Congestion Mitigation for Planned Special Event: Smart Parking, Ride-Sharing Drop-off Locations and Network Configuration

Jun Xiao, Ph.D. and Yingyan Lou[1], Ph.D.
School of Sustainable Engineering and the Built Environment
Arizona State University

Keywords

Special Event Planning, Congestion Mitigation, Ridesharing Drop-Off Locations, Parking Search, Lane Reversal

Introduction

A planned special event (PSE) such as a sports game or a concert at the heart of an urban area can greatly affect the regular operation of a transportation system due to significantly increased travel and parking demand, and often leads to severe congestion [1]. For event-goers, getting to the event location and finding parking could be a struggle. Some attendees are turning to ride-sharing services such as Uber/Lyft, rather than driving by themselves. For event planners and traffic operators, the massive congestion is a concern for both traffic operations and traffic safety. The road network is usually reconfigured for a PSE, such as road closures, reversed lanes, and limited access to parking facilities. For recurring PSEs, event-goers are often provided with recommended routes to designated parking areas in advance. Such network reconfiguration and route and parking recommendations are, however, often ad-hoc in practice; and the effectiveness of such measures is often unclear.

This presentation focuses on the PSE traffic planning problem. We propose to simultaneously consider parking, ride sharing drop-off locations, and network configuration from the perspectives of both event-goers and event planners. The problem is formulated as an optimization problem with integer decision variables. We developed a flow-based traffic simulation tool that is able to incorporate parking and lane-changing (cannot be ignored around ride-sharing drop-off locations) to evaluate the objective function. We also developed effective and efficient heuristic solution algorithms. The models and algorithms are tested the real network around the University of Phoenix Stadium in Glendale, AZ with actual special event traffic data from Super Bowl XLIX in 2015. The results show that our methods and approaches are able to produce an effective comprehensive traffic plan with reasonable computation time. For the Super Bowl XLIX case study, the resulting optimal plan is able to save 39.6% of the total vehicle-hours compared to default network configurations. Sensitivity analysis has also been conducted with respect to the compliance rate of travelers following recommended routes. It is found that the resulting near-optimal PSE traffic plans are able to tolerate some uncertainty in the compliance rate.

---

[1] Presenting author. Associate Professor, Yingyan.lou@asu.edu, 480-965-6361, 660 S. College Ave., Box 873005, Tempe, AZ 85287

Methodology

The PSE Planning Problem

The objective of the PSE planning problem is to minimize total travel time experienced by even-goers. The decision variables are the number of lanes on each link (lane-reversal configuration), recommended routes, and ridesharing drop-off locations. A customized link-transmission model (LTM) incorporating parking and lane-changing is used to evaluate the total travel time.

One key feature of our network model is that each physical road segment is modeled as three separate links: a main block in the middle where only through movement is allowed, and two transition areas on both ends that have the ability to model additional turning bays and channelized turning. This allows our optimization model more flexibility in the lane-reversal configuration decision space.

The customized LTM accounts for parking search by modeling the probabilities of finding parking at destination nodes and assigning a new parking node for vehicles that do not find parking. The customized LTM also explicitly models the reduced capacity and congestion at ridesharing drop-off locations caused by frequent lane-changing [2].

Solution Algorithm

The PSE planning problem cannot be solved by gradient-based methods due to its integer nature and the employment of a customized LTM to evaluate the objective function. We developed a metaheuristic algorithm that employs customized genetic algorithm (GA) and secondary optimization models based on estimated shadow costs.

The algorithm decomposes the solution space into two parts: one part consists of ridesharing locations and recommended routes and the other part concerns the lane configurations. The first part is explored by GA, while the lane configurations are optimized through a congestion relief (CR) algorithm inspired by the bottleneck relief heuristic [3]. In the proposed CR algorithm, we first developed a method to estimate the shadow costs [4] of changing the lane configuration based on cumulative link flow resulting from the customized LTM simulation. A secondary integer program is then formulated to improve current lane configuration using the estimated shadow costs.

Case Study of Super Bowl XLIX

The Super Bowl XILX was held on February 1, 2015 at the University of Phoenix Stadium in Glendale, AZ. Figure 1 shows the transportation network surrounding the stadium and our network model. The network model has 98 nodes and 308 links, among which 98 are main-block links and 210 are transition links. The default number of lanes on each link is obtained from OpenStreetMap data API while the missing data are made up manually using satellite photos. The network has 6 origins (red circles) and 5 destinations (parking lots). The probabilities of finding parking at the destinations are set to 1. The origin-destination demand are estimated using actual link flow data collected during the event. We adopted the $(1-\alpha)$-

soft assignment rule [5] for route assignment, where α is the compliance rate. Lane-changing intensity for links with ridesharing drop-off locations is set as 1.1, indicating the effective density is 1.1x the actual value. The simulation time step is set as 3.6 seconds.

