高速道路合流部の渋滞時における割り込み場所選定手法の構築

Lane-Changing Space Selection at Congested Merging Area

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Introduction

- Automated driving is being put to practical use
- Expected to reduce traffic accidents and ease traffic congestion
- Mixed environment of automated and manually operated vehicles

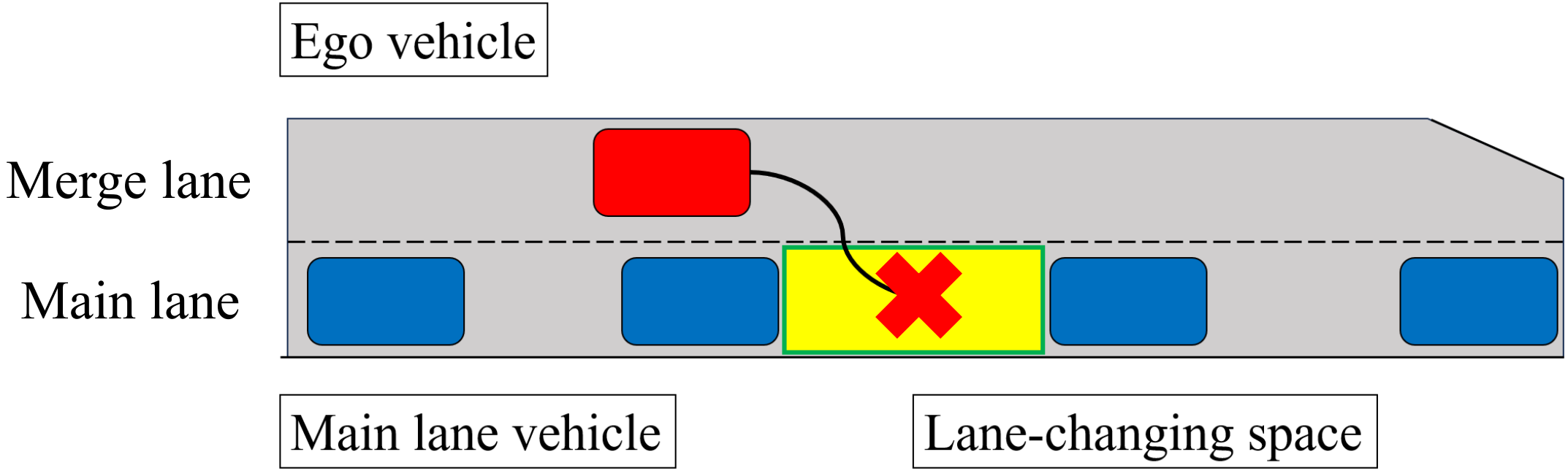
Baidu「Apollo Go」(1)

(1) https://www.afpbb.com/articles/-/3258528?pid=3258528001

Problem

Current autonomous driving systems have difficulty merging onto congested main lines due to safety considerations

→ Need a system that can be lane-changing



Previous Studies

- Vehicle-to-vehicle communication for lane change at merging area[2]
  - Sends a message to surrounding vehicles to give way

All vehicles must be equipped with device

- Lane change at merging traffic jams[3]
  - Building a merging model from human lane-changing data

Lane-changing space have not considered

(2)矢島颯斗, 高見一正, “自動運転車と手動運転車混在時の 進路交譲のための車車間通信プロトコルと試作評価”, マルチ メディア,分散,協調とモバイル(DICOMO2017)シンポジウム, pp1679-1687 (2017)
(3) Hanwool Woo, Hiroto Tetsuka and Jongseong Gwak: “Automatic Lane-Changing System on Congested Highway”, Journal of Robotics and Mechatronics, Vol.36, No.3 (2024)

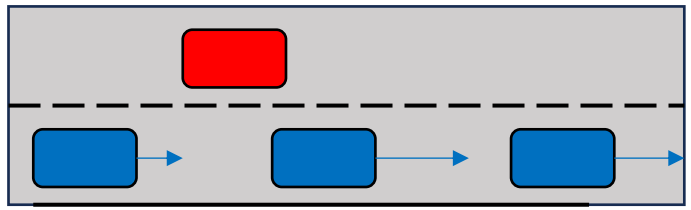
Objectives

Construction a method for selecting interrupt locations without use vehicle-to-vehicle communication

