

Institute for Transport Studies

FACULTY OF ENVIRONMENT



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# Towards a Generic Guidance for Modelling Motorway Merge

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*European Transport Conference 2008*

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# Background





## Background

- Traffic models used widely to evaluate motorway improvements schemes
- Modelling motorway merging long regarded as a weak area
- *“we know the model predictions under-estimated delays at (merge) junctions ... but don’t have enough data to verify it...”*
- To establish general principals in modelling traffic interaction at merge and improve representation of merge performance:
  - Investigate the use of microsimulation models of merge
  - Improve understanding of factors involved in the performance at merge
  - Inform the development of better traffic models of merge



- Adequacy of current modelling approach?
- Consistency in government advice?
- Effects of traffic conditions and driver behaviour?
- Implications for modelling?
- Implications for policy?



- Merging area modelled as a give-way node
  - No concept of the acceleration lane, or merge design
- Standard gap-acceptance model
  - with absolute give-way by the merge traffic to the mainline traffic
  - Merging traffic find gaps in Lane 1 mainline traffic only
- Delay to merge traffic is calculated based on queuing model:
  - Use of maximum queue length to prevent infinite queue when  $V/C > 1$
- No delays to mainline traffic

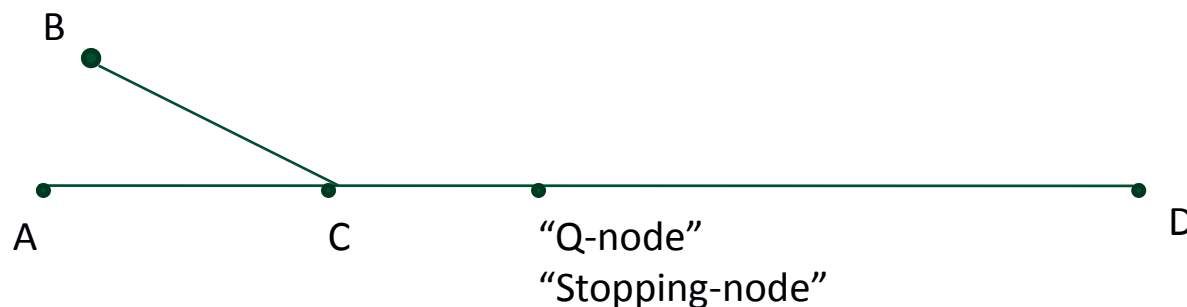


- One fixed gap by time of day, by population
  - Cannot distinguish different user class/vehicle type
  - No difference in the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, ... gap a driver accepts => under estimation of entry capacity
- Gaps are often inferred from average flow-delay functions
  - In SATURN, this is suggested to be the inverse of saturation flow
- Vertical queuing model
  - all vehicles wait by the stopline
- No explicit consideration of acceleration lanes



# Correction methods in SATURN

- Cooperative lane choice: the use of parameter “Apresv”
  - To represent willingness of mainline traffic to accommodate merging
  - Moving a proportion of lane 1 traffic to lane 2
- Adding merge delay to post-merge traffic
  - To model delays to mainline traffic at merge
  - Insert a dummy node downstream of merge (up to 2km)
  - “Q-node” method: delay based on COBA delay function
  - “Stopping-node” method: delay due to capacity constraint



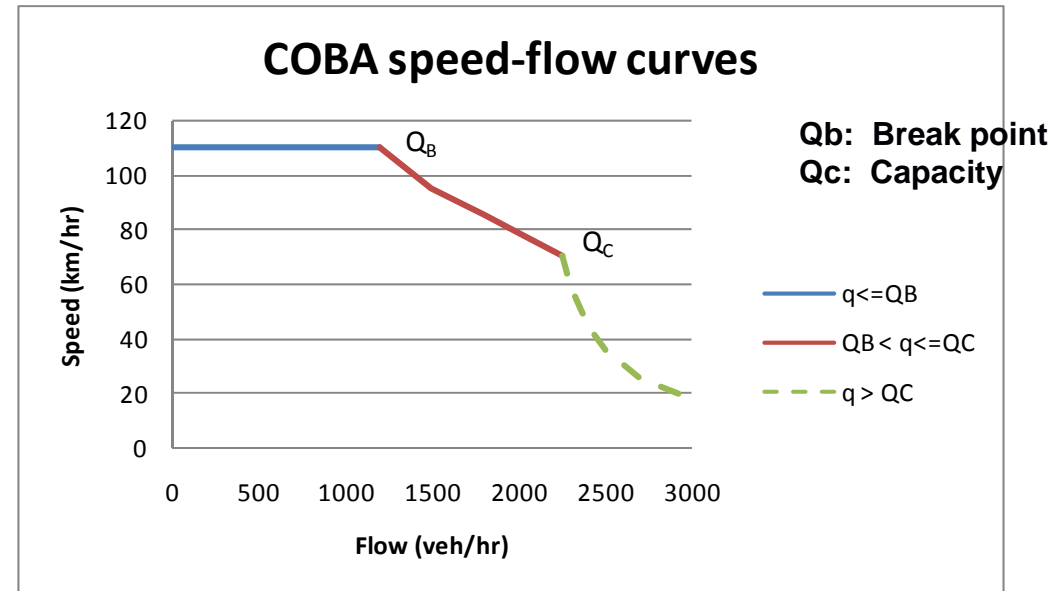


- Not being understood and applied widely in practice
- Lane-choice independent to vehicle types
  - Unable to model the influence of HGVs in other traffic's lane choice
- Lack of validation and behavioural support
  - Luke (2007) found “Q-node” method produced excessive delays



