

# Investigation of ACPE performance tested by creeping procedure

National Traffic Safety and Environment Laboratory

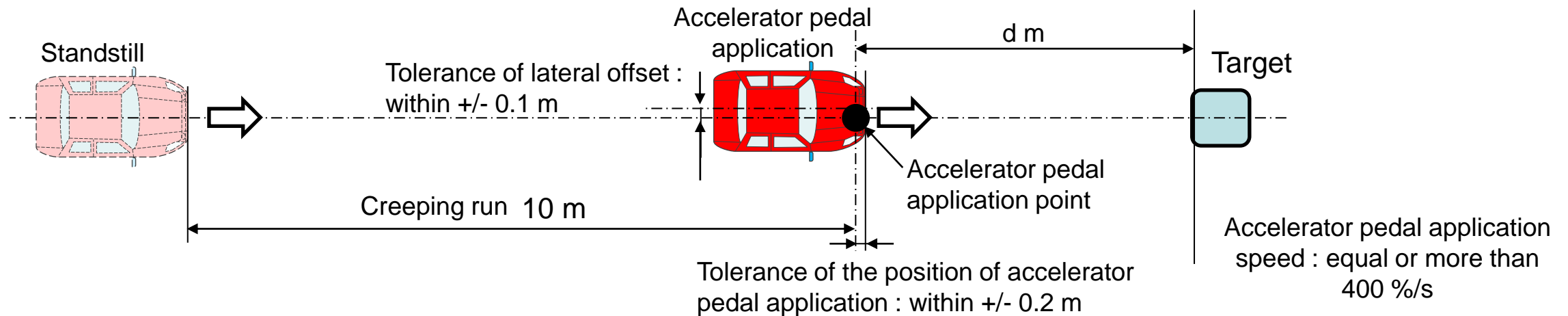


# Purpose of the investigation

The purpose of this investigation is to investigate ACPE performance of a current Japanese production model when the creeping test procedure is conducted. And through the experimental result, it is intended to examine whether the creeping test procedure is appropriate or not for 00/01 series of the new ACPE regulation.

# Abstract of the experimental procedure

- The driver released brake pedal. And the vehicle runs 10 m with creeping speed.
- The driver applies accelerator pedal at the accelerator pedal application point which is fixed. The reason why the distance of creeping run and the position of accelerator pedal application are fixed is in order to minimize the deviation of the distance as much as possible between the position of accelerator pedal application and the target.
- Both the steering control and accelerator pedal were operated within the tolerances by a professional driver.



# Experimental conditions and parameters

## <Targets>

- 3D type vehicle target (in accordance with ISO 19206-3:2018)
- Adult pedestrian target (in accordance with ISO 19206-2:2018)
- Child pedestrian target (in accordance with ISO 19206-2:2018)
- No target



## <Vehicle speed>

Creeping (Air conditioner of the vehicle was activated)

## <Accelerator pedal application speed>

Equal or more than 400 %/s (It was applied so as to reach 100 % within 0.25 s).

# Experimental conditions and parameters

<Distance from the accelerator pedal application point to the target>

- 1 m
- 1.5 m
- 2 m
- 3 m

<Running direction of the vehicle>

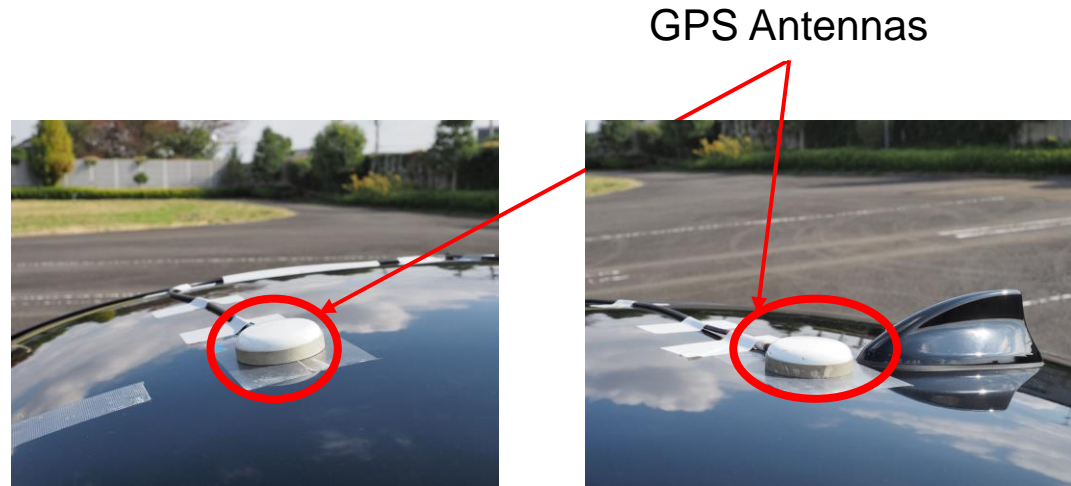
- Forward direction
- Backward direction

<The number of trials>

In principle, 3 trials were conducted in each experimental condition.

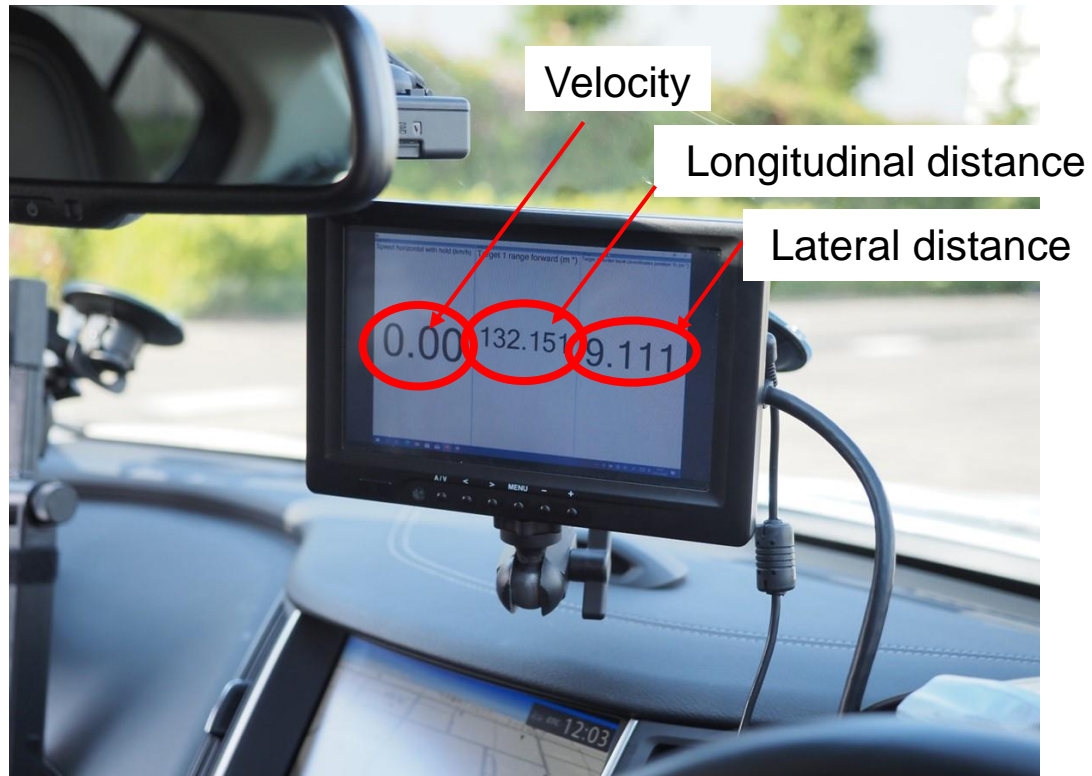
# Measurement of data

- Longitudinal and lateral position of the vehicle and velocity of the vehicle were measured accurately by RTK GPS (OxTS RT-range).
- Accelerator pedal position was measured by recording the change of voltage.





- Through the monitor on the dashboard, velocity, longitudinal distance and lateral distance of the vehicle were provided to the driver in real time as the guidance in order to drive within the tolerances.



# Profile of the experiment vehicle

Registration	2020	
Powertrain	3.5 litre petrol engine and motor (Hybrid system) 7 speeds automatic transmission	
Driven wheels	Rear	
Sensing system	Front	Camera, Millimeter wave radar and sonars
	Rear	Sonars
ADAS functions	ACC, LKAS, AEBS, ACPE etc.	
Deactivation of ACPE	Both AEBS and ACPE can be manually deactivated simultaneously (It is impossible to be deactivated individually)	

Millimeter wave radar (front)

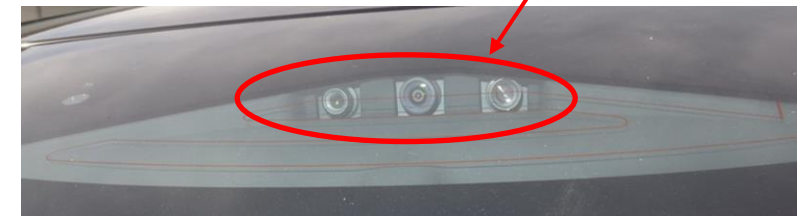


Sonar (front)



Sonar (rear)

Camera (front)

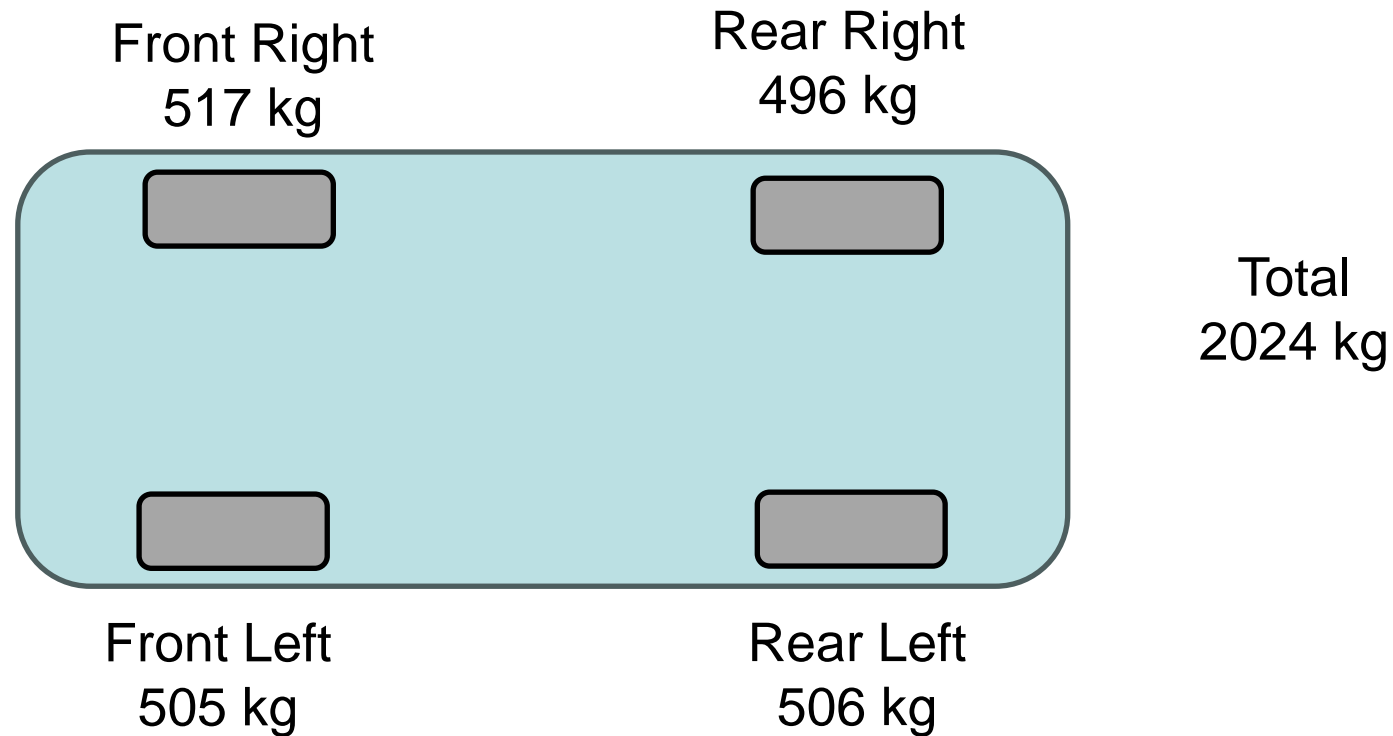




# Profile of the experiment vehicle

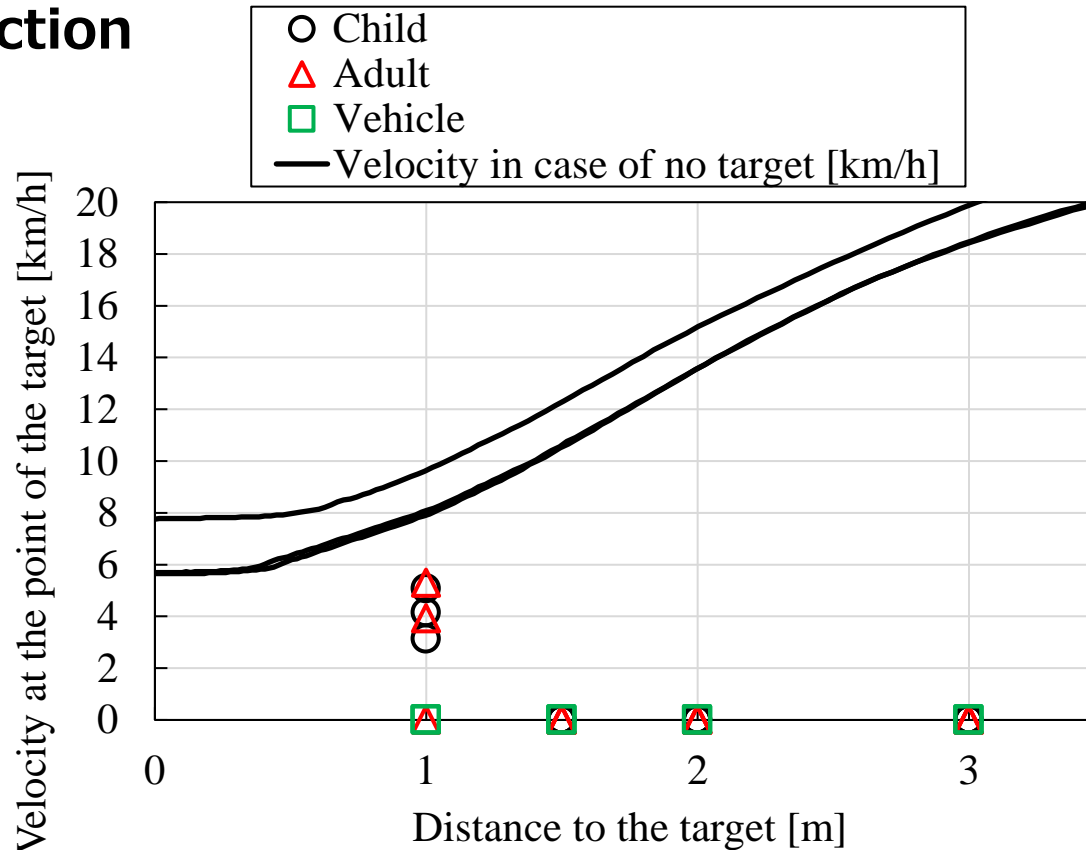
## Vehicle mass during the experiment

(including the measurement devices, the driver, and second person who is responsible for measurement of data)



# Experimental result (Velocity at the point of the target)

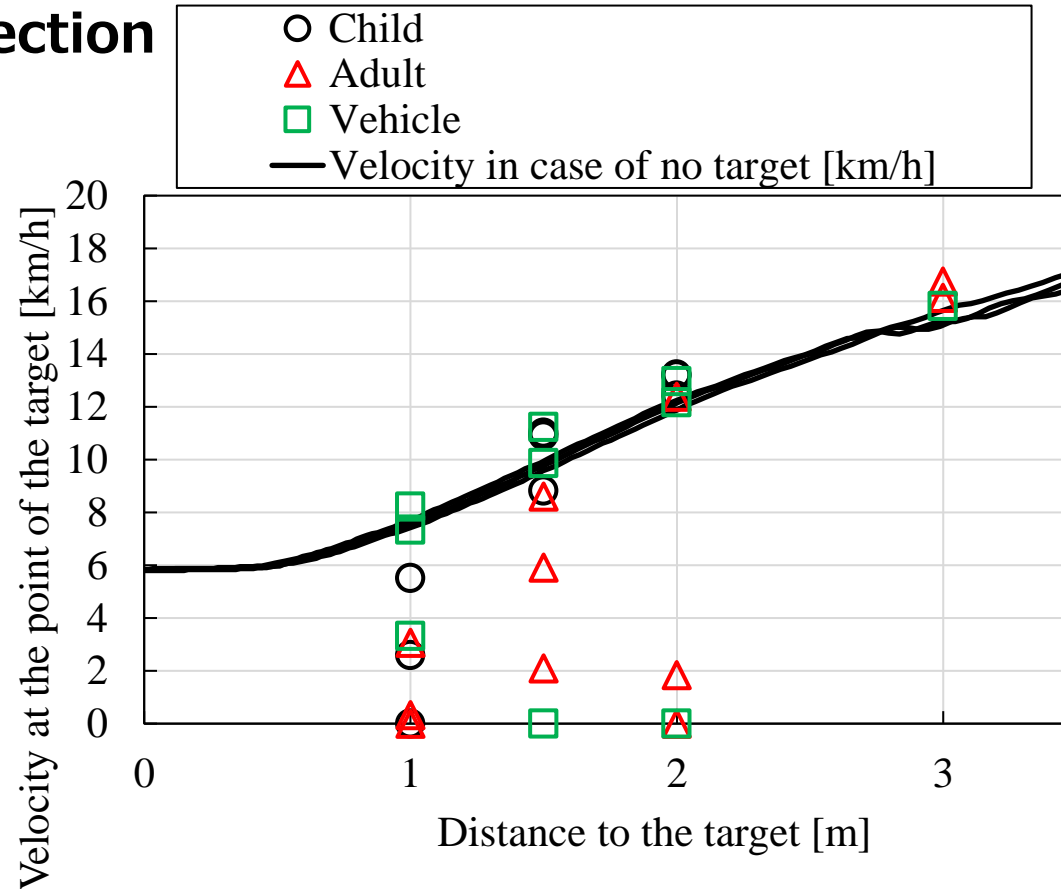
## Forward direction



- In case of the vehicle target, acceleration was controlled and the vehicle was stopped by brake control in all the distance conditions.
- In case of the adult target and the child target, acceleration was controlled in 1 m condition, and the vehicle was stopped by brake control after acceleration control in the condition of 1.5 m, 2 m and 3 m conditions.
- In case of “no target”, about 2 km/h deviation of velocity among 3 trials was observed.

# Experimental result (Velocity at the point of the target)

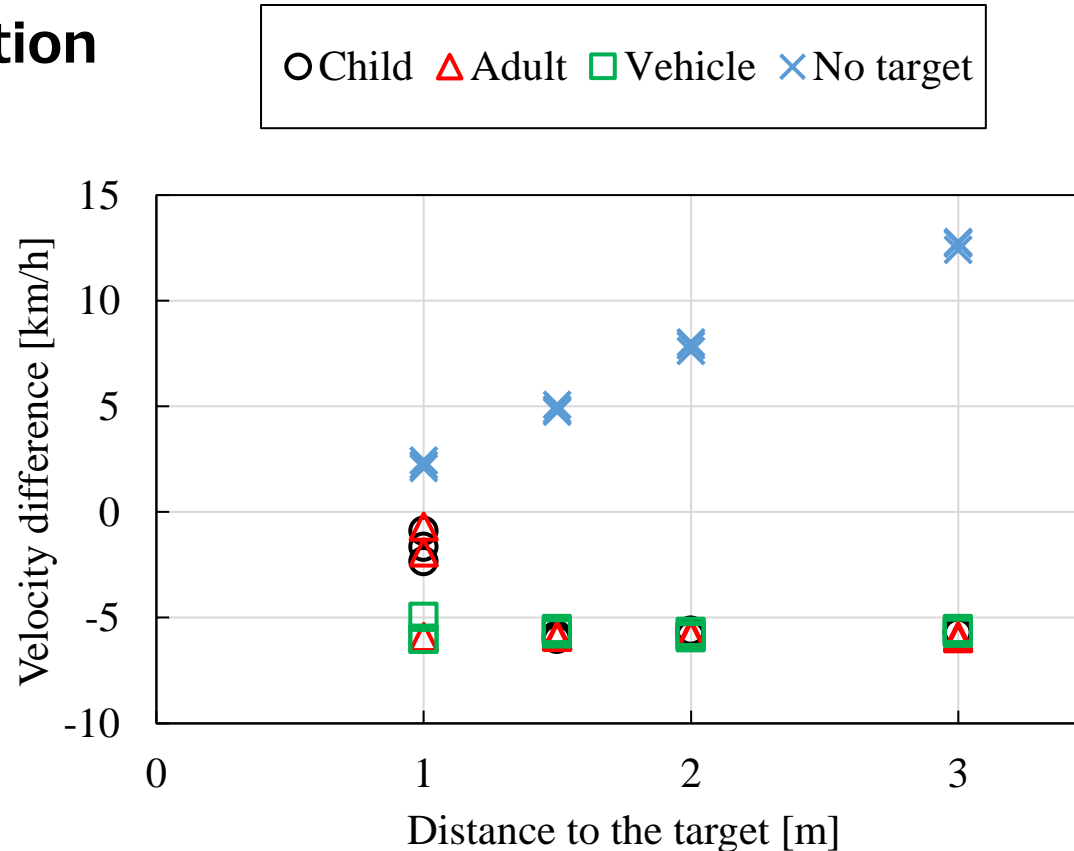
## Backward direction



- The cases in which no acceleration control were observed were seen regardless the of the targets and the distances.

