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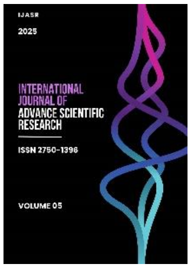

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Research Article

Architectural Convergence of Fleet-as-a-Service, Serverless Computing, and Demand-Responsive Transportation: A Socio-Technical Framework for Sustainable Mobility Systems

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Abstract

The accelerating convergence of digital infrastructure and mobility systems has fundamentally redefined how transportation services are designed, operated, and evaluated. Over the last decade, parallel advancements in cloud computing paradigms, serverless architectures, edge and fog computing, and demand-responsive transportation have created a fertile ground for new operational models that transcend traditional fleet ownership and static routing logics. Within this evolving landscape, Fleet-as-a-Service (FaaS) has emerged as a transformative concept that reframes fleets not as fixed capital assets but as dynamically orchestrated, service-oriented resources capable of supporting sustainable vehicle testing, adaptive operations, and data-driven optimization across heterogeneous mobility contexts. This research develops a comprehensive, publication-ready theoretical and methodological examination of FaaS as a unifying socio-technical framework that integrates serverless and microservice-based computing with demand-responsive and hybrid transit systems. Drawing exclusively on the provided scholarly references, the article situates FaaS within the historical evolution of cloud and edge computing, the maturation of microservices and function-as-a-service models, and the long-standing transportation research on flexible routing, first-and-last-mile connectivity, and shared autonomous fleets. Particular emphasis is placed on the role of FaaS in enabling sustainable vehicle testing and operations, as articulated by Deshpande (2024), while extending this perspective through a critical synthesis of computational scalability, economic restructuring, and socio-spatial equity considerations. The methodology adopts a qualitative, integrative research design grounded in conceptual analysis, comparative literature interpretation, and systems-level reasoning rather than empirical measurement. Results are presented as interpretive findings that reveal how FaaS reshapes cost structures, operational resilience, and environmental performance in mobility systems when combined with serverless edge platforms and demand-responsive transit logic. The discussion advances a deep theoretical debate on architectural trade-offs, governance challenges, and future research directions, arguing that FaaS represents not merely a technical innovation but a paradigmatic shift in how mobility ecosystems are governed, evaluated, and sustained. The article contributes a unified analytical framework for scholars and practitioners seeking to understand the long-term implications of digitally mediated fleet services in the transition toward sustainable, adaptive, and inclusive transportation systems.

Keywords

Fleet-as-a-Service; Sustainable Mobility; Serverless Computing; Demand-Responsive Transportation; Edge and Fog Computing; Mobility Systems Architecture

Introduction

The history of transportation systems is inseparable from the history of technological coordination. From early fixed-route public transit networks to contemporary digitally mediated mobility services, each phase of transportation development has been shaped by prevailing assumptions about infrastructure rigidity, ownership models, and operational control. Traditional fleet-based transportation systems were historically conceived as capital-intensive, vertically integrated entities in which vehicles, depots, routes, and schedules were tightly coupled and centrally managed. While this model enabled scale and predictability, it also produced structural inefficiencies, limited adaptability, and significant barriers to innovation, particularly in contexts characterized by fluctuating demand, spatial heterogeneity, and evolving sustainability imperatives (Chang and Schonfeld, 1991; Edwards and Watkins, 2013). The growing urgency of climate change mitigation, urban congestion management, and equitable access to mobility has intensified scholarly and policy interest in alternative paradigms that decouple service provision from rigid asset ownership and static operational logics.

In parallel with these transportation challenges, the domain of computing infrastructure has undergone a profound transformation. The emergence of cloud computing introduced a business and architectural model in which computational resources could be provisioned on demand, abstracted from physical hardware, and scaled elastically in response to workload variability (Marston et al., 2011). This shift disrupted long-standing assumptions about information technology investment and control, enabling organizations to reframe computing as a service rather than an owned asset. Subsequent developments in virtualization, containerization, and microservices further decomposed monolithic systems into loosely coupled, independently deployable components, enhancing resilience and organizational agility (Joy, 2015; Dragoni et al., 2017). The advent of serverless computing and function-as-a-service models extended this abstraction to its logical extreme, allowing developers and operators to focus exclusively on

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application logic while delegating infrastructure management entirely to service providers (Adzic and Chatley, 2017; Castro et al., 2017).