Approach

- Evaluate the possibility on vehicles status and remaining distance

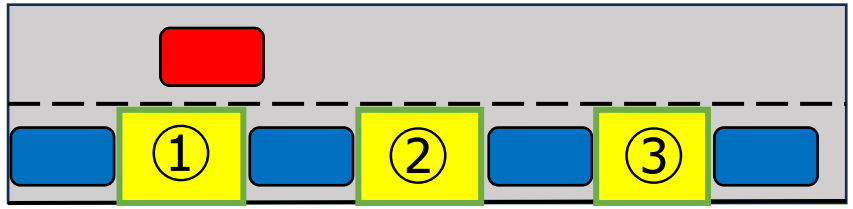
Measurements



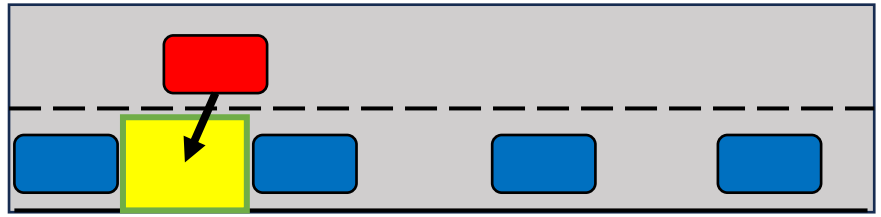
Vehicles status

Remaining distance

Assessment

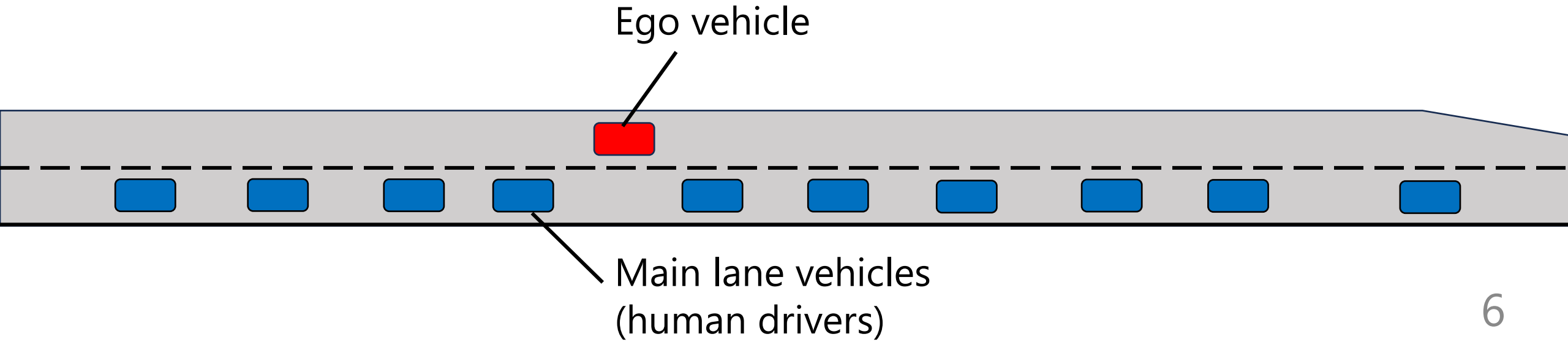


Selection



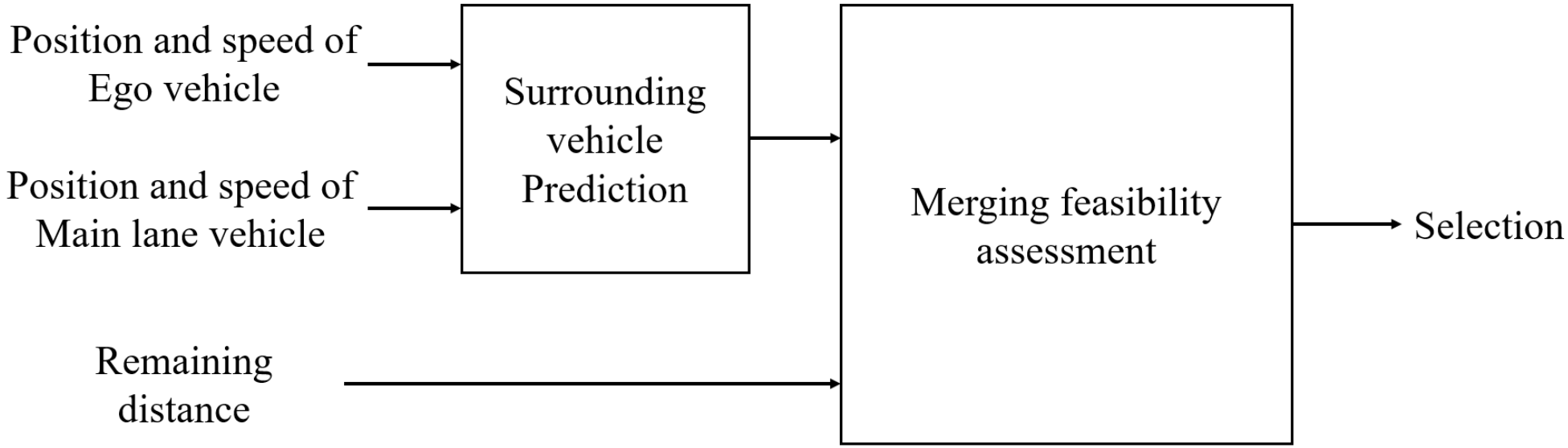
Problem definition

- Assumes two lanes of congested main lane and merging lane
- Ego vehicle equipped with measurement equipment
- Main lane vehicles are human drivers



Method

- Predicts position based on current position and speed
- Evaluate feasibility based on location prediction and remaining distance

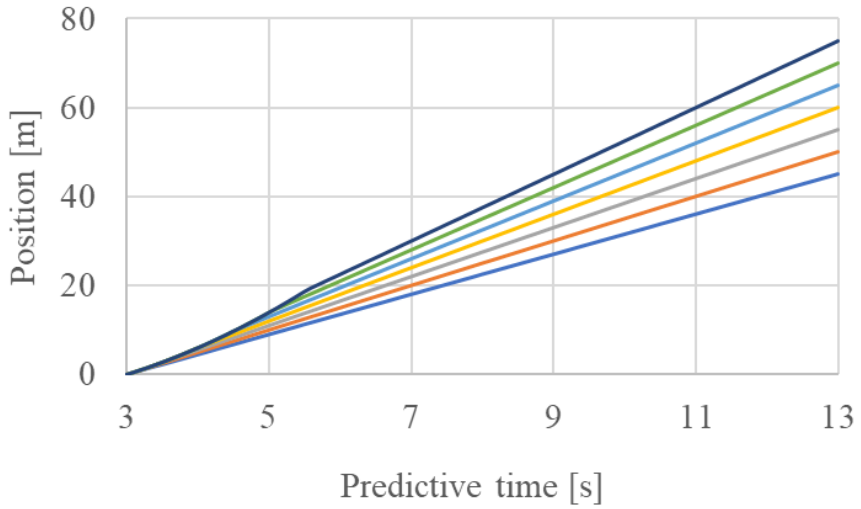


Schematics of proposed method

Prediction of position

- **Ego vehicle**

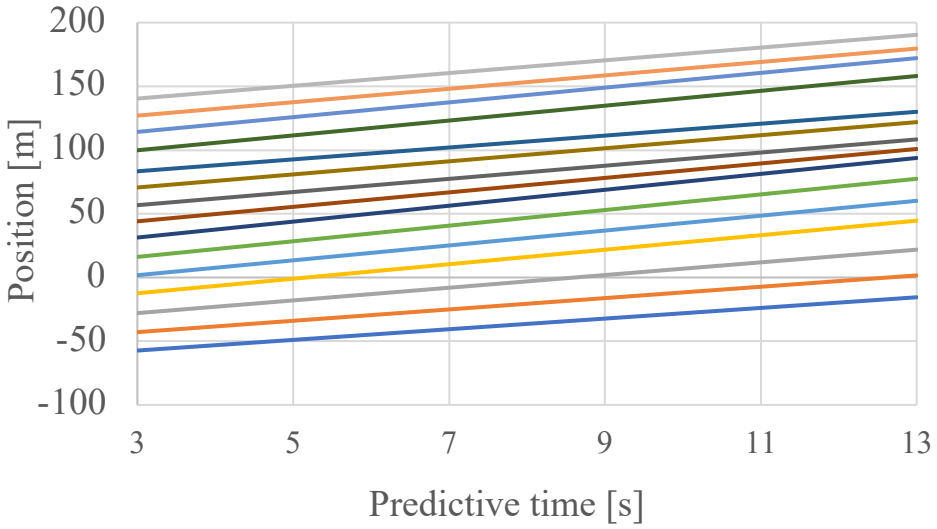
Travelling within speed and acceleration limits