# Experimental result (Velocity difference\*)

## Forward direction

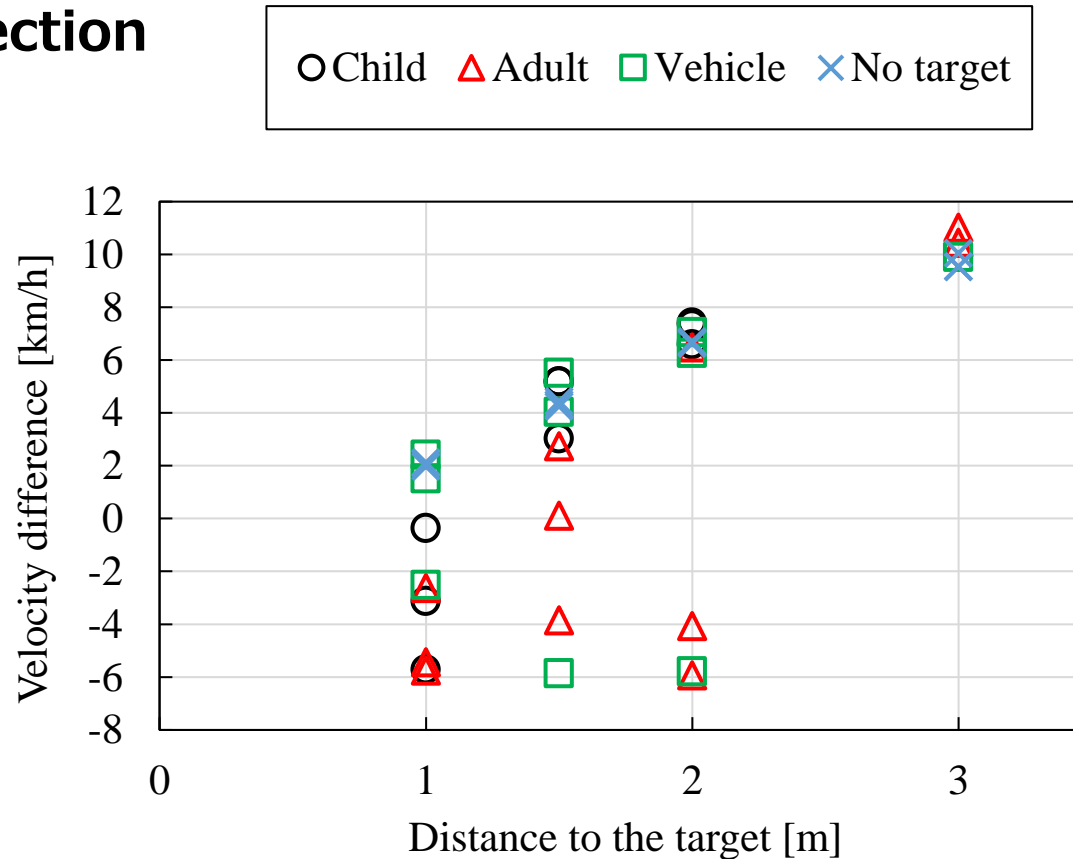


- In all of the targets, velocity difference is below 0 km/h in each distance condition (acceleration control was activated).
- Even if the case of “no target” condition (without acceleration control), the velocity differences with velocity at the point of accelerator pedal application was less than 8 km/h in 1 m, 1.5 m and 2 m.

\*Velocity difference = (Velocity at the point of target) – (Velocity at the point of accelerator pedal application)

# Experimental result (Velocity difference\*)

## Backward direction

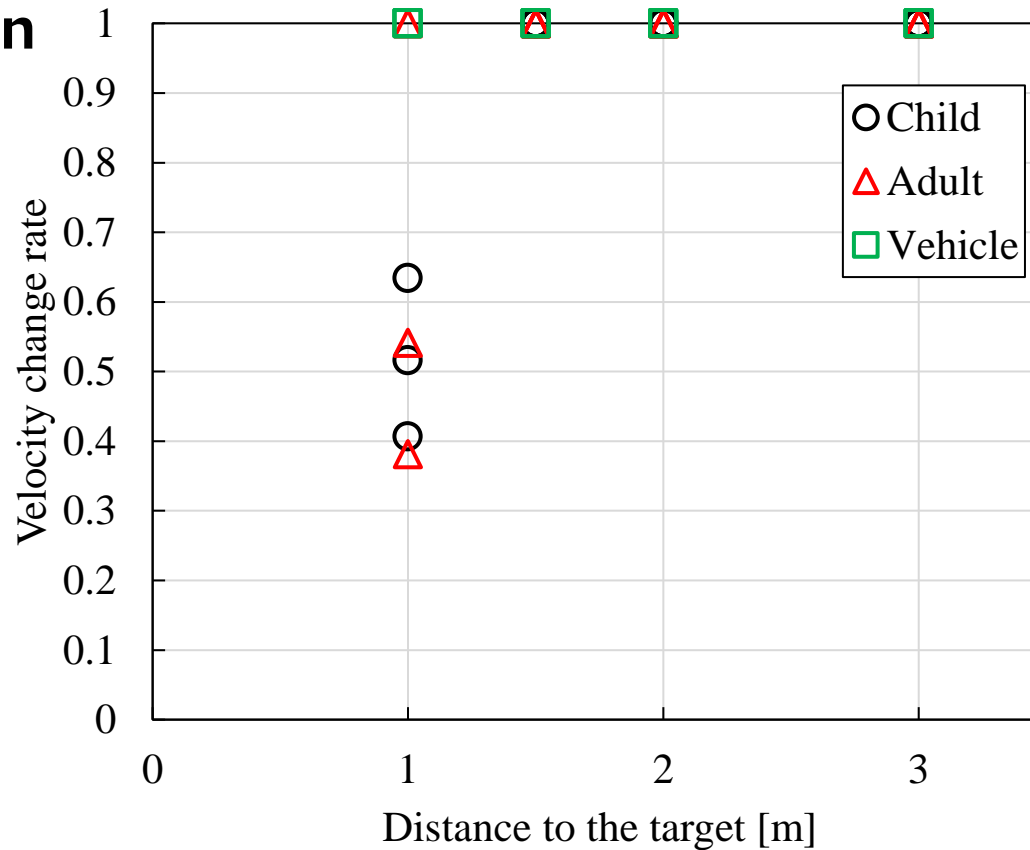


- In all of the targets, such cases in which acceleration control was not activated were observed. On the other hand, such cases in which acceleration control was activated were observed except 3 m.
- Even if the case of “no target” condition (without acceleration control), the velocity differences with velocity at the point of accelerator pedal application was less than 8 km/h in 1 m, 1.5 m and 2 m (similar to forward direction).

\*Velocity difference = (Velocity at the point of target) – (Velocity at the point of accelerator pedal application)

# Experimental result (Velocity change rate\*)

## Forward direction



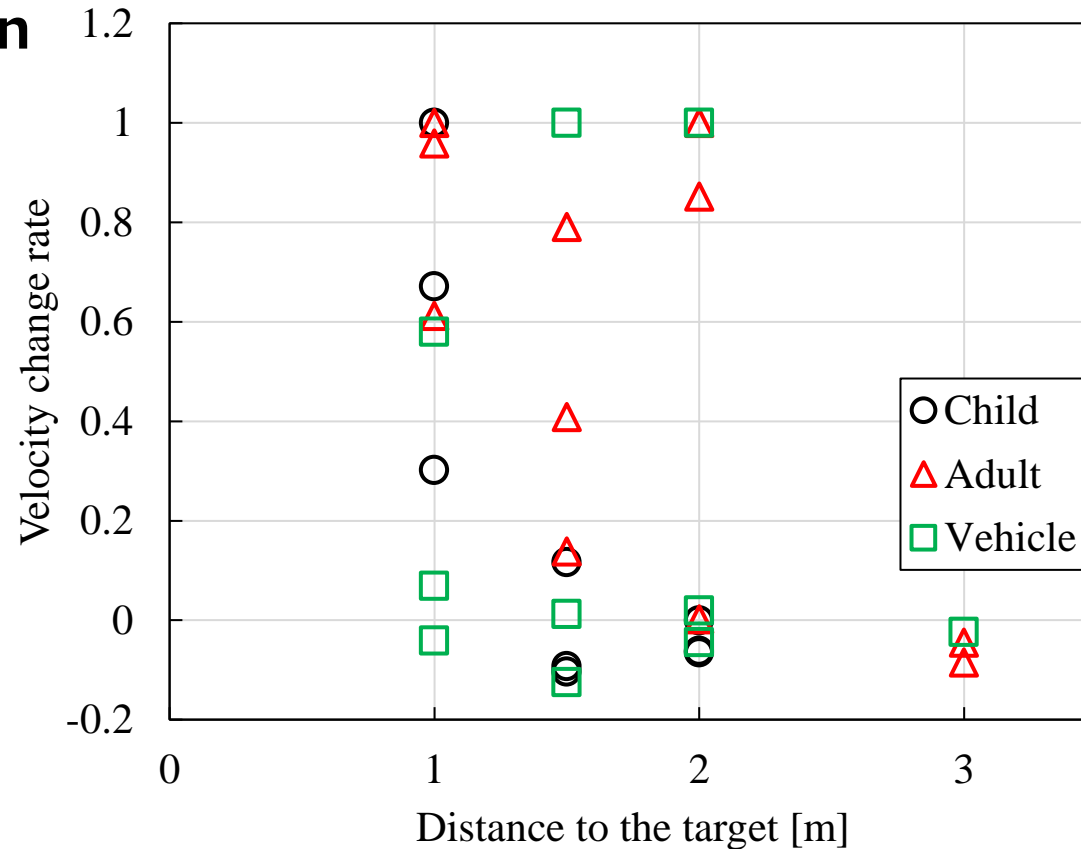
- In all of the targets, velocity difference is from 0.4 to 1.0.
- In all of the target, velocity change rate was 1.0 (the vehicle was stopped by braking control) in 1.5 m, 2m, and 3m.

$$\text{*Velocity change rate} = \frac{(\text{velocity at the point of target with "no target"}) - (\text{velocity at the target point with a target})}{(\text{velocity at the point of target with "no target"})}$$



# Experimental result (Velocity change rate\*)

## Backward direction



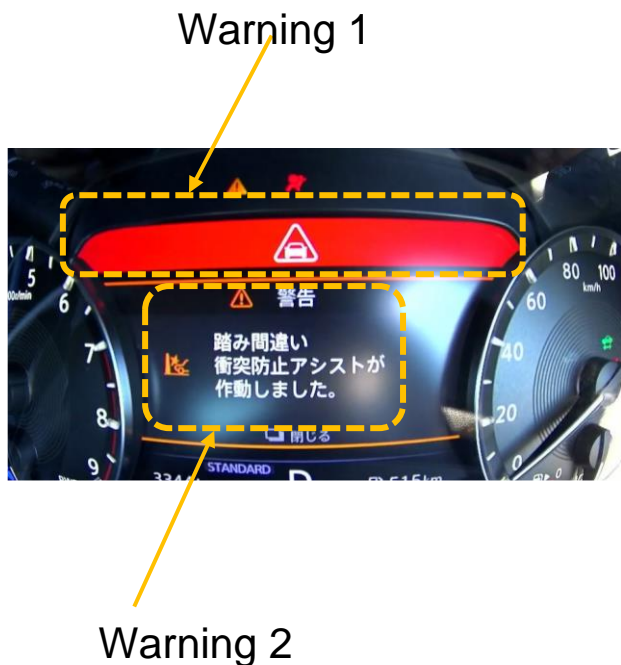
- Data of velocity change rate in 1 m, 1.5 m and 2 m is distributed in wider range compared to forward direction.
- In case of the child target, velocity change rate was equal to or below 0 in 1.5 m and 2 m (Experiment was skipped in 3 m).
- In 3 m, velocity change rate was equal to or below 0 in both cases of the vehicle and adult targets.

$$\text{*Velocity change rate} = \frac{(\text{velocity at the point of target with "no target"}) - (\text{velocity at the target point with a target})}{(\text{velocity at the point of target with "no target"})}$$

# Experimental result (Detail data in each experimental condition)

The following slides shows the detail data in each experimental conditions (each target, distance to the target 1 m and 1.5 m).

## Definition of the words in the figures



Warning 1 : The warning which inform the driver that emergency braking control function is being activated. This warning is shown, either when emergency braking control of AEBS or low speed emergency braking control of ACPE is activated.

Warning 2 : The warning which inform the driver that ACPE is being activated. This warning is specified for ACPE.

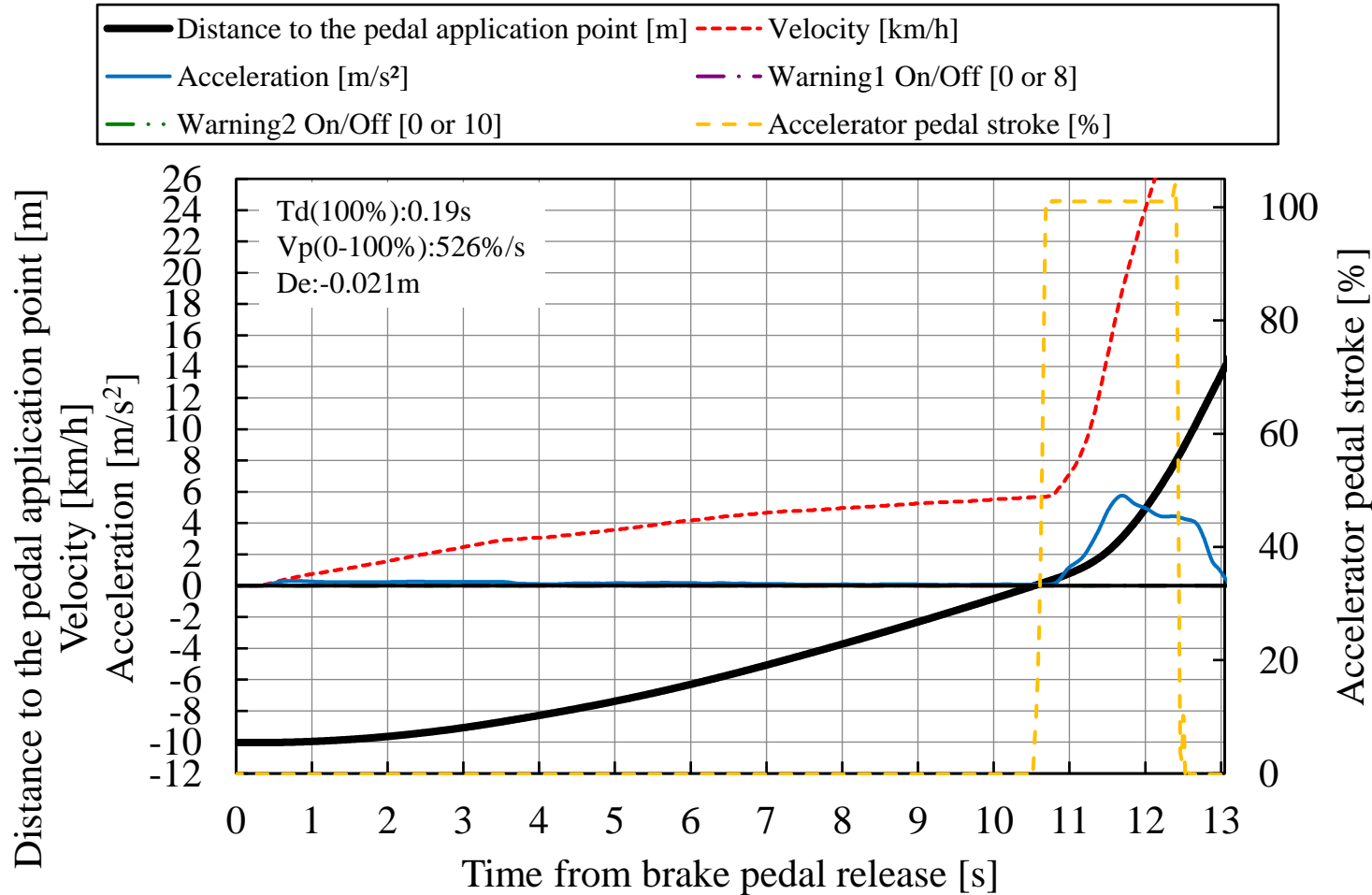
Td(100%) : The time of accelerator pedal application from 0% to reaching 100% [s]

Vp(0-100%) : Accelerator pedal application speed [%/s]

De : Error of distance at the point of accelerator pedal application [m]

# Experimental result (Detail data in each experimental condition)

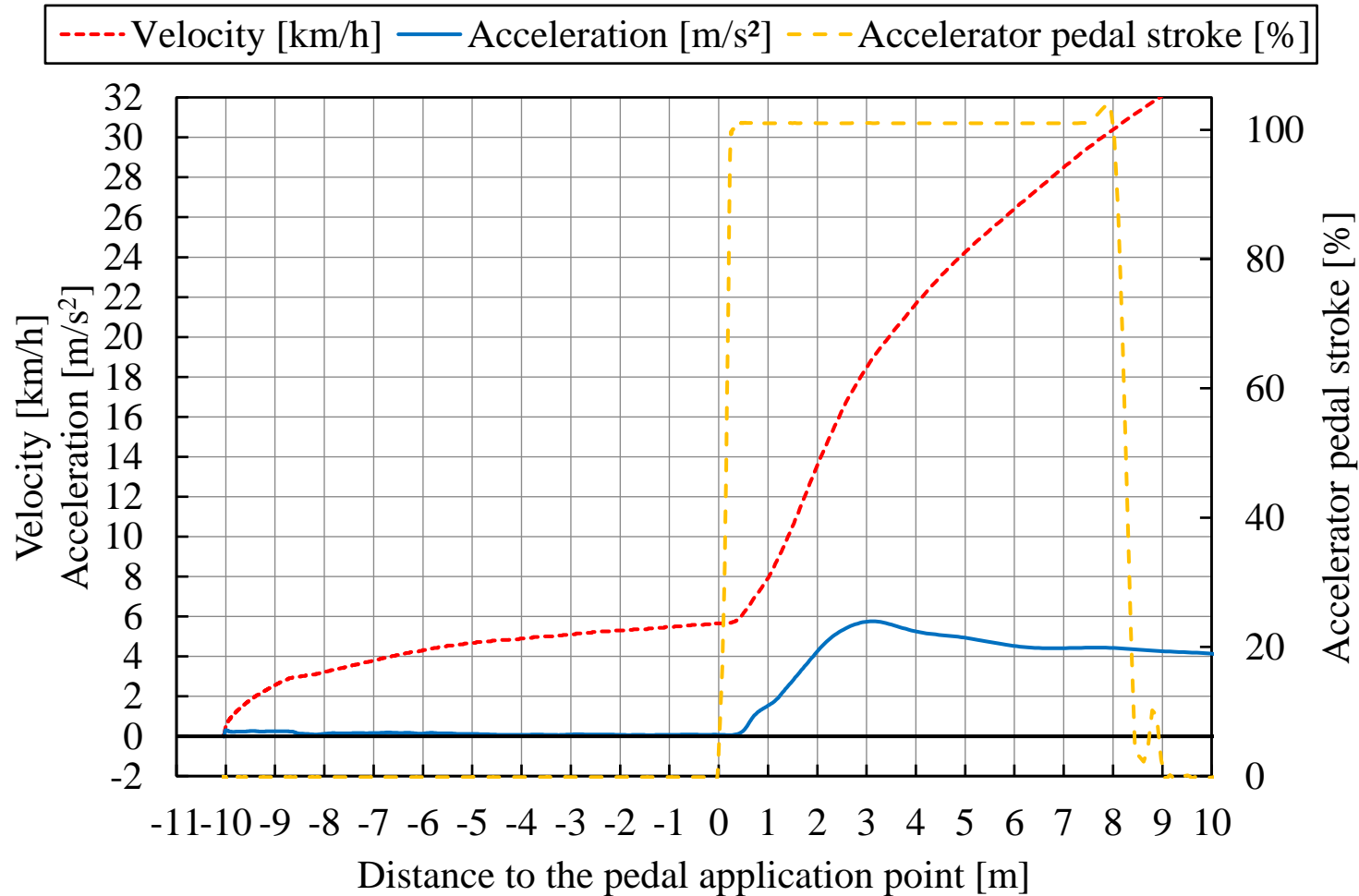
## Forward\_\_NoTarget\_\_No.1



- Maximum acceleration of the vehicle was approximately 6 m/s<sup>2</sup> in the condition of “no target”.