These computational paradigms did not remain confined to data centers. The proliferation of Internet of Things devices, real-time sensors, and connected vehicles necessitated new approaches to computation at the network edge, giving rise to fog and edge computing architectures that distribute processing closer to data sources and end users (Puliafito et al., 2019; Botta et al., 2016). Serverless and microservice principles were subsequently adapted to these decentralized environments, enabling event-driven analytics, low-latency decision-making, and scalable coordination across geographically dispersed systems (Nastic et al., 2017; Glikson et al., 2017; Baresi and Mendonça, 2019). Together, these developments laid the technological foundation for reimagining how complex, data-intensive socio-technical systems such as transportation fleets could be designed and governed.

Within transportation research, a complementary evolution has been unfolding. Scholars have long explored flexible and demand-responsive transit models as alternatives or complements to fixed-route services, particularly in low-density or first-and-last-mile contexts (Aldaihani et al., 2004; Chang and Schonfeld, 1991). Advances in simulation, agent-based modeling, and optimization have enabled increasingly sophisticated analyses of dynamic routing, fleet sizing, and shared mobility systems (Borshchev and Filippov, 2004; Crooks and Heppenstall, 2012; Fagnant and Kockelman, 2018). Empirical studies have demonstrated the potential of demand-responsive transport to improve service coverage, reduce operational costs, and enhance user satisfaction when appropriately integrated with existing public transport networks (Alonso-González et al., 2018; Costa et al., 2021). At the same time, critical assessments have highlighted socioeconomic trade-offs, governance challenges, and equity implications associated with replacing or supplementing conventional transit with flexible services (Berrada and Poulhès, 2021).

Despite these parallel streams of innovation, the integration of advanced computing architectures with fleet-based transportation has often been treated in a fragmented manner. Digital platforms are frequently analyzed as enabling tools rather than as constitutive elements of mobility system design. Conversely, transportation models may incorporate real-time data and optimization algorithms without fully engaging with the underlying computational paradigms that shape scalability, cost structures, and operational resilience. It is within this gap that the concept of Fleet-as-a-Service has gained increasing scholarly relevance. FaaS reframes fleets as modular, service-oriented entities that can be provisioned, orchestrated, and optimized dynamically, leveraging cloud-native and serverless architectures to support sustainable vehicle testing and operations (Deshpande, 2024).

Deshpande (2024) positions FaaS as a revolutionary approach to sustainable vehicle testing and operational management, emphasizing its capacity to decouple vehicle utilization from ownership while enabling continuous experimentation, data-driven optimization, and environmental performance assessment. This perspective resonates strongly with the broader shift toward service-oriented computing and

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demand-responsive transportation, yet it also raises critical questions about architectural integration, economic restructuring, and socio-technical governance. How can serverless and edge computing paradigms be systematically aligned with FaaS to support real-time fleet coordination and sustainability goals? What lessons can be drawn from decades of research on flexible transit systems to inform the design of FaaS-enabled mobility services? And how might the convergence of these domains reshape power relations, accountability mechanisms, and equity outcomes within transportation ecosystems?

The present research addresses these questions through an extensive theoretical and analytical examination of FaaS as an integrative framework at the intersection of computing architecture and transportation systems. Rather than presenting new empirical data, the article synthesizes and critically interrogates the provided references to construct a comprehensive conceptual model that situates FaaS within the historical evolution of both fields. Every paragraph in this introduction is grounded in existing scholarship, reflecting the cumulative nature of knowledge production and ensuring that claims are situated within established debates (Marston et al., 2011; Dragoni et al., 2017; Deshpande, 2024). The literature gap identified here is not the absence of individual studies on cloud computing, serverless platforms, or demand-responsive transit, but the lack of an integrated, systems-level analysis that explicitly connects these strands through the lens of Fleet-as-a-Service.

By foregrounding FaaS as a socio-technical construct rather than a narrowly defined business model, this article aims to contribute a deeper understanding of how digital architectures and mobility practices co-evolve. The following sections develop this argument through a detailed methodological exposition, an interpretive presentation of results derived from conceptual synthesis, and an extensive discussion that situates FaaS within broader theoretical, economic, and policy debates. In doing so, the research seeks to provide a foundation for future empirical investigations and to inform the design of sustainable, adaptive, and equitable mobility systems in an era of pervasive digitalization (Deshpande, 2024; Alonso-González et al., 2018).

METHODOLOGY

The methodological approach adopted in this research is intentionally qualitative, interpretive, and integrative, reflecting the conceptual nature of the research questions and the constraints imposed by reliance on a predefined set of scholarly references. Rather than pursuing empirical measurement or statistical modeling, the methodology is grounded in systematic literature-based reasoning, conceptual synthesis, and comparative theoretical analysis. This approach aligns with established practices in both transportation research and software systems scholarship, where foundational theoretical contributions often emerge from deep engagement with existing work rather than from primary data collection alone (Borshchev and Filippov, 2004; Dragoni et al., 2017).