Prediction of position of ego vehicle

- **Main lane vehicles**

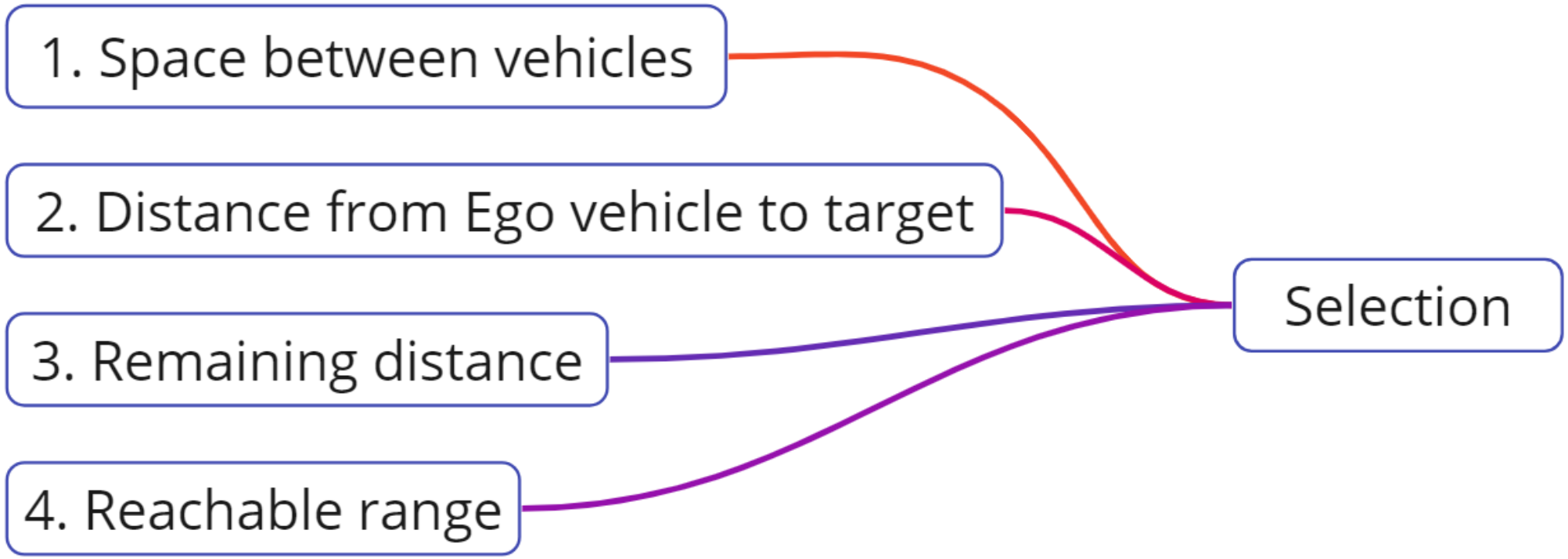
Assumed to run at constant speed and only their positions updated



