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An Integrated ABC–XYZ and Simulation-Based Framework for Optimizing Urban Public Transport Logistics: A Case Study of Tashkent, Uzbekistan

Shokhzod Shodiev
Tashkent State Transport University (TSTU), Tashkent, Uzbekistan
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Abstract: Urban public transport systems require routing and fleet-management decisions that simultaneously account for passenger demand, service variability, and limited operating resources. This study develops a conceptual logistics optimization framework for large cities, with Tashkent, Uzbekistan, as the reference context. The framework integrates a systems-based diagnosis of the transport network, ABC–XYZ route classification according to passenger-flow intensity and operational disruption, passenger route-choice considerations, discrete-event or stochastic simulation of route operating times, and reserve-fleet allocation. The analytical synthesis is based on the author's master's dissertation, which identifies route differentiation and scenario-based scheduling as promising tools for service coordination. The resulting framework links route classes to differentiated managerial actions: highly variable, high-demand services warrant intensive monitoring, timetable robustness checks, and targeted vehicle reserves, whereas less critical services may require simpler operational controls. The source dissertation reports methodological feasibility but does not provide a sufficiently reproducible numerical dataset to estimate quantitative gains or statistical significance. Consequently, this paper presents a structured methodological contribution and an explicit validation protocol rather than claiming demonstrated efficiency improvements. The framework offers a testable basis for future operational evaluation of public transport networks in Tashkent and comparable cities.

Keywords: urban public transport; transport logistics; ABC–XYZ analysis; simulation; passenger flow; timetable reliability; Tashkent.

1. Introduction

Public transport in large cities is a complex service system in which passenger travel decisions, route-network design, vehicle availability, congestion, and operating costs interact. In Tashkent, the coordination of surface transport with metro services is a particularly relevant planning concern. The master's dissertation underlying this article describes difficulties related to peak-period crowding, service irregularity, insufficient satisfaction of passenger demand, and the need to coordinate network development with passenger behavior. These observations establish a practical motivation for a decision framework that considers both the intensity of demand and the reliability of service delivery [1,2].

Traditional route planning may prioritize ridership or vehicle productivity in isolation. However, routes with similar demand can differ markedly in their susceptibility to congestion and operating-time

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disturbances. This distinction matters when dispatchers allocate spare buses, select monitoring intensity, or adapt timetables. The dissertation proposes differentiating routes using an ABC–XYZ logic and complementing the classification with simulation, vehicle reservation, and a just-in-time logistics concept.

The research question is: How can route-demand classification and service-variability assessment be combined with simulation to guide differentiated operational management in an urban passenger transport system? The objective is to articulate a transparent methodological framework derived from the dissertation and specify how it can be tested with operational data. The working hypothesis is that jointly classifying demand importance and operational uncertainty yields more actionable management categories than demand-only segmentation. This hypothesis remains to be empirically tested [3,4].

2. Materials and Methods

2.1. Study design and evidence base

This is a methodological synthesis of the master's dissertation "Development of Models for Optimizing Logistics Processes of Public Passenger Transport in Large Cities" by Shodiev. The transport system of Tashkent is used as the principal illustrative context. The dissertation addresses transport operators, passenger flows, route-network organization, and urban logistics management. No new field survey or simulation experiment was performed specifically for this manuscript. All expressions introduced below are operational definitions proposed for reproducible future implementation; they should not be interpreted as measured values from the dissertation [2].

2.2. Systems diagnosis and route-level data

The analysis begins by mapping routes, interchange points, operators, vehicle types, passenger demand, and temporal service characteristics. The minimum prospective dataset comprises: route identifier; observed boardings per day or time period; scheduled and actual trip times; headways; planned and completed trips; vehicle capacity; missed-trip or delay events; reserve-vehicle availability; and route-level costs. Separate records should be compiled for peak and off-peak periods because operating-time variability is likely to differ [4].

2.3. ABC–XYZ route segmentation

For route i, let Q_i denote passenger boardings during a fixed observation horizon. Rank routes by descending Q_i, calculate each route's share $s_i = Q_i / \Sigma Q_j$, and its cumulative share $S_i = \Sigma_{j \le i} s_j$. Classes A, B, and C represent high, intermediate, and low cumulative demand contributions. For an operational application, the cut-offs (for example 80% and 95% cumulative ridership) must be selected a priori and reported; these example cut-offs are not empirical findings of the source dissertation.

