An Analysis of Traffic Breakdown Phenomena Using a Platoon-based Traffic Flow Model

Kyoto University Yasuhiro SHIOMI

Contents of my talk

1. The reason why I choose Kitamura sensei

2. Current research related to Kitamura sensei
   - Research of my colleagues
   - My PhD studies

3. The influence and teach of Kitamura sensei

Self Introduction

Apr, 2000　Kyoto University

Apr, 2001　First meeting with Kitamura sensei
(in the class, “Statistics”)

Oct, 2002　Second meeting with Sensei
(in the class, “Traffic Engineering”, co-organized by Prof. Iida)

Apr, 2003　Join “Kitamura Lab.”

Apr, 2004　Graduate school of Engineering, Kyoto University

2005-2007　TA of Sensei class (“Traffic Management Engineering”)

Sep, 2008　Doctor of Engineering, Kyoto University
(Supervised by Kitamura sensei)

Oct, 2008-　Assistant Professor, Kyoto University (ITS Lab.)

Why I choose “Kitamura Lab” ?

Because …

“I was interested in urban problems, especially in transportation system.”

“I knew Kitamura sensei and Kikuchi sensei, who was assistant professor in Kitamura lab. “

Inspiration

(Choosing Kitamura lab is the best decision I have ever made.)

The member of Kitamura lab. 2003

STAFF

Prof. Kitamura

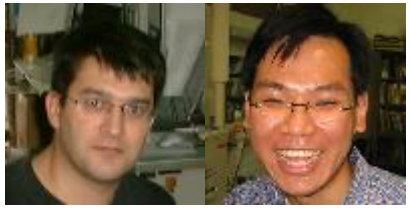
Assoc. Prof. Yoshii

Assist. Prof. Kikuchi

Secretary

Inagaki

Doctor



Senbil Yusak

M2

Arief Arthit Hashiue Ikeda Maeda Yano

M1

Ashikawa Hara Ushiwaka Pirapol Nakano Nakamura Murakami

B4

Sakamoto Koi Hanada Yamaoka Shiomi

Researcher

Bayarma Matsuda Nishiuchi Nishino

A study for the amusement activities in the public realm by the suburbs residence (2001)

Kei Maeda

Maeda

A study for the amusement activities in the public realm by the suburbs residence

- What makes our life “true” well-being?
- The death of suburban residential area.

à The necessity of “Oldenburg’s the third place”

Hypothesis

Suburbs, where “Oldenburg’s the third place” are lacked, are not attractive place for resident.

- Analyzing Keihanshin area-PT data (1990)
- Questionnaire for customers of “Izakaya (pubs)” in urban and suburban area.

Conclusion

1. Some “Oldenburg’s third place” could be found also in suburban area.
2. In reality, suburban residence had less amusement activities due to time constraint.

A study on the perception of the public space in the city (2003)

Risa Koi

Koi

A study on the perception of the public space in the city

- In typical suburban area, some public space where the community and social welfare can mature were equipped.
- There are fewer social welfare and community in suburban areas.

Hypothesis People never aware the “public” feelings in the suburban areas.

- “Public” = Diversity in (people + faculty + activity) + History
- Questionnaire asking which factors affect the cognition of “public” feeling.

Typical suburban area

Typical urban area

Koi

A study on the perception of the public space in the city

- In typical suburban area, some public space which can create community and social welfare were equipped.
- There are few social welfare and community in suburban areas.

Hypothesis

People never aware the “public” feelings in the suburban areas.

Conclusion

1. Residence in urban area tend to perceive urban space as “public”, whereas residence in suburban area tend to perceive suburban area as “public”.

2. Residence in suburban area were less sociable than in urban area.

Worldviews, lifestyle and sustainability: A search for a primordial determinant of environmental friendliness (2005)

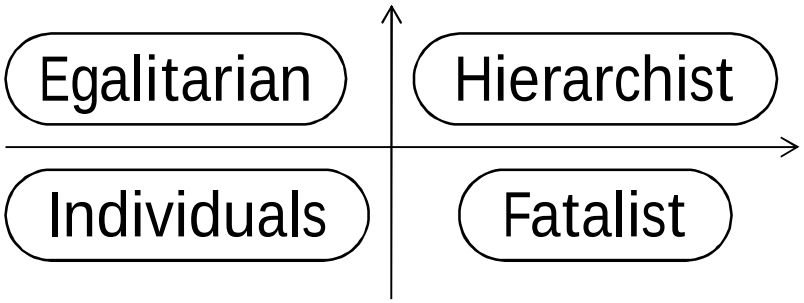
Kyotaro Sakamoto

Sakamoto

Worldviews, lifestyle and sustainability: A search for a primordial determinant of environmental friendliness

Worldviews

An individual's way of thinking and attitude, which have strong influence to the social recognition and behavior

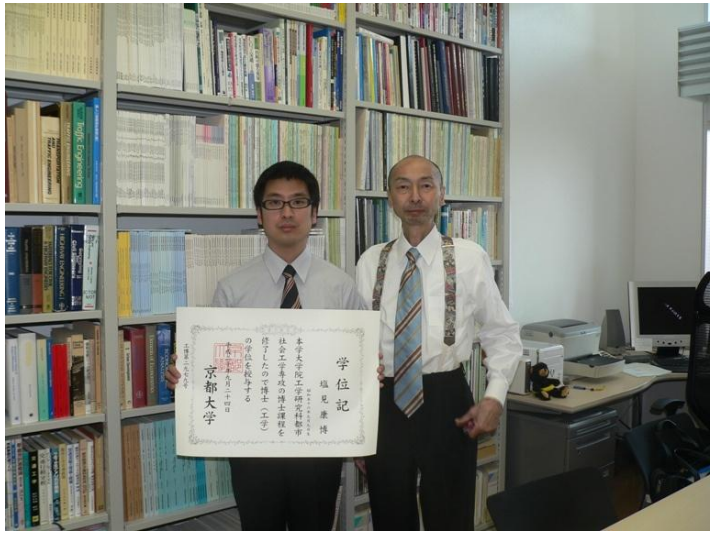


u Questionnaire about worldviews and attitude towards transportation, environment, residential area and society was done in some areas