# COBA delay estimation

- Link speed-flow curves



- Merge junction modelled as “no priority”
- Merge delay =  $227 (V/C - 0.75)$  sec/vehicle
  - Added on top of link speed-flow curve
  - Equally to all mainline and merging vehicles

# The capacity functions



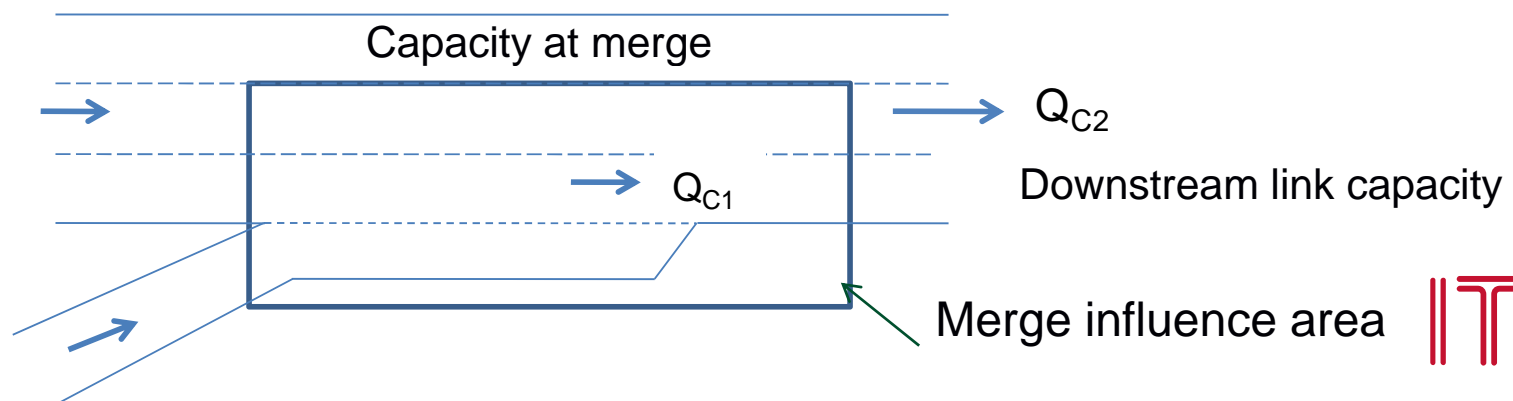
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Advice	Variable	Functions and Values
COBA	$f_{HV}$	2.5
	$Q_{C2}$ (veh/hr/ln)	$2330/[1+0.01P_{HV}(f_{HV}-1)]$ at speed limit = 70mp
		$0.9*2330/[1+0.01P_{HV}(f_{HV}-1)]$ at speed limit = 60mph
HCM	$f_{HV}$	1.5, 2.5 and 4.5 for flat, rolling and mountainous
	$Q_{C1}$	$0.88*2300/[1+0.01P_{HV}(f_{HV}-1)]$
	$Q_{C2}$	$0.88*[2300+5*(V_{Fm}-100)]/[1+0.01P_{HV}(f_{HV}-1)]$
HBS	$f_{HV}$	1.3 – 1.7 variable with flows
	$Q_{C1}$	2200 pcu/hr
	$Q_{C2}$	$1900/[1+0.01P_{HV}(f_{HV}-1)]$ at speed limit = 120kph
		$1933/[1+0.01P_{HV}(f_{HV}-1)]$ at speed limit = 80,100kph



# Different concept of capacity

Concept	COBA	HCM	HBS
Merge influence area	2km	450m, 2 lanes	1 lane
Concept of capacity	$Q_{c1} = Q_{c2}$	$Q_{c1}$ , $Q_{c2}$ separate	$Q_{c1}$ , $Q_{c2}$ separate
Measurements	15-min peak flow	15-min peak flow	
Peak flow profile correction	no	Yes	
Observation or modelling	Model fitting to observation	Direct observation	