XYZ categorization is determined using an explicit operational variability indicator, such as the coefficient of variation of observed trip times, $CV_i = SD(T_i)/mean(T_i)$, or the proportion of trips experiencing a specified delay threshold. X, Y, and Z denote low, intermediate, and high uncertainty, respectively. Thresholds must be calibrated using local data and stated before route comparison. The

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combination yields nine categories (AX, AY, AZ, BX, BY, BZ, CX, CY, CZ). The dissertation specifically discusses AZ routes as requiring more resource-intensive operational methods [5].

2.4. Passenger route choice and network coordination

For a passenger selecting among feasible paths k, a generalized travel disutility may be specified as $G_k = \alpha \cdot$in-vehicle time$_k + \beta \cdot$waiting time$_k + \gamma \cdot$transfer penalty$_k + \delta \cdot$fare$_k$. The weights require local estimation or defensible sensitivity analysis. This expression operationalizes the dissertation's emphasis on passengers as active decision-makers who respond to temporal and monetary differences between travel options. Transfer coordination with rapid transit should be represented explicitly where relevant.

2.5. Simulation and reserve-fleet policy

Simulation should represent stochastic route running times, dwell times, dispatch intervals, passenger boarding, and disturbances. Alternative schedules are compared under identical demand and disturbance scenarios. For highly variable/high-demand routes, targeted reserve vehicles can be activated when specified lateness or missed-trip thresholds are met. A basic fleet constraint is $\Sigma_i (n_i + r_i) \leq N$, where n_i is planned active vehicles on route i, r_i is allocated reserve, and N is total available fleet. The objective may combine passenger waiting time, unserved demand, missed trips, and operating costs, with weights specified transparently.

2.6. Evaluation protocol

The proposed framework should be evaluated against current dispatch practice and a demand-only allocation baseline. Recommended indicators are mean passenger waiting time, 95th-percentile delay, completed-trip rate, headway variability, vehicle utilization, reserve activations, and operating cost per completed vehicle-kilometre. Use held-out operating days, repeated simulation runs with documented random seeds, and uncertainty intervals for differences between policies. No inferential results are reported here because underlying simulation outputs are not supplied [8].

3. Results

3.1. Integrated decision framework

The source dissertation supports a sequential planning logic comprising (i) system analysis, (ii) comparison with analogous metropolitan transport systems, (iii) route segmentation, and (iv) operational optimization using simulation and reserve allocation. The proposed contribution of this manuscript is to express these components as a replicable decision sequence: collect standardized route data → calculate demand shares → quantify reliability variation → assign ABC–XYZ classes → select management measures → test schedules and reserve allocations → compare performance with baseline operations.

3.2. Route-specific management actions

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Route class	Interpretation	Proposed management action
AZ	High-demand / high-variability	Simulation-led timetables, real-time monitoring, dedicated or pooled reserves
AX–AY	High-demand / lower or moderate variability	Frequent monitoring, headway coordination, targeted adjustments
B groups	Intermediate-demand routes	Periodic schedule evaluation, conditional reserve access
C groups	Lower-demand routes	Cost-sensitive supply setting; preserve accessibility constraints

Table 1. Proposed interpretation of route classes. Entries are management recommendations, not observed outcomes. The AZ recommendation is specifically rooted in the source dissertation; the other recommendations are logical extensions requiring validation.