Conclusion

1. Strong relationship between individuals' worldviews and attitudes towards residential area.
2. The utility of market research for public works based on the worldviews was discussed.

Platoon-based Traffic Flow Model to Estimate Traffic Breakdown Probability on Freeway Bottlenecks



9/24/2008 at Kitamura sensei's office

Kyoto University Yasuhiro SHIOMI
Kyoto University Toshio YOSHII
Kyoto University Ryuichi KITAMURA

Background (i)-Traffic Capacity

- "Traffic Capacity" has played important roles in...

Planning

Design

Operation

- "Traffic Capacity" is defined as the maximum number of vehicles that can pass a point per unit of time.

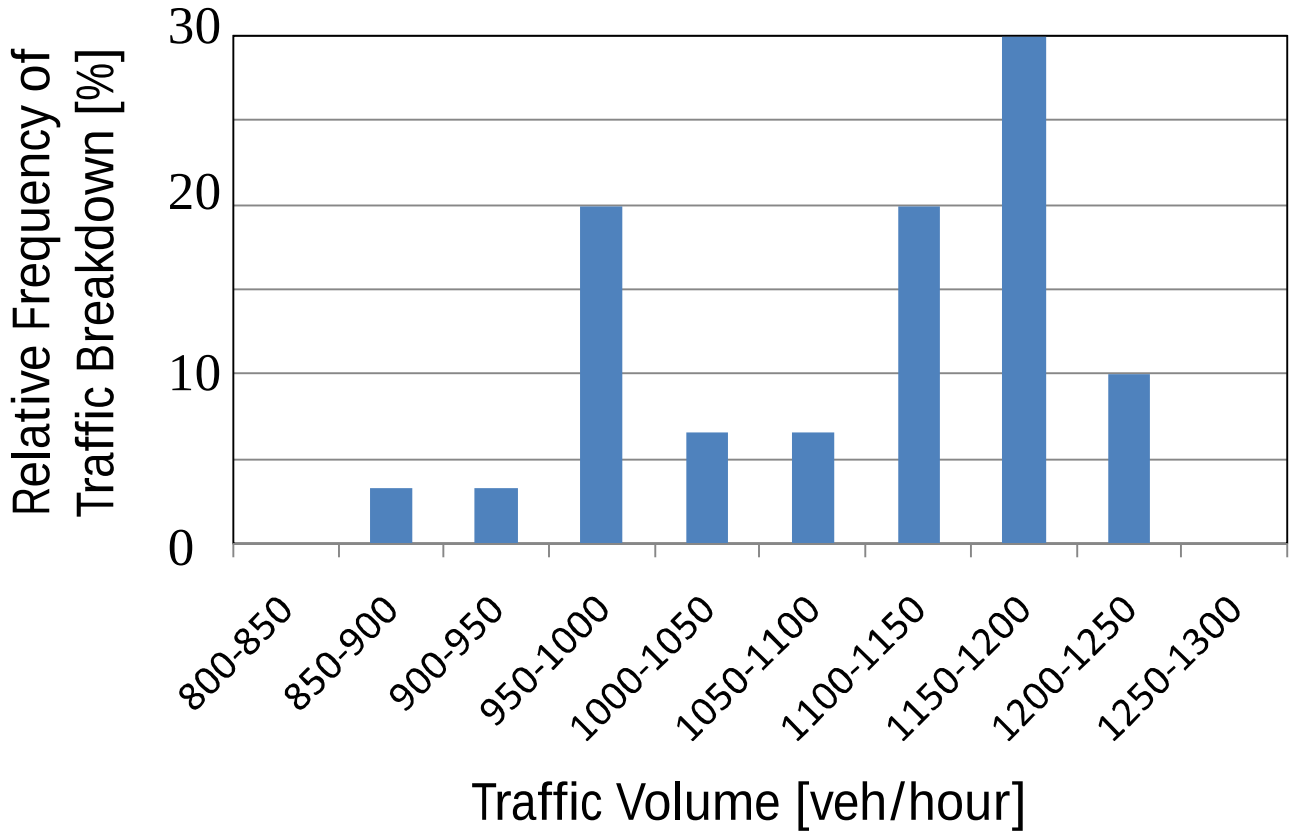
In this concept, traffic congestion occurs
only when traffic demand exceeds the maximum flow rate.

- In reality, this is not so simple issue....

Background(ii)-Stochastic Phenomena

- "Traffic Breakdown" occurs stochastically to the traffic volume.

