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Intelligent Connected Technology for Campus Vehicle Applications: A Review

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Abstract

Intelligent connected technology (ICT), a product of the deep integration of artificial intelligence (AI), the Internet of Things (IoT), communication technologies, big data, and autonomous driving, aims to increase transportation safety, efficiency, and comfort through synergistic "intelligence" and "connectivity." This synergy enables real-time information interaction and collaborative decision-making among vehicles, road infrastructure, users, and cloud platforms, ultimately fostering a smarter, greener, and more efficient transportation system. With the increasing application of ICT in confined environments, university campuses, as typical microcosms of urban settings, are witnessing a transformation in vehicle usage demands—shifting from mere commuting to social, collaborative, and scenario-integrated needs. This review focuses on the closed-campus context, investigating the mechanisms through which ICT drives the socialization, collaboration, and scenario fusion of campus vehicle use, thereby providing theoretical support for tailoring technology to campus-specific scenarios. Specifically, we synthesize research progress across three critical dimensions: social connectivity, fleet collaboration, and scenario integration. Employing a critical analysis approach, we examine the methodological designs and conclusion applicability of existing studies, highlight their limitations, and substantiate our arguments with empirical cases from pilot initiatives at Chinese universities. Moving beyond the prevailing singular focus on "technical functionality," this paper pioneers a "demand-technology-scenario" triadic interactive perspective to reveal the adaptation gap between technology and social needs in campus mobility. On the basis of an analysis of 35 literature sources, primarily from the last five years, we identify significant shortcomings in technology-scenario adaptation. Future efforts should focus on interdisciplinary integration, targeted innovation, and application scenario expansion to promote the deep integration of ICT with campus vehicle ecosystems.

Keywords

intelligent connected vehicles, socialization of campus vehicle use, campus fleet collaboration, scenario integration, social connectivity

1. Introduction

Recent advancements in V2X communication, vehicular network platforms, and autonomous driving assistance systems have laid a foundation for restructuring transportation systems in confined areas such as university campuses. The primary users of campus transportation are undergraduate and graduate students, characterized by strong social demands (e.g., group research, club activities), high acceptance of new technologies, and frequent, diverse travel needs (including commuting and intercampus exchanges).

Additionally, the transportation requirements of faculty, staff, and visitors collectively constitute a unique “microbility ecology” on campuses.

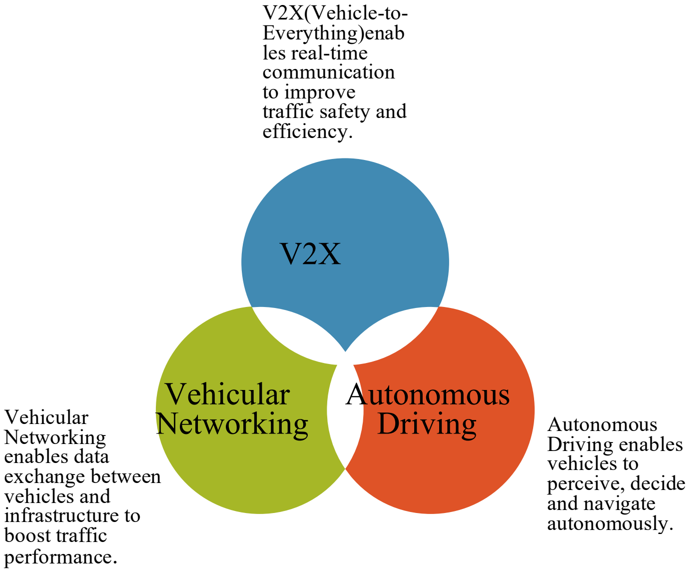
As “microcosms of cities,” campuses offer an ideal testing ground for ICT due to their semiclosed environment, high user density, and controllable traffic flow (Peng et al., 2025), presenting lower verification risks than urban roads do and being more aligned with public needs than industrial parks are. The intelligent transformation of campus mobility holds significant promise: (1) alleviating congestion during peak class hours to increase travel efficiency and safety; (2) providing a reference for traffic management in other closed communities and industrial parks; and (3) leveraging demand-driven factors, such as “social vehicle use,” to optimize technology iteratively and prevent a disconnect between technological capabilities and practical applications.