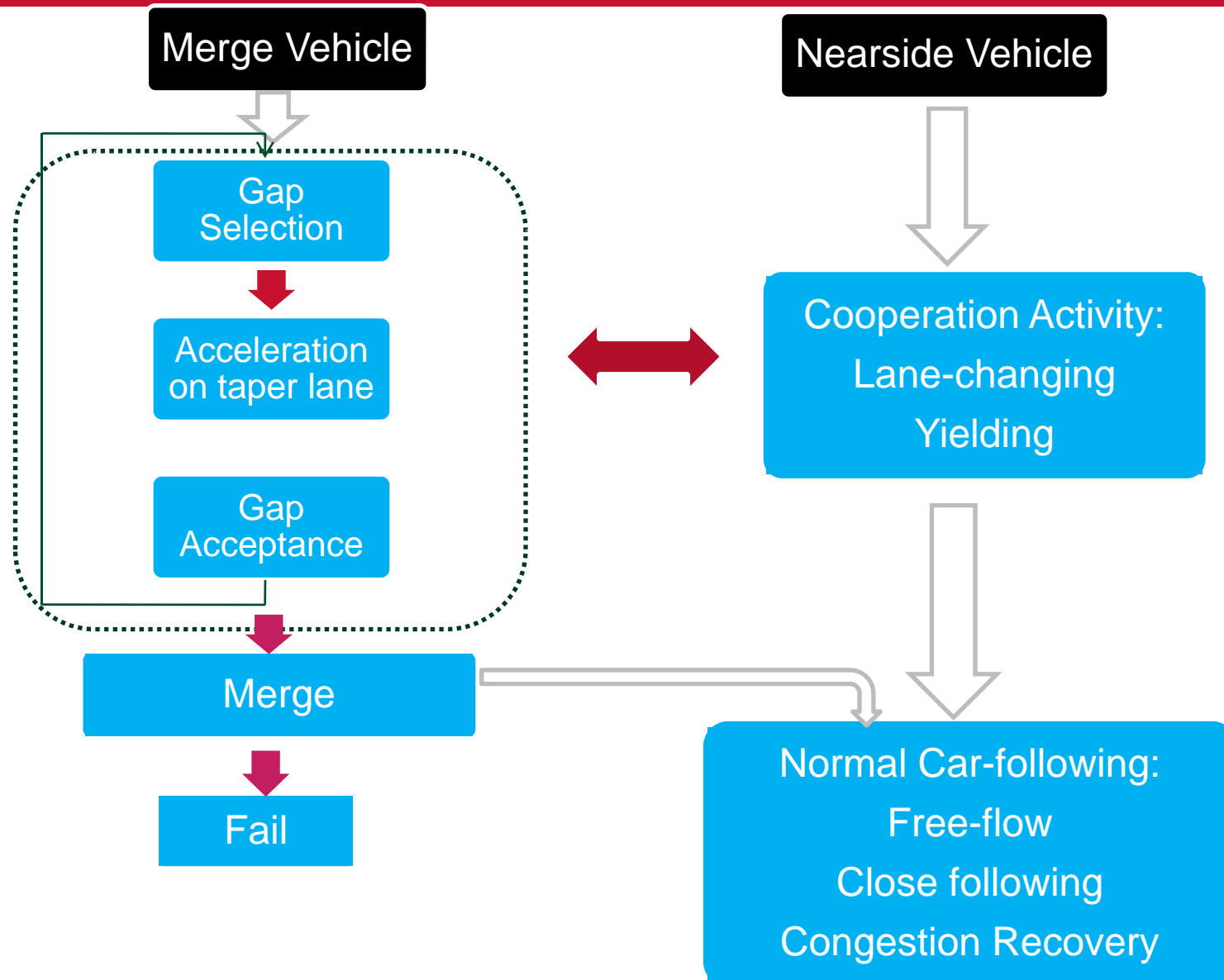


- Using the MergeSim microsimulation model
  - A model of motorway network and traffic, to represent:
    - Geometric designs (merge design, taper length, design speed)
    - Traffic conditions (free-flow, congestion, flow breakdown)
    - Traffic composition (cars, HGVs, etc)
    - Driver behaviour:
      - Close-following
      - Variable responses under different congestion conditions
      - **Cooperative lane-changing and yielding at the merge**
    - Designed to study driver interactions on merge delays and network congestion

# MergeSim model framework



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- How does the merging process influence the traffic flow?
- How do heavy goods vehicles affect the performance at merge?
  - Speed-flow relationships
  - Capacity at merge
  - Delays and average speed
- How does driver behaviour affect merge performance?



- A single merge network of length 3000m

Input variables	Default value
Length of acceleration lane	150m
Designed (free-flow) speed	70 mph
Total upstream demand (mainline/merge=2:1)	2300 veh/hr
Demand profile of the mainline flow	Peaked
Demand profile of the merging flow	Flat
Probability of cooperative lane-changing	10%
Probability of courtesy yielding	12%
Proportion of heavy goods vehicles (PHV)	10%