Prediction of position of main lane vehicles

Merging feasibility assessment

- Determined based on the following four points

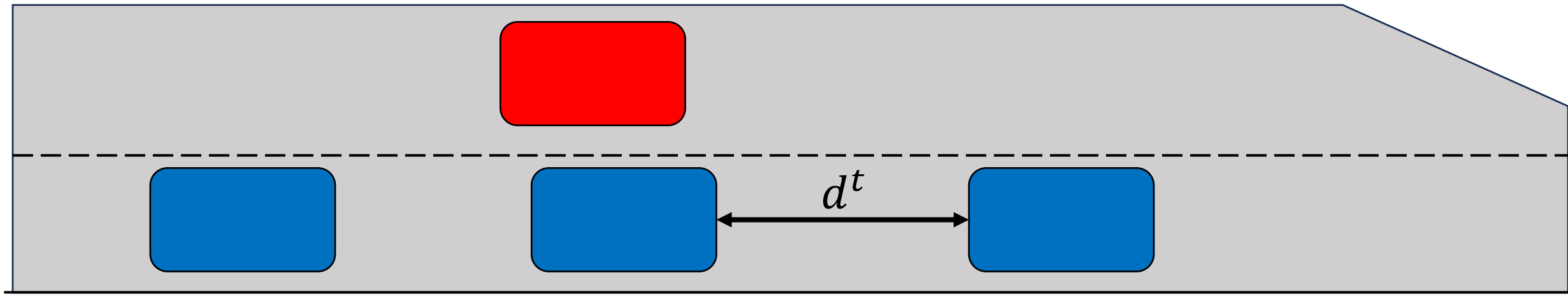


1. Space between vehicles

- The greater the distance between vehicles, the higher the assessment

$$\alpha = \min(1,\ d^t c)$$

d^t : Space between vehicles at time t
c : Constant

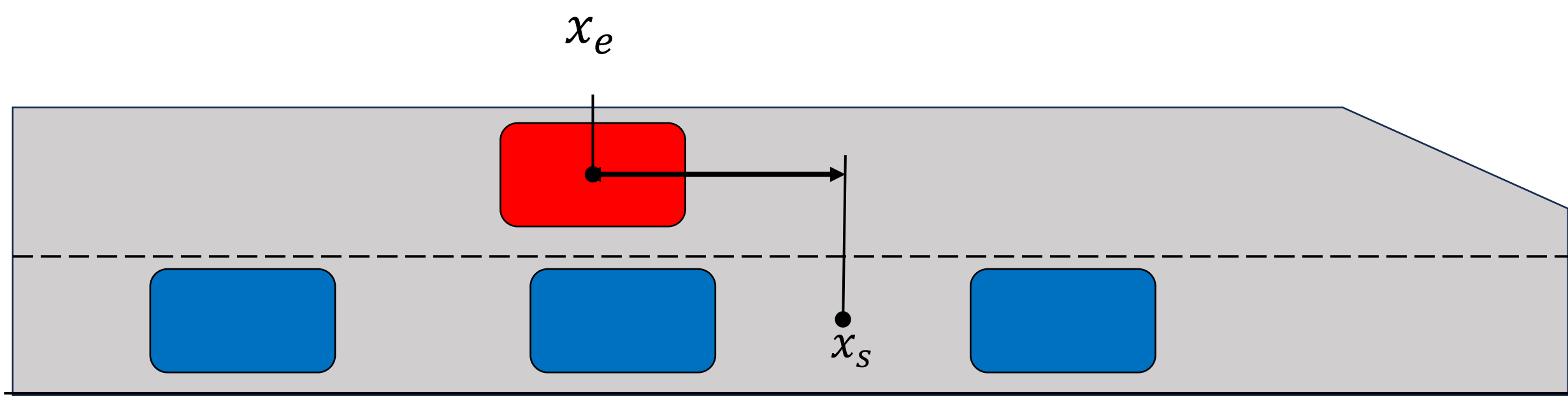


2. Distance from Ego vehicle to target

- The closer the vehicle is to its ego vehicles, the higher the assessment

$$\beta = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{(x_s - x_e)^2}{2\sigma^2}\right)$$

x_s : Mid-point between vehicles
x_e : Position of ego vehicle

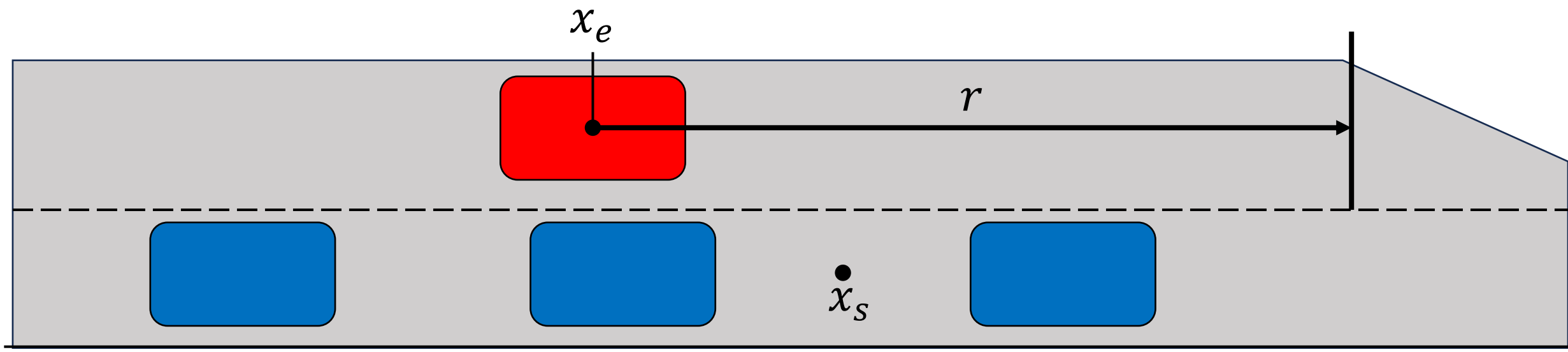


3. Remaining distance

- The shorter the remaining distance, lower the assessment

$$\gamma = \min\left(1, 1 - \left(\frac{x_s - x_e}{r}\right)\right)$$

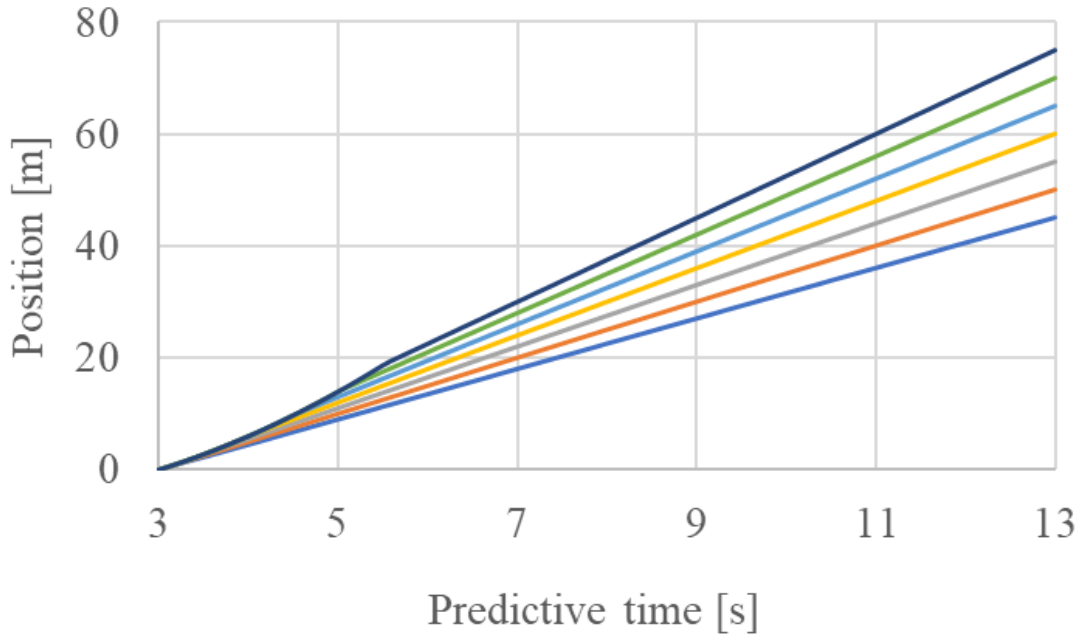
x_s : Mid-point between vehicles
x_e : Position of ego vehicle
r : Remaining distance



