Modeling Selfish Routing: Experimental Analysis of Wardrop's First Principle of Equilibrium, Social Optimum, the Price of Anarchy, and Congestion Pricing in Conyers, Georgia

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Traffic congestion is one of the most persistent urban challenges in the United States, costing Atlanta-area commuters over 65 hours and approximately $1,164 per driver in 2024. Traffic congestion arises when individual drivers' choices are suboptimal and fail to minimize total system travel time. This project models selfish routing behavior along Highway 138 in Conyers, Georgia, and addresses congestion by evaluating whether user decisions align with Wardrop Equilibrium (WE) and the Social Optimum (SO), and quantifies inefficiency by calculating the price of anarchy (PoA). Three scenarios were modeled during 4:00pm-6:00pm: (1) Route A vs. Route B, (2) Route A vs. Route B vs. Connector, and (3) Route A + toll vs. Route B vs. Connector + toll. Linear travel time functions were derived from Georgia Department of Transportation data to calculate equilibrium and socially optimal flow allocations. Total system travel time was computed under both conditions to determine the PoA, defined as the ratio of total travel time at worst-case equilibrium cost (WE) to the most optimal outcome (SO). The PoA values were 1.004 (Scenario 1), 1.021 (Scenario 2), and 1 (Scenario 3), indicating inefficiencies of .4%, 2.1%, and 0.0%, respectively. Participants evaluated each scenario in a controlled setting and overwhelmingly selected Route B. Chi-squared goodness-of-fit tests compared observed choices to theoretical predictions. In all cases except Scenario 2 under the Social Optimum, p-values were less than a = 0.01, providing sufficient evidence to reject the null hypothesis that user choices align with theoretical models. These findings quantify the inefficiency of selfish routing and demonstrate the potential of congestion pricing to improve system-wide efficiency in urban areas.

Awards Won:
American Mathematical Society: Honorable Mention and One-Year Membership to AMS (for 5 projects with up to 3 team members per project)