# Experimental result (Detail data in each experimental condition)

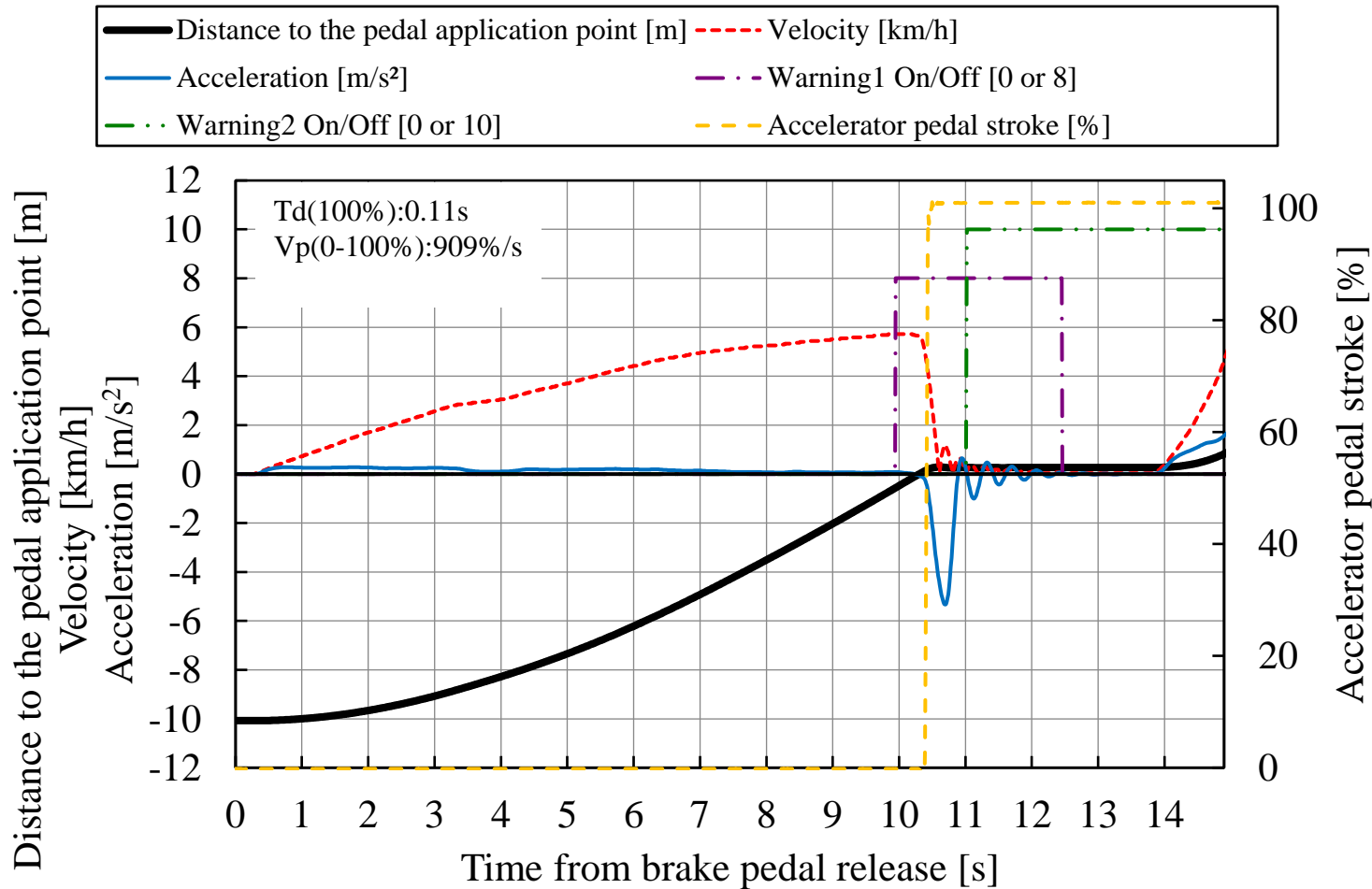
## Forward\_\_NoTarget\_\_No.1



- Velocity of the vehicle was approximately 6 km/h just when the vehicle reached the accelerator pedal application point, however velocity was not steady value (gradual acceleration was ongoing).

# Experimental result (Detail data in each experimental condition)

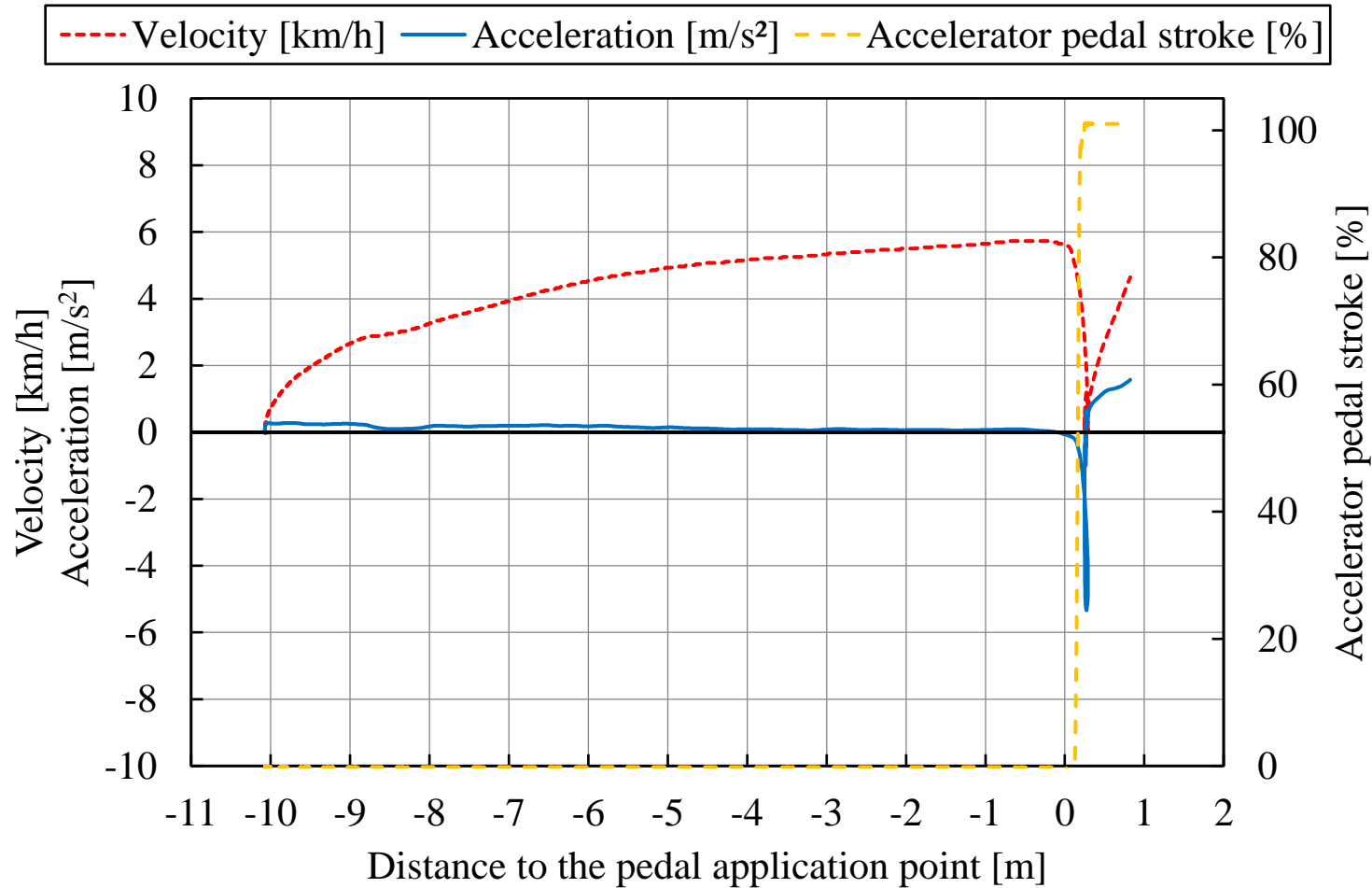
## Forward\_Vehicle\_1m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

Forward\_Vehicle\_1m\_No.1

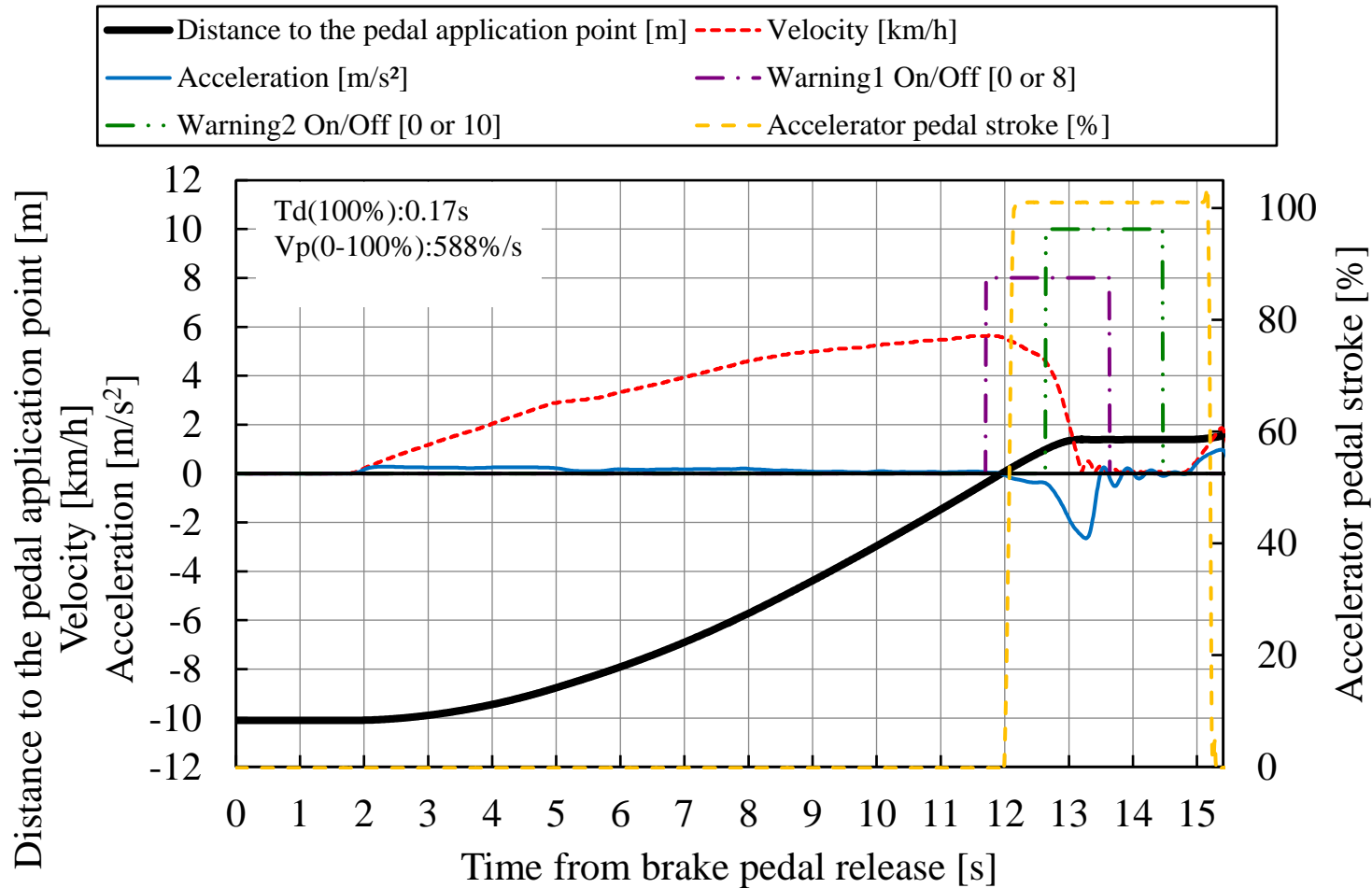


- Collision with the target was avoided by braking control.



# Experimental result (Detail data in each experimental condition)

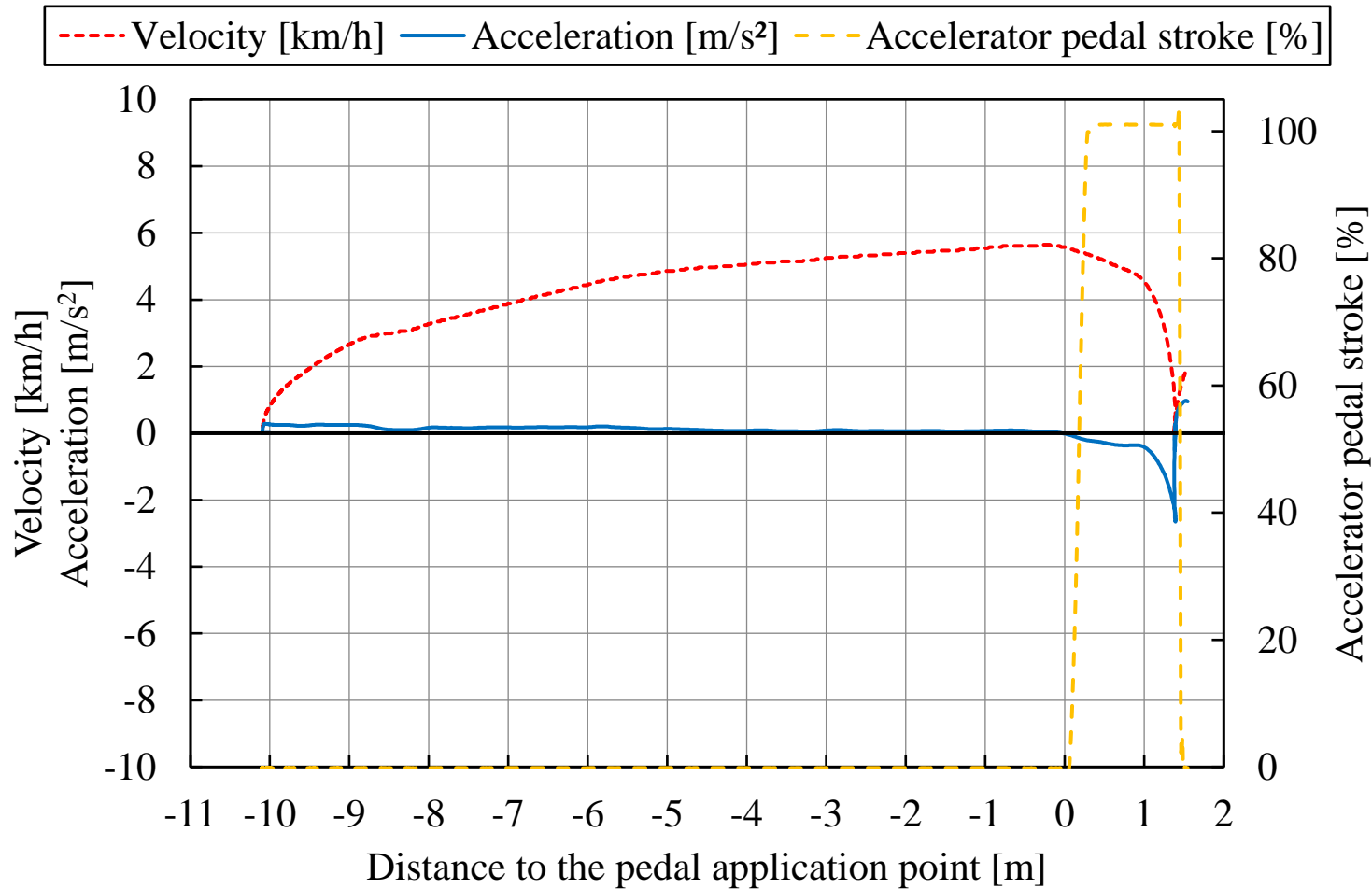
## Forward\_Vehicle\_1.5m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

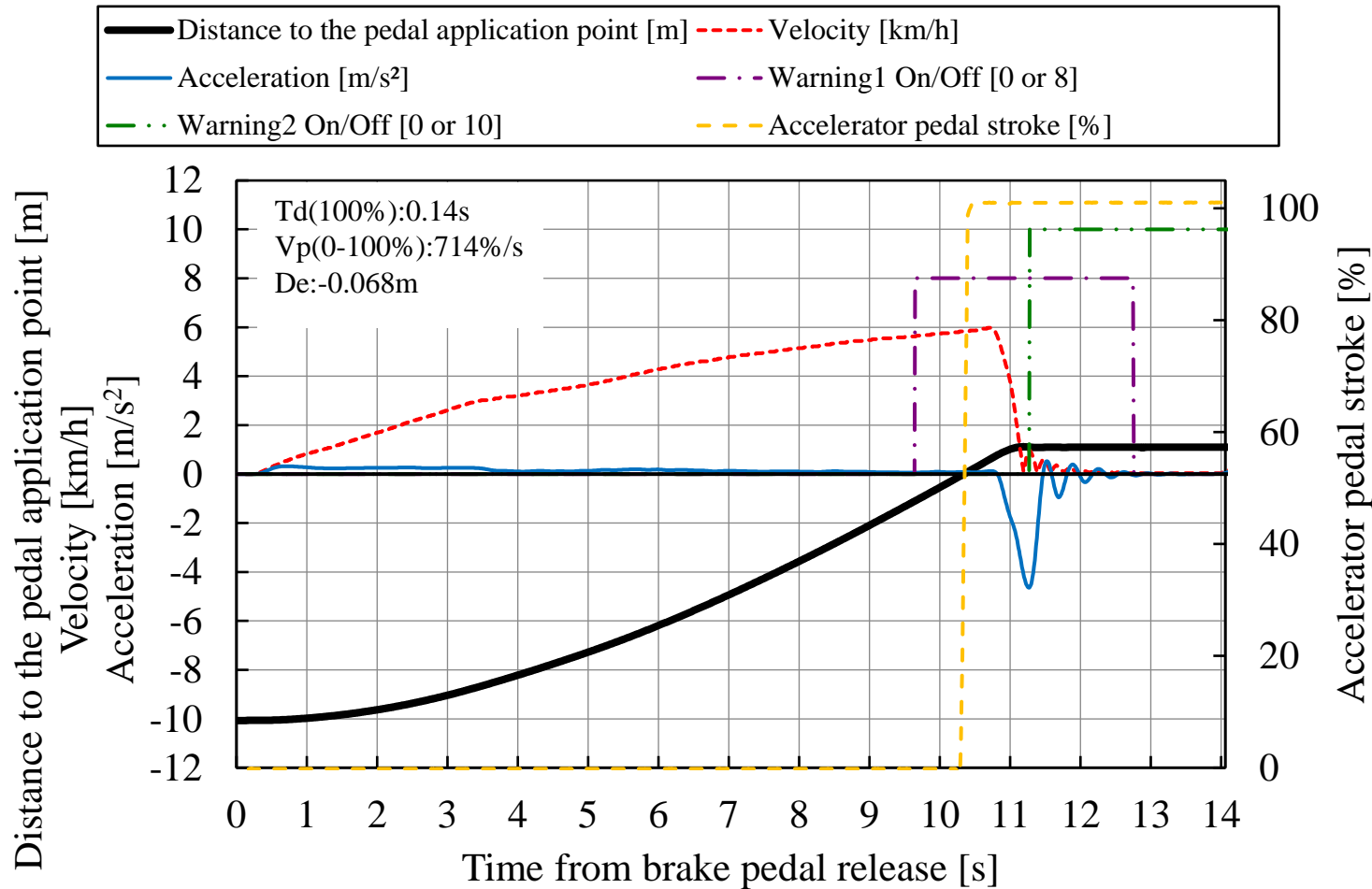
Forward\_Vehicle\_1.5m\_No.1



- Collision with the target was avoided by braking control.