4. Reachable range

- Exclusion from choices when above speed and acceleration limits

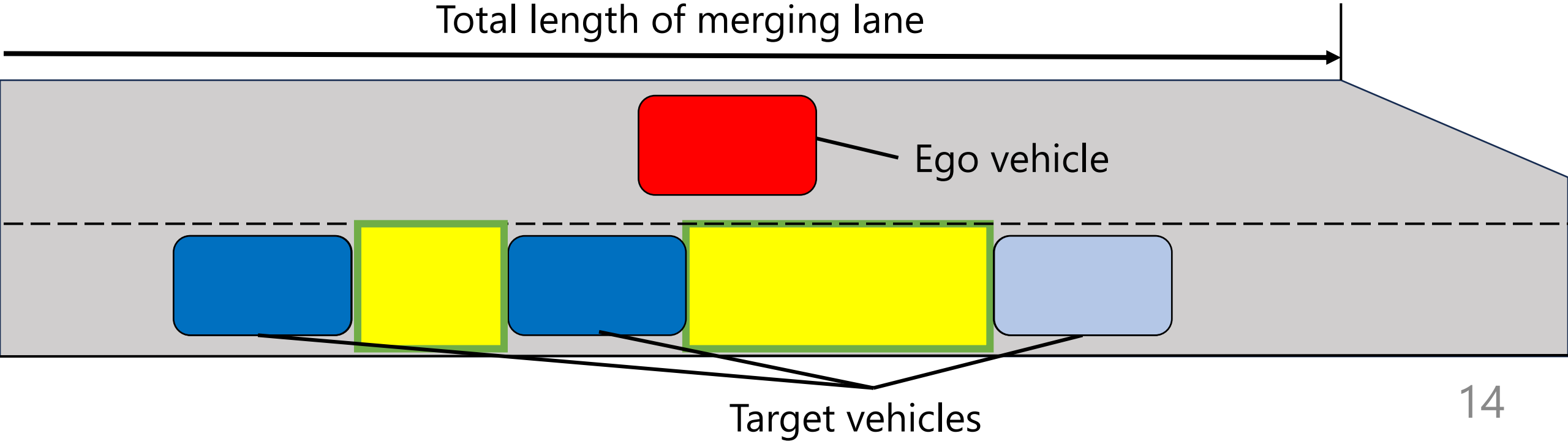
$$x_{min}^{t} \leq x_{e}^{t} \leq x_{max}^{t}$$



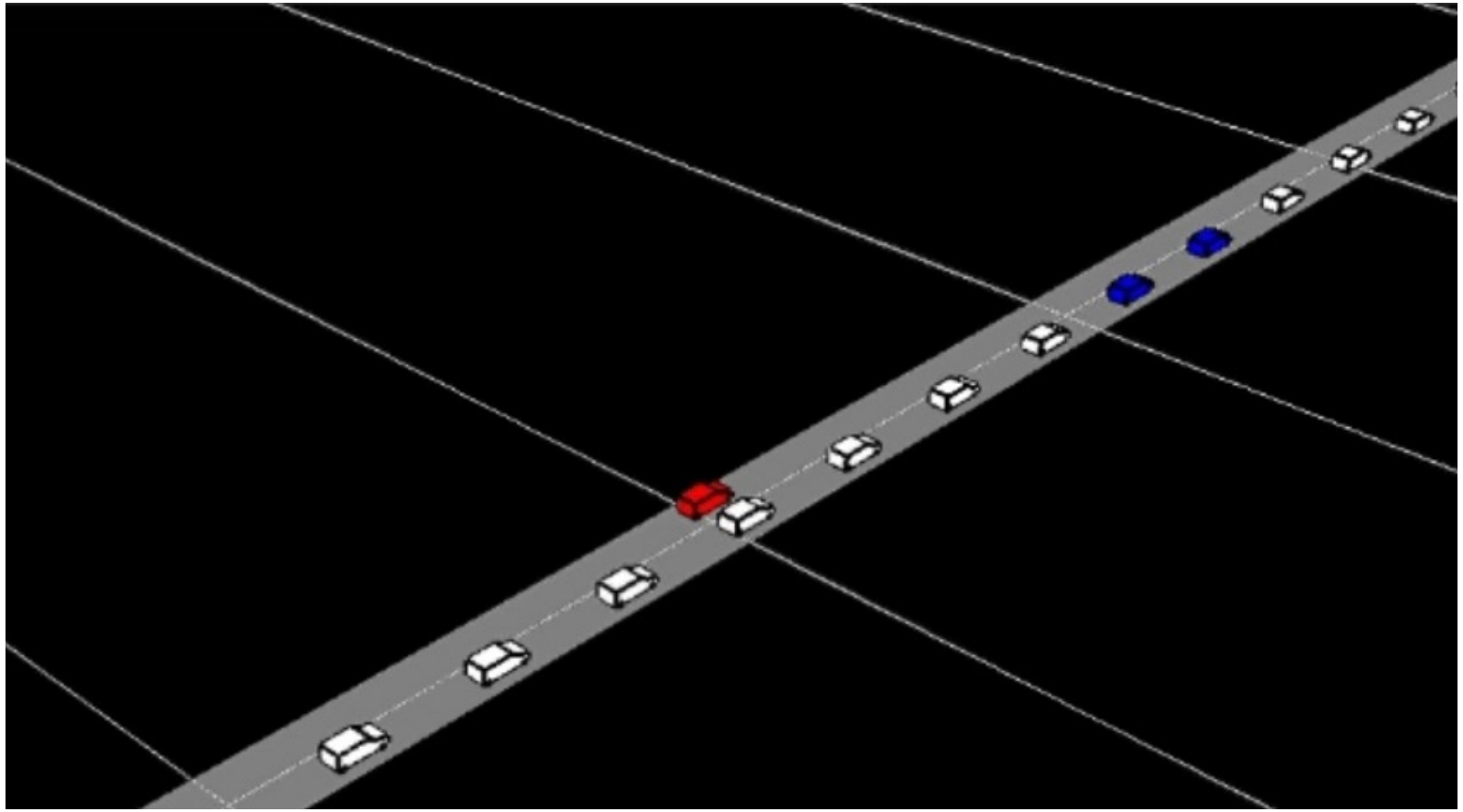
Prediction of position of ego vehicle

Simulation

- Environment where the total length of merging lane is 480m and 240m
- Ego vehicle merge between target vehicles
- Main lane vehicles take different amounts of time to give way

