

Review of

Introduction to modern traffic flow theory and control

The long road to three-phase traffic theory

Boris S. Kerner (2009)

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Traffic Flow Webinar - 10 September 2010

Outline

Part I Three phase traffic theory (3PT)

- ▶ Traffic phases
- ▶ Phase transitions

Part II Impact on transportation engineering

- ▶ Control
- ▶ Fundamental diagram (FD)
- ▶ 3PT-models

Review & discussion

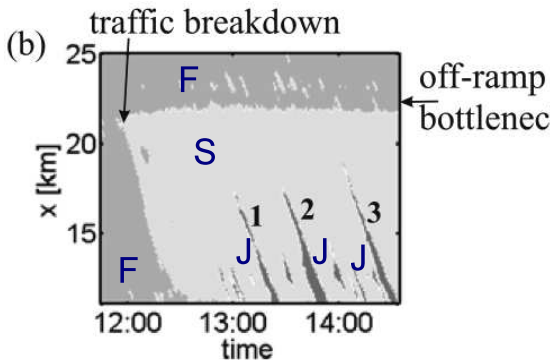
Part I: Three-phase traffic theory

3 traffic phases:

F Free flow

J Moving jam

S Synchronized flow



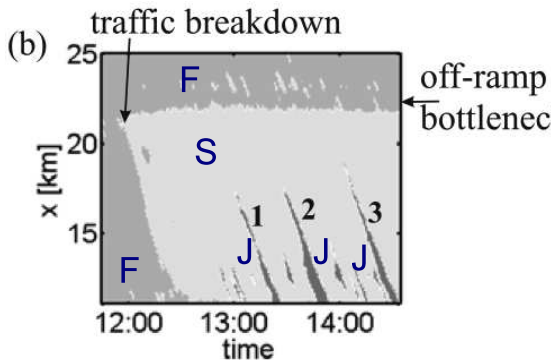
Part I: Three-phase traffic theory

3 traffic phases:

F Free flow

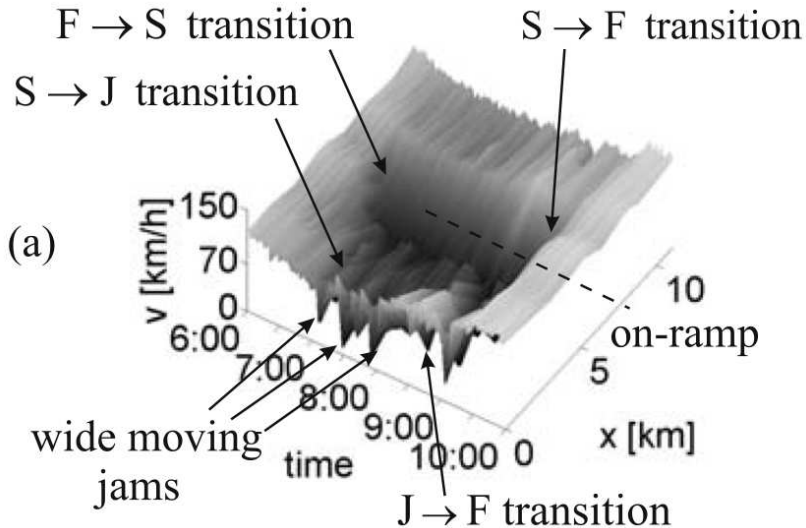
J Moving jam

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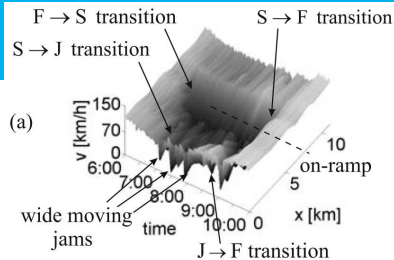


- ▶ Transitions from one to other phase
- ▶ Accelerations, decelerations, lane changing