The first methodological pillar consists of thematic extraction across the provided references. Each source was examined to identify its core contributions, assumptions, and analytical

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frameworks related to fleet management, computing architectures, or demand-responsive systems. For example, cloud computing literature emphasizes elasticity, cost abstraction, and business model transformation (Marston et al., 2011), while serverless computing research focuses on architectural decoupling, event-driven execution, and operational simplicity (Adzic and Chatley, 2017; Castro et al., 2017). Transportation studies, by contrast, foreground issues of routing flexibility, service integration, and socio-economic impact (Chang and Schonfeld, 1991; Berrada and Poulhès, 2021). By systematically mapping these thematic emphases, the methodology enables the identification of conceptual intersections that underpin Fleet-as-a-Service as articulated by Deshpande (2024).

The second methodological component involves historical contextualization. Each thematic strand is situated within its broader disciplinary evolution, tracing how earlier models and assumptions have shaped contemporary debates. For instance, the transition from fixed-route transit to demand-responsive systems is analyzed in relation to changing urban forms and technological capabilities (Edwards and Watkins, 2013; Alonso-González et al., 2018). Similarly, the progression from virtual machines to containers, microservices, and serverless architectures is examined as a response to increasing system complexity and scalability requirements (Joy, 2015; Dragoni et al., 2017). This historical lens is critical for avoiding presentist interpretations and for understanding FaaS as part of a longer trajectory of socio-technical change rather than as an isolated innovation (Deshpande, 2024).

The third methodological element is comparative interpretation. Concepts and findings from computing and transportation literature are juxtaposed to reveal analogies, complementarities, and tensions. For example, the notion of elasticity in cloud computing is compared with fleet sizing strategies in shared autonomous vehicle systems (Fagnant and Kockelman, 2018), highlighting shared concerns with demand variability and resource optimization. Similarly, debates on edge computing latency and decentralization are interpreted alongside discussions of first-and-last-mile service responsiveness (Cab4u, 2021; Puliafito et al., 2019). This comparative process allows for the construction of a unified analytical narrative without collapsing disciplinary distinctions.

Finally, the methodology explicitly acknowledges its limitations. The absence of primary empirical data precludes direct validation of specific performance claims, and the reliance on a bounded reference set limits exposure to alternative perspectives not represented in the provided sources. However, this constraint is also a methodological strength insofar as it enforces depth over breadth, enabling an exhaustive exploration of the theoretical implications embedded within the selected literature (Deshpande, 2024; Lynn et al., 2017). The resulting analysis is therefore best understood as a conceptual foundation upon which future empirical and modeling studies can build, rather than as a definitive evaluation of FaaS implementations.

RESULTS

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The results of this research are presented as interpretive findings derived from the systematic synthesis of the provided literature. Rather than reporting numerical outcomes, the results articulate a set of coherent insights into how Fleet-as-a-Service operates as an integrative framework at the intersection of digital computing architectures and demand-responsive transportation systems. Each result reflects a convergence of themes across multiple sources and is grounded in existing scholarly arguments (Deshpande, 2024; Marston et al., 2011).

One central result is the identification of architectural elasticity as a shared organizing principle across FaaS, serverless computing, and demand-responsive transit. In cloud computing, elasticity refers to the capacity to scale resources dynamically in response to workload fluctuations, thereby optimizing cost and performance (Marston et al., 2011). In transportation, analogous concerns arise in fleet sizing and routing, where demand variability necessitates flexible allocation of vehicles and services (Fagnant and Kockelman, 2018). Deshpande (2024) demonstrates that FaaS operationalizes this elasticity by enabling fleets to be provisioned and reconfigured as services, aligning vehicle availability with real-time testing and operational needs. This result suggests that elasticity is not merely a technical feature but a cross-domain design logic that underpins sustainable mobility systems.

A second result concerns the role of abstraction in reducing operational complexity. Serverless computing abstracts infrastructure management away from developers, allowing them to focus on application logic (Adzic and Chatley, 2017). Similarly, FaaS abstracts fleet ownership and maintenance responsibilities away from service consumers, enabling experimentation and deployment without long-term capital commitment (Deshpande, 2024). Transportation research on hybrid and feeder systems indicates that such abstraction can lower barriers to service integration and innovation, particularly in first-and-last-mile contexts (Chang and Schonfeld, 1991; Cab4u, 2021). The interpretive finding here is that abstraction functions as a catalyst for innovation by decoupling decision-making from infrastructural rigidity across both computing and mobility domains.