However, existing research predominantly focuses on the technology itself or open urban roads, leaving three main gaps in the context of campus vehicle use: (1) a disconnect between technology and user needs, with insufficient exploration of campus-specific scenarios such as in-vehicle social networking or interest-based group travel; (2) a lack of collaborative studies, where fleet networking and campus scenarios are merely “functionally superimposed” without achieving systematic synergy among “people-vehicles-roads-facilities-management” (Qian et al., 2024); and (3) an absence of critical perspective, failing to adequately address constraints such as campus pedestrian complexity and management barriers.

While current ICT research has established a multidimensional framework and existing reviews offer theoretical insights, specific limitations persist in the campus context. For example, the extended disturbance observer (EDO) method (Yan et al., 2024), although optimized for general traffic scenarios against physical disturbances such as road unevenness and wind resistance, may not adequately address the real-time and dynamic nature of campus environments despite the use of reinforcement learning (RL) for strategy optimization. Similarly, the multitask learning framework in (Wu et al., 2021) focuses primarily on vehicle dynamics performance (e.g., path smoothness, collision avoidance rate), potentially improving traffic efficiency without incorporating socialization objectives (e.g., ride-sharing matching success rate, in-vehicle interaction comfort). There is a notable deficiency in systematically analyzing the relationship between ICT and the social needs of campus users (particularly students), optimizing for low-speed, high-pedestrian-density, and frequent stop-and-go characteristics of campus environments, and exploring the synergistic mechanism of “technical features-user needs-campus scenarios.”

To address these gaps, this paper examines how ICT drives social connectivity, fleet collaboration, and scenario integration in campus vehicle use. By reviewing research progress and critically analyzing methodological limitations (e.g., application of generic models) and conclusion controversies (e.g., the trade-off between fleet efficiency and road capacity), we identify research voids and propose an interdisciplinary research approach that integrates “transportation engineering + sociology + management science.” Focusing on closed-campus scenarios, we explore the application of V2X (Priya and Kavitha, 2025), vehicular networks, and autonomous driving technologies (Du et al., 2024) in segmented campus contexts while analyzing the impact of constraints such as pedestrian density and management models to support the development of an intelligent campus vehicle system.

Figure 1. Introduction to the three technologies: V2X, connected vehicle network, and autonomous driving.

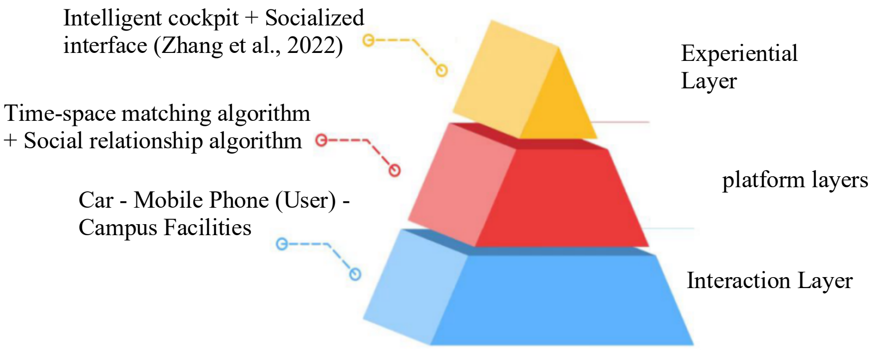


2. ICT-Driven Social Connectivity in Campus Vehicle Use

2.1 Research overview

ICT provides a three-layer technical foundation for socializing campus vehicle use, as illustrated in Figure 2:

Figure 2. Three-layer technical architecture for enabling social connectivity, comprising the interaction, platform, and experience layers.



Interaction Layer: V2X technology is utilized to facilitate real-time human–machine interaction among vehicles, individuals (via smartphones), and campus infrastructure (Cai et al., 2023), enabling the sharing of location, needs, and preferences.

Platform Layer: Vehicular social platforms integrate spatiotemporal matching algorithms (e.g., enhanced Dijkstra's algorithm (Jellid and Mazri, 2023)) and social relationship algorithms (e.g., acquaintance networks, interest-based tagging) to support efficient scheduling for ride-sharing and car-sharing services (Peng et al., 2025).