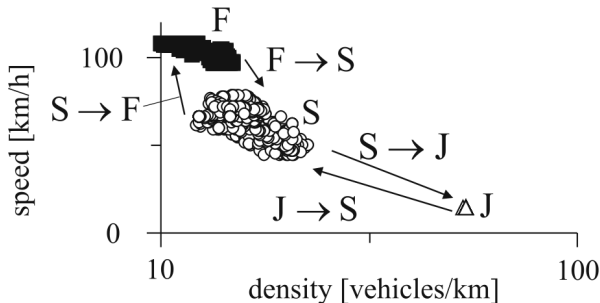
Spatiotemporal patterns



Spatiotemporal patterns



- (b) ■ free flow (F) ○ synchronized flow (S)
 △ moving blanks within wide moving jam (J)



Phases

Free flow

- ▶ small density
- ▶ interactions are negligible or small
- ▶ until limit point of free flow
- ▶ line in flow (or speed)-density plane

Congestion

Moving jam (J)

Synchronized flow (S)

Phases

Free flow

Congestion

- ▶ speed lower than in free flow
- ▶ congestion is synchronized flow or moving jam
- ▶ S and J are characterized by fronts

Moving jam (J)

Synchronized flow (S)

Phases

Free flow

Congestion

Moving jam (J)

- ▶ both fronts move upstream with same constant velocity
- ▶ very low vehicle speed
- ▶ abrupt changes in speed at fronts
- ▶ is maintained through other states

Synchronized flow (S)

Phases

Free flow

Congestion

Moving jam (J)

Synchronized flow (S)

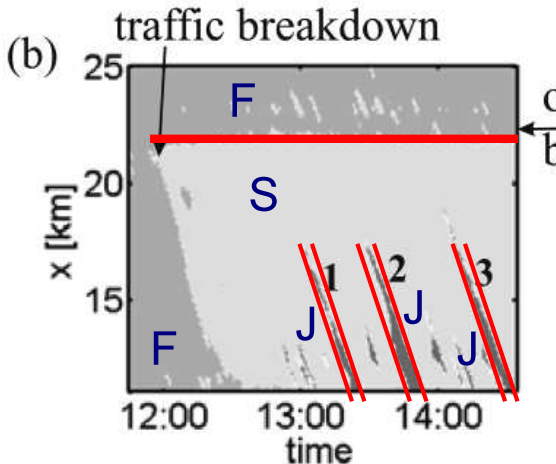
- ▶ congestion but not moving jam
- ▶ downstream front often at bottleneck
- ▶ trend to vehicle speeds equal over all lanes

Phases and transitions revisited

F High speed

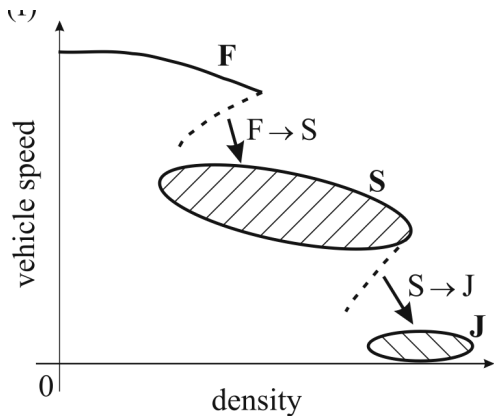
J Fronts move upstream with constant velocity

S Downstream front at bottleneck

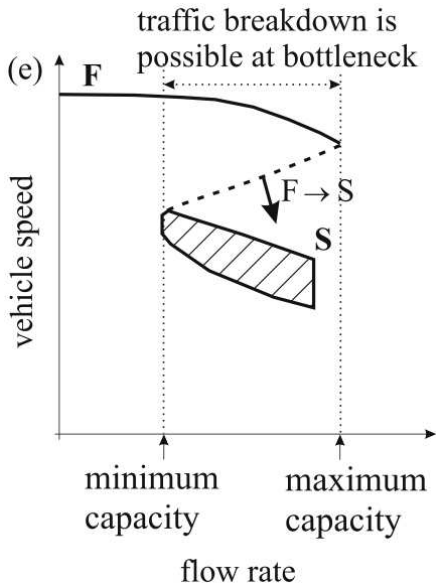
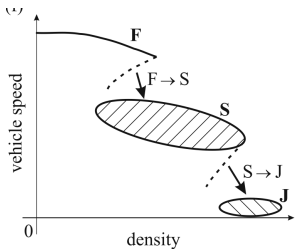