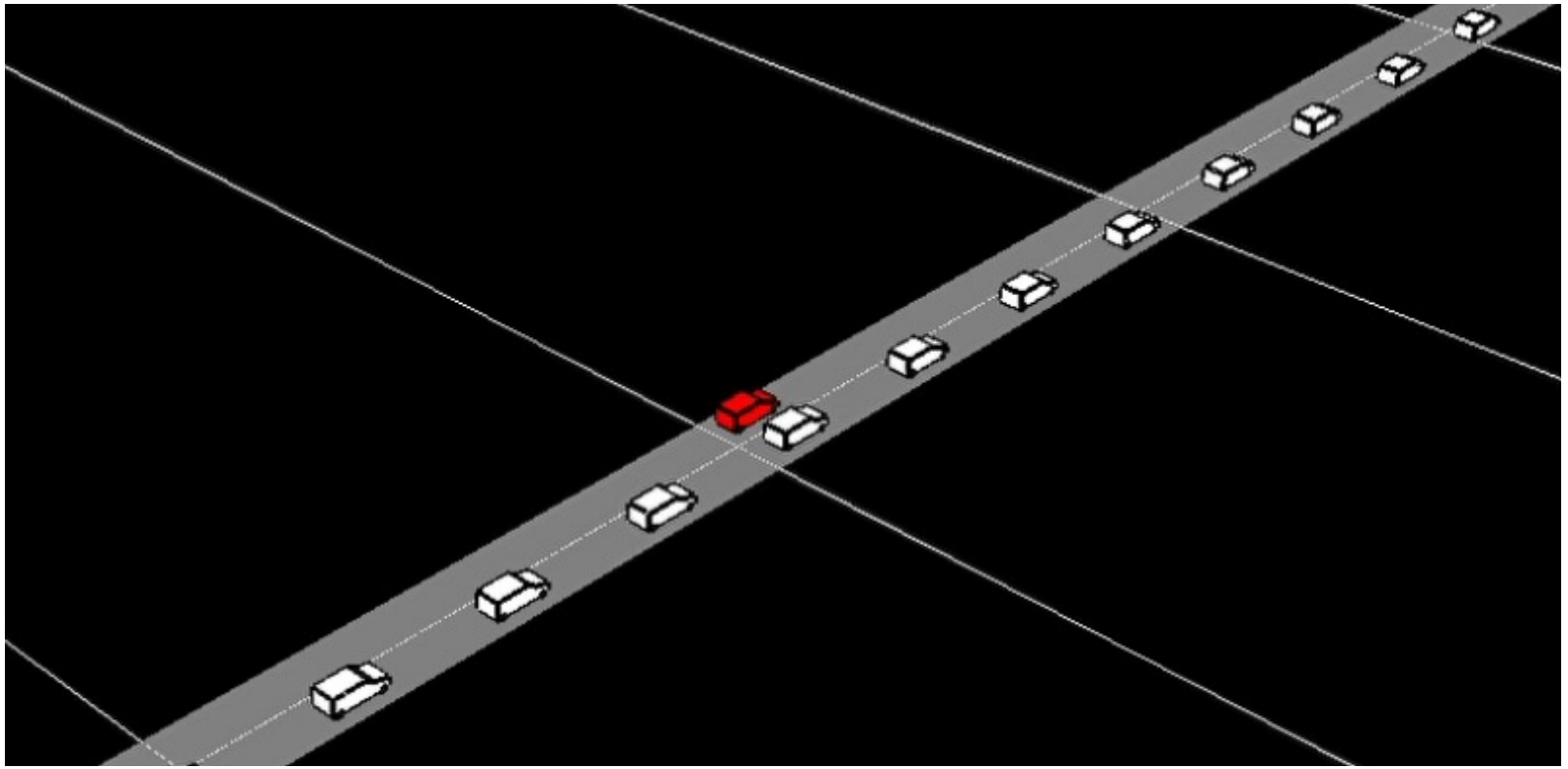


Simulation (Select front)



Red : Ego vehicle
Blue : Target vehicles
Yellow : Ego vehicle (blinkers-on)

Simulation (Select rear)