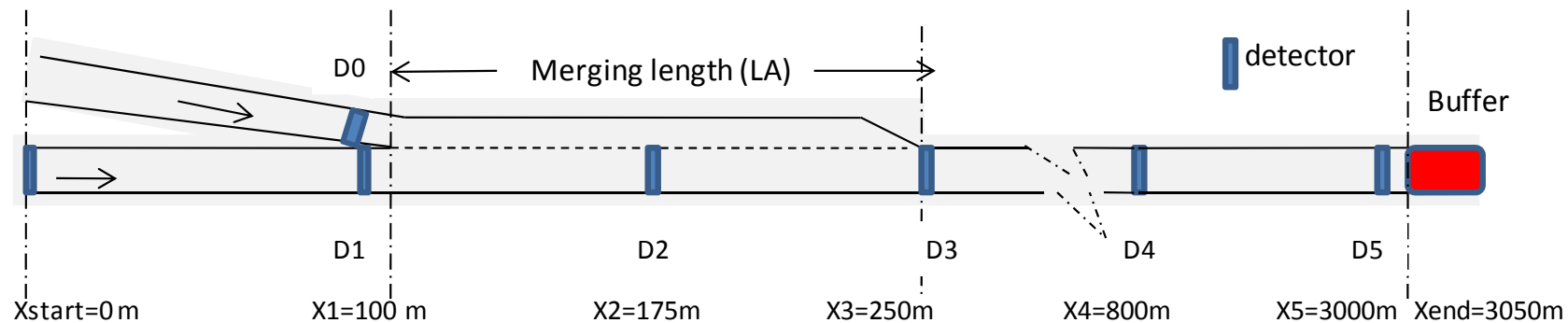


## Simulation test (2)



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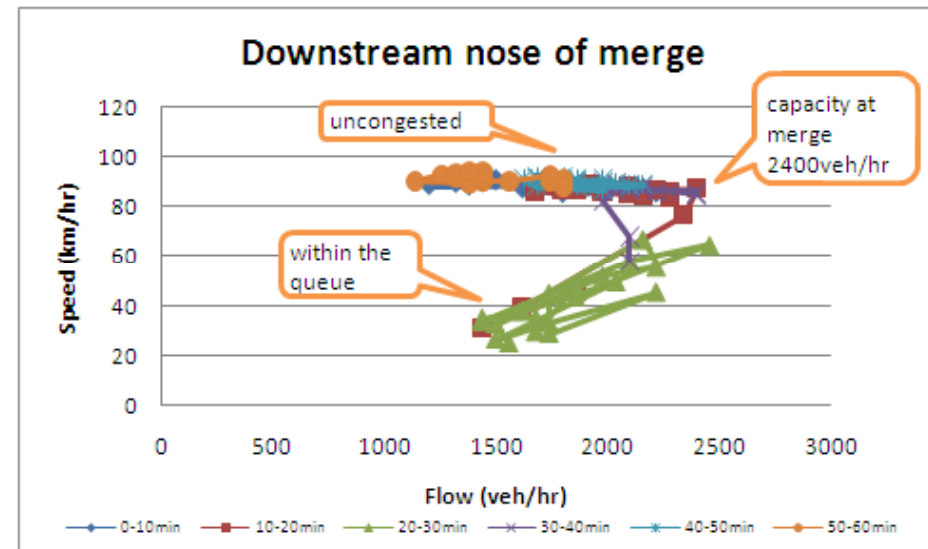
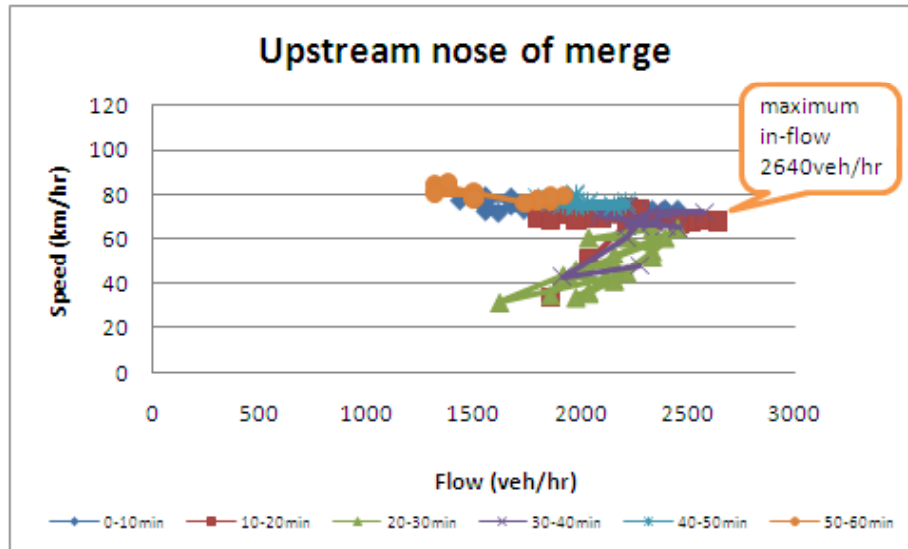
- How does the merging process influence the traffic flow?
  - Detectors placed across the network
  - Outputs: 1-min averaged speed and flow data
- How far downstream will the merging turbulence be felt?