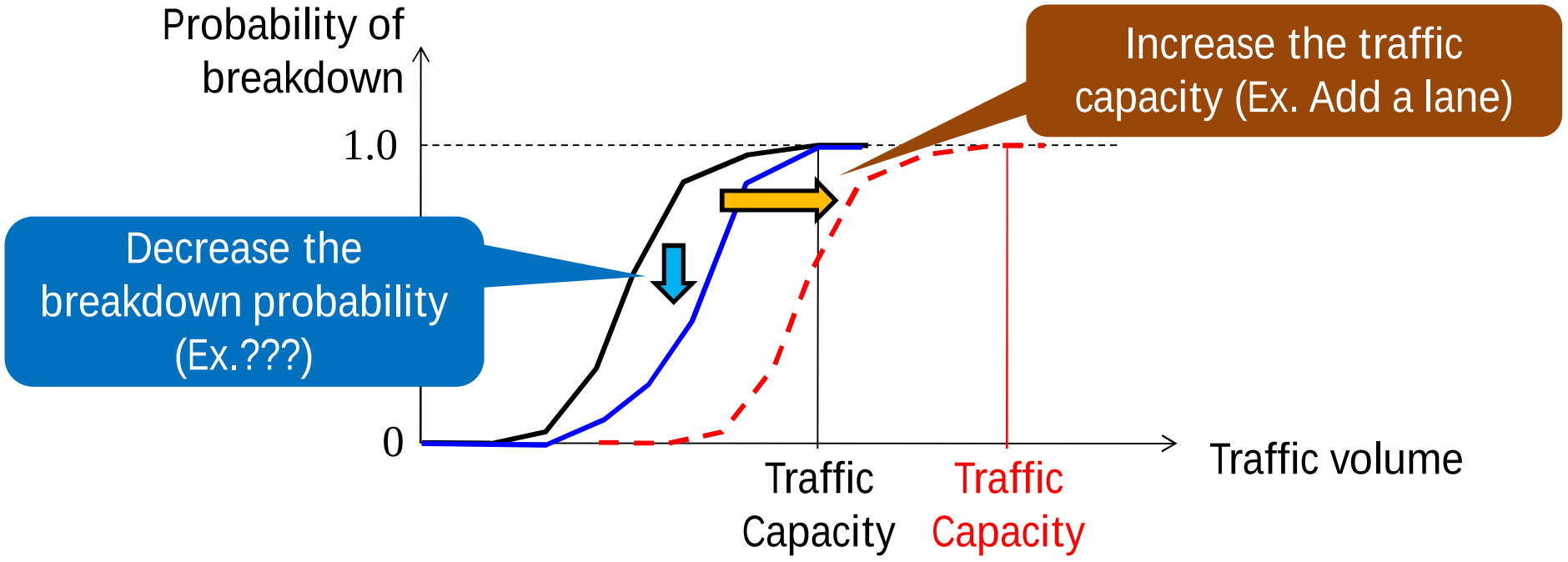
Transition from non-congested state to congested state



*Divided-two lane section in Tokai-hokuriku Expressway, 48.43 kp (2003)

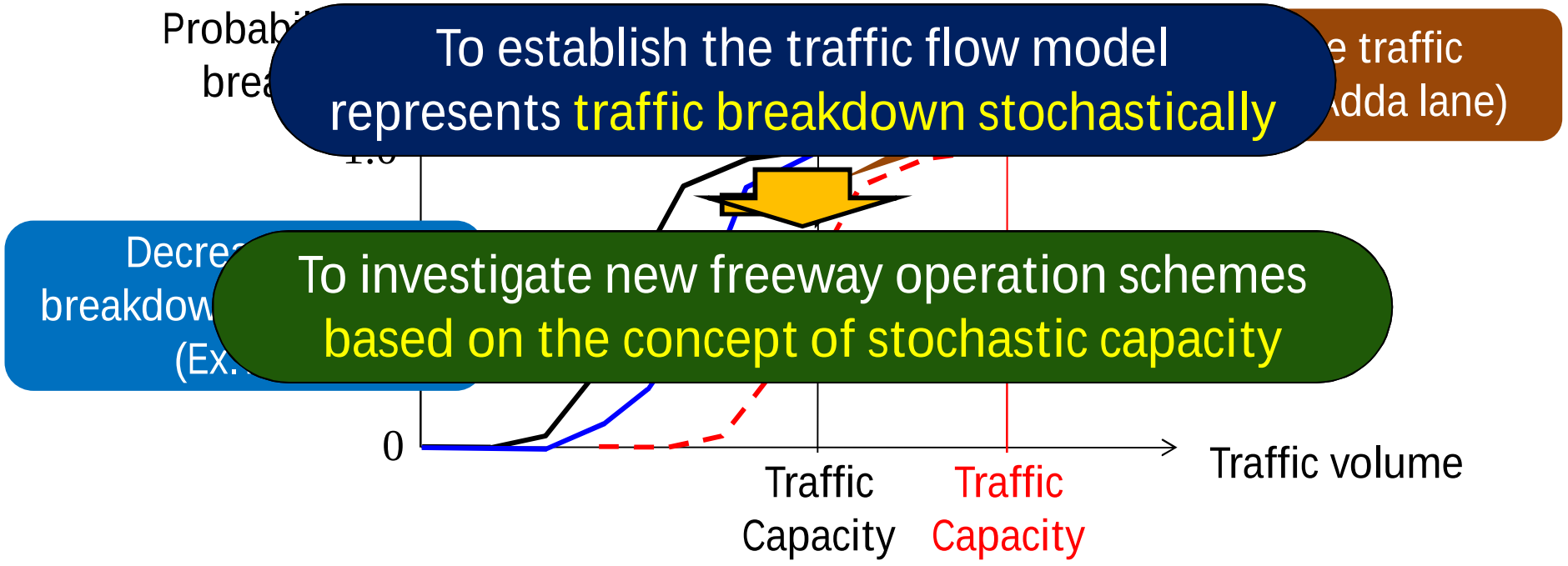
Background(iii)-Stochastic Capacity

- The concept of “stochastic capacity/ breakdown probability” have been suggested. (Brilon et al. (2005), Kuhne (2007) and so on…)