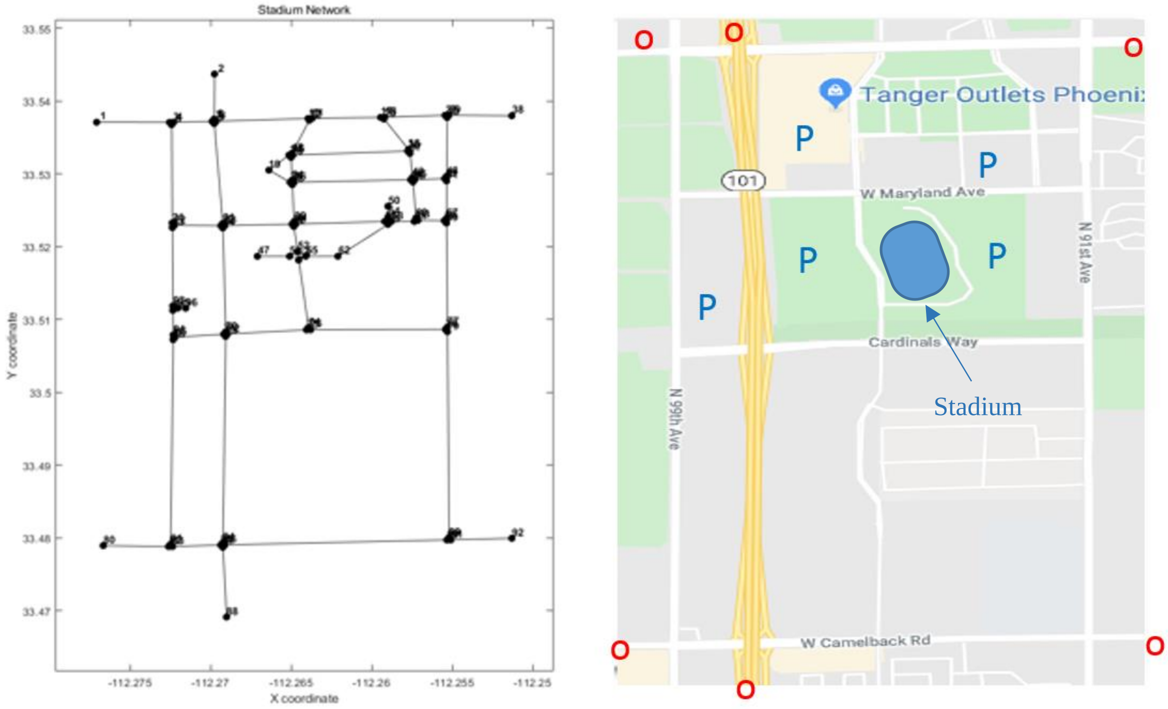

Figure 1 Network Model

Results

Our proposed GA+CR algorithm was able to generate a good solution after the first iteration, saving 34% of total vehicle-hours compared to the baseline network (a reduction from 167.36 to 110.10 vehicle-hours). After two more iterations the total vehicle-hours was further improved to 101.62. The algorithm was stopped after 5 with a final value of 101.08 vehicle-hours (a 39.6% reduction compared to the baseline network).

We further compared the resulting the near-optimal plan to the actual special event configurations. Figure 2 shows the ridesharing location recommended by our solution (dashed red line) and the actual designated ridesharing location, which is on the north side of the road segment marked by the horizontal red line. The latter is less accessible to drivers entering the network from the west: a detour or a U-turn is necessary. A close-up of the intersection in the bottom right corner of the network is also shown in Figure 2. It is noteworthy that all three lanes of the west approach are designated as right-turn only, encouraging demand from the southeast to take local routes instead of the highway. A key intersection close to the stadium is shown in Figure 3. Our solution recommends reversing one receiving lane of the west approach, assigning two lanes each to the two turning movements, and eliminating through traffic. While detailed traffic plan for Super Bowl XILX is not available, the actual configuration for regular season football games does not reverse any lanes of the west approach and has only one left-turn lane. The configuration of the south approach is different as well. While our solution assigns two lanes each as through-only and right-turn only, the actual configuration funnels all northbound traffic to a single left-turn only lane.