Experience Layer: Features smart cockpits equipped with socialized interfaces, such as in-vehicle social apps, AI voice assistants (Qu, 2024), or gesture controls, thereby extending social interactions into the campus mobility context.

2.2 Research Status

Current research on ICT-enabled campus vehicles (summarized in Table 1) remains limited across core dimensions because of an excessive focus on functional objectives generic to transportation scenarios.

Table 1. Research status and limitations across three dimensions: socialization models, algorithmic research, and user behavior.

Research Dimension	Mainstream View	Methodological Limitations	Conclusion Controversies
Socialization Model	Predominantly ride-sharing (cost-driven), car-sharing (resource reuse)	Neglects “nonutilitarian social demands” (e.g., interest-based travel)	Disagreement on the merits of commercial vs. campus-self-built platforms
Algorithmic Research	Focus on spatiotemporal matching algorithm optimization (e.g., GA (Damos et al., 2025))	Lacks integration of social relationship weights (e.g., acquaintance priority)	Controversy over efficiency-priority vs. safety/trust-priority
User Behavior	Cost (62%) and socializing (28%) are core motivations (Becker and Carmi, 2019)	Samples concentrated in top-tier city universities, lacking generalizability	Impact of Gen Z social preferences on system design lacks consensus

Socialization models are guided predominantly by commercial mobility logic, emphasizing cost-sharing and resource reuse while neglecting nonutilitarian social demands, such as interest-based travel, specific to campus environments. Disagreements persist regarding the choice between commercial and campus self-built platforms, stemming from differing considerations of data privacy and scenario adaptability. Algorithm research prioritizes efficiency-first principles, such as those in genetic algorithms (Damos et al., 2025), but overlooks relational weights such as acquaintance networks and trust preferences, indicating an immature balance between technological performance and user experience, which leads to conflicts between efficiency and safety objectives. Although user behavior studies identify cost (62%) and socialization (28%) as primary motivations (Becker and Carmi, 2019), their reliance on samples from universities in major cities limits generalizability. Furthermore, a lack of deep understanding of the personalized social preferences of the Generation Z cohort undermines the universality of conclusions and guidance for design. In summary, existing studies fail to construct a synergistic logic of “technical features - social needs - campus scenarios,” hindering effective adaptation to the complex campus mobility ecosystem.

2.3 Critical analysis

2.3.1 Core Issues

Current research on applying ICT to campus vehicle scenarios presents several core problems. With respect to privacy and security, vehicular platforms that collect user location and social information often fail to consider the particularities of the campus context. The information generated by students and staff in academic exchanges or campus activities is highly sensitive; however, advanced privacy-preserving techniques such as differential privacy are insufficiently studied within campus vehicular networks, leaving data vulnerable to leakage risks.

In algorithm design, prevailing matching algorithms prioritize “efficiency optimization,” neglecting the demand for “social trust” among university students. For example, in stranger ride-sharing scenarios, students are concerned with the safety and reliability of companions, but algorithms lack integrated social trust evaluation mechanisms. This omission makes it difficult to identify and mitigate potential safety hazards, dampening enthusiasm for using ICT-based campus vehicle services.

The functional design also suffers from homogenization. Social features in smart cockpits often mimic commercial apps without delving into campus-specific social scenarios. Activities such as chartered buses for student societies or collective trips during the graduation season possess unique social interaction patterns and needs. However, current smart cockpit functionalities are not tailored accordingly and fail to meet users' social and information-sharing demands in these contexts, leading to resource waste and a suboptimal user experience.

2.3.2 Future Perspectives

(1) **Building Trust Mechanisms:** Current systems are poorly suited for campus vehicle scenarios. Technically, the security of data transmission and storage in vehicular networks is questionable. Socially, effective means of verifying trust are lacking for scenarios such as stranger ride-sharing. Therefore, a dual-trust model that combines "technical trust (e.g., using blockchain (Chen et al., 2025, Surapaneni et al., 2025, Asif et al., 2022) for data security) + social trust (e.g., leveraging campus social networks to assess credibility)" is essential for creating a secure and reliable vehicle-use environment.

(2) **Development of scenario-specific standards:** The regulatory framework for socialized campus vehicle use is virtually nonexistent. Issues such as responsibility partitioning in ridesharing, cost-sharing mechanisms, and driving regulations for specific campus periods (e.g., peak class hours) and zones (e.g., teaching areas, dormitories) lack clear definitions, impeding the effective implementation of ICT on campuses.

