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TRANSPORTATION & LOGISTICS 4.0: EXPLORING INNOVATION
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Real-time control measures for overspilling freeway off-ramps

Έλεγχος υπερχείλισης ουρών σε ράμπες εξόδου αυτοκινητοδρόμων

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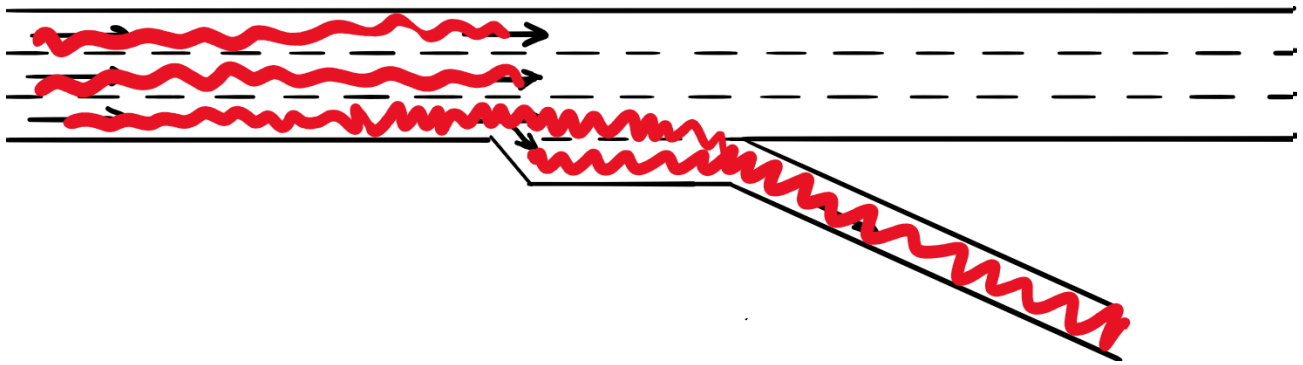
Introduction

- Overspilling freeway off-ramps are blocking exiting freeway lanes and eventually the whole freeway mainstream.
- This is causing operational and safety problems on the freeway mainline.
- Real-time control measures are necessary to avoid overspilling.



What causes the problem?

A. Traffic lights exist downstream of the off-ramp
   i. The capacity of the junction has been reached due to competing demand.
   ii. The capacity of the junction has not been reached, i.e. some approaches are not saturated.

B. No traffic lights exist downstream of the off-ramp
   i. The flow capacity of the off-ramp link cannot serve high off-ramp demand (e.g. due to geometry, layout).
   ii. Congestion is spilling back due to a bottleneck existing further downstream (e.g. the off-ramp is a freeway-to-freeway connection).

Real-time control can solve the problem

A. Traffic lights exist downstream of the off-ramp
   i. The capacity of the junction has been reached due to competing demand.
   - Use real-time traffic signal control that is balancing the queues across antagonistic approaches (e.g. the TUC strategy utilizing occupancy measurement for each approach).
   - Use real-time route diversion towards the same destination if alternative routes are available. *A related tool has been developed and is discussed below.*

   ii. The capacity of the junction has not been reached, i.e. some approaches are not saturated.
   - Use the above or in case of traffic signal control that is based on a library of plans provide flags to activate different signal plans based on estimates of queue on the off-ramp. *A related tool has been developed and is discussed below.*

Real-time control can solve the problem

B. No traffic lights exist downstream of the off-ramp

i. The flow capacity of the off-ramp link cannot serve extremely high off-ramp demand.

- Use real-time route diversion as above.

ii. Congestion is spilling back due to a bottleneck existing further downstream (e.g. the off-ramp is a freeway-to-freeway connection)

- Use real-time route diversion as above.
- Use ramp metering on the freeway-to-freeway connection to avoid activation of the bottleneck and the related capacity drop (e.g. see [1] for an application to a simulated real network in Santiago, Chile).