Figure 2 Comparison between optimal plan & real-world settings (1)

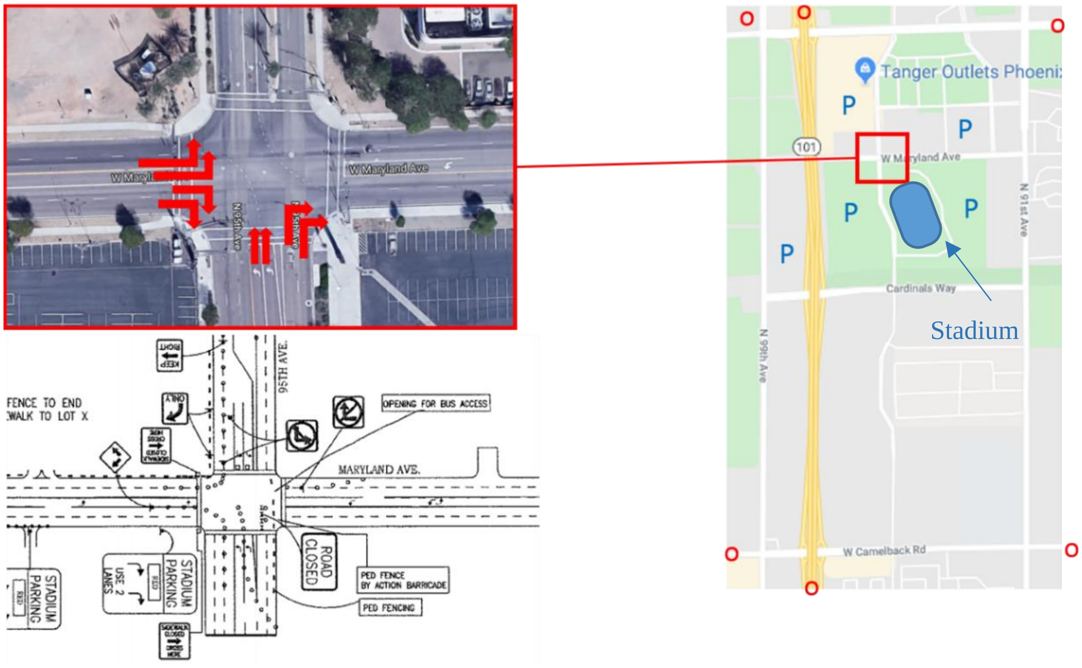

Figure 3 Comparison between optimal plan & real-world settings (2)

Conclusion

We proposed a PSE planning model that explicitly considers the impacts of parking search and ridesharing locations on a network. Effective and efficient algorithms are developed to solve the PSE planning problem. Our case study of Super Bowl XILX shows that our approaches are able to generate a comprehensive network plan (lane configurations, ridesharing drop-off locations, and recommended routes) that is 39.5% better than the default network.

One key limitation of this work is that no pedestrian traffic is modeled. The high volume of pedestrians leads to more frequent vehicle-pedestrian conflicts that further reduces the vehicular traffic capacity of the network. Special practical considerations could also lead to road closures, which are not accounted for in this work either.

References

[1] Kwon, J., Mauch, M., and Varaiya. P. (2007) “Components of Congestion: Delay from Incidents, Special Events, Lane Closures, Weather, Potential Ramp Metering Gain, and Excess Demand.” *Transportation Research Record: Journal of the Transportation Research Board* 1959(1959): 84–91.

[2] Jin, W. (2010) “A Kinematic Wave Theory of Lane-Changing Traffic Flow.” *Transportation Research Part B: Methodological* 44(8–9): 1001–21. http://dx.doi.org/10.1016/j.trb.2009.12.014.

[3] Kim, S., Shekhar, S., and Min. M. (2008) “Contraflow Transportation Network Reconfiguration for Evacuation Route Planning.” *IEEE Transactions on Knowledge and Data Engineering* 20(8): 1115–29.

[4] Lou, Y., Yin, Y., & Lawphongpanich, S. (2009). Robust approach to discrete network designs with demand uncertainty. *Transportation Research Record*, *2090*(1), 86-94.

[5] Sutton, R. S., & Barto, A. G. (1998). *Introduction to reinforcement learning* (Vol. 2, No. 4). Cambridge: MIT press.