Phases and transitions

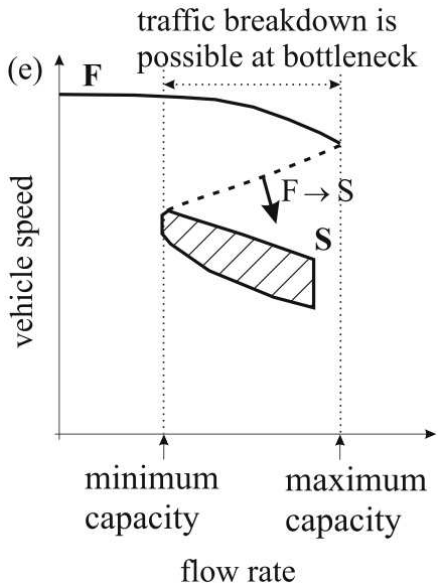
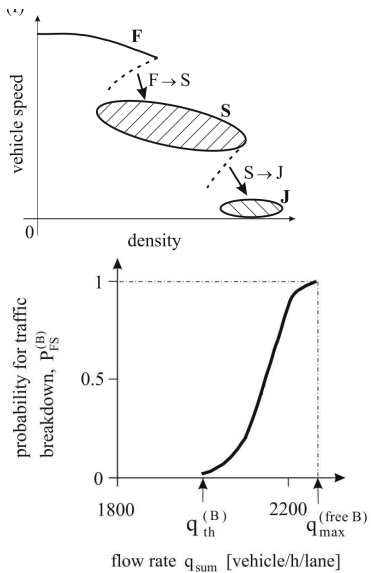
- ▶ 2D regions
- ▶ Transitions in density range



Phases and transitions

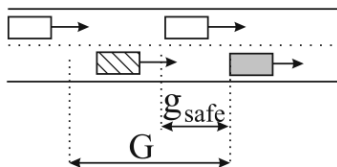


Phases and transitions

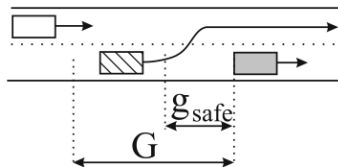


F → S transition


Speed adaptation



Over-acceleration



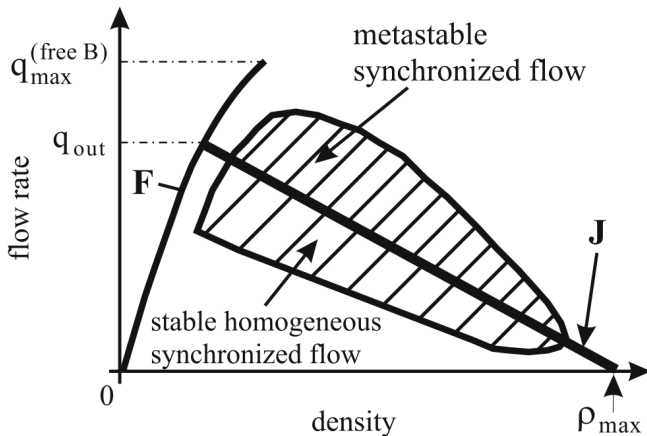
 vehicle under consideration

 slower moving preceding vehicle

Synchronized flow

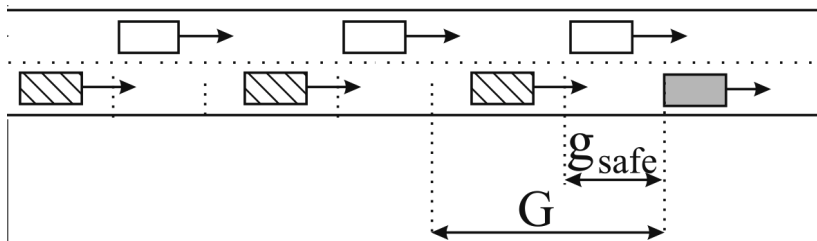
Free flow & strong deceleration (of others)
 \Rightarrow synchronized flow

S → J transition



- ▶ Stable: no transition
- ▶ Metastable: 'large' disturbance \Rightarrow transition