[1] Spiliopoulou A., Papageorgiou M., Herrera, J.C. and Muñoz J.C., Real-time merging traffic control at congested freeway off-ramp areas, *Transportation Research Record,* No. 2554, pp. 101-110, 2016.

Queue estimation tool for off-ramps

- A tool has been developed for queue estimation on off-ramps based on appropriately located loop detectors. The tool provides:
  - queue estimates per exiting movement (left turning, through and right-turning movements);
  - queue tail-reach-reach estimation;
  - appropriate warning and alarm flags, indicating an imminent or occurring spillover of the exit-ramp queue onto the freeway mainstream;
  - estimation of the waiting times per movement.
- The tool has been implemented by VicRoads (DoT), Australia and provides input to the arterial road signals system SCATS.
- The tool has been deployed at 41 off-ramps.

Queue estimation tool for off-ramps

- For the moment, due to the reduction in demand caused by Covid-19 measures, the tool is actively used in 6 locations:
  - M2 CityLink NB/Moreland Road (PM)
  - M1 Monash EB/Clyde Road (AM PM)
  - M1 Monash EB/Ferntree Gully Road (PM)
  - M2 Tullamarine Freeway NB/Mickleham Road (PM)
  - M1 Monash/Foster Road
  - M80 WB/Sunshine Avenue (AM)
- We are able to give the appropriate level of strategic priority to the off-ramp to fully or mostly clear the off-ramp.

Real-time route diversion control[2]

- Feedback control concepts for calculating the splitting rate.
- Three different traffic scenarios are considered by use of macroscopic simulation.
- Implementation using VMSs (pulse-modulation technique may be used) or I2V communication.
- Decisions based on reactive travel times or off-ramp queue length.

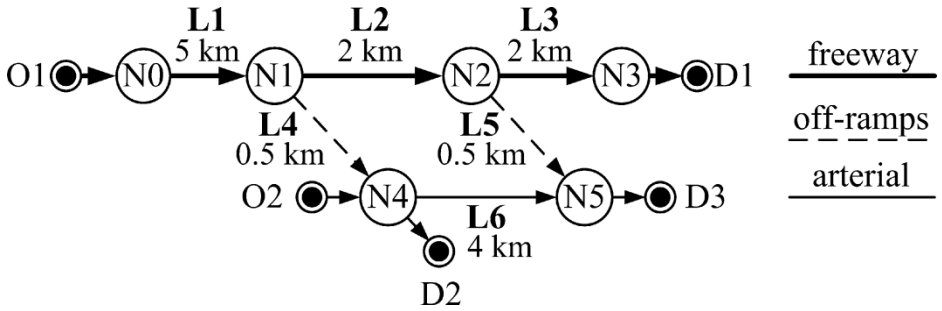
[2] Spiliopoulou A., Kontorinaki M., Papamichail I. and Papageorgiou M., Real-time route diversion control at congested freeway off-ramp areas, *Transportation Research Part A*, Vol. 107, pp. 90-105, 2018.

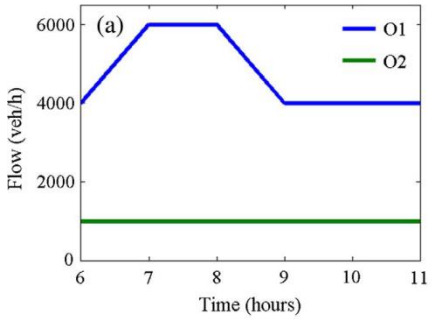
Real-time route diversion control

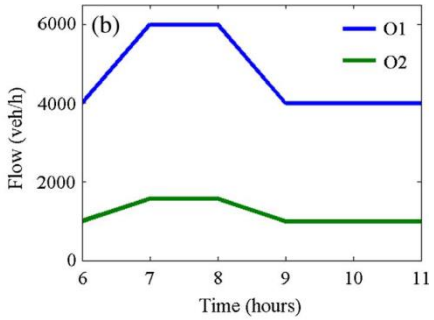
- 1st scenario: the user-optimal conditions may be achieved without off-ramp queue spill-over and creation of mainstream congestion; thus the route guidance system may propose an alternative route without any disbenefit for the compliant drivers.
- 2nd scenario: the user-optimal conditions may be achieved only after the off-ramp queue spills back to the mainstream freeway; thus the route diversion system will have to assume sufficient compliance to the proposed route choice; or be based on mandatory actions, such as temporary off-ramp closures.
- 3rd scenario: the user-optimal conditions cannot be achieved, due to the traffic conditions on the alternative route, thus the route diversion system should decide for the temporary off-ramp closure, when and to the extent needed, in order to prevent formation of mainstream congestion.