# Simulation test (1): result (1)

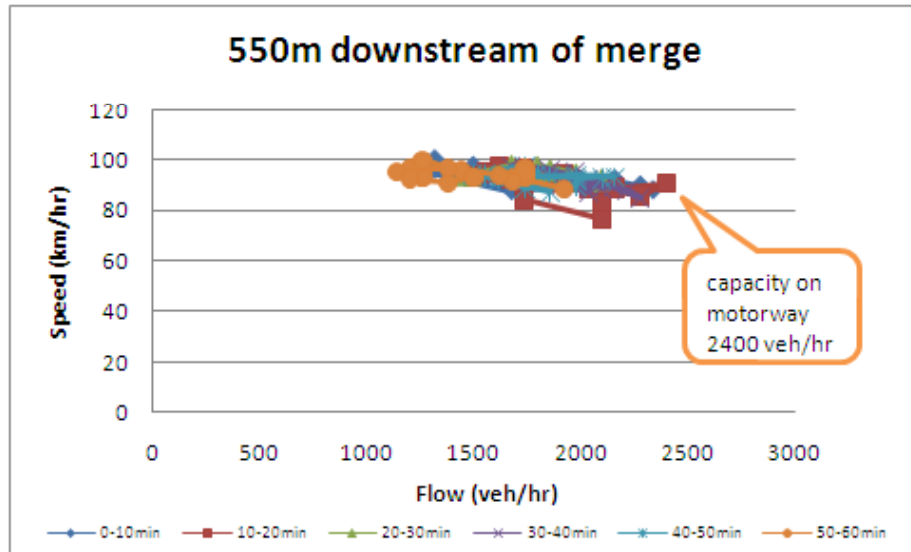


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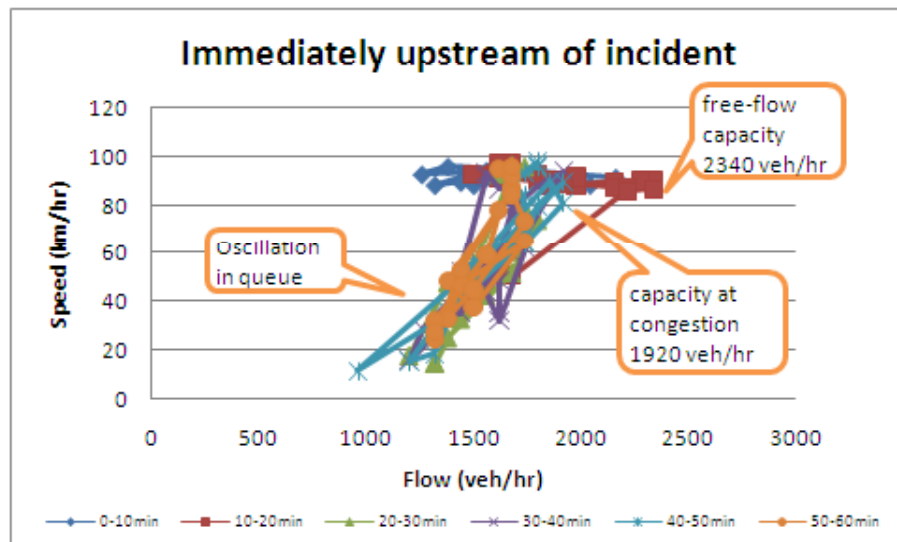


- Maximum combined upstream flow exceeds capacity at merge

# Simulation test (1): result (2)



- Merge influence not extending beyond 550m downstream



- Free-flow capacity higher than capacity at congestion
- Speeds oscillating => congested state not stable

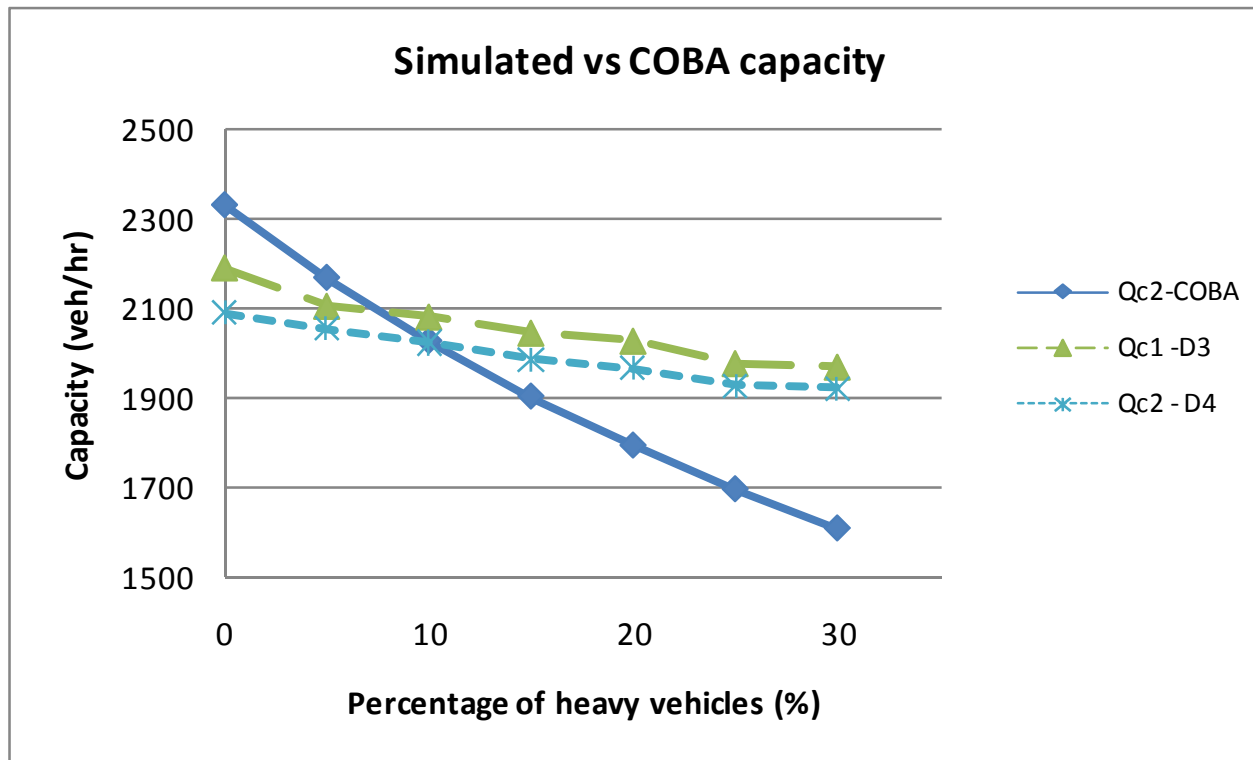


- How does the fleet composition affects the performance at merge?
  - Seven levels of heavy goods vehicle proportions PHV at 0, 5, ..., 30%
  - Test on their effect on capacity, speed and delay
  - The peak 15-min flow from detector D3 as capacity  $Qc1$
  - The peak 15-min flow from detector D4 as capacity  $Qc2$
  - Individual vehicles' journey time through the entire length
  - Space-mean speed over the whole "population"