Objective of this study

- The concept of “stochastic capacity/ breakdown probability” was suggested. (Brilon et al. (2005), Kuhne (2007) and so on…)



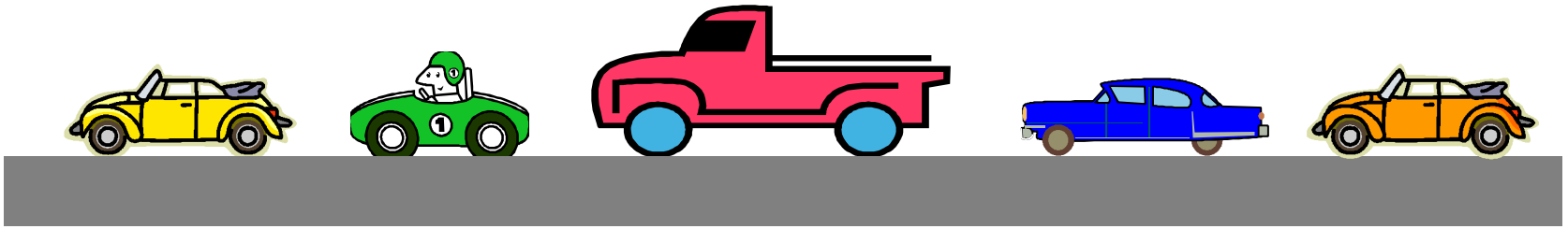
Viewpoint of this study (i) - Heterogeneity

- Why does traffic phenomena have stochastic nature???

⇨ Heterogeneity of vehicles in traffic flow

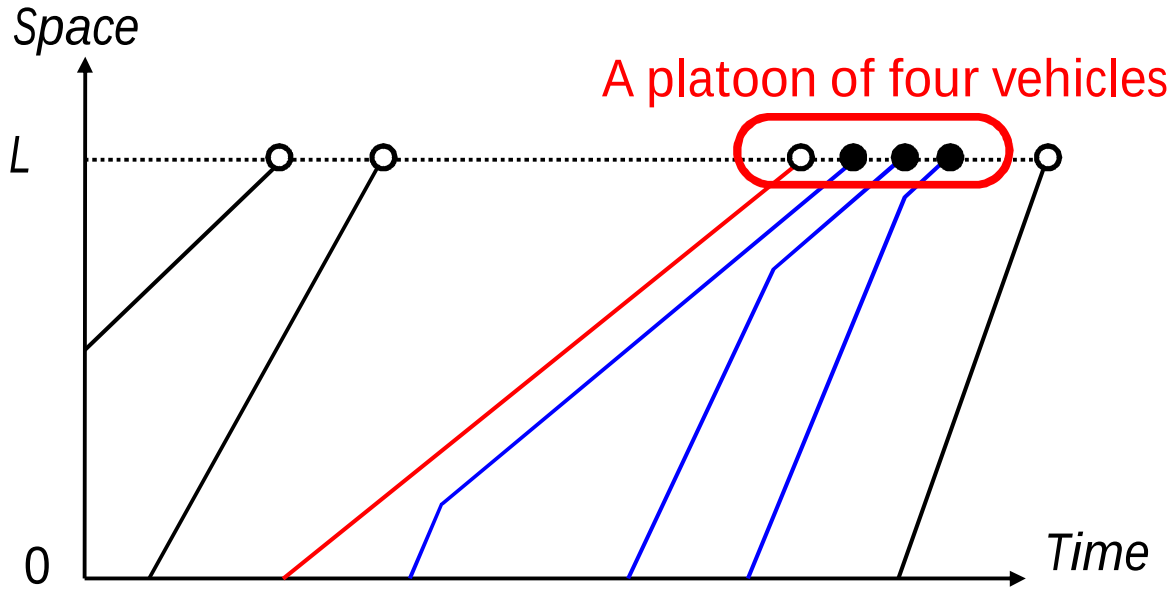
- Desired speeds vary among vehicles.
  - ex) Trucks or sports cars
    Young drivers or senior drivers
    With time limit or without time limit

Desired Speed: the speed a driver would choose for a certain section without any obstacles.