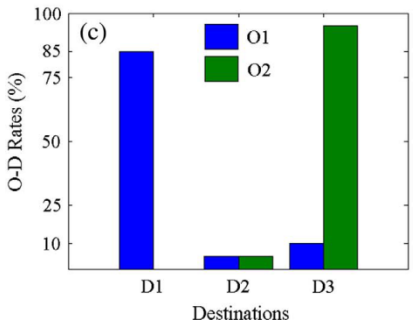
Test infrastructure and demand

Hypothetical, but quite typical, network infrastructure.



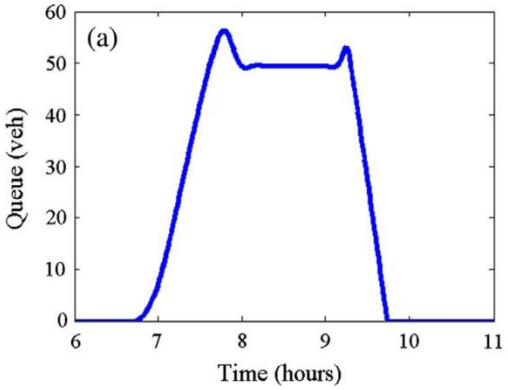


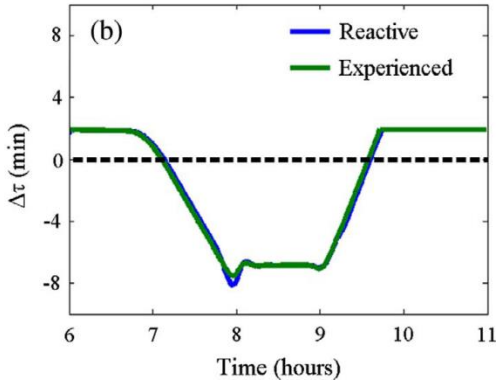




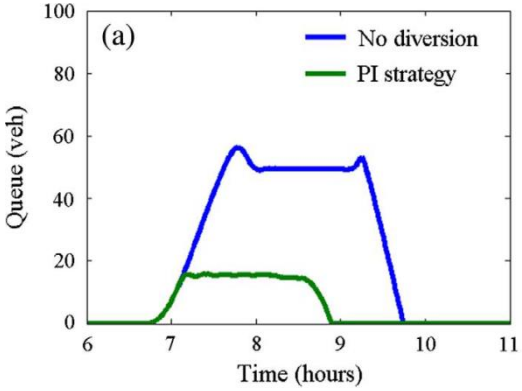
Selected results for the 1st scenario

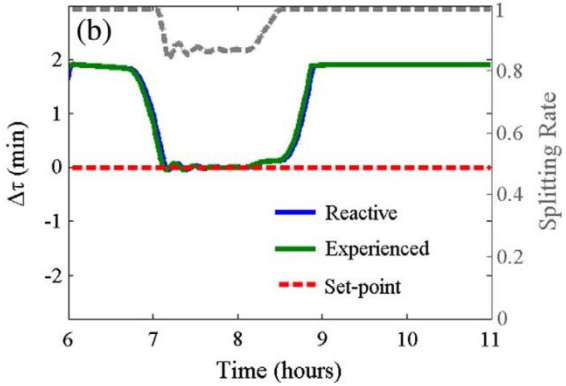
No control





Real-time route diversion control using a PI strategy





Thank you for your attention!

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