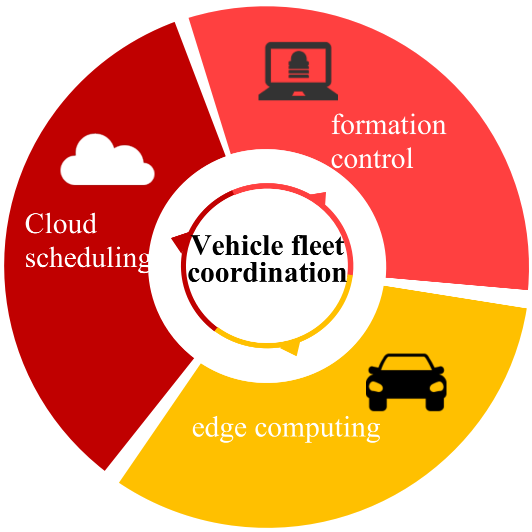
(3) **Interdisciplinary research integration (Dong and Shi, 2023, Raats et al., 2020):** Sociological insights into the nonutilitarian demands of students for "socialized vehicle use," such as self-identity and group belonging, have not been deeply integrated into ICT system design. Current research fails to fully explore the influence of these needs on system design, resulting in interface interactions and functional layouts that mismatch deep-seated user demands, thereby limiting ICT support for campus vehicle socialization.

3. ICT-Enabled Campus Fleet Collaboration

3.1 Research overview

Campus fleet collaboration relies on a technological closed loop that integrates "V2V platoon control + cloud platform scheduling + edge computing" (Figure 3):

Figure 3. Closed-loop technology for fleet collaboration, encompassing platoon control, cloud collaboration, and edge computing.



Platoon Control: V2V communication (Gao et al., 2024) is utilized for dynamic adjustment of the intervehicle distance, speed synchronization, and obstacle warning, which is applicable to campus shuttle bus queues.

Cloud Collaboration: The vehicular network platform integrates real-time traffic conditions and passenger demand to optimize multivehicle path planning (Shan et al., 2024, Mi et al., 2025) and time window allocation (Nafstad et al., 2025).

Edge Computing: Deploying edge nodes at campus base stations reduces the latency for fleet interactions from 50 ms to approximately 10 ms (Tan et al., 2025, Gao et al., 2024), adapting to complex architectural environments.

3.2 Research Status

Academia lacks consensus on technical prioritization: whether to “first optimize platoon control (hardware-driven)” or “first perfect scheduling algorithms (software-driven).” The hardware-driven school argues that enhancing sensor accuracy and actuator response speed is a prerequisite for collaborative scheduling. Conversely, the software-driven school advocates that algorithm optimization can improve fleet efficiency on the basis of existing hardware, avoiding resource waste from excessive hardware investment. This divergence directly affects resource allocation and implementation pace in R&D.

Furthermore, campus fleet collaboration faces management conflicts. Campus management must balance traffic order and safety, often mandating fixed routes, stops, and schedules. Conversely, chartered vehicle demands from student clubs and research teams are often temporary and flexible, with a strong desire for self-dispatching. An effective coordination mechanism has yet to be found to resolve conflicts over usage times and route adjustments.

Existing methods such as Sliding Time Window-based Global Optimal (GO-STW) and First-Come-First-Serve Routing (FCFS-R) are used to optimize the input time (entry into intersections) and routing decisions (entry/exit lanes) (Nafstad et al., 2025), as seen in smart logistics fleets. For semiconfined environments, an adaptive genetic algorithm (AGA)-based path planning method connects vehicles on variable routes. This involves building origin–destination (OD) matrix-based passenger origins/destinations and adjusting vehicle routes according to traffic demand and road network conditions, combined with density-based spatial clustering of applications with noise (DBSCAN) (Mi et al., 2025).

