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Poster

Visualization System for Analyzing Congestion Pricing Policies

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Abstract

Traffic congestion, which increases every year, has a negative impact on environmental pollution and productivity. Congestion pricing policy has been shown to be effective in Singapore, London, and Stockholm as one of the ways to solve traffic congestion. Pricing policy has different effects depending on a target area, pricing scheme, and toll. In general, congestion pricing policy researchers conduct statistical analysis of simulation model predictions within a fixed region and time range. However, existing research techniques make analyzing all traffic data characteristics with spatiotemporal dependency difficult. In this paper, we propose a visualization system for analyzing the influence of congestion pricing policy using SUMO and TCI. Our system provides a district-level analysis process to explore the influence of pricing policy over time and area.

CCS Concepts

• ***Human-centered computing*** → ***Visual analytics; Information visualization;***

1 Introduction

Urban traffic congestion intensifies annually, leading to elevated fuel usage and longer vehicle commute durations. This rise in fuel consumption boosts operational fuel demands and exacerbates environmental pollution through exhaust emissions. Furthermore, prolonged commute times adversely impact urban productivity. As a result, numerous strategies have been introduced to mitigate this congestion challenge. One notable solution is the congestion pricing policy, which was successfully implemented in cities like London, Singapore, and Stockholm.

The congestion pricing policy aims to regulate or diminish traffic demand by levying tolls in specific areas, addressing the challenge of urban traffic congestion. The impact of this policy varies based on the target area, pricing scheme, and toll. Typically, the optimal toll is determined through statistical evaluations of simulated model forecasts for a designated area and time range [CMM*19]. However, tolls deduced from previous simulations and statistical evaluations struggle to capture the complete insight of traffic data, especially when considering spatiotemporal dependencies. Due to traffic data with spatiotemporal dependence, the influence of policy appears differently for each road, depending on time [LYSL17]. Therefore, an analysis technique that includes traffic data characteristics is required. Visualization is good at analyzing spatiotemporal patterns of traffic studies [PYSJ21]. Additionally, visualization helps decision-making for policy design with optimal congestion alleviation effect by analyzing the influence of the policy.

In this paper, we propose a visualization system to analyze the spatial and temporal influence of congestion pricing policy. We use Simulation of Urban MObility (SUMO) and Traffic Congestion Indicator (TCI) to analyze the impact of toll policy [LBBW*18, LKHM22]. SUMO is used to apply the pricing policy set in the system. TCI is a quantitative metric that uses speed. The proposed system provides TCI of roads using a calendar heatmap, histogram, color-scaled heatmap, and parallel coordinate plot according to time and district. Additionally, the system provides district-level analysis of the influence of congestion pricing policy. The design goals of the proposed system are as follows.

G1 The system provides an analysis process to determine an effective target area for the policy. The policy has different congestion alleviation effects depending on the target area and time, so an analysis process is required to select an effective target area.

G2 The system offers a method to identify the optimal toll. Since overly high tolls can exacerbate congestion issues, a dedicated analytical process is essential to establish the right toll amount.

G3 The system provides a process to analyze the influence of pricing policy at the district level. The policy impacts both the implemented region and other areas with distributed traffic. Therefore, a methodology is required to analyze district-level policy impact.

2 System and Use Scenario

Figure 1 shows our visualization system. Figure 1 (a) displays a filter view, presenting average congestion indicators based on location, duration, and specific hours. (b) offers a map view, using color codes to distinguish regions and their corresponding TCI. The lower the TCI, the more congested the road. Note that the lower the TCI, the darker red is encoded. (c) is a district view showing TCI and congested road ratio for each region selected in (a). (c-1) is a parallel coordinate visualization showing the average TCI by region by time. (c-2) shows TCI by region in color encoding and the

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Figure 1: *Our system for analyzing the congestion influence of pricing policy. (a) is a filter view for setting the location and time zone. (b) is a map view that visualizes the TCI of the road in the selected time period. (c) is a district view showing the average TCI of roads in each district. (d) is a target district view showing the total delay of the network according to the pricing scheme and toll of the selected district.*

percentage of congested roads in a bar chart. Color encoding is the same as map view. (d) is dedicated to a target district view, facilitating analysis of the specific area highlighted in (b). The histogram visualization shows the total delay time predicted by SUMO based on the respective pricing scheme and toll.

In this work, we explore for congestion pricing policy design in Gangnam-gu, using our system as a use scenario. We use VD data from 199 roads sampled at 1-hour intervals in this scenario. The traffic manager sets April 18∼22, which has the lowest TCI among weekdays, as the analysis target date, as shown in Figure 1 (a-1). In addition, the analysis target time is set to 15:00∼19:00, which has the lowest TCI in (a-2). The system visualizes data according to the date and time interval into (b) and (c). The analyst selects the area (b-1) with densely congested roads to set the target area. The selected (b-1) is highlighted with a blue line in (c-1). (d-1) and (d-2) are two policy alternatives. (d-1) and (d-2) show SUMO simulation predictions for cases where the toll is set to \$3 and \$6, respectively. Note that (c-2-1) and (c-2-2) depict the TCI and the percentage of congested roads based on the policy implemented in (d-1). In contrast, (c-2-3) and (c-2-4) illustrate the TCI and corresponding congested road percentages as influenced by the policy in (d-2). (c-2-1) shows that the policy in (d-1) reduces congestion in the target area. Additionally, (c-2-2) shows that congestion decreases even in areas excluding the target area. On the other hand, (c-2-3) and (c-2-4) show that the policy of (d-2) reduces congestion in the target area but intensifies congestion in other areas. Therefore, in this scenario, the optimal toll for April 18∼22 and 15:00∼19:00 is \$3.

3 Conclusions and Future Work

In this paper, we proposed a visualization system tailored to assess the spatiotemporal impact of congestion pricing policies. The efficacy of our system was showcased through a scenario utilizing SUMO and the Gangnam-gu dataset. Nevertheless, our current system omits traffic demand and road capacity, pivotal indicators influencing congestion pricing policy, making our analysis predominantly speed-focused. As a forward step, we aim to enrich the system by integrating various indicators to understand congestion pricing policies better. This will be achieved by incorporating enhanced visualization, like glyphs, to convey pertinent information.

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