S→J transition



Low flow (stable)

speed adaptation \Rightarrow
 stay in synchronized flow

High flow (meta-stable)

over-deceleration of multiple vehicles \Rightarrow
 S→J transition

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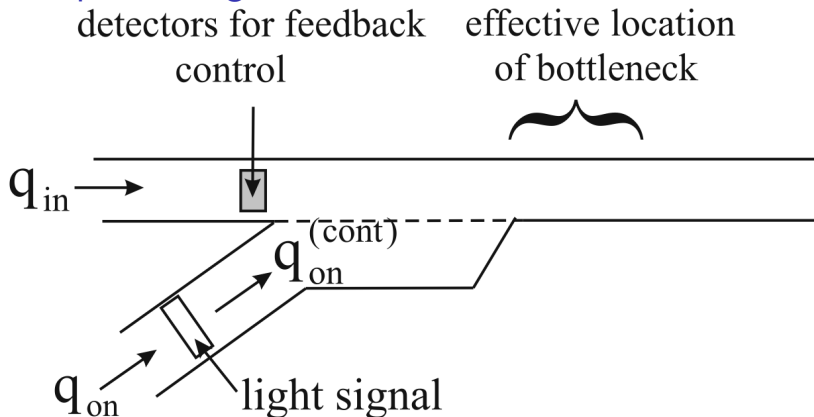
Part II Impact on transportation engineering

- ▶ Control
- ▶ Fundamental diagram (FD)
- ▶ 3PT-models

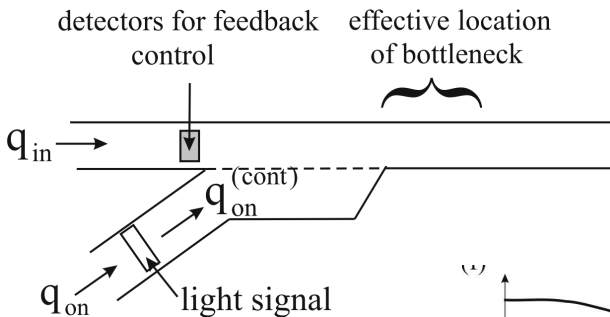
Review & discussion

Part II, Chapter 9 & 10: Control

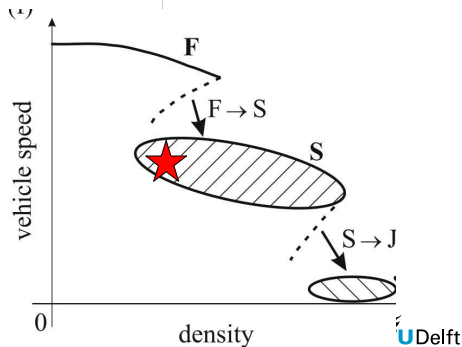
Ramp metering with ANCONA



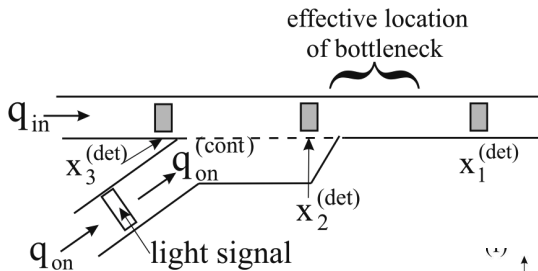
Ramp metering with ANCONA



Target: not too low speed
No $S \rightarrow J$ transition

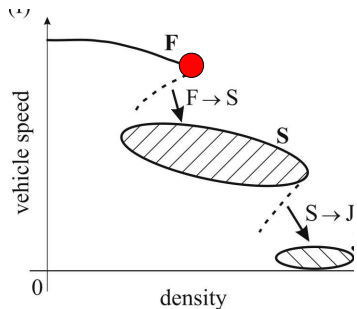


Ramp metering with ALINEA



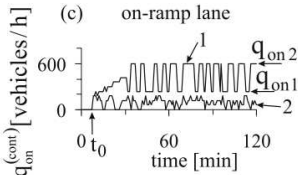
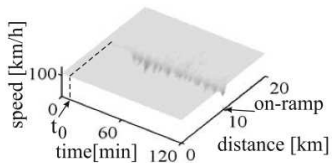
Target: critical density
downstream of bottleneck