3.3 Critical Analysis

3.3.1 Core Issues

At the collaborative algorithm level, although genetic algorithms and reinforcement learning are widely used in fleet scheduling, they often fail to adequately accommodate the unique “high pedestrian density, fixed route” characteristics of campuses. A pilot project based on C-V2X technology in the Fulton County Schools system, Alpharetta, GA, USA, involving the Audi USA, exemplifies this. The campus features winding roads, compact building layouts, and high student flow rates during school hours. Despite vehicles equipped with advanced C-V2X systems communicating with roadside units (RSUs) and other vehicles, traditional collaboration algorithms struggle with precise and rapid path planning in this complex environment. When school buses stop picking up students, accompanied by an influx of private and faculty vehicles, the algorithms cannot facilitate dynamic decision-making at peak times, leading to drastically reduced traffic efficiency and frequent near-miss incidents due to untimely pedestrian avoidance.

With respect to benefit verification, existing studies predominantly focus on traditional metrics such as “energy consumption reduction (15%-30%) and efficiency improvement” but overlook the impact of fleet operations on overall traffic flow. For example, smart retail vehicles introduced at the Shanghai Vocational College of Science and Technology can accurately recognize traffic lights and avoid pedestrians when driving alone. However, during multivehicle platooning, the intervehicle distance control algorithm, which is unadapted to narrow campus roads, often encroaches on bicycle lanes, obstructing bicycles and e-scooters used by students and staff and thereby disrupting the original campus traffic order.

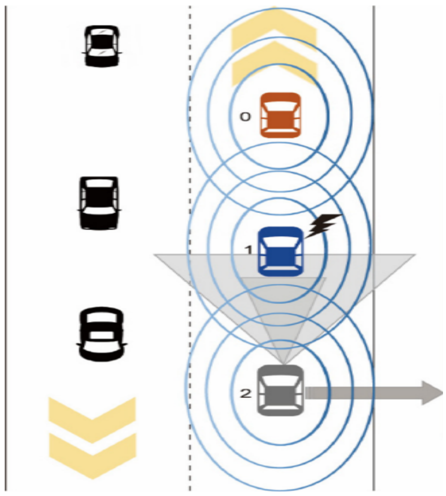
Moreover, research outcomes exhibit significant deficiencies in robustness (Song et al., 2024). If a single vehicle experiences a failure, such as a sensor anomaly, the collaborative operation of the entire fleet can be compromised. For example, during testing at Tianjin University, a smart connected campus bus caused a nearly one-hour delay on its route because a lidar malfunction on one vehicle prevented the system from quickly reorganizing the platoon or reassigning the faulty vehicle's tasks to others.

3.3.2 Future Perspectives

(1) **Develop scenario-specific collaboration models:** There is a need to move beyond adapting algorithms designed for urban roads and create models tailored to the “pedestrian-vehicle-road” characteristics of campuses. Key challenges include adjusting vehicle routing on the basis of traffic demand and network conditions in low-speed environments (Mi et al., 2025) and planning paths for unstructured roads (e.g., campus paths and temporary construction zones).

(2) **Investigate** dynamic reorganization mechanisms (Xu et al., 2021): exploring "task-driven elastic platooning" (Wei et al., 2024) for campus fleets, such as rapid formation and dissolution for temporary chartered vehicles for events, would increase the responsiveness to sudden vehicle usage scenarios.

Figure 4. In reference (Wei et al., 2024), an elastic fleet scheme is drawn: the information is broadcast among vehicles via V2V networks.



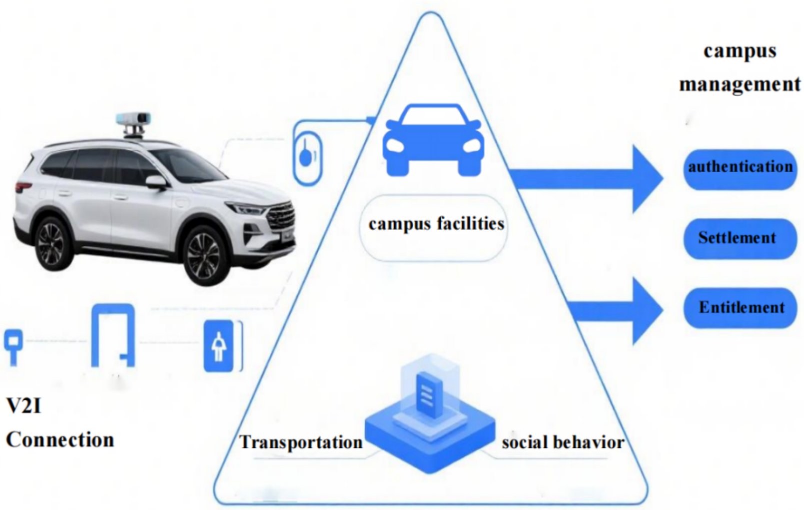
(3) **Promote cross-modal data fusion:** Integrating "traffic flow data + social demand data" would allow fleet scheduling not only to meet efficiency needs but also to respond to social vehicle demands, such as prioritizing vehicle resources for academic conferences or club activities, further refining the precision of campus vehicle services.