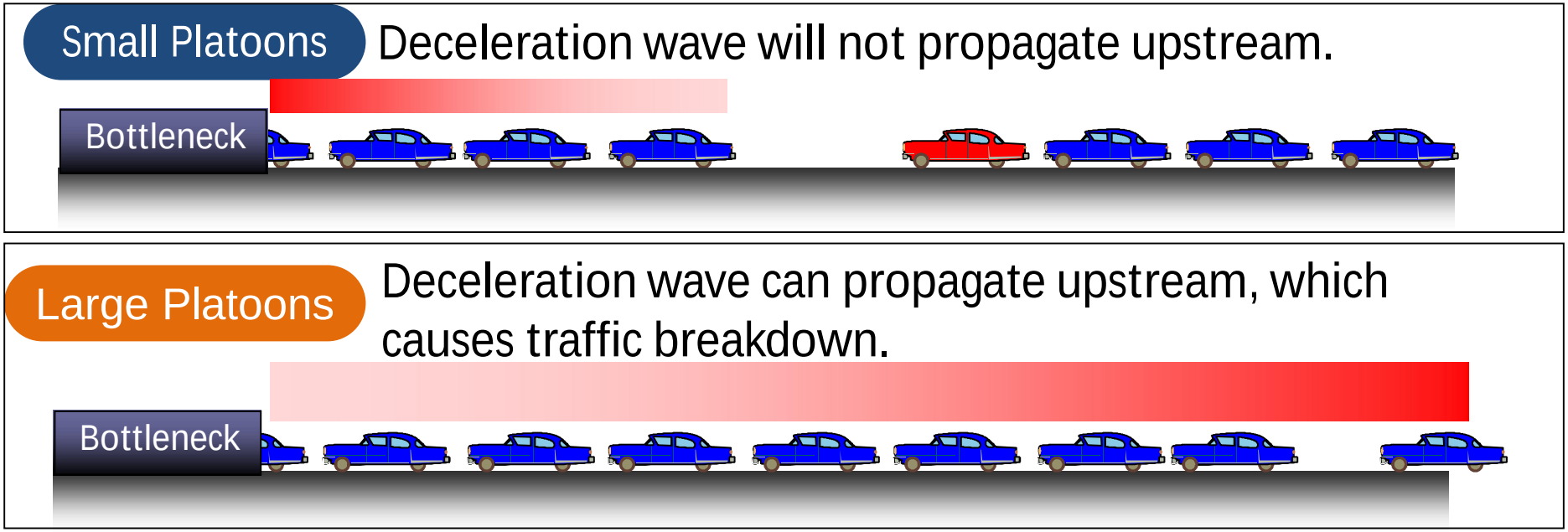
Viewpoint of this study (ii) - Platoons

- Due to the desired speed distribution,
  platoons are formed in stochastic manner.



Viewpoint of this study (iii) - Platoons

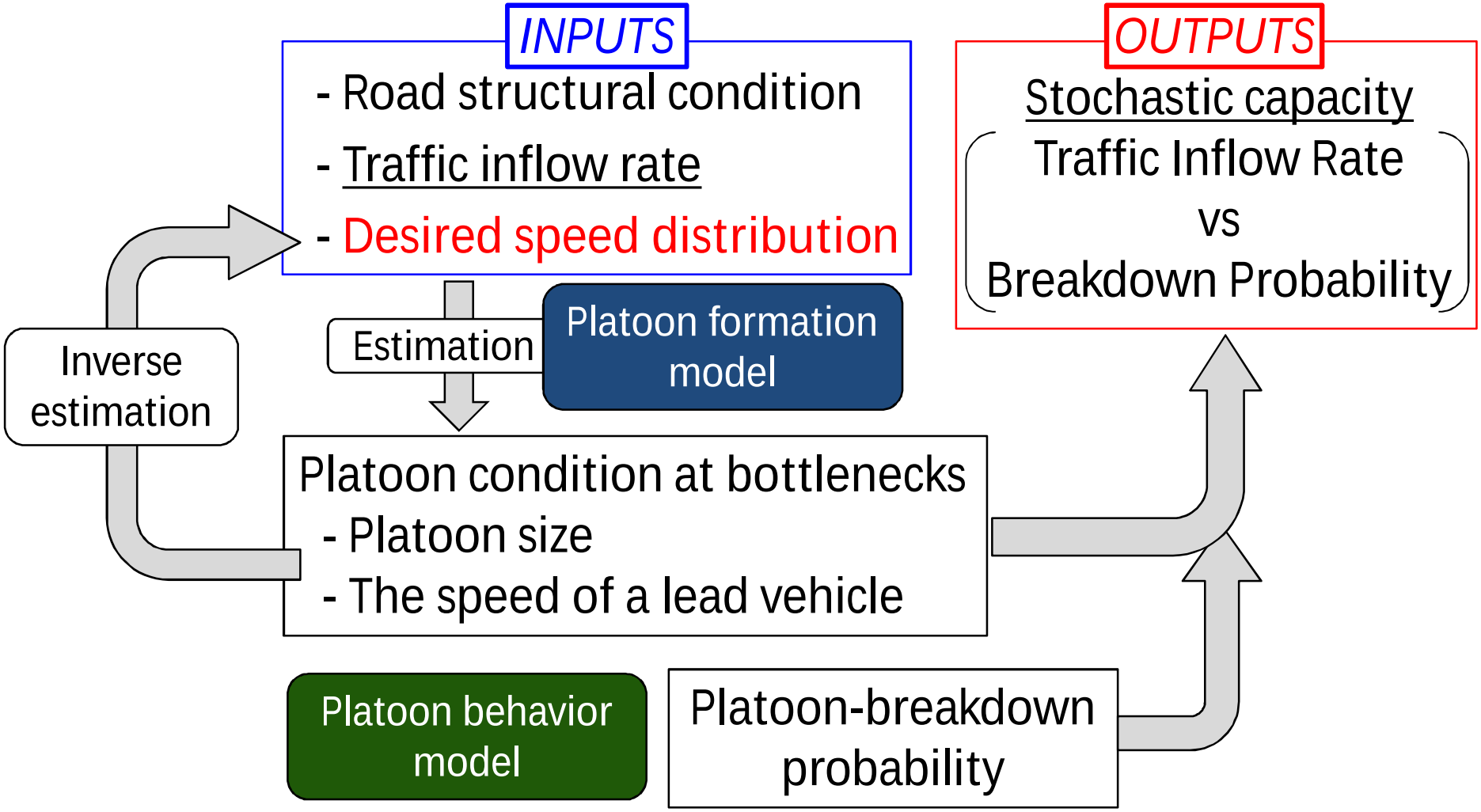
- It is pointed out that platoons cause traffic breakdown (e.g. Koshi, 1986)