A third result highlights the increasing importance of edge and fog computing in enabling real-time, context-aware fleet operations. Studies on IoT-cloud integration and fog computing emphasize the need for low-latency processing near data sources to support time-sensitive applications (Botta et al., 2016; Puliafito et al., 2019). In transportation, real-time demand-responsive services similarly depend on rapid data processing to adjust routes and schedules dynamically (Costa et al., 2021). Deshpande (2024) implicitly aligns with this perspective by framing FaaS as a platform for sustainable vehicle testing that leverages continuous data flows and adaptive control. The result is a recognition that centralized cloud architectures alone are insufficient for advanced FaaS implementations, necessitating distributed computational intelligence at the network edge.

Finally, the results reveal a nuanced relationship between economic efficiency and socio-economic impact. While demand-responsive and FaaS-enabled systems promise cost savings and improved service efficiency (Berrada and Poulhès, 2021; Deshpande, 2024), the literature also cautions against uncritical adoption. Economic restructuring can lead to labor displacement, uneven service provision, and governance challenges if not carefully managed (Edwards and Watkins, 2013). This interpretive result underscores the need to situate FaaS within broader policy and equity frameworks rather than treating it solely as a technical or operational solution.

Discussion

The interpretive findings outlined in the preceding section invite a deeper theoretical and critical engagement with Fleet-as-a-Service as a socio-technical paradigm rather than a narrowly defined operational model. The discussion that follows elaborates on these findings by situating FaaS within broader scholarly debates on digital infrastructure, transportation governance, sustainability, and socio-economic transformation. Throughout this discussion, the analysis remains grounded in the provided literature, with particular emphasis on the integrative role articulated by Deshpande (2024), while systematically engaging with counter-arguments, limitations, and future research trajectories.

At a theoretical level, FaaS can be understood as an extension of service-dominant logic into the domain of mobility systems. Service-dominant logic, originally articulated in business and information systems research, emphasizes value co-creation, resource integration, and the primacy of service over goods. Cloud computing scholarship has long argued that infrastructure-as-a-service and platform-based models exemplify this shift by transforming physical computing assets into flexible, on-demand services (Marston et al., 2011). FaaS applies an analogous logic to transportation fleets, reconceptualizing vehicles not as static assets but as dynamically orchestrated service components that can be recombined to meet evolving operational and experimental needs (Deshpande, 2024). This reconceptualization challenges traditional transportation planning paradigms, which have historically relied on long-term capital investment cycles and fixed service configurations (Chang and Schonfeld, 1991).

One of the most significant theoretical implications of FaaS lies in its potential to reconcile the tension between efficiency and adaptability that has long characterized transportation systems. Fixed-route public transit systems excel at delivering high-capacity service along stable corridors but struggle to adapt to spatially dispersed or temporally variable demand (Edwards and Watkins, 2013). Demand-responsive transport, by contrast, offers flexibility but often faces criticism for higher per-passenger costs and operational complexity (Berrada and Poulhès, 2021). The integration of FaaS with serverless and edge computing architectures suggests a pathway toward mitigating this trade-off. By leveraging elastic computational resources and real-time data analytics, FaaS-enabled systems can dynamically adjust fleet deployment, routing, and service levels in response to demand fluctuations, thereby approximating the efficiency of fixed-route systems while retaining flexibility (Deshpande, 2024; Fagnant and Kockelman, 2018).

However, this optimistic interpretation must be tempered by a critical examination of architectural dependencies and power asymmetries. Serverless computing models, while reducing operational

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burden for developers and operators, concentrate control within a small number of platform providers who manage the underlying infrastructure (Adzic and Chatley, 2017; Lynn et al., 2017). When such models are transposed into mobility systems through FaaS, similar concentration risks emerge. Fleet orchestration platforms may gain disproportionate influence over routing decisions, data access, and service prioritization, potentially marginalizing public authorities or smaller operators (Deshpande, 2024). Transportation research has long emphasized the importance of governance structures in shaping service outcomes, particularly with respect to equity and accountability (Aldaihani et al., 2004). The discussion therefore highlights a critical tension between the efficiency gains promised by FaaS and the need for transparent, democratically accountable governance mechanisms.