# Simulation test (2): result (1)



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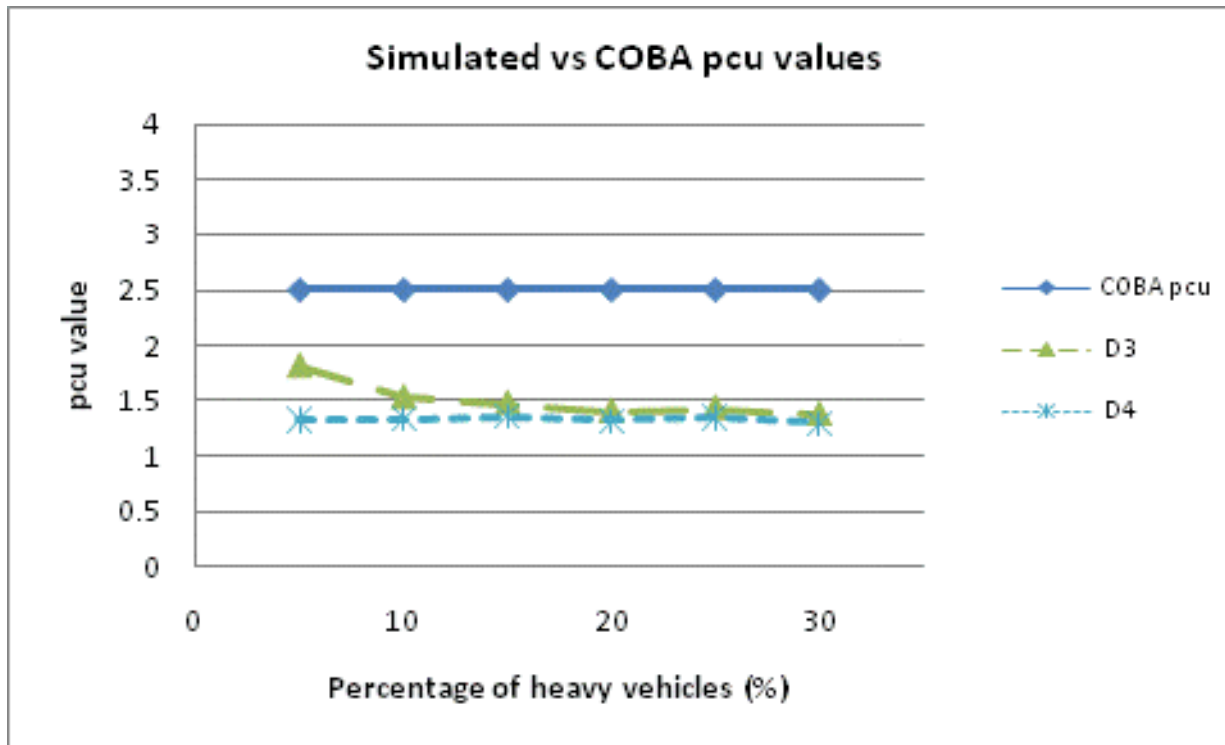
Fixed  $pcu=2.5$  used in the COBA function

- Capacity at merge higher than link capacity, by 60veh/hr (3%)
- COBA capacity decreases with PHV more rapidly

# Simulation test (2): result (2)



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Pcu value estimated from capacity function:

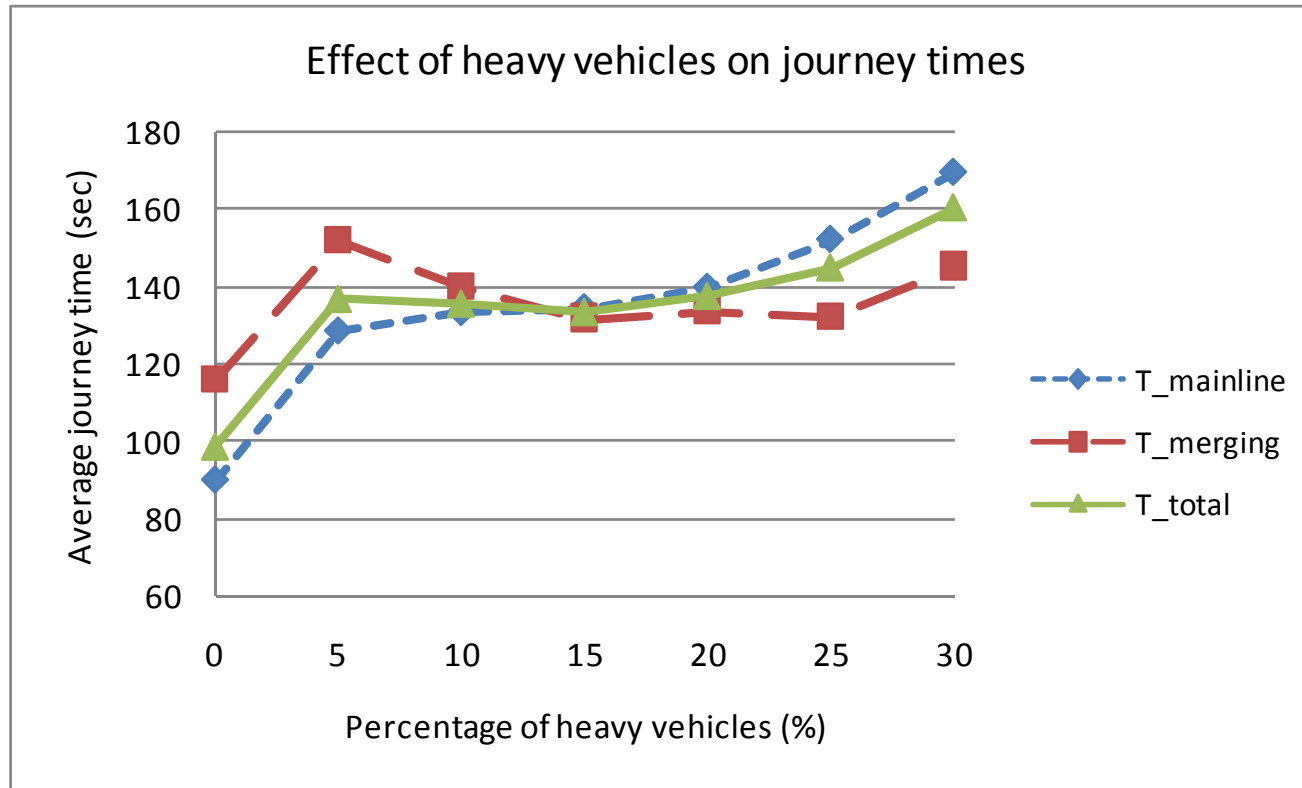
$$Q_C = Q_0 / [1 + 0.01 P_{HV} (f_{HV} - 1)]$$

- Variable simulated pcu values
- COBA pcu value higher

# Simulation test (2): result (3a)



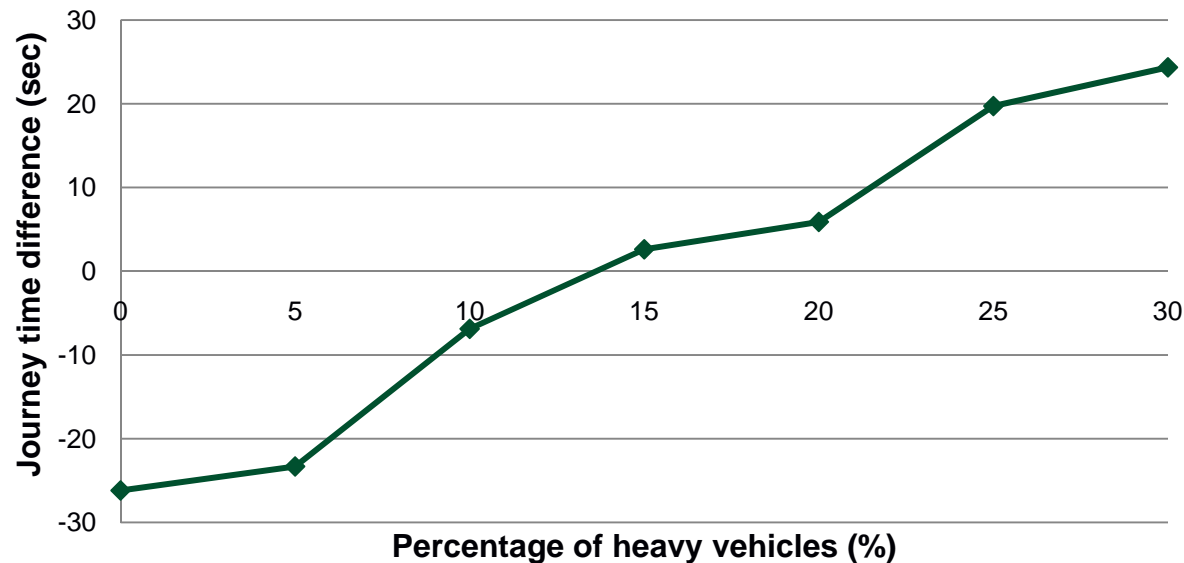
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- Journey times increase with PHV
- Journey time of the mainline traffic different to that of merging traffic



