An Analysis of Relationship between Lane-Changing Behaviors and Traffic Flow based on Microscopic Traffic Simulation

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† Lane utilization rate is an important factor of realizing flow rate.

- One of congestion factors is by high utilization rate of fast lane on bottleneck.

- How to control this rate?
- Control …
  1. Behavior of vehicle
  2. Lane regulation …
Objective

† To analyze relationship between lane-changing behaviors and traffic flow.
   ➢ Microscopic behaviors v.s. macroscopic index

† Method
   ➢ Simulation with simple models.
     ➢ Simple lane-changing model
     ➢ Simple following model
   ➢ Find the benchmark for lane-changing parameters.
Lane-changing model

Based on Gap Acceptance Model

START

5sec from last LC

NO

Current Speed

YES

Has desire to overtake?

NO

LC Desire

Specing

YES

Is following?

NO

target lane=cruising lane

target lane=fast lane

Gap Acceptance

Target lane exist?

NO

Leading/following car exist? on target lane?

NO

YES

Gap on target lane

acceptable gap?

NO

Keep lane

YES

NO

START

END
Lane-changing model

Demand

Improve this situation by LC

10km/h down

No-Demand

Keep lane

10km/h down

Low $\Delta v$ (5km/h)  High $\Delta v$ (15km/h)

LC suppression parameter $\Delta v$

Lane-change is requested when:

Driving speed – desired speed $< \Delta v$

- Indicates how the driver endures the low speed
- Speed gain incentive is suppressed by this parameter.
Following model

† FD based model (Newell 1993)

➢ 3 parameters

\[
\begin{align*}
\text{Desired speed } v_d & \text{ [m/s]} \\
\text{Max flow } q^{\text{max}} & = \frac{T}{\tau} \text{ [veh/s]}
\end{align*}
\]
Following model

† Simplified FD model ignoring congestion

- 2 parameters
  - desired speed $v^d$ & response time $\tau$
- Flow rate won’t be decrease in high density situation.
- To analyze / find some clearly-understandable benchmark

\[ v^d \quad q_{\text{max}} = \frac{T}{\tau} \]

\[ q \quad k \]

Desired speed $\sim$ N (20.0, $1.0^2$~ $4.0^2$)

$1 / \tau = 1 / 2.0$[sec]
Following model

- Desired speed $\sim N(20, 4^2)$
- $v^d = 16\text{m/s}$
- Many lanes, enough space to overtake
- $v^d = 20\text{m/s}$
- Limited lanes, limited space to overtake
- $v^d = 24\text{m/s}$
- #

$q^{\text{max}} = \frac{T}{\tau}$

$q$ vs $k$
Simulation Model Framework

Start a calculation step

Following step
- Calculate moving step
- All veh?
- update location not to crush

Lane-changing step
- Lane-changing now?
- Yes
  - Complete LC?
    - Yes
      - Finish LC
    - No
      - Keep LC
- No
  - Start LC?
    - Yes
      - Start LC to target lane
    - No
      - Keep lane
- All veh?

End
Simulation Settings

1. Lane change suppression (Δv)
   - 0.0 ~ 15.0
2. Distribution of desired speed
   - N (20 m/sec, (1.0, 2.5, 4.0 m/sec)^2)
3. 5 km circular road with 2 lanes
4. Initial density is uniform
   - 2.0 ~ 50.0 veh/km/lane
   - Vehicles with different v^d are located randomly.
5. Gets aggregated values (means)
   - every 125 sec x 100 records for 1 case
Analyze the mean values of fluctuated situations:

\[ \nu^d \sim N(20, 2.5^2) \]

\[ k = 18 \text{ km/veh/lane} \]
Result overview

† Maximum flow rate (=1800veh/h) is derived from response time (=2sec) of following model.
† No-differences on FD of QK among different dv(s)
† In high SD (σ) case, the flow rate is resulted in low value.

![Graph 1](image1.png)

![Graph 2](image2.png)
Flow rate and lane-changing

1. Case with low $\Delta v$
   - Left side of the $\uparrow$ arrows
   - Vehicles with low desired speed are enter the fast lane.

2. Case with middle $\Delta v$
   - Around the $\uparrow$ arrows
   - Vehicles are divided into 2 lanes corresponding those speeds efficiently.

3. Case with high $\Delta v$
   - Right side of the $\uparrow$ arrows
   - Almost all vehicles are located on the cruising lane.

$\sigma = 2.5 \text{ [m/s]}$

$\Delta v = \text{desired speed} - \text{lane-changing speed}$
Flow rate and lane-changing

\[ \Delta v \text{ value which maximizing the flow rate is larger on case with larger standard division.} \]
Middle SD case

Utilization rate of fast lane is around 40% in situation when the flow rate is maximized.
Utilization and lane-changing

\[ \sigma = 1.0 \text{ [m/s]} \]

Small SD case

- Utilization rate of fast lane is around 40% in situation when the flow rate is maximized.
Summary

† Relationship between flow rate, lane utilization, desired speed and LC demand suppression parameter in lane-changing model is analyzed based on simple simulation.

- LC suppression value which maximizes the flow rate is larger on case with larger standard division.
- Utilization rate of fast lane is around 40% in situation when the flow rate is maximized.
- The maximum flow rate is appear when the lane-changing
- Flow rate would increase when lane-changing were limited.