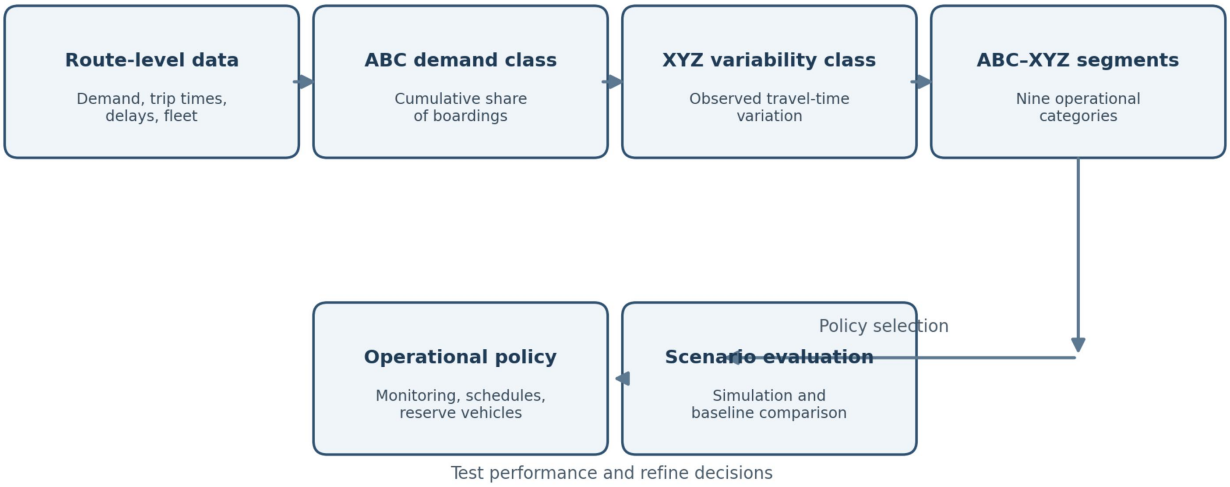


Figure 1. Proposed sequence for integrating passenger-demand segmentation, operating-time variability, route-specific management actions, and simulation-based evaluation.

Figure 1 illustrates the proposed integrated framework for optimizing urban public transport logistics through the combination of passenger-demand analysis, operational variability assessment, and simulation-based decision-making. The framework begins with collecting route-level information, including passenger demand, travel times, service delays, and fleet availability. Subsequently, the ABC classification identifies routes according to their relative contribution to total passenger demand, while the XYZ classification evaluates operational variability. Integrating these dimensions produces nine route categories, each requiring differentiated management strategies[6]. The resulting classification supports the selection of appropriate scheduling, monitoring, and reserve-vehicle

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allocation policies. Finally, simulation-based scenario evaluation provides a mechanism for comparing alternative operational strategies against existing transport practices. Thus, the figure demonstrates how route classification can be linked to operational planning and performance evaluation within a unified decision-support framework.

3.3. Evidence reported in the dissertation

The dissertation concludes that a route-network construction algorithm can integrate systems analysis, analogous-city experience, and logistics concepts through an iterative procedure. It conceptualizes passenger flows as adaptive decision-making systems, rather than entirely passive demand streams. Its conclusions further identify ABC–XYZ differentiation as a way to distinguish management requirements, recommend simulation and dedicated reserves for AZ routes, and state that simulation-based timetable design was explored as a method for representing disruption probabilities. The accessible text does not provide the underlying route-by-route measurements, numerical before–after outcomes, confidence intervals, or independently replicable simulation specifications. Accordingly, no percentage reduction in waiting time, cost, or delays can be attributed to the method [7].