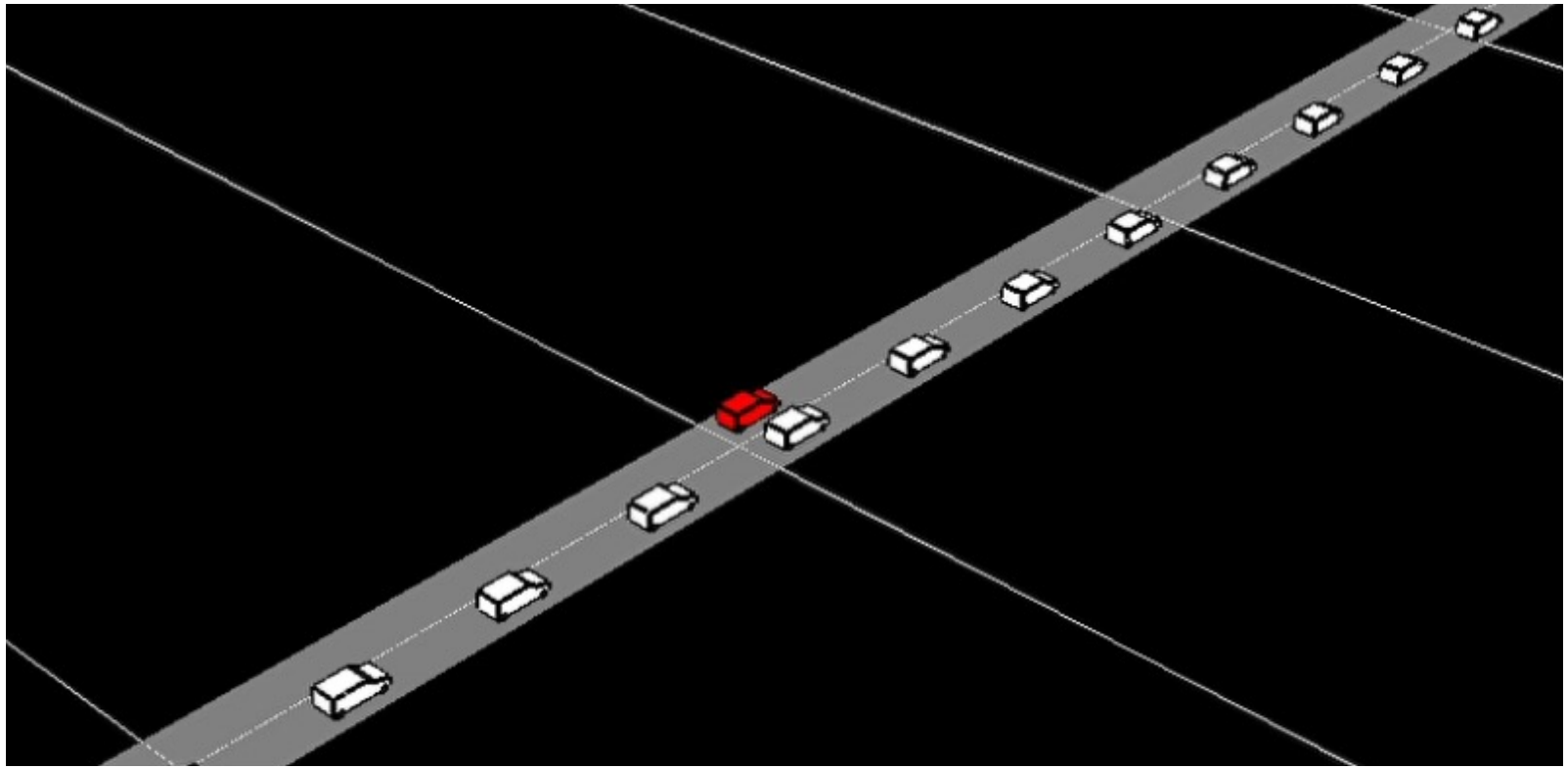


Red : Ego vehicle
Blue : Target vehicles
Yellow : Ego vehicle (blinkers-on)