# Experimental result (Detail data in each experimental condition)

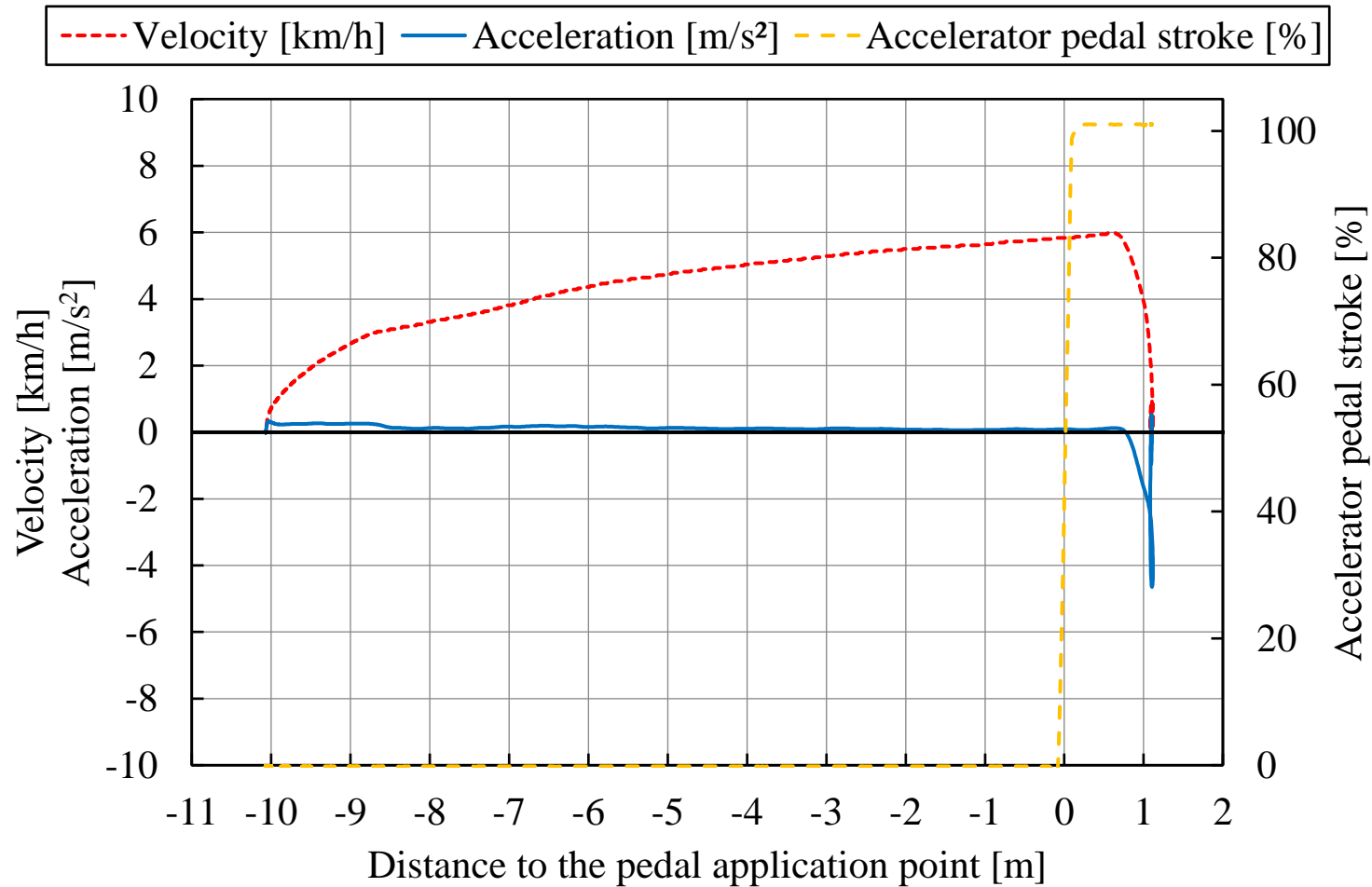
## Forward\_Adult\_1m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

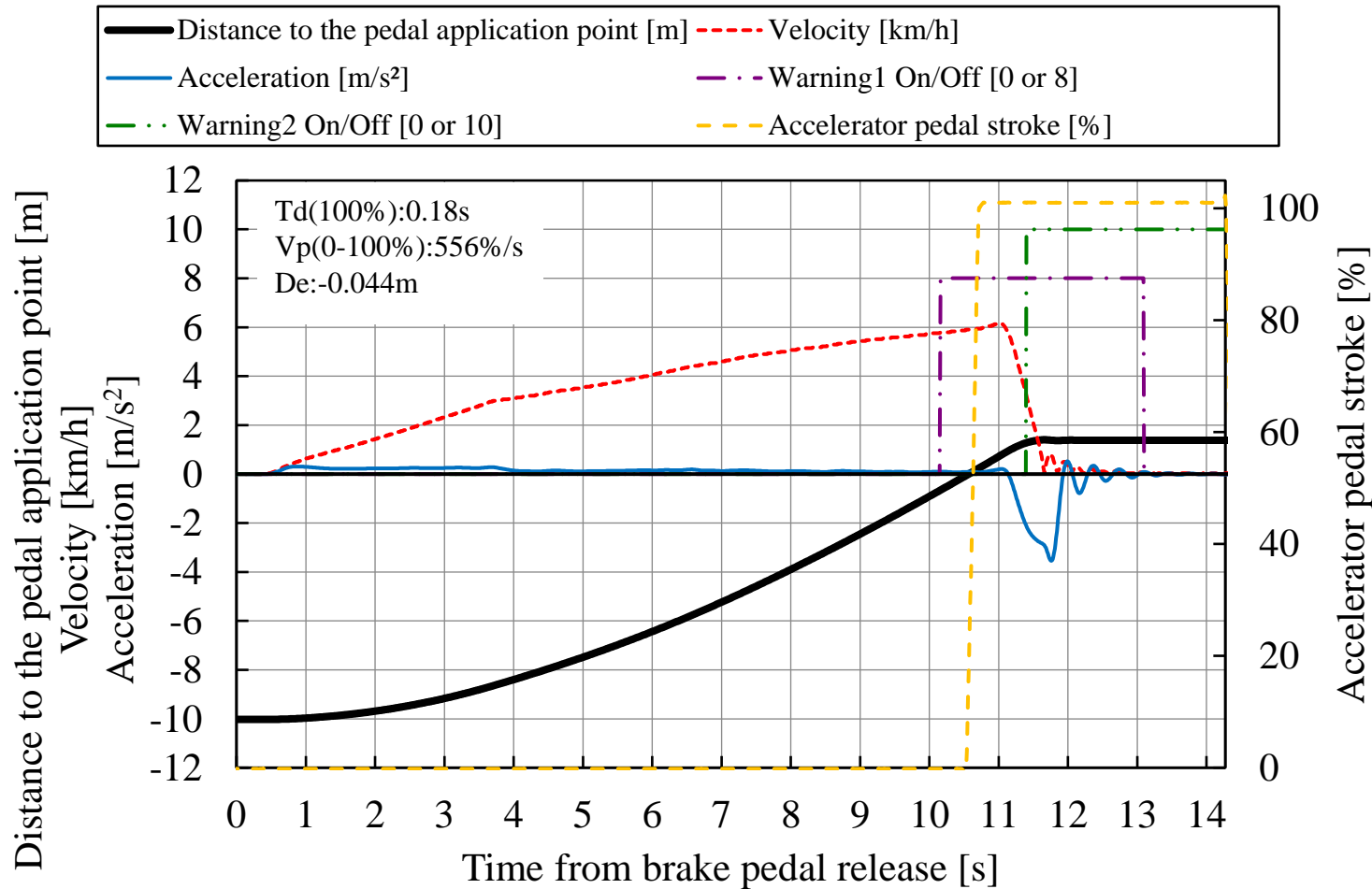
Forward\_Adult\_1m\_No.1



- The vehicle was completely stopped by braking control, but slightly collided with the target (collision speed was approximately 4 km/h).

# Experimental result (Detail data in each experimental condition)

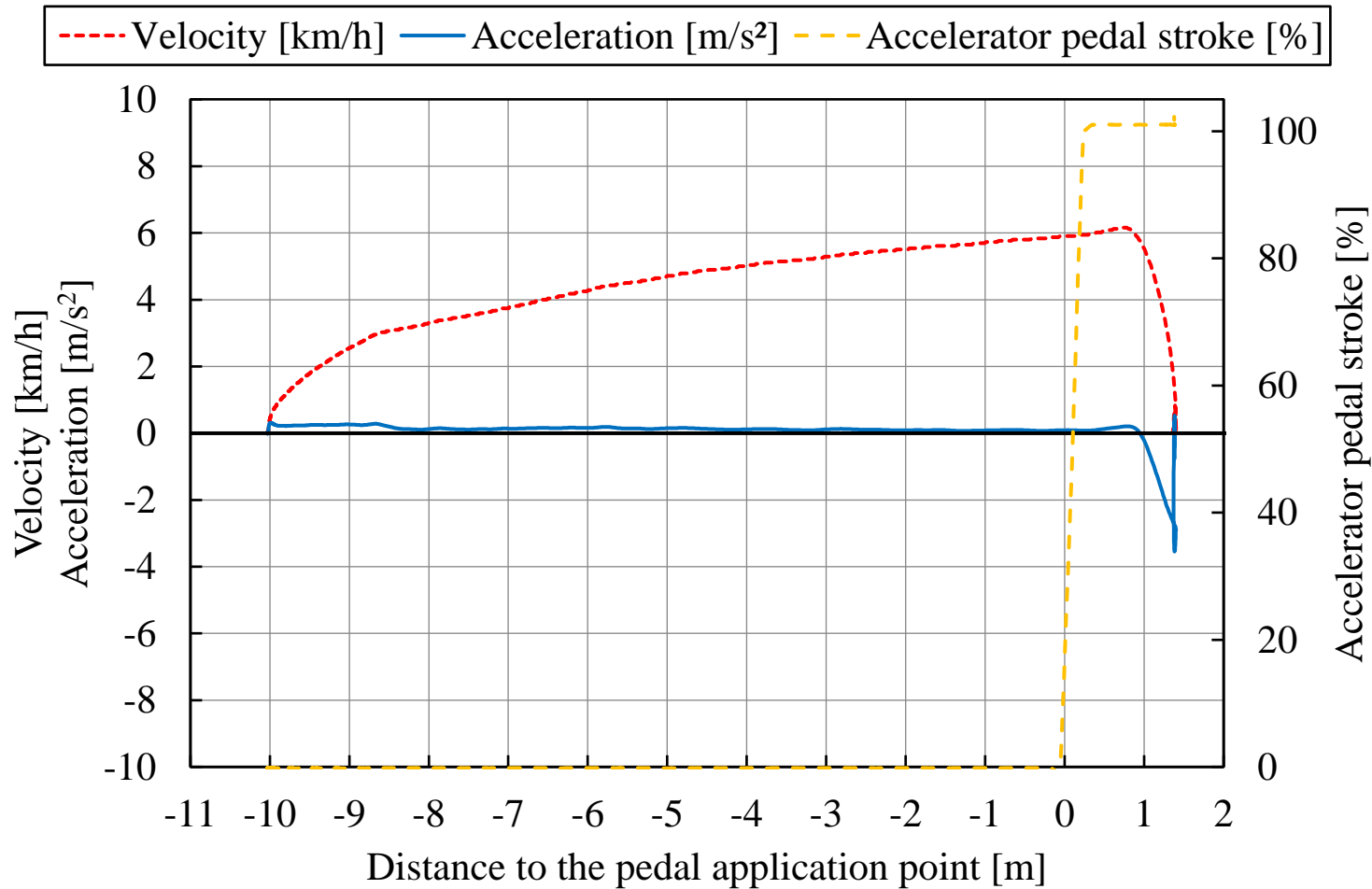
## Forward\_Adult\_1.5m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

Forward\_Adult\_1.5m\_No.1

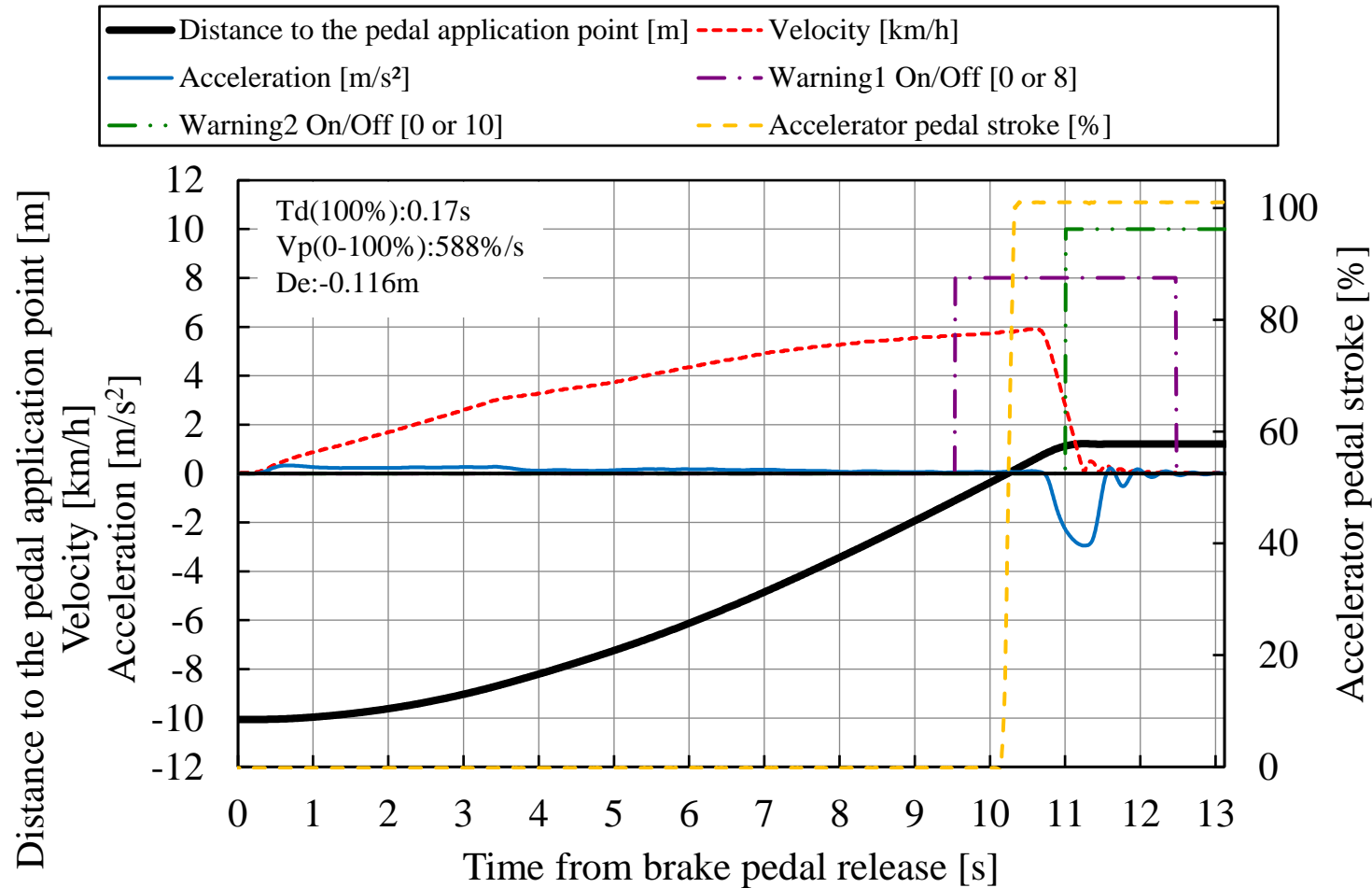


- Collision with the target was avoided by braking control.



# Experimental result (Detail data in each experimental condition)

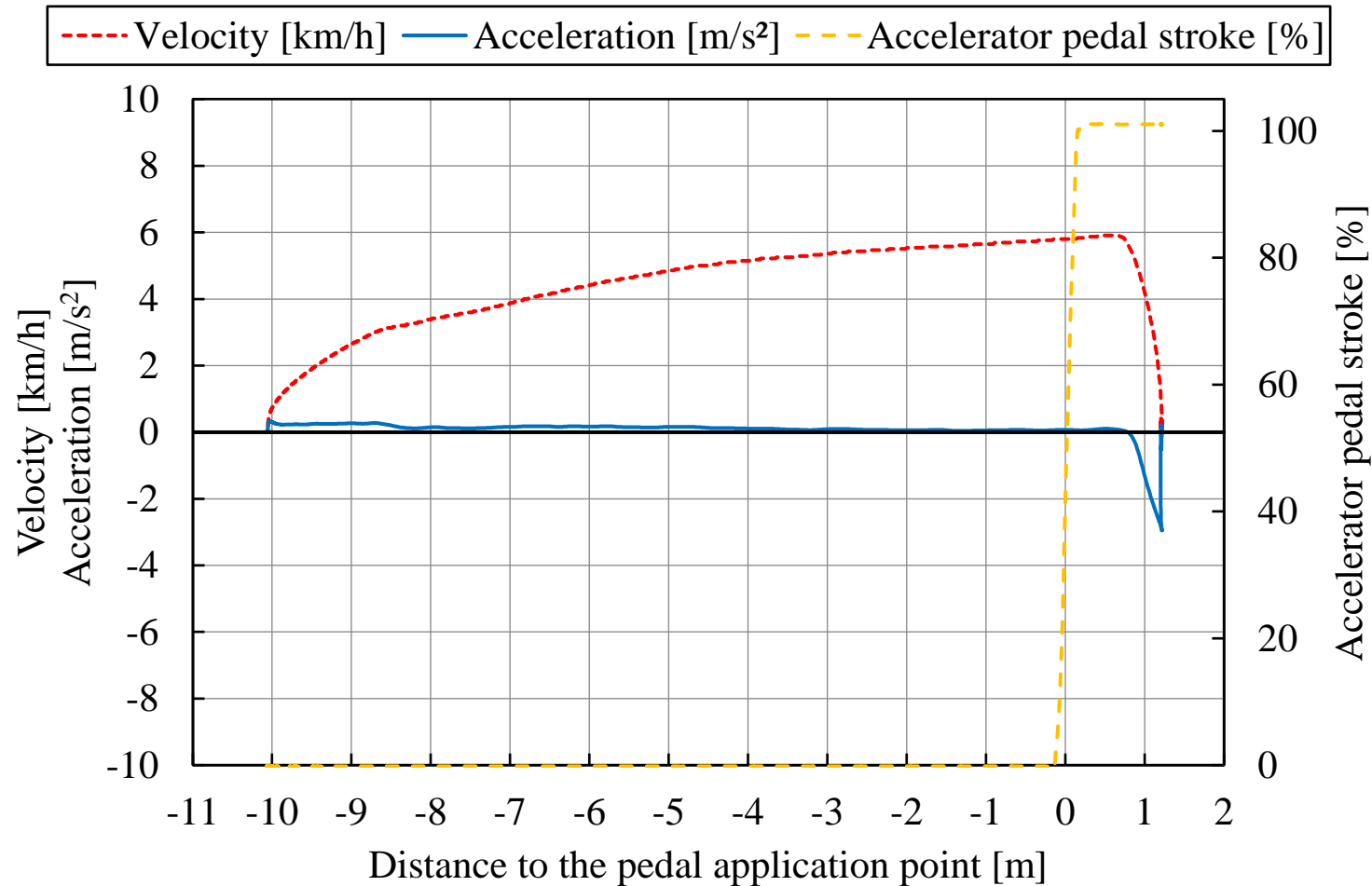
## Forward\_Child\_\_1m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

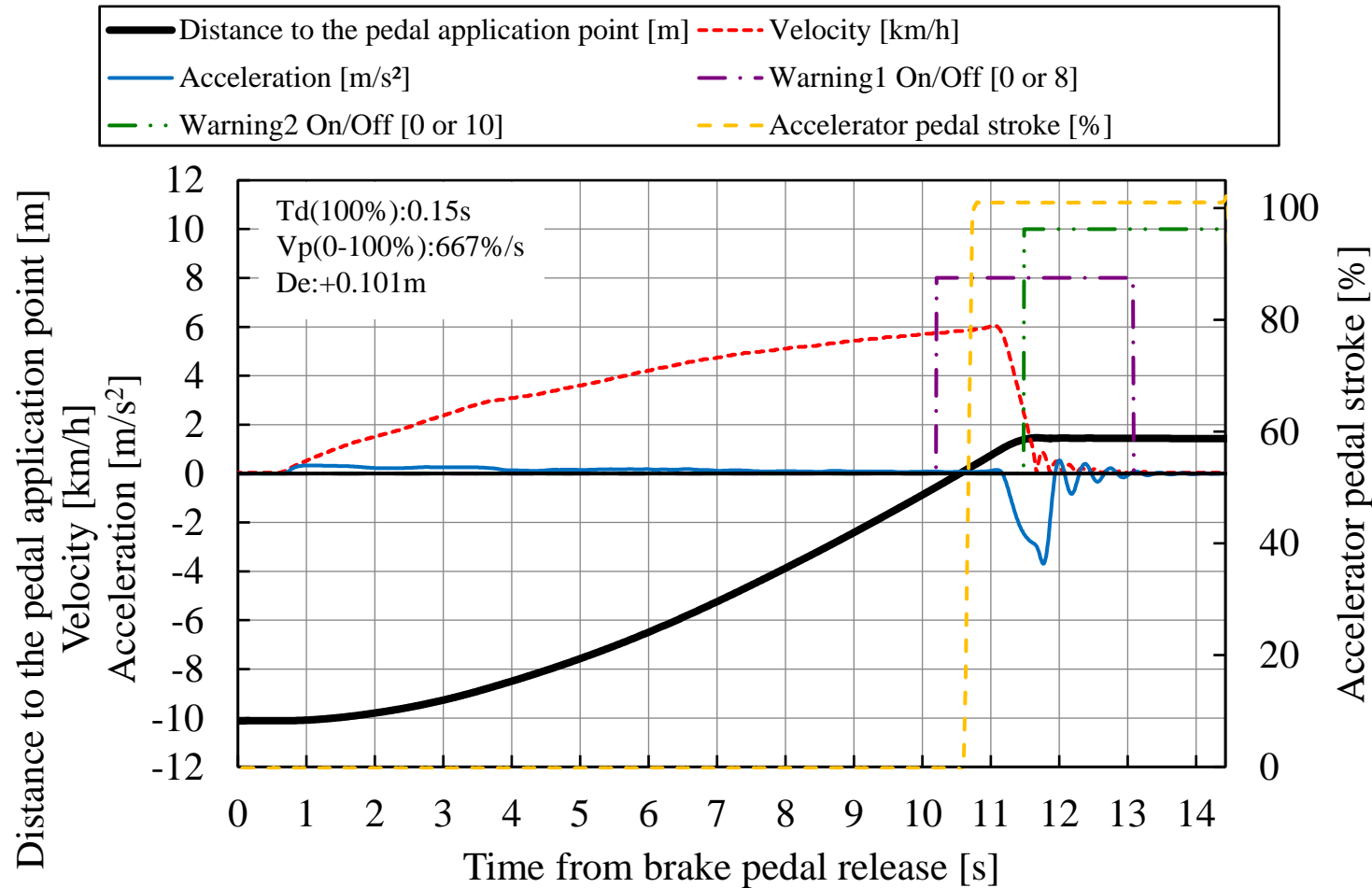
Forward\_Child\_1m\_No.1



- The vehicle was completely stopped by braking control, but slightly collided with the target (collision speed was approximately 4 km/h).

