DEVELOPING A DIGITAL ECOSYSTEM IN TRANSPORT: THEORETICAL FOUNDATIONS AND GLOBAL EXPERIENCE

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In recent years, the modernization of public transport systems has become a key factor in sustainable urban development, especially in rapidly urbanizing countries such as Uzbekistan. The shift from traditional transport models to digital ecosystems is driven by the need to achieve efficiency, convenience, and sustainability. A digital transport ecosystem represents a network of interconnected components and technological services that facilitate delivery, management, and optimization within transport systems. This ecosystem is characterized by collaboration between government agencies, private sector enterprises, and end-users, and is supported by advanced technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, mobile applications, and blockchain[1]. A digital ecosystem in public transport can be broadly defined as a network of interconnected components and technological services that facilitate efficient management and optimization of transportation. This ecosystem is built on data interoperability, platform-based collaboration, and stakeholder engagement, ensuring transparency and effective information exchange between different modes of transport. Mobility services increasingly rely on seamless integration with existing infrastructure, resource optimization, and the reduction of inefficiencies[2].

Uzbekistan is currently implementing digital transformation in the transport sector in line with the "Digital Uzbekistan 2030" strategy. The Presidential Decree of the Republic of Uzbekistan No. PF-6269 dated July 24, 2021, *On measures to improve the infrastructure of public services and expand the population's access to public services*, provides a foundation for introducing digital services, improving management systems, and increasing operational efficiency. However, several challenges remain, such as shortcomings in technological infrastructure, regulatory barriers, and issues of digital literacy. The digitalization gap between urban and rural areas also poses a significant problem.

This thesis examines the theoretical foundations of the digital transport ecosystem, its application in Uzbekistan, the main components of an integrated transport ecosystem, implementation strategies, challenges, legal frameworks, and the proposed model for digitalizing transport in Uzbekistan.

Theoretical foundations of the digital ecosystem in public transport*:*

Systems Theory and Transport Digitalization: Introduced by Bertalanffy (1968), the General Systems Theory (GST) describes a system as a set of interconnected and dynamically interacting components that maintain overall integrity[3]. The transport system is an example of this, where various components—including vehicles, passengers, infrastructure, and operators—must function effectively in coordination with one another.

The key principles of GST relevant to digital transport ecosystems include:

[1] Ashurov, D.Z., Makhmudova, G., & Razakova, B. (2022). Development of digital ecosystem and formation of digital platforms in Uzbekistan

[2] Cohen, A.P., Shaheen, S.A., & Farrar, E.M. (2021). Urban air mobility: History, ecosystem, market potential, and challenges. *IEEE Transactions on Intelligent Transportation Systems*, 22(9), 6074-6087

[3] Bertalanffy, L. (1968). General System Theory: Foundations, Development, Applications.

1. ***Holism*** – The transport system is composed of the sum of its individual components, with functionality emerging from the interactions between vehicles, infrastructure, and users.
2. ***Hierarchical structure*** – The transport system consists of several levels that connect smaller subsystems (e.g., national transit, urban transit, micromobility services).
3. ***Open and closed systems*** – Open transport systems interact with their environment, adapting routes and schedules based on real-time data.
4. ***Feedback*** – AI-driven transport management systems use sensor data and passenger feedback to optimize operations.

Applying systems theory to public transport digitalization enables real-time integration of various transport modes, efficient fleet management through IoT, and demand forecasting using AI. For example, Singapore's Smart City Transport system leverages IoT and AI to optimize bus schedules in real time based on passenger demand[4].

Platform theory and the role of digital platforms in transport: Platform theory explains how digital platforms create added value by facilitating interactions between multiple user groups. Digital platforms leverage network effects to scale operations with minimal cost[5].

A platform is typically a multi-sided market or service that enables transactions and exchanges between various participants (e.g., passengers, transit operators, freight carriers, app developers). Platform theory explains how multi-sided platforms generate strong network effects: as more users and service providers join, the platform's value increases and innovation accelerates. In the transport context, Mobility-as-a-Service (MaaS) applications, ride-sharing marketplaces, and logistics hubs serve as platforms that integrate data and services. Platforms can be categorized into the following types:

- ***Transaction platforms*** – facilitate exchanges between different user groups. Examples: eBay (buyers/sellers), PayPal (money transfers), DoorDash (restaurants/delivery drivers/customers).
- ***Innovation platforms*** – provide a foundation for participating parties to develop innovative products and services. Examples: Apple iOS, Google Play, Amazon AWS.
- ***Hybrid platforms*** – combine transaction and innovation functions. Examples: Amazon (marketplace + AWS cloud services), Microsoft (Windows OS + Xbox gaming ecosystems).
- ***Industrial platforms*** – *designed for manufacturing and the Internet of Things (IoT).*

Business ecosystem model in transport: The business ecosystem model describes how companies operate not individually, but within a dynamic network of interdependent actors — including suppliers, customers, competitors, and other stakeholders — that collectively manage innovation and value creation[6].

In transport, this means that traditional competitors (e.g., public and private transit) and new entrants (mobility startups, technology providers) form a network of suppliers, complementors, and customers. Thus, business ecosystem theory reminds us that successful digital transport systems require synergy among regulators, infrastructure owners, technology

[4] Gohar, A. & Nencioni, G. (2021). The role of 5G technologies in a smart city: The case for intelligent transportation systems. *Sustainability*, 13(9), 5188.

[5] Rochet, J.C., & Tirole, J. (2003). Platform competition in two-sided markets. *Journal of the European Economic Association*, 1(4), 990-1029.

[6] Moore, J.F. (1993). Predators and prey: A new ecology of competition. *Harvard Business Review*, 71(3), 75-86.

companies, and end users. A collective strategy — such as coordinated innovation, joint investments, and adaptive regulations — often replaces purely competitive behavior to foster the overall development of the ecosystem.

Comparative analysis of traditional and ecosystem-based business models

Traditional business	Ecosystem-based business
Linear value chain	Network, non-linear relationships
Competition-based strategy	Cooperation + competition (co-opetition)
Independent business operations	Interdependent stakeholder system
Focus on individual enterprise growth	Striving for shared value creation

Applying the business ecosystem model enables better coordination between private and public transport providers, supporting seamless multimodal mobility solutions[7]. Several global case studies demonstrate the advantages of digital ecosystems in transport:

•Helsinki's mobility model integrates ride-sharing, public transport, and micromobility into a single digital platform, enhancing user convenience and reducing congestion.

• China's smart public transport system uses AI-based predictive analytics to improve planning and fleet management.

• Estonia's X-Road system ensures seamless data exchange between transport agencies and users, improving efficiency and transparency.

• In Chicago, the Launchpad project employs a fully digital platform that integrates various modes of transport, enabling users to plan journeys involving buses, trains, and rideshares through a single app. Public participation in solution design is a key factor in Launchpad's success—engaging citizens during the design phase and gathering feedback ensures that services effectively meet user needs, highlighting the importance of participatory approaches in public transport digitalization.

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