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Transport Capacity Maximization in Rail Mass Transit Stations Under Uncertainty

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Abstract-

Urban railways play a critical role in promoting sustainable transportation by providing high-capacity, efficient, and low-emission alternatives to road-based travel. As cities continue to grow, the demand for mass transit rail transport is steadily increasing, posing significant challenges to existing infrastructure, particularly at terminal stations, which often become bottlenecks due to their complex operations. Addressing these capacity limitations is essential not only for improving the quality of service but also for supporting the broader goals of urban sustainability. This paper introduces a two-level optimization model designed to maximize the practical transport capacity of mass transit railway stations. At the upper level, a genetic algorithm determines the optimal sequence of train services and platform assignments. These solutions are then evaluated by a linear programming model at the lower level to estimate the resulting transport capacity. For a more realistic assessment of practical capacity, fuzzy modelling is employed to manage uncertainties in train delays and operational variations. The model incorporates critical operational constraints of urban railways, including minimum turn-around times, track occupancy, and constant headways between train services of the same type. A detailed simulation model is used to evaluate route intervals based on train dynamics and signalling systems. Simulation results based on real-world data demonstrate the model’s effectiveness in maximizing capacity under uncertain conditions and different operational schemes, contributing to more efficient and sustainable mass transit railway systems. This research highlights the importance of optimizing rail transport capacity as a key component of sustainable urban development.

Index Terms- Mass transit railway, transport capacity, fuzzy logic, genetic algorithm, bi-level optimization.

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