# Experimental result (Detail data in each experimental condition)

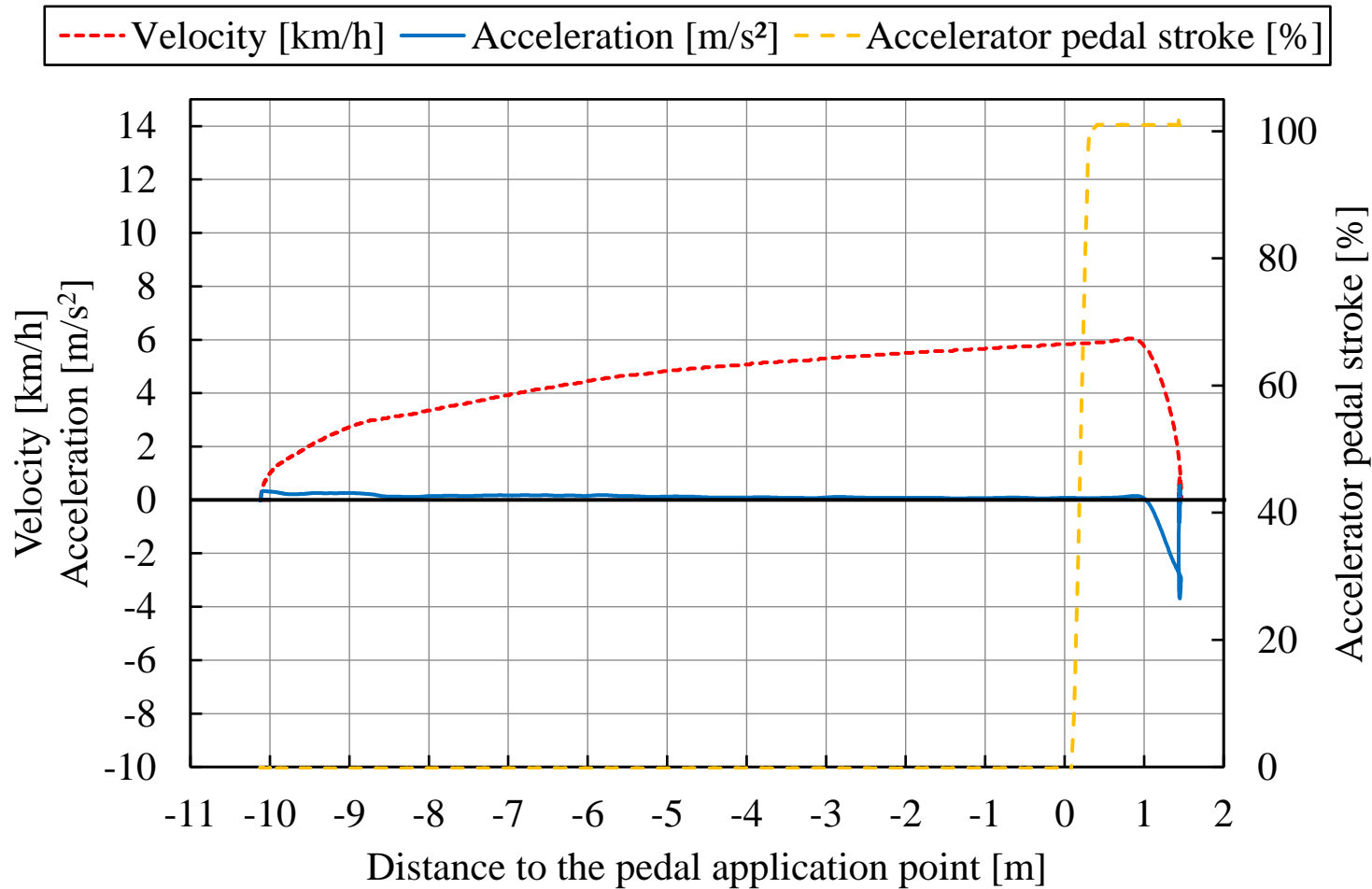
## Forward\_Child\_1.5m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- It is difficult to distinguish whether braking control was carried out by AEBS or ACPE, because the warning 1 was begun just before the start of accelerator pedal application.

# Experimental result (Detail data in each experimental condition)

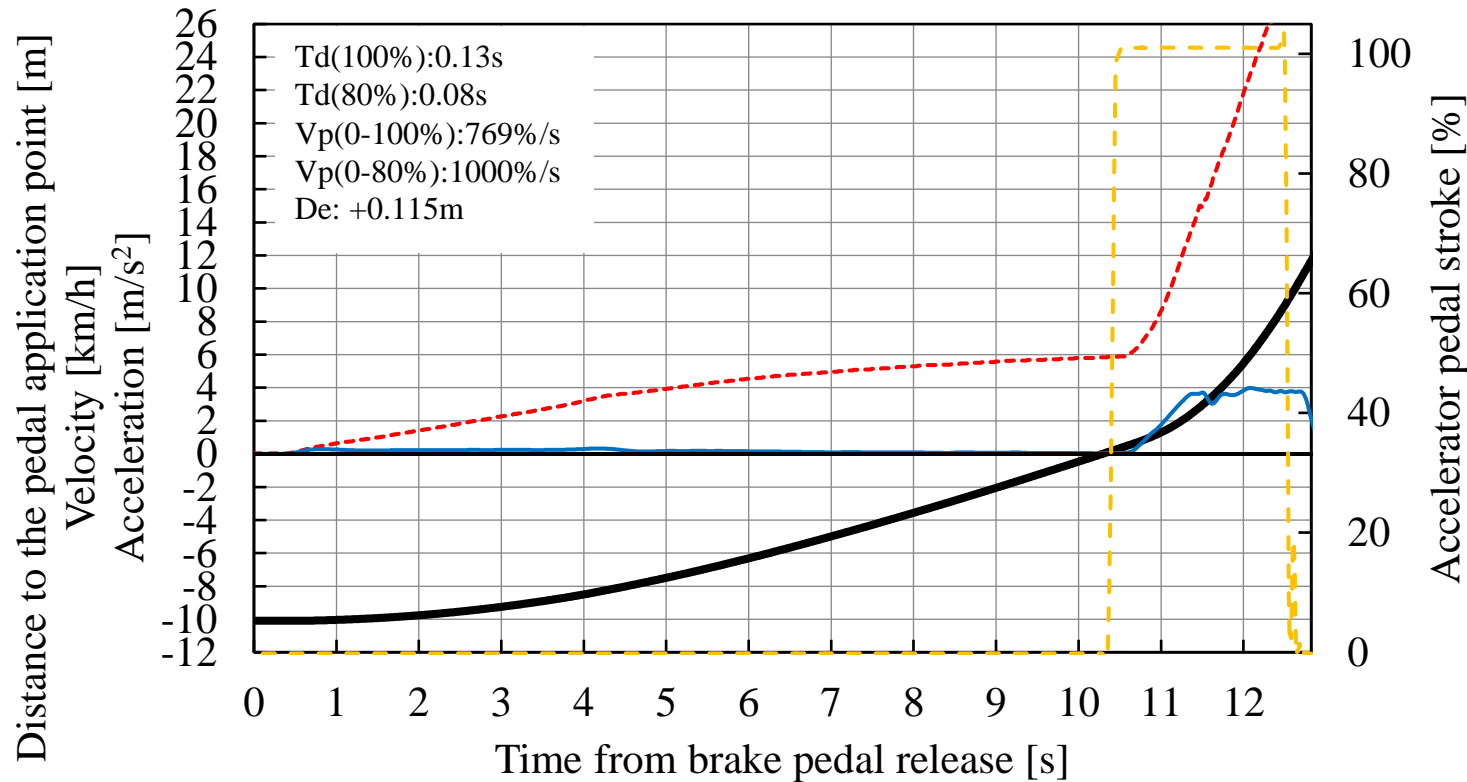
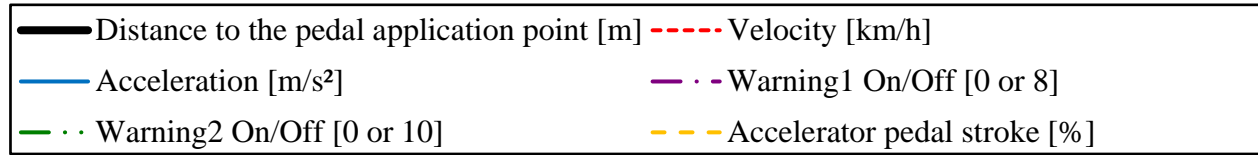
Forward\_Child\_1.5m\_No.1



- Collision with the target was avoided by braking control.

# Experimental result (Detail data in each experimental condition)

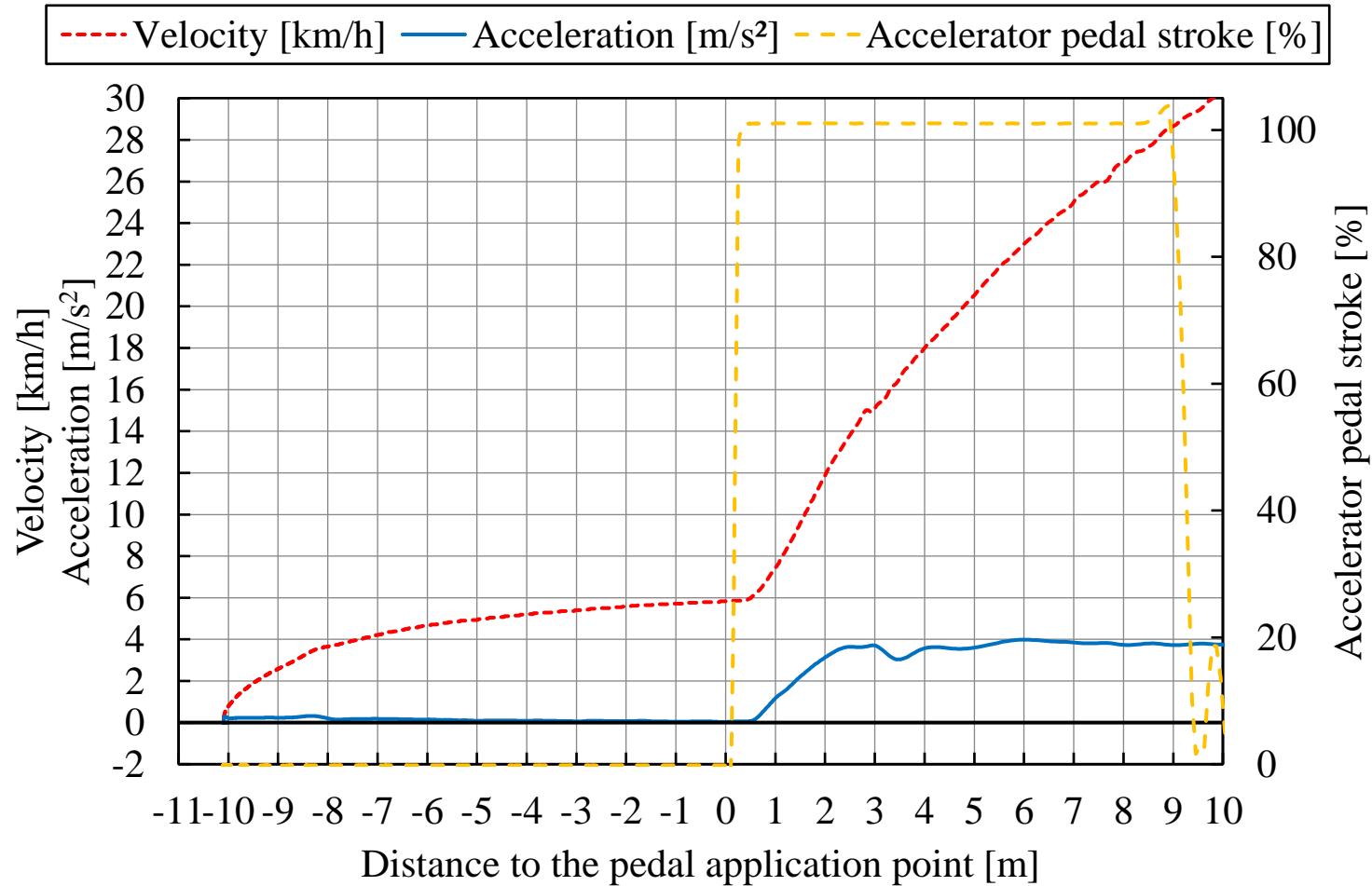
## Backward\_NoTarget\_No.1



- Maximum acceleration of the vehicle was approximately 4 m/s<sup>2</sup> in the condition of “no target”.

# Experimental result (Detail data in each experimental condition)

## Backward\_NoTarget\_No.1

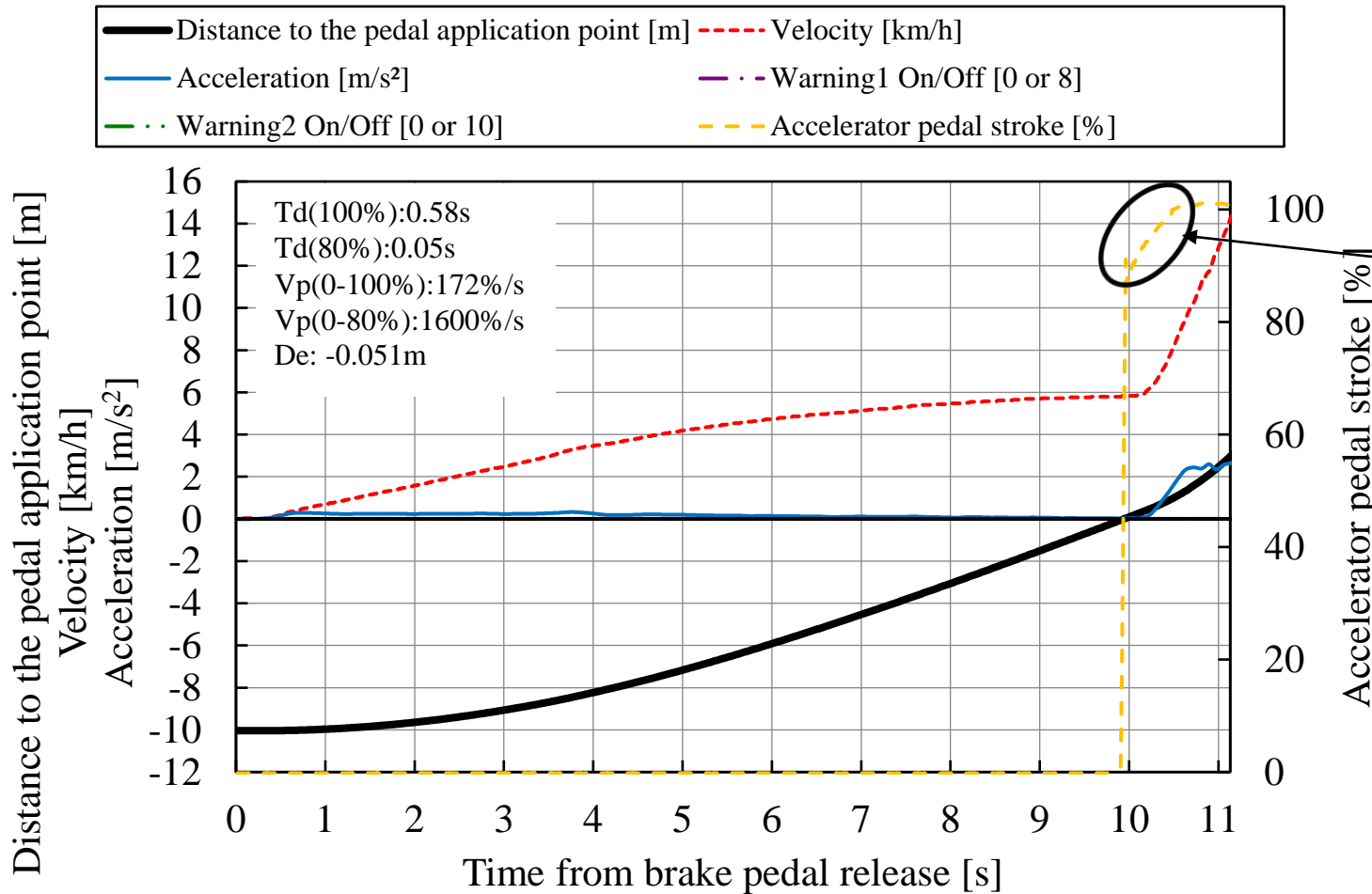


- Velocity of the vehicle was approximately 6 km/h just when the vehicle reached the accelerator pedal application point, however velocity was not steady value (gentle acceleration was ongoing). It was same tendency as forward direction.



# Experimental result (Detail data in each experimental condition)

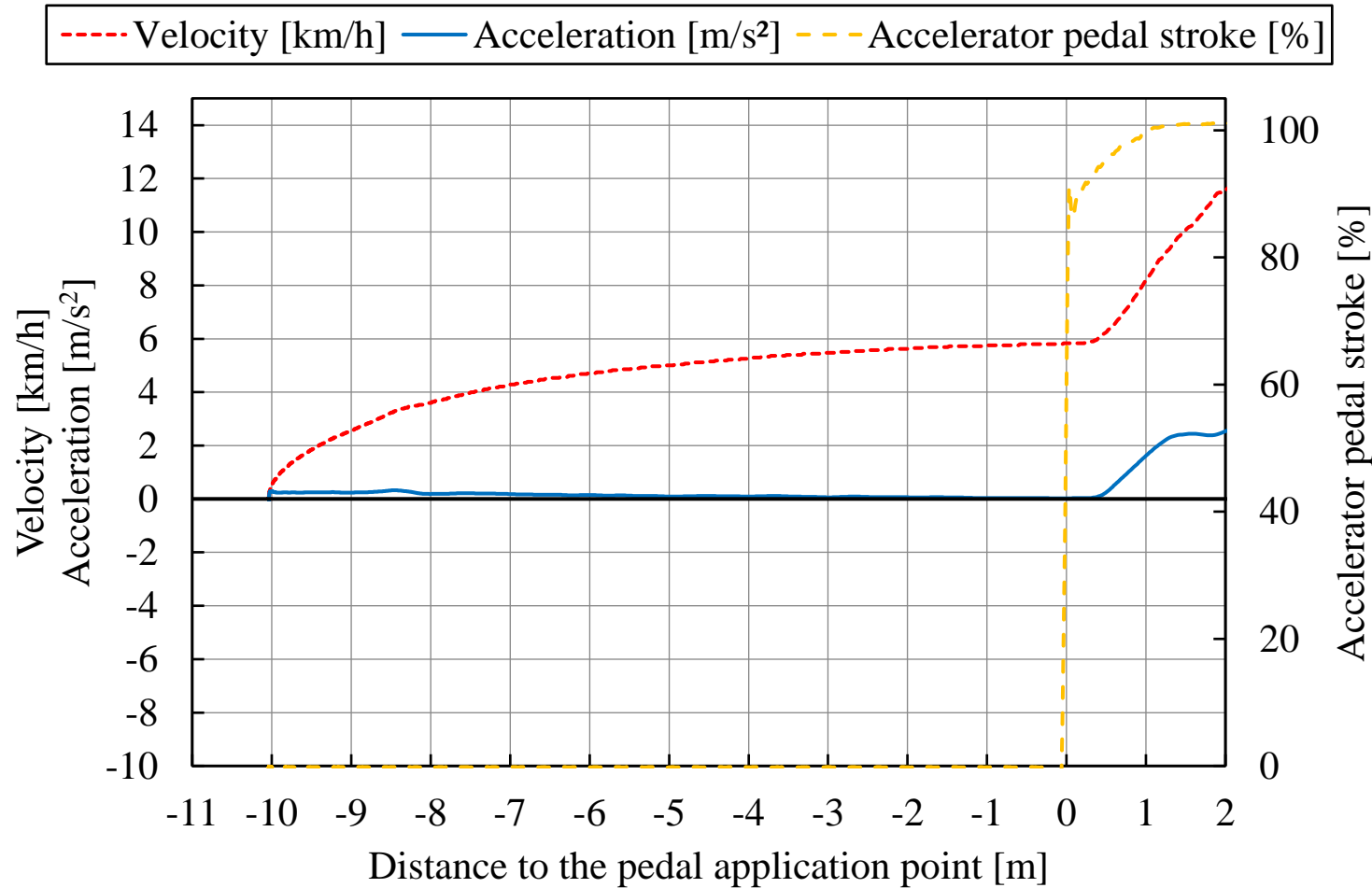
## Backward\_Vehicle\_1m\_No.2



- Both warning 1 and warning 2 were not shown, and acceleration control was not observed.
- Accelerator pedal could not be applied 100% stroke with the speed of 400%/s due to the change of reaction force of the pedal.