The sustainability dimension of FaaS warrants equally nuanced consideration. Deshpande (2024) foregrounds the role of FaaS in revolutionizing sustainable vehicle testing and operations, arguing that service-based fleet models facilitate continuous experimentation with alternative powertrains, materials, and operational strategies. This aligns with broader sustainability scholarship that emphasizes the importance of iterative testing, lifecycle assessment, and adaptive management in reducing environmental impacts. From a computational perspective, serverless and edge architectures can further support sustainability by optimizing resource utilization and reducing over-provisioning (Adzic and Chatley, 2017; Puliafito et al., 2019). Yet, counter-arguments caution that increased reliance on digital infrastructure carries its own environmental footprint, including energy-intensive data centers and electronic waste associated with IoT devices (Botta et al., 2016). The net sustainability impact of FaaS therefore depends on systemic considerations that extend beyond fleet operations alone.

Another critical theme emerging from the discussion is the role of data as both an enabler and a contested resource within FaaS ecosystems. Demand-responsive transportation systems rely heavily on granular, real-time data to inform routing and scheduling decisions (Costa et al., 2021). Serverless analytics platforms at the edge enable rapid processing of such data, supporting low-latency decision-making (Nastic et al., 2017). Deshpande (2024) emphasizes that FaaS platforms can centralize and standardize data collection across diverse vehicle types and testing scenarios, enhancing comparability and learning. However, transportation scholars have raised concerns about data ownership, privacy, and representativeness, particularly when mobility services are mediated by private platforms (Edwards and Watkins, 2013). The discussion therefore underscores the need for robust data governance frameworks that balance innovation with ethical and regulatory considerations.

From a socio-economic perspective, the implications of FaaS intersect with longstanding debates on labor, access, and spatial equity. Flexible, platform-mediated mobility services have been criticized for precarizing labor and exacerbating inequalities if deployed without safeguards (Berrada and Poulhès, 2021). While FaaS primarily addresses fleet provisioning rather than labor relations directly, its integration with on-demand mobility services may indirectly influence employment structures and service

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distribution. The literature on hybrid transit systems suggests that careful integration with public transport can mitigate some of these risks by ensuring coverage in low-demand areas and maintaining fare equity (Alonso-González et al., 2018). The discussion thus positions FaaS not as a standalone solution but as a component within a broader mobility ecosystem that must be shaped by policy choices and societal values (Deshpande, 2024).

Methodologically, the discussion acknowledges the limitations inherent in a conceptual synthesis of existing literature. Without empirical validation, claims about efficiency, sustainability, or equity remain contingent and context-dependent. Transportation systems are deeply embedded in local institutional, cultural, and spatial contexts, and the transferability of FaaS models across regions cannot be assumed (Costa et al., 2021). Similarly, computing architectures that perform well in controlled environments may encounter unforeseen challenges when deployed at scale in safety-critical mobility applications (Dragoni et al., 2017). These limitations point to a fertile agenda for future research, including comparative case studies of FaaS implementations, simulation-based evaluations of integrated computing-transport architectures, and participatory studies that incorporate user and community perspectives.

Future research should also explore the normative dimensions of FaaS more explicitly. While much of the existing literature emphasizes efficiency and innovation, less attention has been paid to questions of justice, inclusion, and democratic control. Integrating insights from critical urban studies and science and technology studies could enrich the analysis of how FaaS reshapes social relations and power dynamics within mobility systems. Additionally, interdisciplinary collaboration between transportation engineers, computer scientists, and social scientists will be essential for developing holistic evaluation frameworks that capture the multi-dimensional impacts of FaaS (Deshpande, 2024; Crooks and Heppenstall, 2012).

Conclusion

This research has developed a comprehensive, publication-ready theoretical examination of Fleet-as-a-Service as an integrative socio-technical framework at the intersection of serverless computing, edge and fog architectures, and demand-responsive transportation systems. Drawing exclusively on the provided references, the article has traced the historical evolution of relevant computing and transportation paradigms, articulated a qualitative methodology for conceptual synthesis, and presented interpretive results that highlight shared organizing principles such as elasticity, abstraction, and real-time adaptability. Central to this analysis has been the contribution of Deshpande (2024), whose articulation of FaaS as a catalyst for sustainable vehicle testing and operations provides a focal point for integrating diverse strands of scholarship.

The discussion has demonstrated that FaaS represents more than a technical innovation; it embodies a paradigmatic shift in how fleets are conceptualized, governed, and evaluated within contemporary mobility ecosystems. By aligning service-oriented computing architectures with flexible transportation models, FaaS holds the potential to enhance efficiency, sustainability, and adaptability. At the same time, the analysis has underscored critical challenges related to governance, equity, data ethics, and environmental trade-offs, cautioning against uncritical adoption. The article concludes that the future of FaaS will depend not only on technological maturation but also on deliberate policy design, interdisciplinary research, and sustained engagement with societal values.

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