Problem

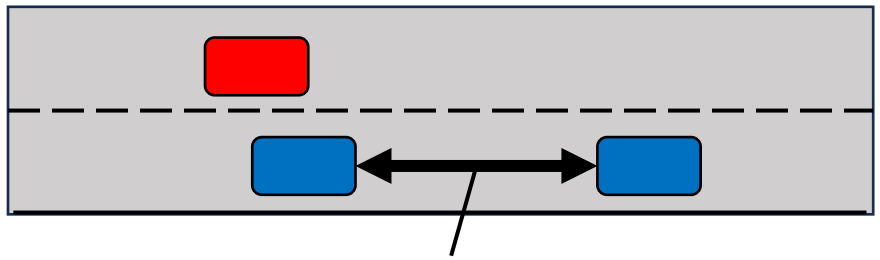
- Selected despite shrinking space

  → Proximity to space is the preferred select

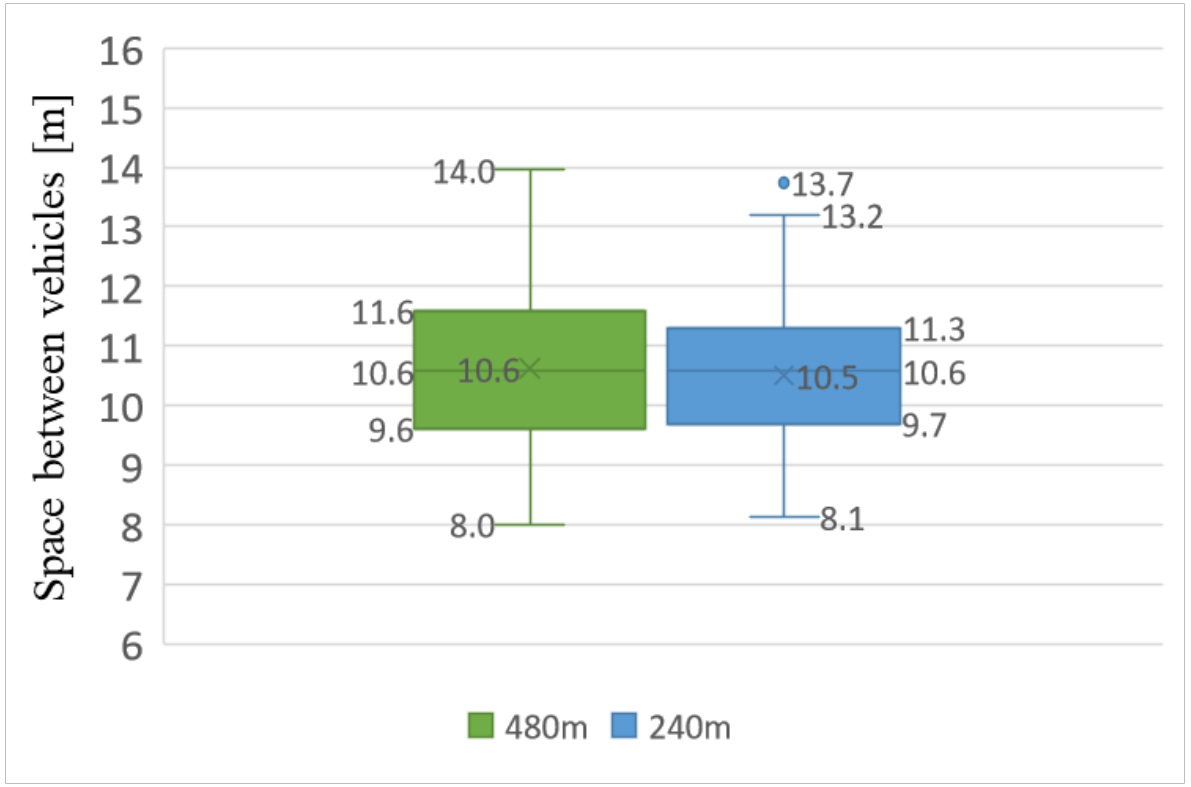


Space results

- No change was observed in the two results
- Select a space of about 10 meters



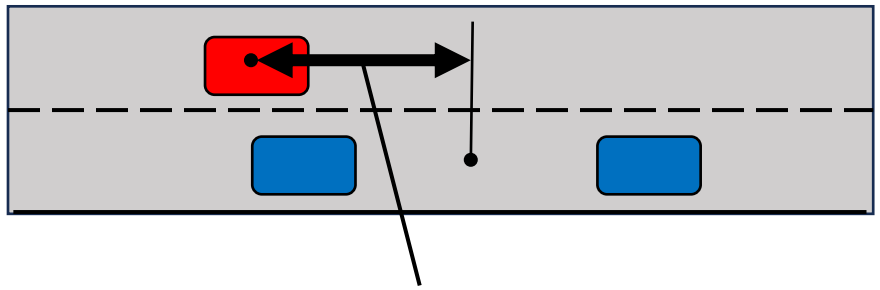
Space between vehicles



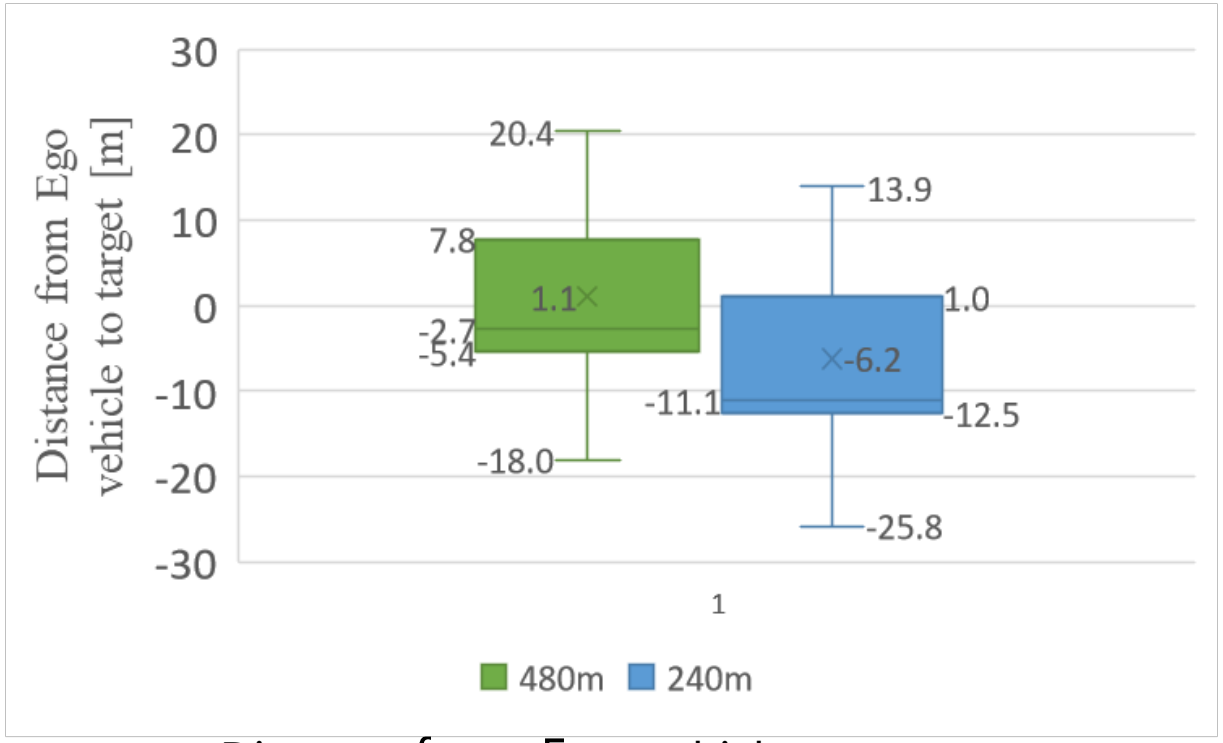
Space between vehicles

Distance results

- 240m Results were more backward than 480m



Distance from Ego vehicle to target



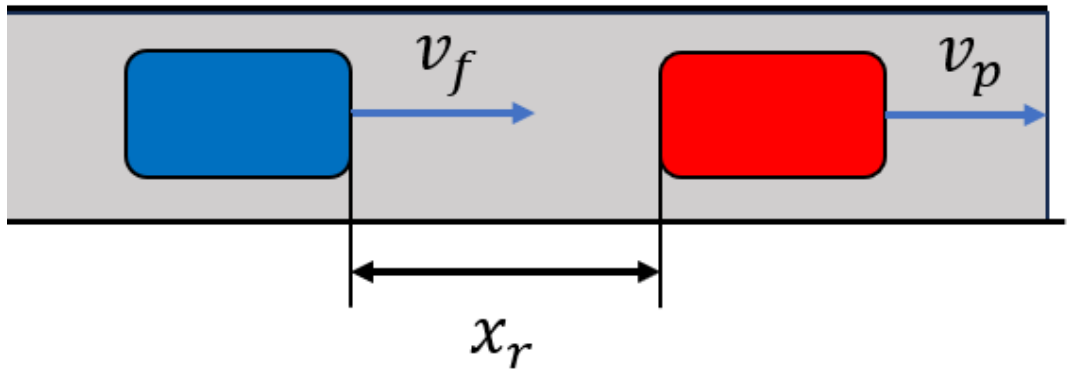
Distance from Ego vehicle to target

Safety assessment

- Margin-To-Collision

Indicates whether there is a collision between vehicle

(Deceleration：0.7 G= － 6.9 m/s^2)



$$MTC = -\frac{-x_r - \frac{v_p^2}{2A_p}}{\frac{v_f^2}{-\frac{v_f^2}{2A_f}}}$$

x_r ： distance between two vehicles
v_p ： Forward vehicle speed
v_f ： Rear vehicle Speed
$A_p = A_f = -6.9 m/s^2$

Safety assessment result

- Margin-To-Collision less than 1
  → Likelihood of collision

- Safe interruptions are possible as a result of Margin-To-Collision

Result of Margin-To-Collision

	Avg.	Min.
480 m	6.06	3.71
240 m	5.98	3.87

Conclusions

- Lane-changing space selection at Merging Area was proposed
- Evaluate the possibility on vehicles status and remaining distance
- Margin-to-collision found to be highly secure

Future work

- Obtain human lane-changing and compare with proposed results