# Experimental result (Detail data in each experimental condition)

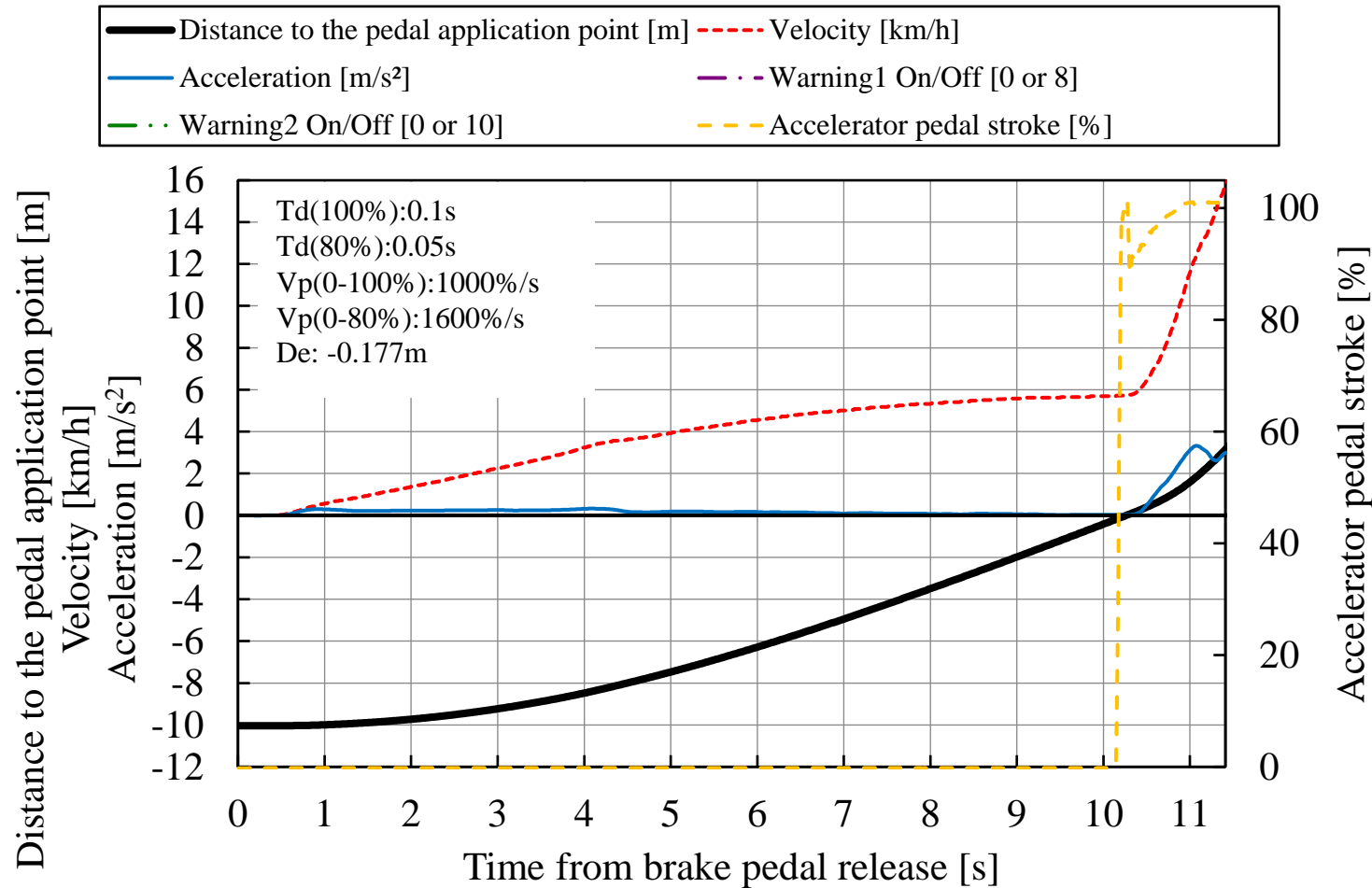
Backward\_Vehicle\_1m\_No.2



- Collision speed was approximately 8 km/h.

# Experimental result (Detail data in each experimental condition)

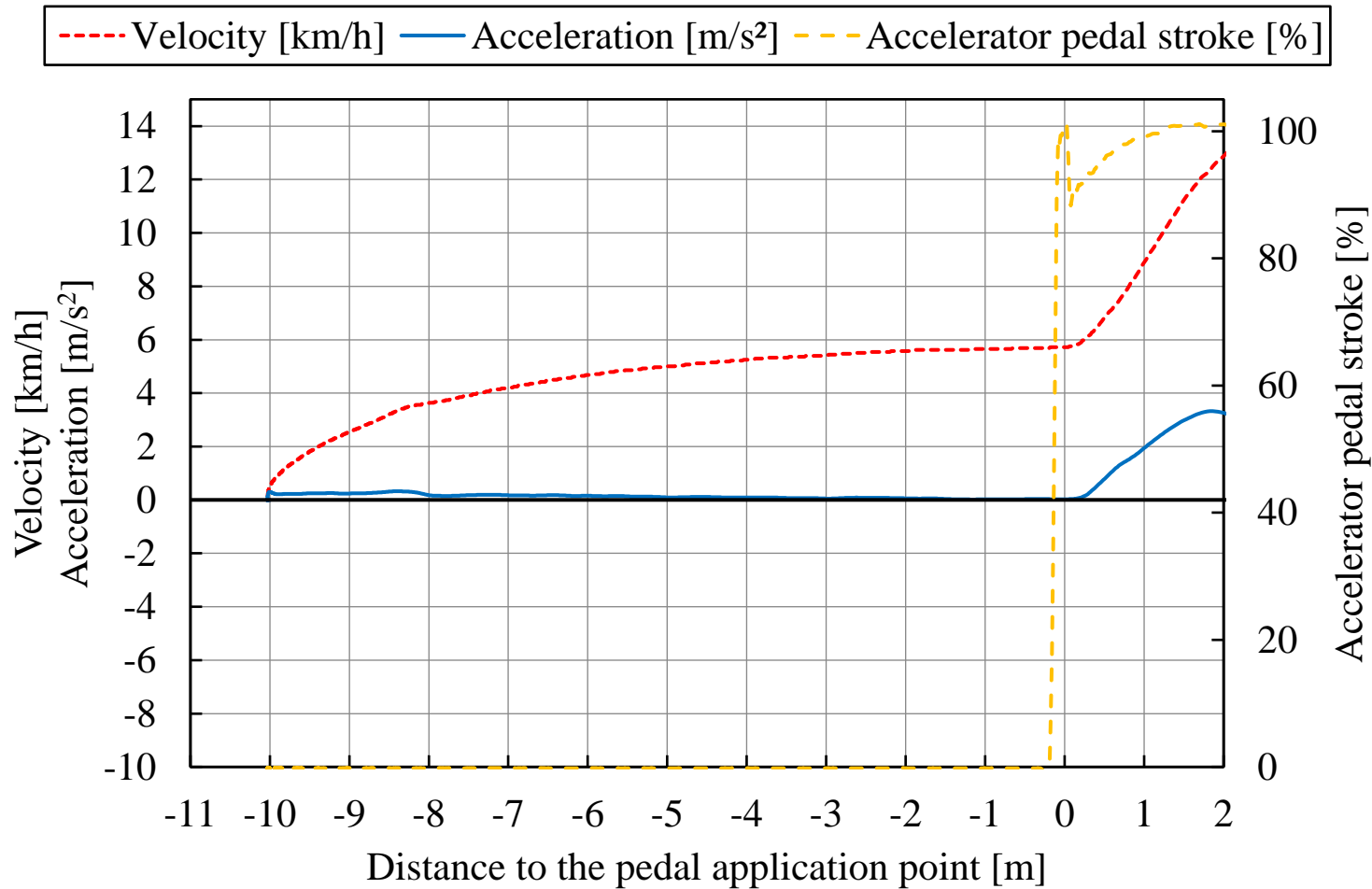
## Backward\_Vehicle\_1.5m\_No.1



- Both warning 1 and warning 2 were not shown, and acceleration control was not observed.

# Experimental result (Detail data in each experimental condition)

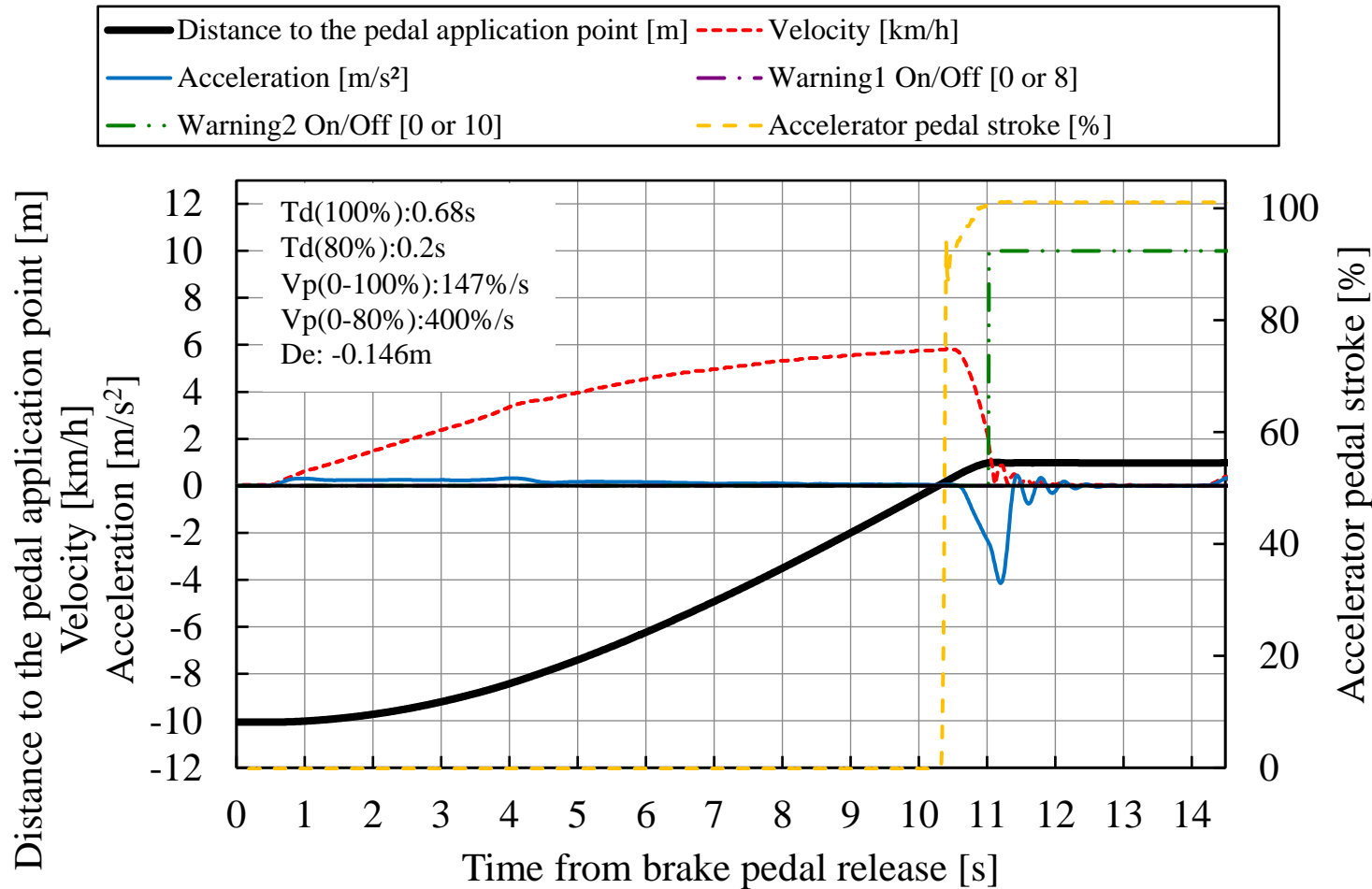
Backward\_Vehicle\_1.5m\_No.1



- Collision speed was approximately 11 km/h.

# Experimental result (Detail data in each experimental condition)

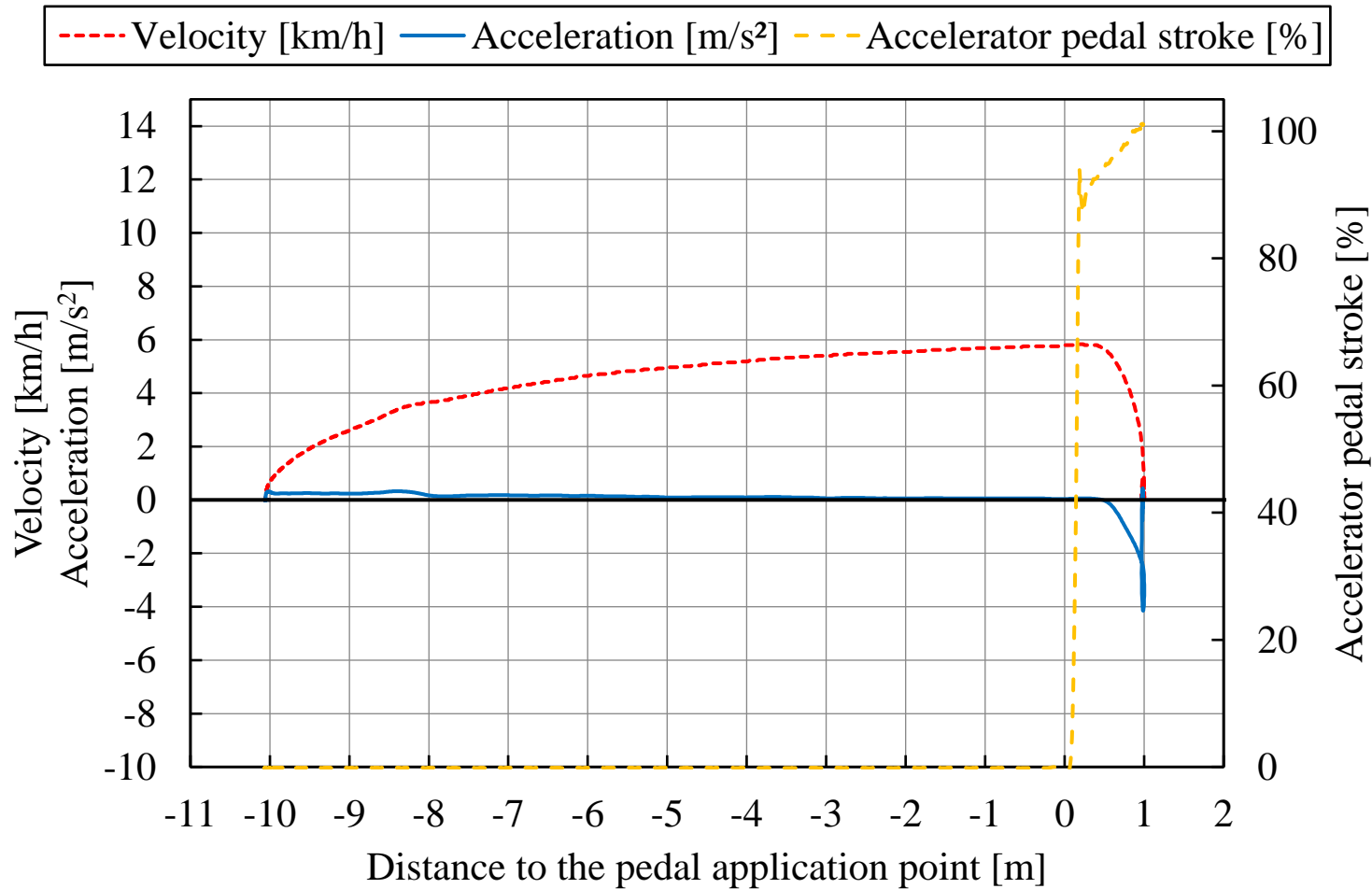
## Backward\_Adult\_\_1m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- In this case, it is considered that braking control was carried out by ACPE, because this vehicle doesn't have AEBS function for backward direction.

# Experimental result (Detail data in each experimental condition)

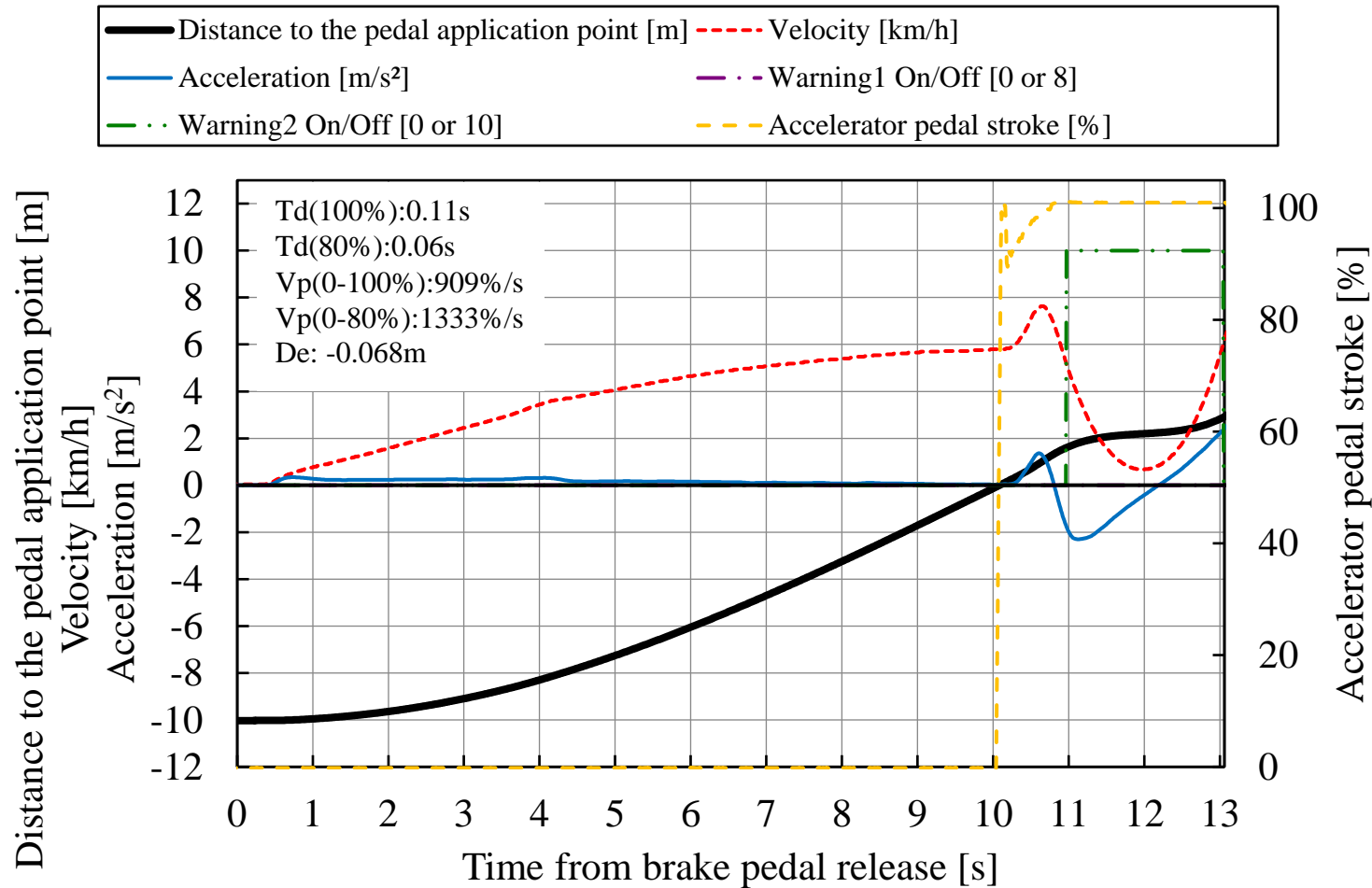
Backward\_Adult\_\_1m\_No.1



- Collision with the target was avoided by braking control.

# Experimental result (Detail data in each experimental condition)

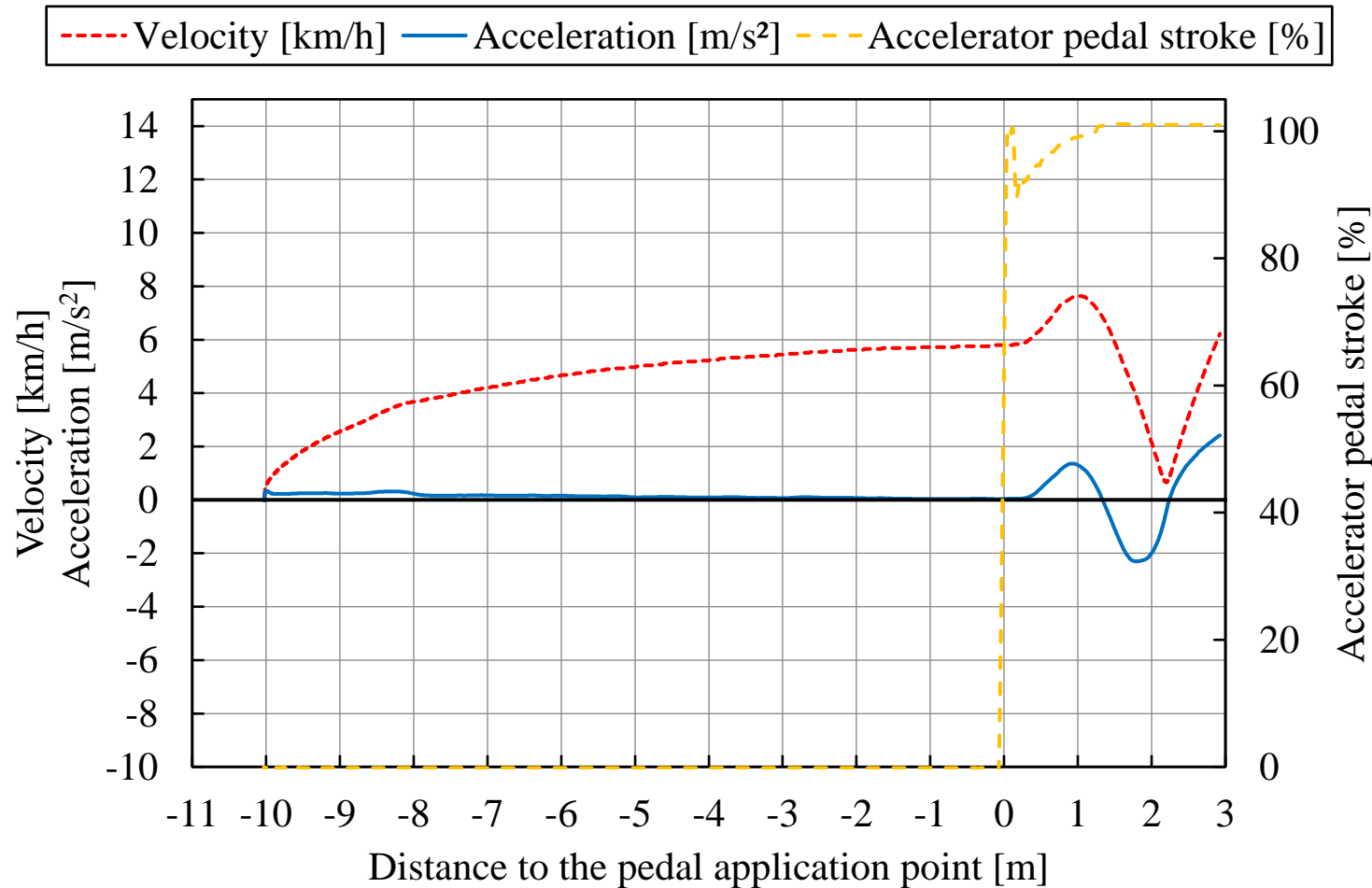
## Backward\_Adult\_\_1.5m\_No.2



- Both acceleration control was continued for more than 2 s.
- The vehicle was decelerated, but braking control was finished just before the vehicle was completely stopped.
- In this case, it is considered that braking control was carried out by ACPE, because this vehicle doesn't have AEBS function for backward direction.