### Journey time difference between mainline and merging traffic

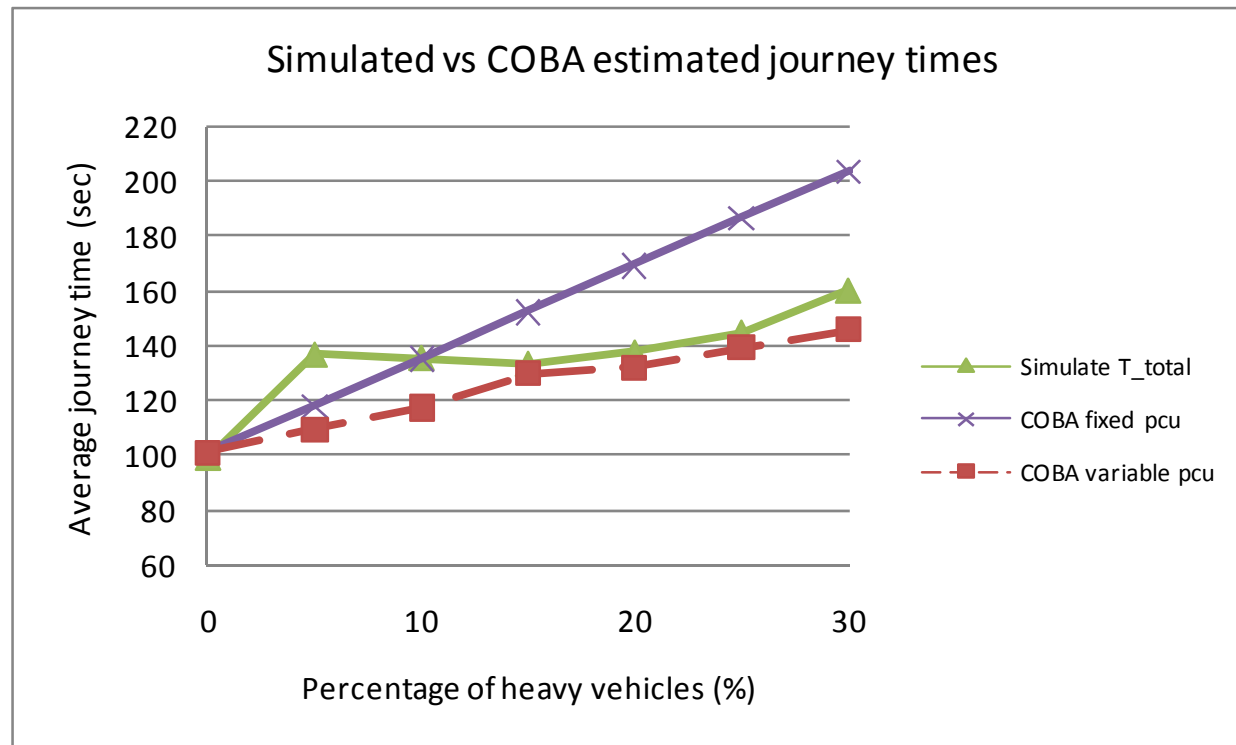


- Mainline to merging journey time difference steadily increases with PHV
- Perhaps, with more HGVs, more platoons forming, making merge easier?

# Simulation test (2): result (3c)



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- COBA over estimates at higher PHV, under-estimates at lower PHV
- Simulated results fits well with a variable pcu at value ~1.5

# Simulation test (3)



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- How does driver cooperation affect merge performance?

Scenario	Prob. lane-changing	Prob. yielding
Base	10%	12%
Only CY	0%	12%
Only CLC	10%	0%
No coop.	0%	0%

# Simulation test (3): result



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- Journey time difference compared to the base scenario (sec)

Scenario	Mainline traffic	Merging traffic	Total
Only CY	30.4	7.8	21.9
Only CLC	-7.6	-4.8	-6.6
No coop.	22.3	-6.1	11.6

- Cooperation has an impact on the merging performance (but not entirely as one expected)
- **Perhaps random CY interferes with the natural gap-selection and merging?**
- Overall, cooperation brings benefits to the merging traffic, at the expense of the mainline traffic



- If results are affected, what are the implications for policy?
- If models used to look for schemes which meet specified performance criteria:
  - Use of higher capacity values:
    - adoption of lower-specification design, but
    - the scheme that may not cope with the real situation
    - Encourages close-following, unsafe driving
  - Use of lower capacity values:
    - adoption of more expensive schemes
    - Misuse of resources
    - Over supply of capacity leads to induced demand
    - Results in safer design, but when drivers didn't drive safely in reality, incidents may occur



- Current traffic models inadequately represent the behaviour interactions at merge
- Current UK method was based on studies of traffic data 20 years ago; new interpretation need to take into account:
  - Changes in traffic flow characteristics (e.g. faster traffic)
  - Effect of peak flow profiles
  - Variable impacts of HGVs
  - Differences between junction capacity and link performance
  - Differences in delays to mainline and to merging traffic

## Conclusions (2)



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- Merging turbulences confine within 500m downstream
- COBA capacity overly sensitive to PHV
- Variable pcu values better represent the effect of heavy vehicles
- Effect of PHV on delays to mainline traffic are clearly different to that of the merging traffic:
  - Merging traffic can even benefit from having more trucks on mainline
  - COBA under-estimates delays at low PHV, over-estimates it at higher PHV
- Effect of driver cooperation at merge may not always be as expected
  - Courtesy yielding may cause confusion to merging vehicles





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Develop better models!

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- Continued “gap searching”, “gap acceptance”, and “to merge or not to merge” decisions along the entire length of the acceleration lane
- Cooperative lane-changing by the mainline traffic
- Courtesy yielding by the mainline traffic
- Influence of HGVs on mainline congestion and lane usage
- Effect of weather and light conditions
- Effect of traffic speed (even at the same flow?)
- Effect of variable, inhomogeneous gap-acceptance behaviour
- Etc, etc