Sustainability Effects of Traffic Management Systems

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Overview

• Project background
• Global setup
• Controlling traffic flows
  – Some applicable control measures
  – Characterising sustainability
  – Belgium as a case study?
  – Optimisation
• Conclusions
Belgian government funding

• Federal Science Policy.

• Sustainable production and consumption patterns – “Cluster Transportation”.

• PODO II – DWTC CP/40.

• Duration: 12/2001 – 11/2004 (three years).
• Budget: approximately 550,000 euro.
Partners involved

• All involved partners are universities:
  – *Katholieke Universiteit Leuven*
    • Department of Electrical Engineering
    • Department of Civil Engineering
    • Centre for Economic Studies.
  – *Université Catholique de Louvain*
    • Centre for Systems Engineering and Applied Mathematics.
  – *Universiteit Gent*
    • Electrical Energy, Systems, and Automation.

• Reporting to an external usergroup.
Global setup

- “Traffic is dynamic in nature”

Demand \[\rightarrow\] Supply

(travellers/traffic flows) \[\rightarrow\] (road infrastructure)

Optimise the traffic using the existing road infrastructure!

Tools for optimisation? \[\rightarrow\] adaptive control strategies

Optimisation criterion? \[\rightarrow\] sustainable cost function
Some applicable control measures

- Change the number of departing trips.
- Change the departure time of drivers (i.e., leave earlier/later).
- Influence the drivers’ route choice.
- Congestion pricing.
- Overtaking prohibitions for trucks.
- Use ATMS:
  - ramp metering,
  - speed harmonisation,
  - ...

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Ramp metering

- “Try to control the inflow by drops”
The idea behind ramp metering

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RM-MPC versus ALINEA

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Dynamic speed limits (with MPC)

- Research from T.U. Delft (The Netherlands).

upstream moving shockwave

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Characterising sustainability

- Characterise the concept of ‘sustainability’:

\[ SCF = \text{emissions (air, noise)} + \text{incident risks} + \text{travel times} + \text{resource costs} - \text{tax receipts} \]

- Environment friendly capacity throughput

**Important:** the SCF involves a *trade-off*!
Air pollution costs

• Typically, pollution effects are site specific: 
  → construct a dispersion model and use exposure-response curve to determine costs. 
  Too expensive and time consuming!

• Our methodology consists of:
  – determine the fleet mix: diesel and petrol cars, light and heavy goods vehicles, and buses,
  – specify the speed related emission factor for all pollutants (e.g., carbon monoxides, benzene, …), 
  – calculate total emissions on each link of the network and convert to monetary units.
Noise costs

• Similar to air pollution costs, in that they are site specific.
• Calculate **noise exposure** (in dB) above a given reference level:
  – using traffic flow variables and housing density.
• All based on long term (annual) data and at a country wide scale with little data for Belgium:
  – **disaggregate** to Belgium road network.
Accident costs

- **Economic cost of an accident:**
  - users’ *willingness to pay* for safety,
  - friends’ and relatives’ WTP for the user,
  - and the costs to the rest of the society (police, ...).

- **Number of accidents:**
  - affected by many factors (speed, weather, ...),
  - expected **U-shaped function** of traffic variables.

- Difficult to apply theoretical forms and to generalise from empirical studies:
  - calculate accident risks w.r.t. a **reference flow**.

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Time costs

• Are a significant component of the SCF.
• The used traffic flow model returns the travel times:
  – convert to VOT (value of time).
• Incorporate time costs for early and late arrivals.
• Currently we distinguish between:
  – passenger cars, trucks, and buses.
  – A future extension is to include income effects.
Belgium as a case study?

• Tackling the entire (highway) road network is too ambitious!

  Reduce the scope to a simplified topology.
Test bed network topology

- Total length of the network is some **11.4 km** (a vehicle traverses 7 minutes at 100 km/h).

3 origins

3 destinations

- **highway** (3 lanes, 120 km/h)
- **urban road** (2 lanes, 90 km/h)
- **city region** (1 lane, 70 km/h)
Optimisation

• Determine the steady state distribution of the flows (this is the set point), using:
  – the sustainable cost function,
  – equality constraints:
    • conservation of vehicles,
    • origin/destination matrices,
  – inequality constraints:
    • positive flows,
    • maximal flows.

• Try to achieve the set point using control measures (current research).

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Conclusions

• Most important aspect:
  – **sustainable cost function**.

• Modular setup:
  – incorporate SCF in traffic control methodology.

• During the project, we have also developed:
  – heterogeneous extension of the LWR-model,
  – **particle filter** approach for incomplete data,
  – **congestion charging** and queue spill-back effects,
  – investigate an **overtaking prohibition** for trucks,
  – distributed **traffic cellular automata** (in progress).