# Experimental result (Detail data in each experimental condition)

Backward\_Adult\_\_1.5m\_No.2

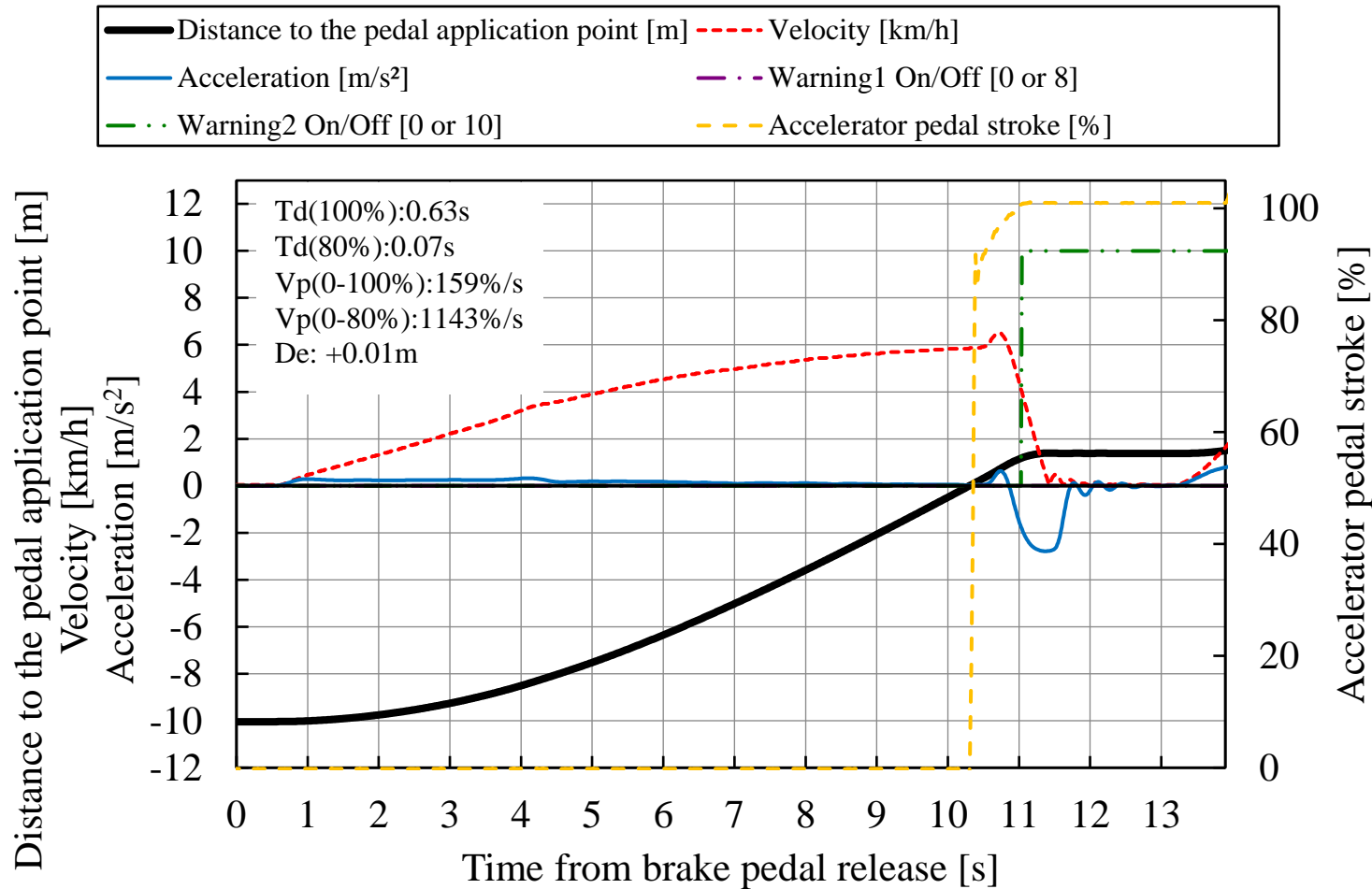


- Collision speed was approximately 6 km/h.
- The vehicle accelerated just after the collision with the target. It is estimated that the vehicle could not detect the target any more after the adult pedestrian target fell over.



# Experimental result (Detail data in each experimental condition)

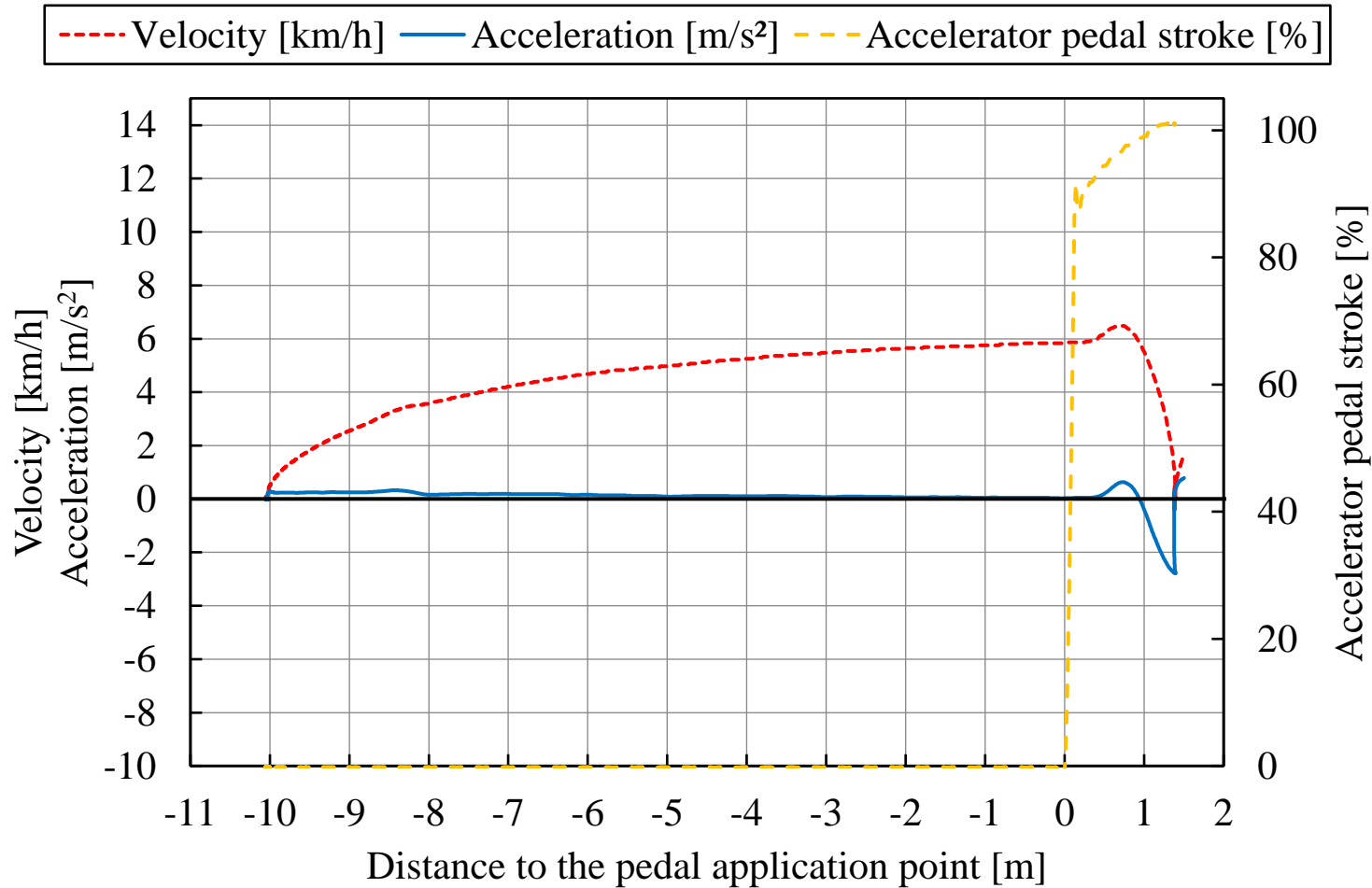
## Backward\_Child\_\_1m\_No.1



- Acceleration control was continued for more than 2 s.
- The vehicle was decelerated and completely stopped.
- In this case, it is considered that braking control was carried out by ACPE, because this vehicle doesn't have AEBS function for backward direction.

# Experimental result (Detail data in each experimental condition)

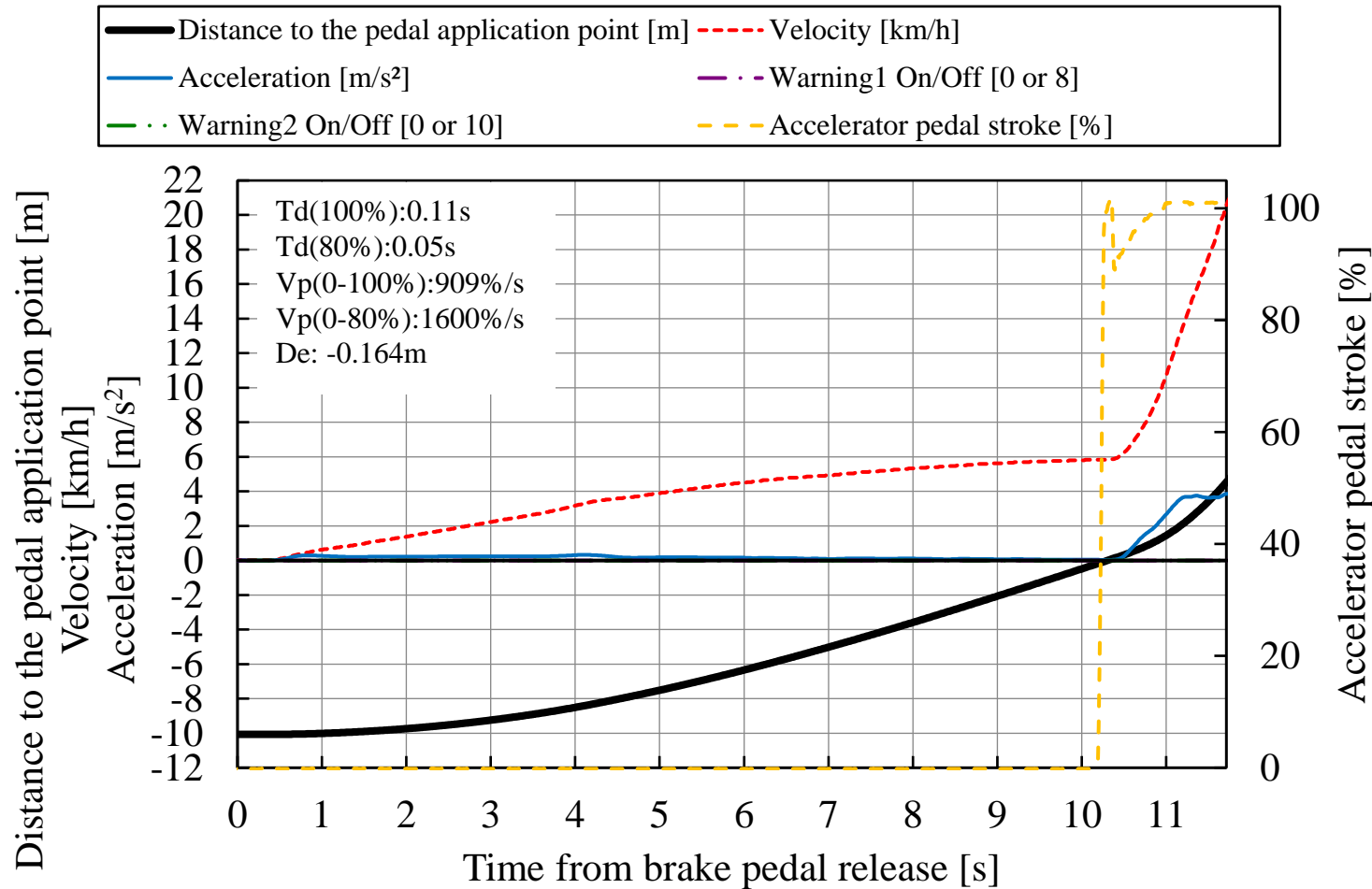
Backward\_Child\_\_1m\_No.1



- Collision speed was approximately 5.5 km/h.

# Experimental result (Detail data in each experimental condition)

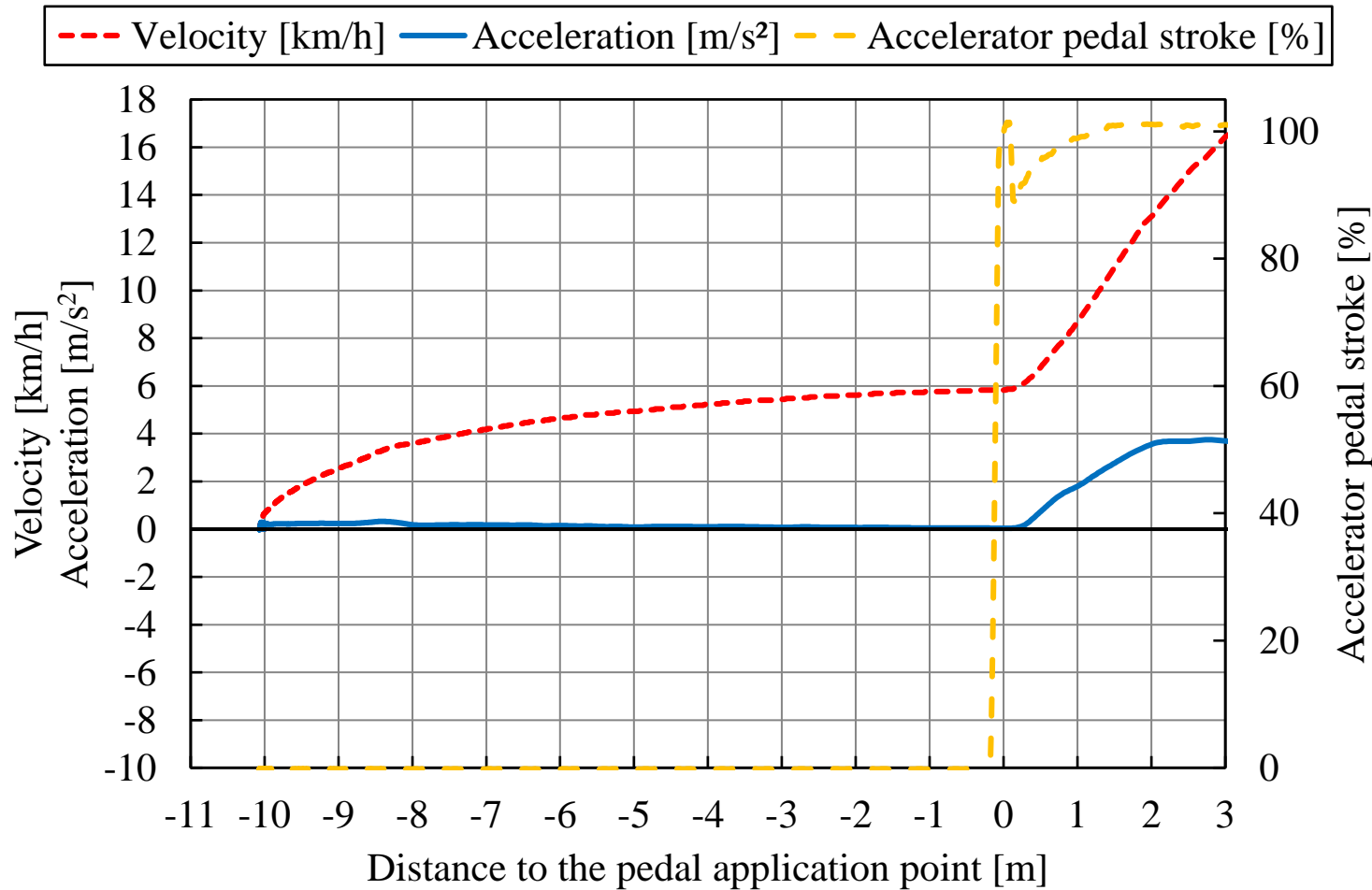
## Backward\_Child\_\_1.5m\_No.1



- Both warning 1 and warning 2 were not shown, and acceleration control was not observed.

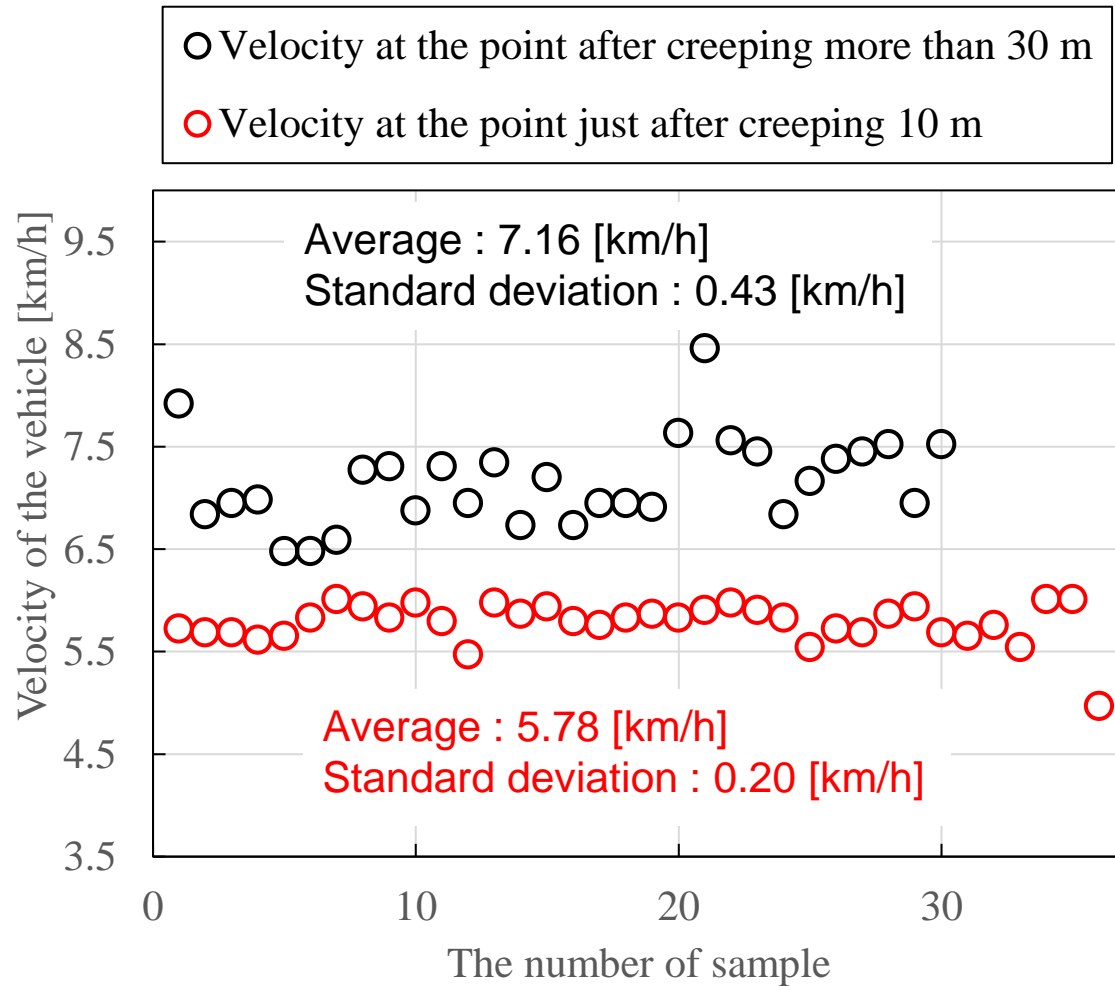
# Experimental result (Detail data in each experimental condition)

Backward\_Child\_\_1.5m\_No.1



- Collision speed was approximately 11 km/h.

