure requirements, and distributional effects can reinforce or offset vehicle-level benefits. Evaluation should therefore distinguish technical capability from system-level outcome.

B. Policy and Future Development

The future of autonomous transportation is partly a policy and planning question. A transportation system dominated by private autonomous vehicles may preserve many characteristics of the current U.S. system, whereas shared mobility, connected infrastructure, and autonomous freight networks could create broader structural changes.

Different regions are also likely to develop differently. Dense metropolitan areas may place greater emphasis on Robotaxis, shared mobility, and public-transit integration, while regions with significant interstate freight activity may experience autonomous trucking more directly. A single national pattern should therefore not be assumed.

As transportation becomes increasingly connected, policy must address issues beyond individual vehicle safety, including cybersecurity, data privacy, system resilience, accessibility, workforce transition, spectrum and interoperability, and the governance of network-level transportation decisions.

C. Limitations

This review has several limitations. First, the analysis is qualitative and does not estimate adoption thresholds, deployment timelines, effect sizes, or causal relationships. Its conclusions identify mechanisms and plausible development paths rather than quantitative outcomes.

Second, the emphasis on the United States limits direct transferability to countries with different urban forms, regulatory institutions, transit systems, freight structures, and communication infrastructure.

Third, the paper synthesizes published literature rather than generating original empirical evidence. Several arguments therefore depend on findings from simulation studies, scenario analyses, reviews, and other secondary evidence whose assumptions differ across studies. The four future scenarios developed in Section X are unvalidated analytical constructs intended to organize the literature; they should not be interpreted as forecasts.

Fourth, autonomous-driving technology, commercial deployment, and the regulatory environment are changing rapidly. The evidence base reflects literature and regulatory sources identified through August 2026, and some technological, commercial, and policy conditions may evolve faster than the peer-reviewed literature can document them. Consequently, the discussion should be interpreted as a synthesis of the evidence available at the time of review rather than as a description of a stable or final transportation environment.

TABLE II: Comparison of Future U.S. Autonomous Transportation Scenarios

Scenario	Main Model	Primary Environment	Potential Opportunity	Main Uncertainty
Private Autonomous Mobility	Individually owned autonomous vehicles	General roads, suburban areas, and intercity travel	Greater travel convenience and reduced driving burden	Higher VMT and continued dependence on private vehicles and parking
Robotaxi and Shared Mobility	On-demand shared autonomous fleets	Urban and metropolitan areas	Reduced ownership and parking demand; improved access to public transit	Empty vehicle miles, low occupancy, and possible competition with transit
Autonomous Freight Corridors	Fleet-based autonomous trucking	Interstate highways and major freight corridors	Improved logistics efficiency and vehicle utilization	Workforce transition, infrastructure readiness, and regulation
Highly Connected Integrated Transportation	Coordinated passenger, freight, transit, and infrastructure systems	Metropolitan and interregional transportation networks	Network-level coordination and multimodal integration	Cybersecurity, system resilience, privacy, governance, and participation scale

Finally, possible publication bias should be acknowledged. Cooperative-control and simulation studies may disproportionately represent technically feasible or positive performance results, while null, negative, unstable, or implementation-constrained findings may be less visible. This review did not formally test for such bias. Reported benefits of CACC, cooperative merging, routing, and network coordination should therefore not be interpreted as expected real-world effects without corresponding operational evidence.

D. Conclusion

This paper examined the potential future of connected autonomous transportation in the United States from a qualitative, narrative-review perspective. It does not predict a specific adoption rate, deployment timeline, or quantitative transportation outcome. Instead, it identifies the mechanisms through which passenger and freight automation can affect traffic, mobility, urban systems, economic activity, environmental performance, and transportation governance.

The synthesis indicates that the long-term significance of autonomous vehicles may depend less on the ability of an individual vehicle to drive itself than on how autonomous vehicles become integrated with other vehicles, infrastructure, mobility services, freight networks, and public transportation.

Autonomous transportation may therefore represent not only a change in vehicle technology, but a change in the organization of transportation itself. The most consequential long-term transition may be from independently operated vehicles toward an increasingly connected, coordinated, and service-oriented system for moving both people and goods across the United States.

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