Or measure upstream
UP-ALINEA

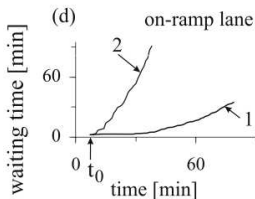
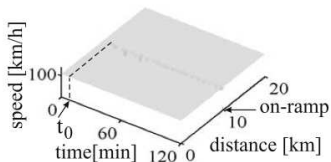


Comparison results ANCONA and UP-ALINEA

(a) ANCONA

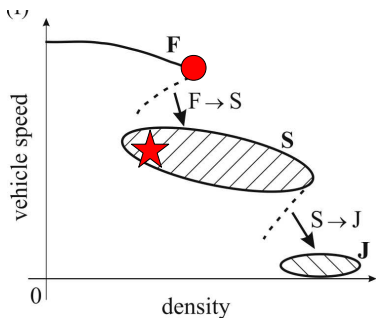


(b) UP-ALINEA



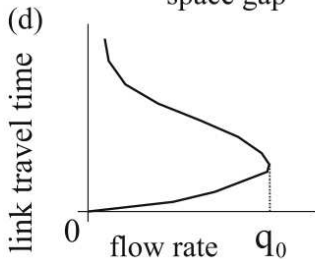
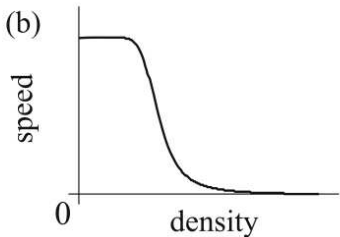
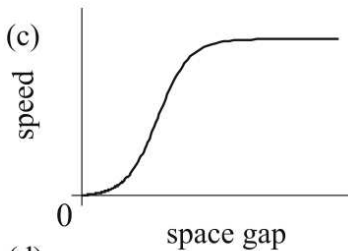
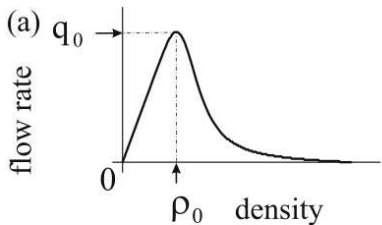
- ▶ (UP-)ALINEA not based on empirics (i.e. 3PT)
- ▶ Throughput
- ▶ Waiting times
- ▶ Upstream propagation of congestion

Unfair comparison?

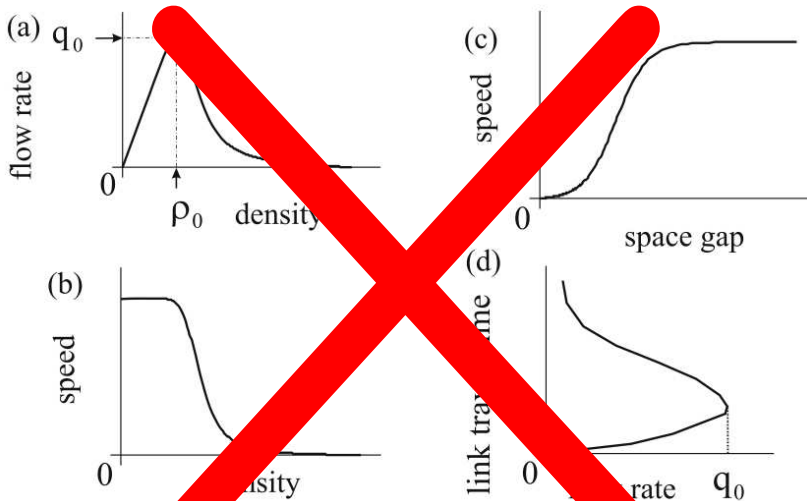


- ▶ Based on (not described) simulation
- ▶ Breakdown at densities lower than critical
- ▶ (UP-)ALINEA doesn't 'see' breakdown & can't react appropriately
- ▶ No discussion of algorithm UP-ALINEA

