Capacity Drop: A Relation Between The Speed In Congestion and The Queue Discharge Rate

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Abstract

It has been empirically observed for years that the queue discharge rate is lower than the pre-queue capacity. This is called the capacity drop. The magnitude of capacity drop varies over a wide range depending on the local traffic conditions. However, up to now it is unknown what determines the capacity drop value. In fact, there is still no thorough empirical analysis revealing a reliable relation between the congestion level and the capacity drop. This paper tries to fill in the gap by revealing the relation between the vehicle speed in congestion and the queue discharge rate through empirical analysis. The queue discharge rate is shown to increase considerably with increasing speed in the congestion. This finding indicates a promising speed-control scheme for increasing queue discharge rates.

Methodology

- Analyze a traffic scenario: a bottleneck gets active immediately after a stop-and-go wave passes
- Apply shock wave analysis to identify traffic situations
- Apply slanted cumulative counts to calculate queue discharge rates
- Speed in stop-and-go wave is the average of all the lowest speed in downstream locations when wave passes
- Speed in standing queue is the average of speed at location close to congestion front
- Analyses data in different weather and freeways to see whether it is necessary to do situation-specific validation

Shock Wave Analysis

- Lane-drop bottleneck

- On-ramp bottleneck

![Fundamental diagram](image1)
![x-t plot](image2)

Study Sites

- Two freeways (A4 & A12) in the Netherlands;
- Lane-drop & On-ramp bottlenecks
- 1 min aggregated loop data
- 6 days of observations (3 days for each site)

- Around 500m between every two detect locations
- At least 3.5km homogeneous freeway section in the downstream of the bottleneck
- Two sunny days and one rainy day (March 18, 2011) of observations on freeway A12
- Three sunny days of observations on Freeway A4

Conclusions

As the speed in congestion decreases, the outflow decreases substantially. In this study, the range of speed in congestion is broad enough, from 6 km/h to 60 km/h. The flow at three-lane section ranges from 5220 veh/h to 6840 veh/h. The quantitative relation requires calibration because discharge rates are greatly influenced by local traffic situations, such as weather and proportion of trucks. The finding can provide fundamental theory for promising control strategies.