CONJECTURE

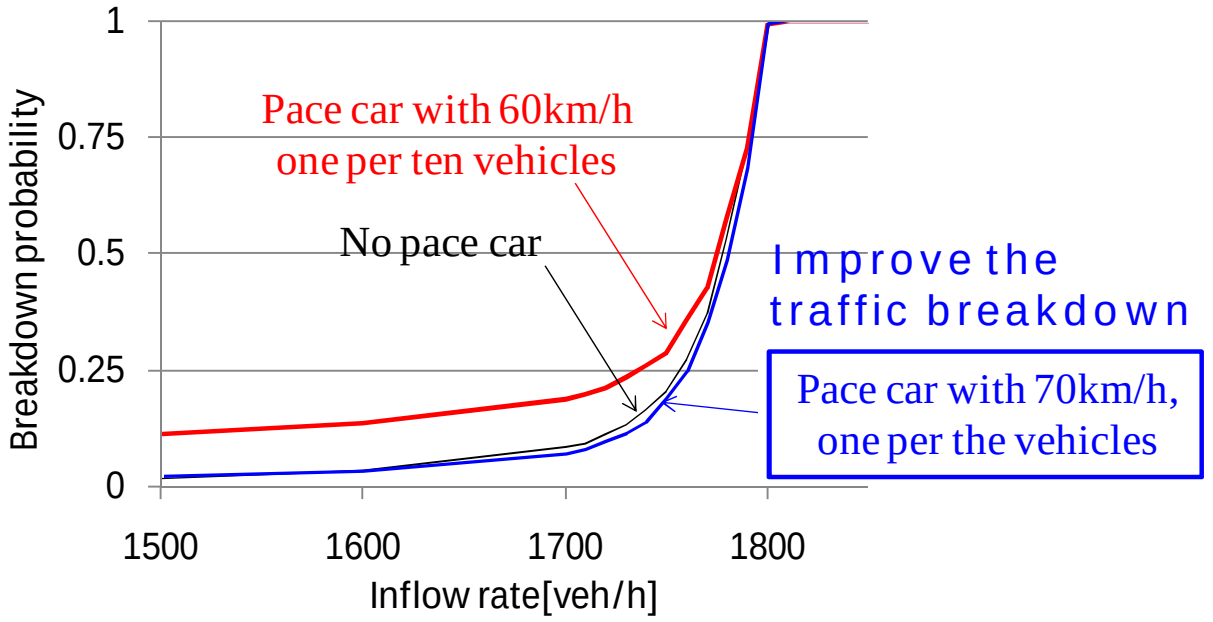
Each platoon has breakdown probability, influenced by its platoon size.

Frameworks of this study



Summary of the result

- Desired speed distribution was estimated in unbiased way.
- Breakdown probability to the traffic inflow rate was defined.
  - The relationship between traffic flow rate and breakdown probability could be explained by desired speed distribution.
  - Reducing the variance of DSD and installing pace cars are effective way to reduce breakdown probability.



Kitamura sensei's teaching

- Through the PhD research,
  "what I was asked by Kitamura sensei" are…

  "What is traffic capacity?"

  "What is traffic congestion?"

  "What is a platoon?"

- In many cases, I could not answer correctly.

- To think by myself is worth. Just "information" is meaningless.

Impressive talk of Kitamura sensei

- At the end of his class, “traffic management engineering”, for before under graduate 3rd year students, 2006.

- Fortunately, I joined his class as a teaching assistant.

Kitamura sensei to the student in the class:

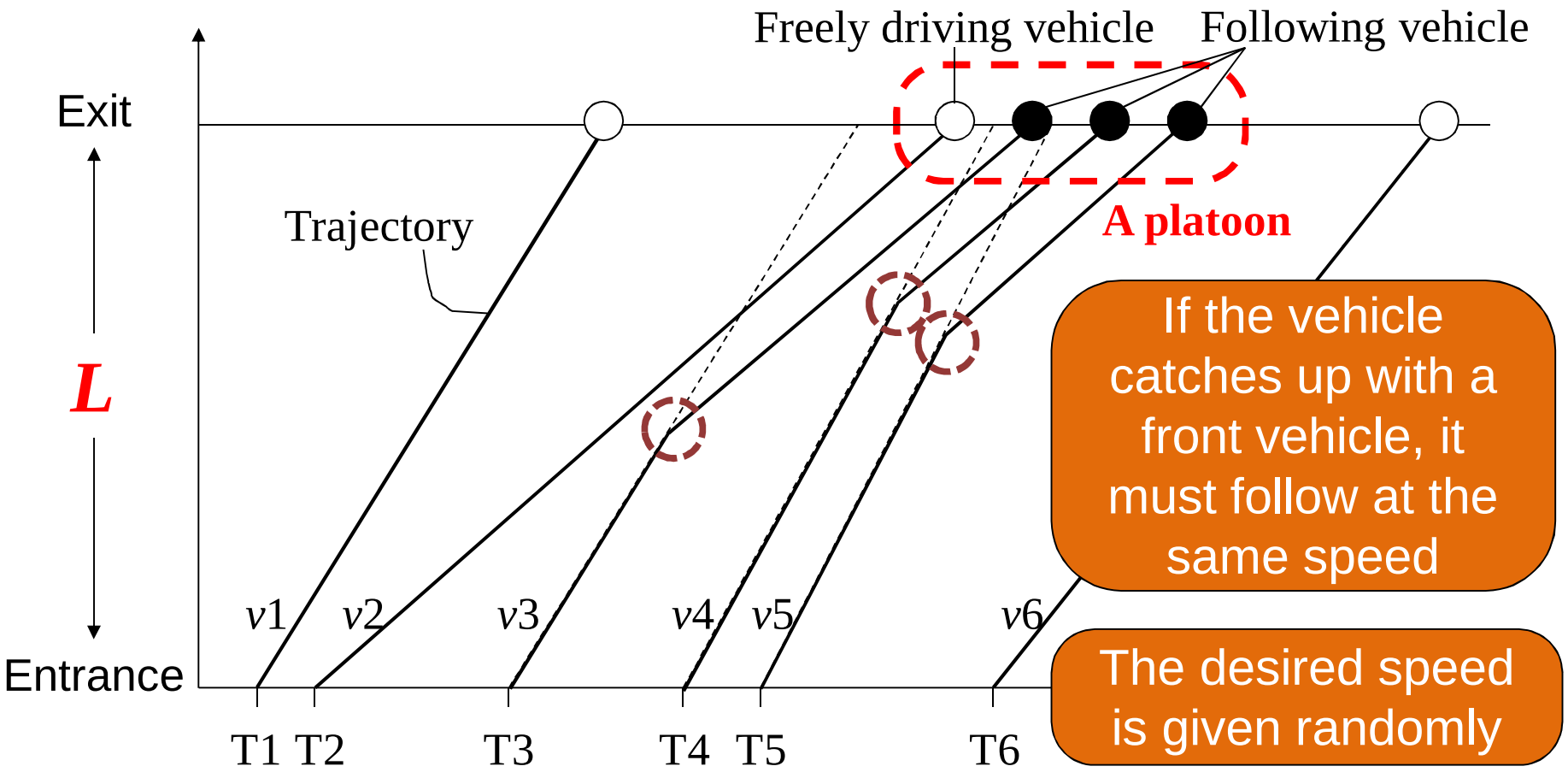
“In the future when you become a civil engineer and engage in land development, please keep this promise at least:
don’t cut this existing tree. ”

“

”

Thank you for your attention.

Assumptions in traffic flow



Inputs

- Each vehicle's entrance time
- Desired speed distribution

Platoon Formation

- This model outputs "lead vehicle speed and platoon-size distribution"

$$\text{Prob}[v_i, k_i] = f(v \mid \hat{\mathbf{a}}) \cdot p^{lead}(v) \cdot p_{k-1}(v)$$

$f(v \mid \hat{\mathbf{a}})$: PDF of desired speed distribution (parameter vector β)

$p^{lead}(v)$: Probability that a vehicle with DS v becomes the lead

$$p^{lead}(v) = \prod_{k=1}^{\infty} \left[\int_{d_{i,i-k}(v)}^{\infty} f(u)du \right]$$

$d_{i,i-k}(v)$: Variable related to inflow rate and the bottleneck outflow rate

$p_{k-1}(v)$: Probability that k-1 vehicles catch up with a vehicle at speed v

$$p_{k-1}(v) = \left[\prod_{j=1}^{k-1} \left\{ \int_{d_{i+j,i}(v)}^{\infty} f(u)du \right\} \right] \cdot \left[\int_{d_{i+k,i}(v)}^{18.06} f(u)du \right]$$

Desired speed distribution

- The parameter vector β can be estimated by applying maximum likelihood estimation

$$\hat{\mathbf{a}}^{*} = \arg\max L(\hat{\mathbf{a}}) = \prod_{i=1}^{N} \text{Prob}[\tilde{v}_i, \tilde{k}_i \mid \hat{\mathbf{a}}]$$

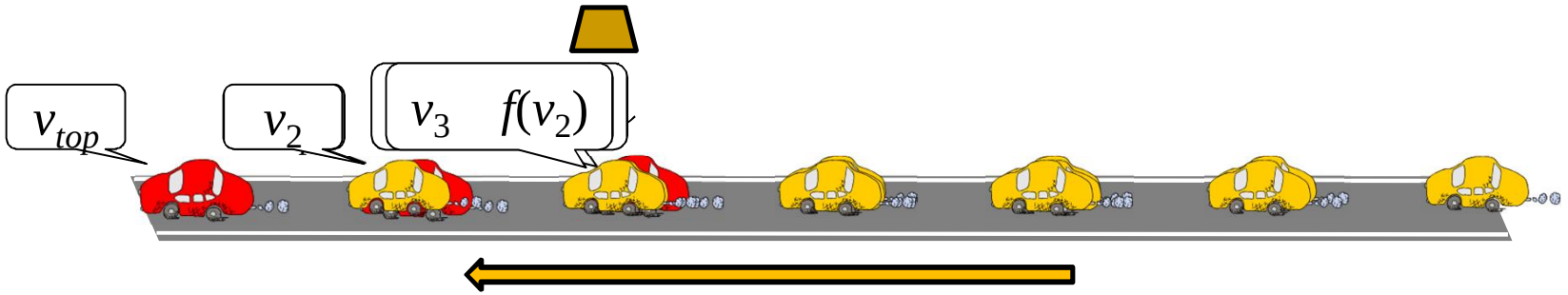
N : Observed number of platoons

$\tilde{v}_i$: the speed of the lead vehicle of the observed platoon i

$\tilde{k}_i$: the size of the observed platoon i

Assumptions in platoon flow

- Assumption 1: Speed transition within a platoon can be treated as Markov Chain



- Assumption 2: Traffic Breakdown à under 40 km/h

$$\mathbf{P} = \begin{pmatrix} 1 & 0 & \cdots & 0 \\ p_{S_1S_0} & p_{S_1S_1} & \cdots & p_{S_1S_n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{S_nS_0} & p_{S_nS_1} & \cdots & p_{S_nS_n} \end{pmatrix}$$

$$p_{plt}\left(v^{lead}, L \in \left(\mathbf{p}\left(v^{lead}\right)^{n-1}, e_1\right)\right)$$