Part II, Chapter 10: FD approach & 3PT



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Kerner's arguments against FD approach

- ▶ No association with empirical basis of 3PT
- ▶ Average characteristics in FD
- ▶ Lines instead of 2D regions
- ▶ No spatiotemporal features

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Kerner's arguments against FD approach

- ▶ No association with empirical basis of 3PT
- ▶ Average characteristics in FD
Not in 3PT?
- ▶ Lines instead of 2D regions
Non-equilibrium speeds are possible
- ▶ No spatiotemporal features
Wave velocity in congestion
- ▶ Nothing wrong with FD approach, just not fit for spatiotemporal analysis

Models based on FD approach

Critics on LWR model:

- ▶ Traffic breakdown \Leftrightarrow density $>$ critical
- ▶ No probabilities for phase transition
- ▶ Fixed capacity
- ▶ No hysteresis
- ▶ Empirical features can not be explained

Critics on GM models: 'higher order', micro

- ▶ Predicts $F \rightarrow J$ instead of $F \rightarrow S \rightarrow J$

Part II, Chapter 11 & 12: 3PT models

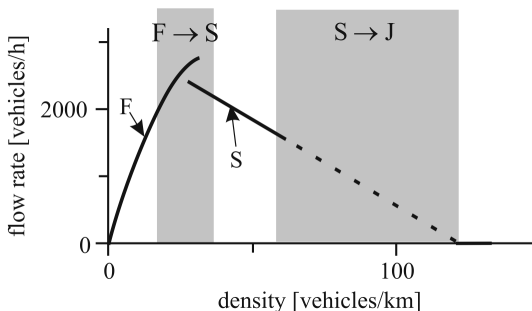
- ▶ Deterministic acceleration time delay (ATD) model (micro)
- ▶ Stochastic model (micro)
- ▶ Stochastic cellular automata (CA) model

Part II, Chapter 11 & 12: 3PT models

- ▶ Deterministic acceleration time delay (ATD) model (micro)
- ▶ Stochastic model (micro)
- ▶ Stochastic cellular automata (CA) model
- ▶ *Too many parameters*
27 (deterministic model)
17 (stochastic microscopic model)

From 3PT model to FD model

- ▶ 2D regions replaced by lines (1D)
- ▶ 2 capacities
- ▶ No over-acceleration probability
- ▶ \Rightarrow Failure to explain coexistence F, S and J



Outline

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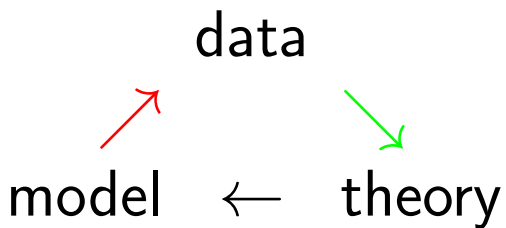
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Review & discussion

Review



Review: pro's

- ▶ 'Summary' of previous book:
The Physics of Traffic (2004)
- ▶ 3PT is a good and creative idea
- ▶ Explains many features
- ▶ Applicable to freeways

Review: cons

- ▶ Focus on $F \rightarrow S$ and $S \rightarrow J$ transitions:
Little discussion of $S \rightarrow F$, $J \rightarrow S$ or $J \rightarrow F$
- ▶ Too harsh on other approaches
- ▶ Control chapters not convincing
- ▶ Other models don't capture 'everything':
but that is what modeling is about
- ▶ 3PT models: too many parameter,
no comparison based on simulations or data
- ▶ Treiber et. al. *TR-B* (2010) argue same
features can be reproduced by 2 phase models

Disqualification of 'traditional' models?

- ▶ Engineering answer: they do work!
- ▶ Not all features are explained, should each model/theory explain everything?
- ▶ Many extensions have been proposed
 - ▶ capacity not fixed at density
 - ▶ multi-class
 - ▶ capacity drop & hysteresis

Discussion

” [...] the important question is **what driver behavioral characteristics** should be taken into account in a traffic flow model to call the model as the model for traffic flow. This means that the model must **describe traffic breakdown** at a bottleneck and resulting **congested patterns** as found in real measured traffic data.”

p. 242

Thanks!

Q&A

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