4. ICT-Driven Campus Scenario Integration

4.1 Research overview

Campus scenario integration requires breaking through the triadic integration of "vehicles - facilities - management systems" (Figure 5):

Figure 5. Organic integration of vehicles, facilities, and management systems enabled by data flow.



V2I Integration (Lin et al., 2024): Enables real-time interaction between ICVs and campus facilities (e.g., charging piles, automated parking systems, access control), such as automatic recognition of charger status and path guidance.

System Integration (Zhang et al., 2023): Requires seamless connectivity between the vehicular network platform and campus management systems (including identity authentication, payment settlement, and authority management modules) to achieve “one-stop service.” For example, students and faculty can unlock vehicles via their campus ID card, with fees automatically deducted, streamlining the usage process.

Data Closed Loop: Leveraging synergy between edge and cloud computing to construct a campus traffic digital twin model. This model enables real-time simulation of traffic flow changes and social travel demands, providing accurate data for continuous system optimization.

4.2 Research Status

4.2.1 Research Controversies

Controversies surrounding ICT-enabled campus vehicles in academia and practice focus on two main aspects.

First, there is disagreement over the dominant position of scenario integration. The school-led side emphasizes safety as the core, advocating for strict control over vehicle speed, routes, and data access permissions. The enterprise-led party prioritizes efficiency, believing that flexible scheduling and rapid technological iteration can reflect the value of services. However, the two sides find it difficult to reach a consensus on management authority, responsibility assumption, and other aspects.

Second, there is a vacuum in standard systems. Technically, unified communication frequencies and data interface standards are lacking, preventing information exchange between vehicles of different brands. Managerially, accident liability is ambiguous. For example, liability allocation among the school, enterprise, and technology provider in a collision between an autonomous vehicle and a pedestrian lacks a clear basis.

4.3 Critical Analysis

4.3.1 Core Issues

Current ICT implementation in campus scenarios faces multidimensional core problems. First, significant compatibility barriers hinder the effectiveness of technological applications. The adaptability between existing campus infrastructure and ICVs is insufficient, particularly in terms of energy replenishment. Older charging piles commonly use the OCPP 1.6 standard protocol, whereas most automakers employ proprietary communication protocols to maintain technological barriers, resulting in a failure rate as high as 30% for the connection. For example, smart shuttles introduced at one university experienced frequent charging interruptions due to protocol incompatibility, directly impacting daily operational scheduling.

Second, data security risks permeate the entire service process. Campus management systems need to share basic user information (students/staff), vehicle scheduling data, etc., with the vehicular platform for service synergy. However, vague data-sharing boundaries and insufficient application of encryption technologies create prominent privacy leakage risks. Sensitive information, such as student class schedule movement trajectories and on-campus consumption records, could be illegally obtained through platform vulnerabilities, violating data security regulations and eroding trust in the smart vehicle service.

Third, neglecting scenario constraints makes technology difficult to realize. Autonomous driving technology applied on campuses often needs better adaptation to the unique traffic environment: during the 10-minute class break peak, pedestrian density around teaching buildings can reach 1.2 persons per square meter, causing vehicle obstacle avoidance algorithms to respond with lag; unstructured roads such as campus pedestrian streets and wooded paths lack clear traffic signs, leading to frequent misidentification of vegetation or temporary facilities by lidar, resulting in constant vehicle stops and starts that impair traffic efficiency.

4.3.2 Future Perspectives

(1) **Standardization systems:** Standard systems covering technology and management processes must be developed while considering campus characteristics. Technically, unifying communication protocols and data encryption standards can address compatibility issues between facilities and vehicles. Managerially, clarifying accident liability allocation and data usage boundaries provides institutions for service implementation.