Speed Transition Probability Matrix

Description of breakdown probability

- Breakdown probability at a bottleneck can be expressed as:

$$P_{BD}(Q) = \sum_{i} \sum_{v_{top}} \left\{ N \cdot \text{Prob}\left[v^{lead}, i \mid \hat{\mathbf{a}}, Q \right] \right\} \cdot t_{plt}\left(v^{lead}, i \right)$$

Q: given, β: inversely estimated, $\mathbf{P}$: observed

Where,

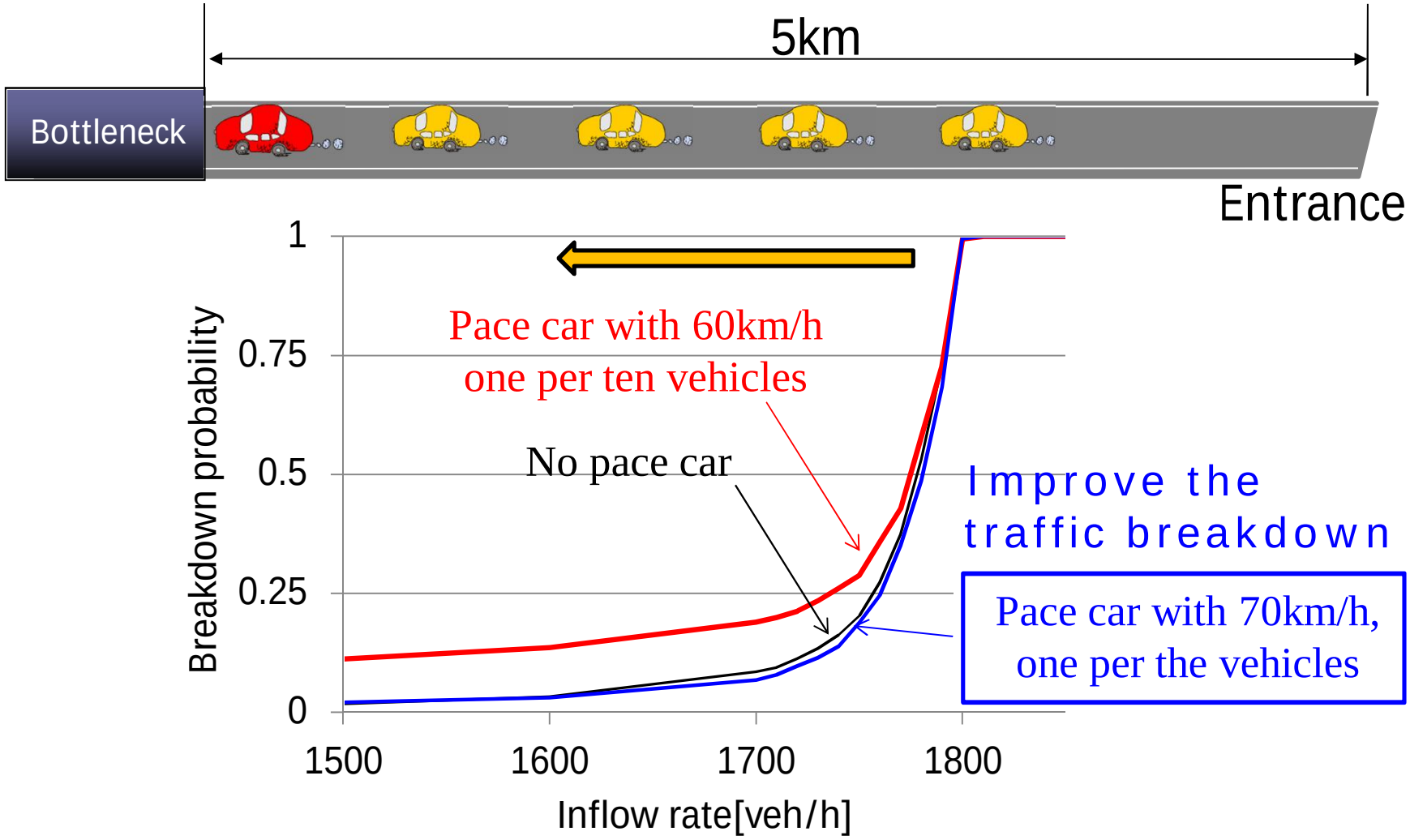
N : The number of observable platoons per unit of time

$$N = \frac{Q}{\sum_{i} i \cdot \left(\sum_{v} \text{Prob}\left[v, i \mid \hat{\mathbf{a}}, Q \right] \right)}$$

$t_{plt}\left(v^{lead}, i \right)$: Time of a platoon with $\left(v^{lead}, i \right)$ to pass through a BN

Numerical example

- Single-lane section of 5km is considered.



Conclusion

- Single-lane section of 5km is considered.