Motorway Traffic Control via Variable Speed Limits

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Motorways were originally conceived to provide virtually unlimited mobility to road users, but ...
Ile-de-France Expressway Network

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Capacity Drop (CD)

- Capacity Drop (CD) not well-understood but is deemed to occur due to vehicle acceleration.

- Diagram showing the relationship between flow, density, upstream capacity, and downstream capacity.
2. VARIABLE SPEED LIMITS
- **Automatic VSL** operation started in Germany (around 1970)
- Many application stretches in Germany (> 60 systems covering a total of 1200 km), The Netherlands, U.K., U.S.A., Australia, ...
- VSL are great for traffic safety: **20-30% less accidents**
- **Simplistic** field-applied control strategies
  - hardly any efficiency increase!
Calibration of Fundamental Diagram (U.K. data)

→ monotonically decreasing free speed \( v_f \)

→ monotonically increasing critical density \( \rho_{cr} \)

→ monotonically decreasing capacity
How to decrease travel times with lower VSL?

VSL as flow control actuator

→ MTFC (Mainstream Traffic Flow Control)
  - permanent vehicle storage for sufficiently low VSL (demand > capacity)
  - temporary vehicle storage (demand < capacity)
Why should we hold back (store) vehicles on the mainstream?

- Vehicle acceleration area (~ 400 m) to avoid CD
3. LOCAL FEEDBACK MTFC USING VSL

![Diagram of a traffic system with local feedback control using VSL technology. The diagram includes traffic signals, detectors, and low-speed stretch areas.]
Simple feedback regulator
- **PI-type** or similar

\[ q(k) = q(k-1) - K_p[p(k) - p(k-1)] + K_I[p_{cr} - p(k)] \]

- calculates flow \( q(k) \) to bottleneck
- to maintain \( p_{cr} \) at bottleneck
- for maximum throughput

If >1 actuators available
- split flow among actuators
  - balance of delays or queues – equity!
  - queue management

Possibility to consider multiple bottlenecks
→ selection of the currently critical one
U.K. Motorway Network
Macroscopic simulation (METANET) 
(validated with real data)
Real demand data
VSL Actuator at Lane Drop (Work Zone)  
(*single* bottleneck, *single* actuator)  
A3 Motorway (Germany)  
(*real* demand, *validated* micro-simulation)

**PI-controller:**

\[ vsl(k) = vsl(k-1) + K_I (\rho_{cr} - \rho(k)) + K_P (\rho(k-1) - \rho(k)) \]
## Videos

06:15:00.400

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### Control

<table>
<thead>
<tr>
<th>Zurückhalte- (Drosselungs-) zone</th>
<th>Beschleunigungs- und Spurwechsel- zone</th>
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### No Control

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Network-wide Integrated Feedback Control:
- Integration with Ramp Metering (HERO)
- Control strategy developed
- Field test agreed in Melbourne, Australia
4. CONCLUSIONS

- VSL may reduce travel times
- Feedback MTFC via VSL is simple and efficient
- De-activation of active bottlenecks
  \[\Rightarrow\] throughput maximisation
- Integration with Ramp Metering
- Further field tests are welcome