(2) **Advance Digital Twin Integration:** Constructing a multimodal campus digital twin system (Feng, 2025). Integrating traffic flow data, social travel demand data, and daily behavioral trajectory data into a dynamically updated digital twin allows accurate prediction of vehicle demand during morning/evening peaks and for club activities chartered vehicles, enabling proactive vehicle scheduling and optimized resource allocation.

(3) **Establishing Emergency Collaboration Mechanisms:** Research should focus on rapid collaboration strategies between “vehicles - facilities - management” during campus emergencies (e.g., large events, extreme weather), such as efficient dispatch of emergency fleets and timely adjustment of facility priorities, thereby enhancing the campus's ability to respond to contingencies.

5. Supplementary Practical Cases

Several universities worldwide have initiated ICV pilots, providing practical evidence for theoretical research. The Imperial College London focused on fleet collaboration technology, introducing V2V communication into campus shuttle buses for three-vehicle platooning. The pilot initially found a 1.2-second response delay in the original algorithm when the platoon yielded pedestrian flows between classes, posing safety risks. After optimizing by incorporating a “pedestrian trajectory prediction model,” the response delay was reduced to 0.3 seconds, and the number of scratch incidents decreased to zero during the trial. However, a new issue emerged: platooning requires a lateral spacing of 1.4 meters between vehicles, increasing the occupied bicycle lane width by 20% and reducing bicycle traffic efficiency by 15%. This phenomenon directly corroborates the aforementioned “impact of fleet operations on campus traffic flow.”

Cornell University deployed 20 ICV shared cars on campus. Through deep integration between the vehicular platform and the campus ID system, a “one-stop service” was realized where students tap their campus card to unlock and have fees automatically deducted from their student account (some vehicles support facial recognition unlocking, adapting to diverse user habits). In social function testing, students can initiate “interest-based ride-sharing” through a dedicated app. The system matched riders on the basis of class schedules, club activity calendars, and historical travel patterns. After a six-month trial, the ride-sharing success rate increased by 40%, and student satisfaction reached 82%, validating the feasibility of aligning socialization needs with technological adaptation.

These pilot cases demonstrate that deploying ICT on campuses requires retaining technological advantages while continuously optimizing for the particularities of campus pedestrian flow and management models, providing practical justification for the “scenario-specific adaptation” direction proposed in this paper.

6. Conclusion

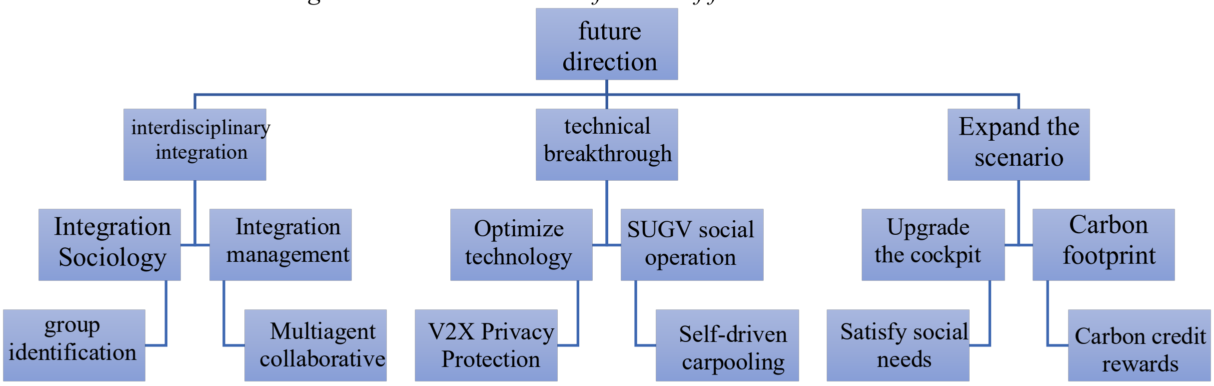
This review systematically addresses the core issues of how ICT drives social connectivity, fleet collaboration, and scenario integration in campus vehicle use. We synthesized research overviews, current status, and critical analyses across these three directions. The study revealed that ICT provides the technological potential for transforming campus mobility. However, significant gaps exist in adapting technology to campus needs, interdisciplinary integration, and the construction of management mechanisms. Through critical analysis and empirical case studies, we propose a “demand-technology-scenario” triadic interactive perspective. Pathways forward include interdisciplinary fusion, campus-specific technology development, and expanded social scenarios to promote deep integration of ICT with campus vehicle ecosystems. This study fills a gap in the systematic analysis of ICT application within specific campus contexts, providing a theoretical reference and practical direction for the scenario-specific adaptation and sustainable development of this technology.