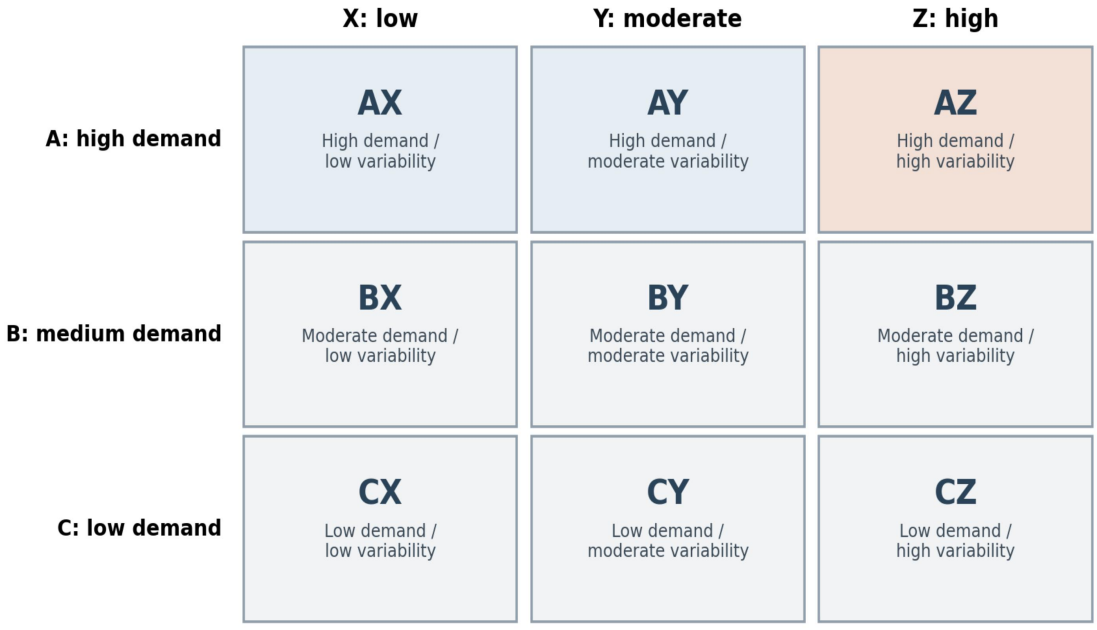


Figure 2. Conceptual ABC–XYZ matrix for urban bus-route management. A–C indicate high-to-low passenger demand, whereas X–Z represent increasing operational variability.

Figure 2 presents the conceptual ABC–XYZ classification matrix developed to differentiate urban public transport routes according to passenger-demand intensity and operational variability. The ABC dimension distinguishes routes with high (A), moderate (B), and low (C) passenger demand, whereas the XYZ dimension represents low (X), moderate (Y), and high (Z) variability in transport

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operations. Combining these criteria generates nine categories: AX, AY, AZ, BX, BY, BZ, CX, CY, and CZ. Particular attention is given to the AZ category, which represents routes characterized by high passenger demand and substantial operational uncertainty. Such routes may require simulation-based timetable adjustments, continuous operational monitoring, and strategically allocated reserve vehicles. In contrast, routes with relatively stable operating conditions may be managed through more predictable scheduling procedures. The matrix therefore provides a structured basis for prioritizing operational interventions and allocating transport resources according to route-specific characteristics.

4. Discussion

The proposed framework connects strategic route planning with operational dispatch decisions. Its main advantage is the separation of route importance from route unpredictability: high ridership alone does not establish which lines need reserve capacity or real-time intervention. Simulation adds an explicit mechanism for evaluating schedule robustness under variable conditions, while passenger-choice modeling recognizes that journey quality and transfers affect realized demand.

A central implementation challenge is the definition of variability. The traditional XYZ method is often formulated in terms of demand predictability, whereas the dissertation's examples emphasize the likelihood of disruptions. Applying XYZ to operating-time or delay variability is therefore a stated methodological choice and must be distinguished from conventional demand-variability segmentation. Threshold selection, observation windows, route heterogeneity, seasonal effects, and missing GPS data could all alter route classification [2,3,4].

The approach is also constrained by distributive concerns. A low-ridership route may provide essential mobility; therefore, C-category classification should not by itself justify discontinuation. Minimum service coverage and accessibility requirements need to be built into optimization constraints. Future comparisons should additionally test whether a shared reserve pool outperforms route-dedicated reserves and whether decisions remain stable under changes in passenger demand and travel-time variability [6,7,8].

Study limitations are substantial. The work is based on synthesis of an academic dissertation rather than a newly executed simulation study. The accessible dissertation has limited reproducible numerical information and does not permit statistical verification of effectiveness. Specific numerical performance claims and causal conclusions about benefits would be premature. Moreover, any policy statements in the underlying source reflect its period of preparation and should be checked against updated regulations before submission.

5. Conclusion

An integrated ABC–XYZ classification and simulation-based approach provides a coherent methodological structure for urban public transport logistics. It links ridership significance and operational uncertainty to route-specific timetable management, monitoring, and reserve-fleet allocation. In the Tashkent context, the dissertation highlights the practical relevance of multimodal coordination and passenger-centered planning. The present manuscript contributes a transparent

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operationalization and future validation protocol; it does not establish numerical optimization gains. Empirical testing with route-level passenger, vehicle-location, and delay data is the next necessary step before the framework can support evidence-based policy recommendations.

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