

An interpretable generative probabilistic framework for demand characterization and consistency checking in dock-based bicycle-sharing systems: the case of BiciMad

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Abstract-

Bicycle-sharing systems (BSS) have become an important component of sustainable urban mobility, but their demand remains difficult to model. Usage varies across hours, stations, weather conditions, and types of day, while the available data often provide only a partial view of the underlying demand process. This study proposes an interpretable probabilistic framework to characterize and generate synthetic demand for BiciMad, Madrid's dock-based BSS, using trip-level data from 2018 and 2019. The contribution is not the introduction of new probability distributions, but the calibrated integration of standard probabilistic components into a demand-side generative framework. Trip distances are modeled with Gamma distributions, and hourly trip counts are represented with Negative Binomial distributions conditioned on hour, day type, and precipitation. These components are combined with empirical station-popularity profiles to generate synthetic origin–destination demand under explicit contextual assumptions. Validation against observed data shows that the framework provides calibrated uncertainty estimates, with empirical coverage of the 95% prediction intervals close to the nominal level across contextual scenarios. An external consistency check using 2019 data further shows the practical value of the approach, as it helped identify systematic timestamp misattributions that were later confirmed by the data provider. The proposed framework is not intended as a full capacity-aware operational simulator. Instead, it provides a simple, interpretable, and uncertainty-aware baseline for demand characterization, synthetic demand generation, exploratory disruption analysis, and data-quality consistency checking in dock-based bicycle-sharing systems.

Index Terms-

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Citation:

Vallez Fernández, C.M.; Contreras, D.; Castro, M. "An interpretable generative probabilistic framework for demand characterization and consistency checking in dock-based bicycle-sharing systems: the case of BiciMad", *Scientific Reports*, vol.16, pp.26735, December, 2026.