Among the three categories of methods reviewed, ICT promotes the transformation of the campus vehicle system at different levels: social connectivity methods, which rely on V2X communication, social matching algorithms, and smart cockpit interaction, aim to build a user-centric demand–response mechanism. However, these methods suffer from weak privacy protection and insufficient social trust building in practical applications. Fleet collaboration methods, which are centered on V2V platoon control, cloud scheduling, and edge computing, aim to increase operational efficiency and resource reuse in multivehicle cooperation. However, current algorithms often need help in adapting to campuses' unique high-density pedestrian and low-speed, stop-and-go traffic environments, easily leading to localized traffic efficiency degradation and low system robustness. Scenario integration methods focus on deep integration among "vehicle-facility-management" systems, building an integrated service ecology through V2I communication, identity/payment system linkages, and digital twin technology. However, these methods are constrained by practical bottlenecks such as incompatible facility protocols, significant data security risks, and a lack of standards.

Critical analysis reveals that most existing research remains predominantly focused on technological functionality implementation, paying insufficient attention to the realistic constraints of social attributes, management complexity, and multiagent collaboration in campus scenarios. This leads to a significant gap between research and practical application. Furthermore, the lack of an interdisciplinary perspective limits the deep integration and sustainable development of ICT in the unique campus environment.

7. Future Perspectives

Figure 6. Hierarchical classification of future research directions



7.1 Future research directions (Figure 6)

7.1.1 Interdisciplinary Research Integration

(1) **Integration with Sociology:** The demand for "socialized vehicle use" among university students manifests in group identity (e.g., exclusive vehicles for communities) and self-expression (e.g., personalized car decals). System stickiness can be enhanced by designing features incorporating community usage profiles, personalized interactions, and social credit systems.

(2) **Integration with** management science: Constructing a multistakeholder (university-enterprise) collaborative governance framework for campus ICVs, balancing safety, efficiency, and user experience.

7.1.2 Technological breakthrough directions

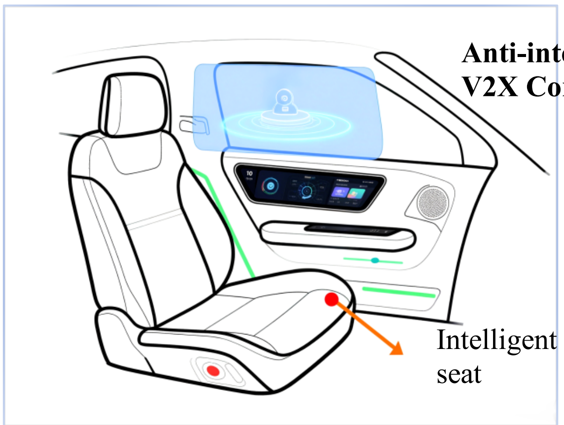
Optimize Campus-Specific Technologies: Develop anti-interference V2X communication solutions (e.g., millimeter-wave + UWB fusion) and privacy-computing techniques (e.g., applying Federated Learning (Alqubaysi et al., 2025) in socialization contexts).

Explore Socialized Operation of Autonomous Vehicles: Experiment with "fully autonomous social ride-sharing" modes for campus autonomous vehicles, such as automatic grouping on the basis of interest tags and dynamic route planning.

7.1.3 Application scenario expansion

(1) **Upgrade Smart Cockpits:** Integrate functions such as virtual companions and interest-based interactions to create "mobile social spaces" that meet socialization needs. (As shown in Figure 7)

Figure 7. Function diagram of the rear seat AR social interaction intelligent seat



(2) **Design Socialized Carbon Footprint Incentives:** Align with campus carbon peak goals by introducing a socialized carbon credit system, e.g., implementing ride-sharing carbon reduction rankings and awarding carbon credits to collaboratively traveling fleets.

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Conflicts of Interest

The authors declare no conflict of interest.

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