# Experimental result (data plot of creeping velocity)

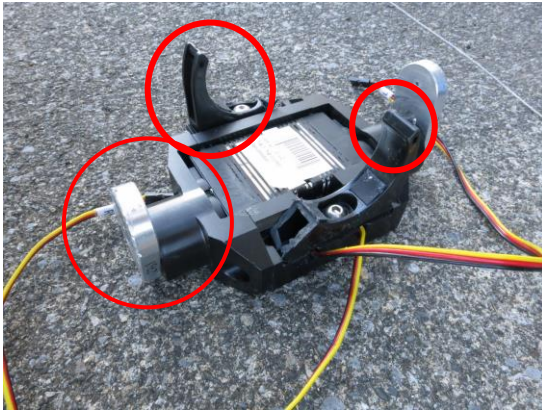


- Difference of average value is approximately 1.4 km/h.
- Standard deviation of creeping velocity after the vehicle ran more than 30 m is larger than that at the point of just after creeping 10 m.
- It is considered that the creeping distance or the creeping time should be considered carefully, if the creeping procedure is applied as the ACPE test.



# Experimental result (damages of the pedestrian targets)

Adult pedestrian target



Child pedestrian target



○ Damaged parts



- The pedestrian targets were significantly damaged by repeated collisions.
- Especially, holding accelerator pedal position 100 % for a few seconds much influences degree of damages.
- In case of the child pedestrian target, it is easy to get in under the floor of the vehicle after a collision.



# Summary of the investigation

- It was confirmed that conducting the ACPE test by creeping procedure is possible.
- In case of the tested vehicle, in almost all of the conditions and cases, ACPE was activated certainly in forward direction. However, in many cases, ACPE was not activated in backward direction.
- The pedestrian targets were significantly damaged by repeated collisions. If the target is seriously damaged during the type approval test, the test would not be continued.
- It takes longer time until creeping velocity of the vehicle becomes constant. Appropriate time or distance for creeping should be re-considered.
- If we consider state of the art technology, it is considered that adopting creeping procedure from the beginning seems too early. It should be discussed in later stage.

# Appendix

The following slide shows the detail data in each experimental conditions.

Target : Vehicle target, Adult pedestrian target and Child pedestrian target

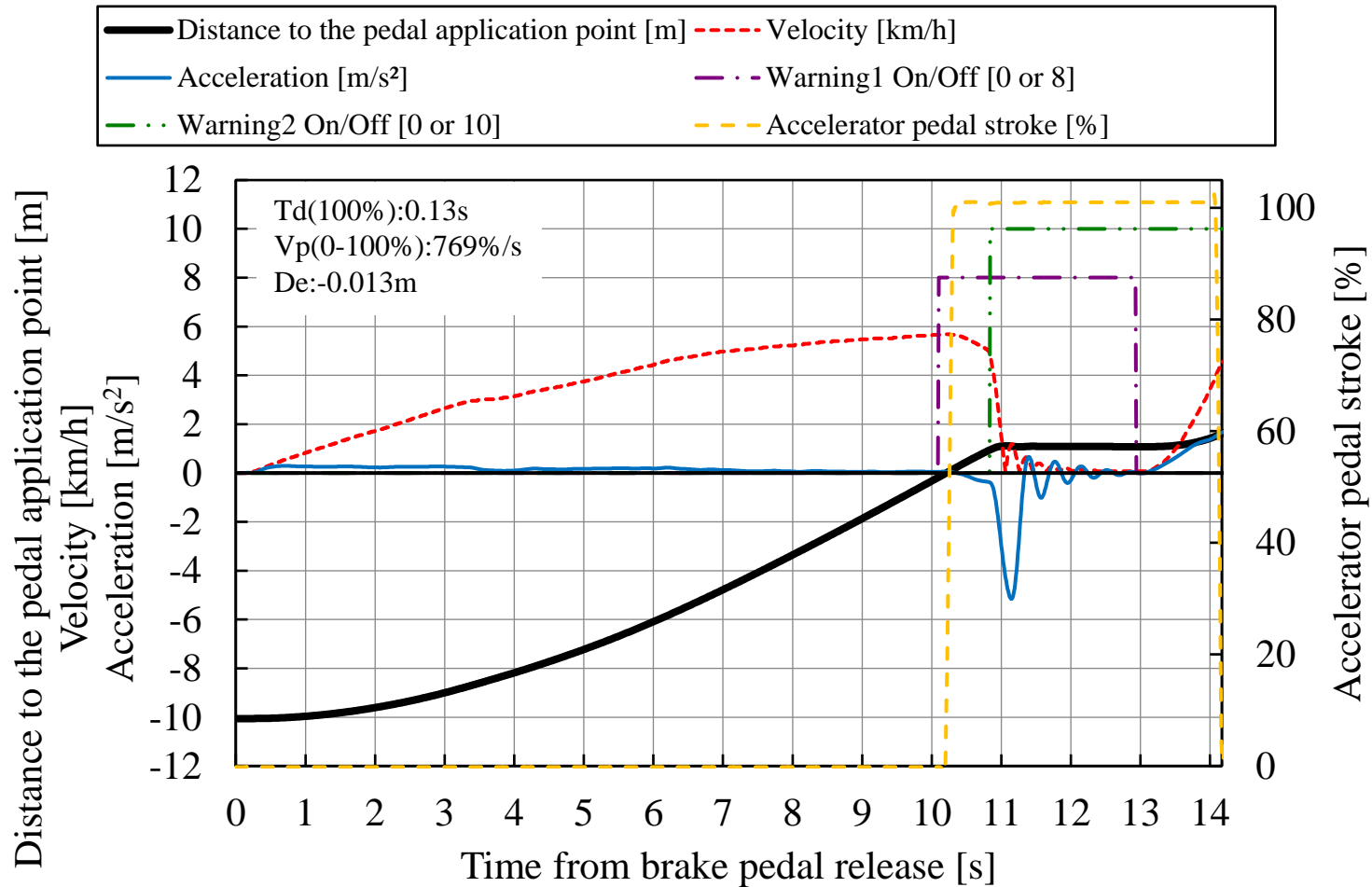
Running direction : Forward direction and Backward direction

Distance to the target : 2 m and 3 m\*

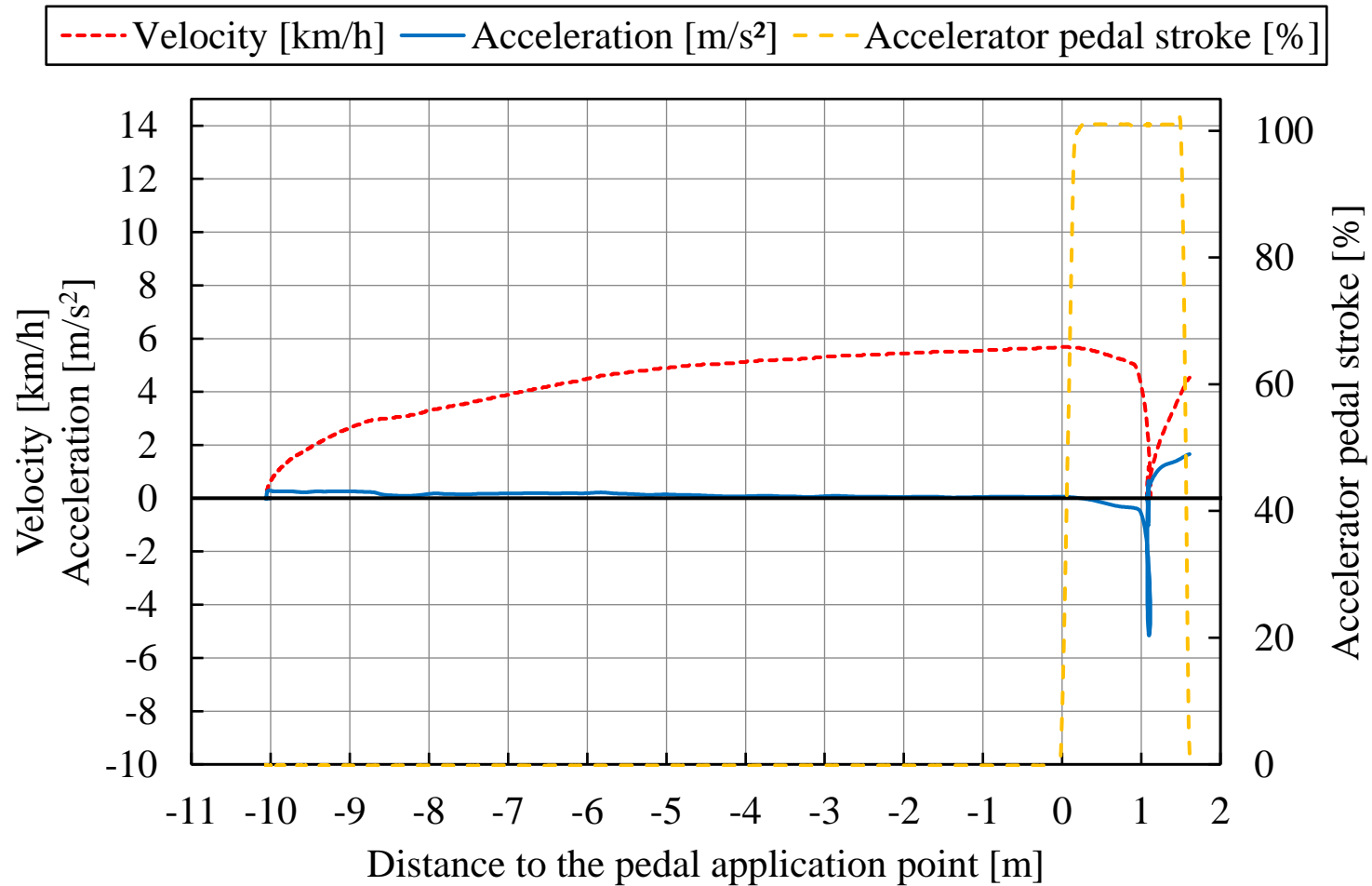
\*Except for child pedestrian target in backward direction



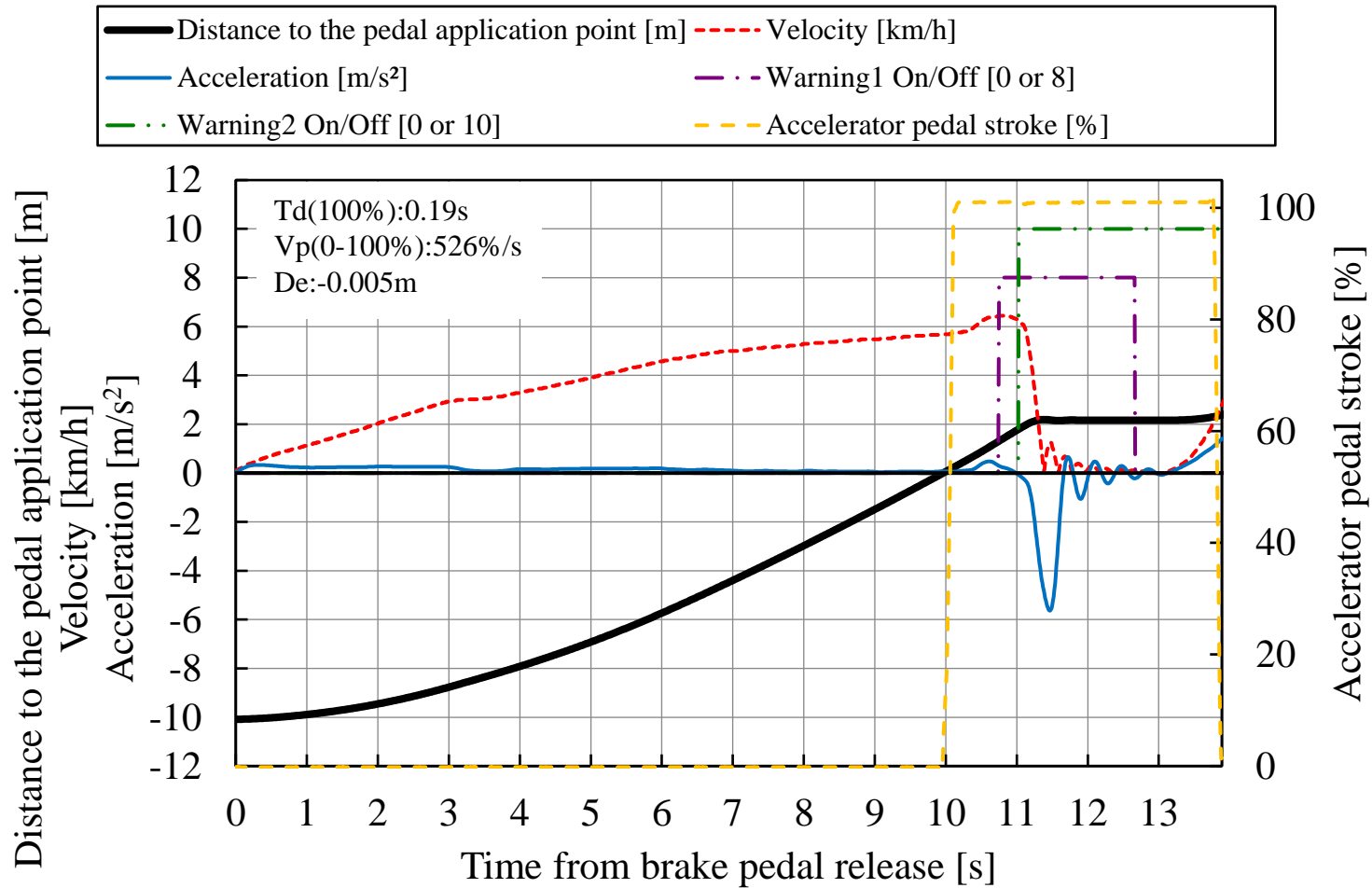
### Forward\_Vehicle\_2m\_No.1



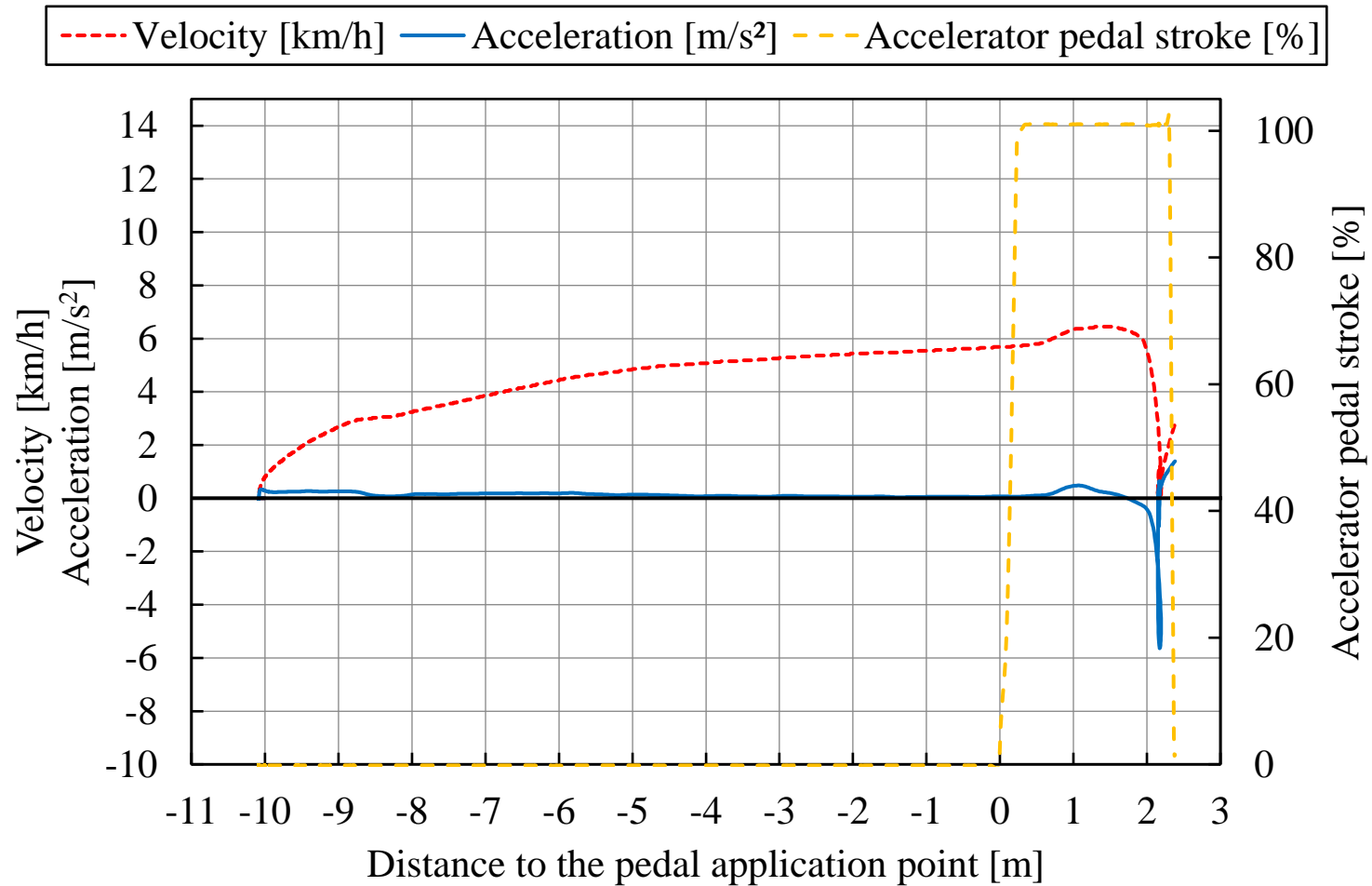
### Forward\_Vehicle\_2m\_No.1



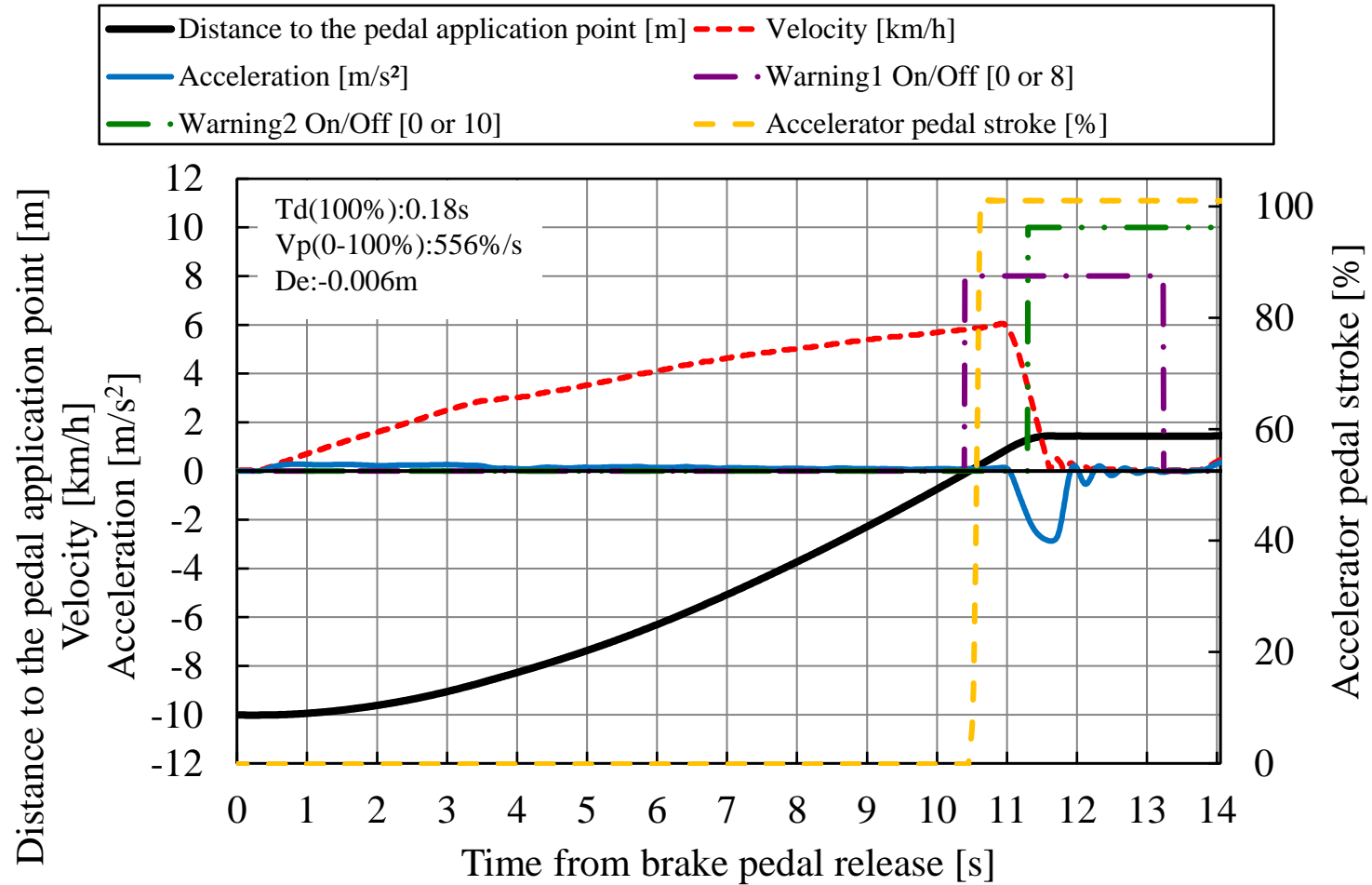
### Forward\_Vehicle\_3m\_No.1



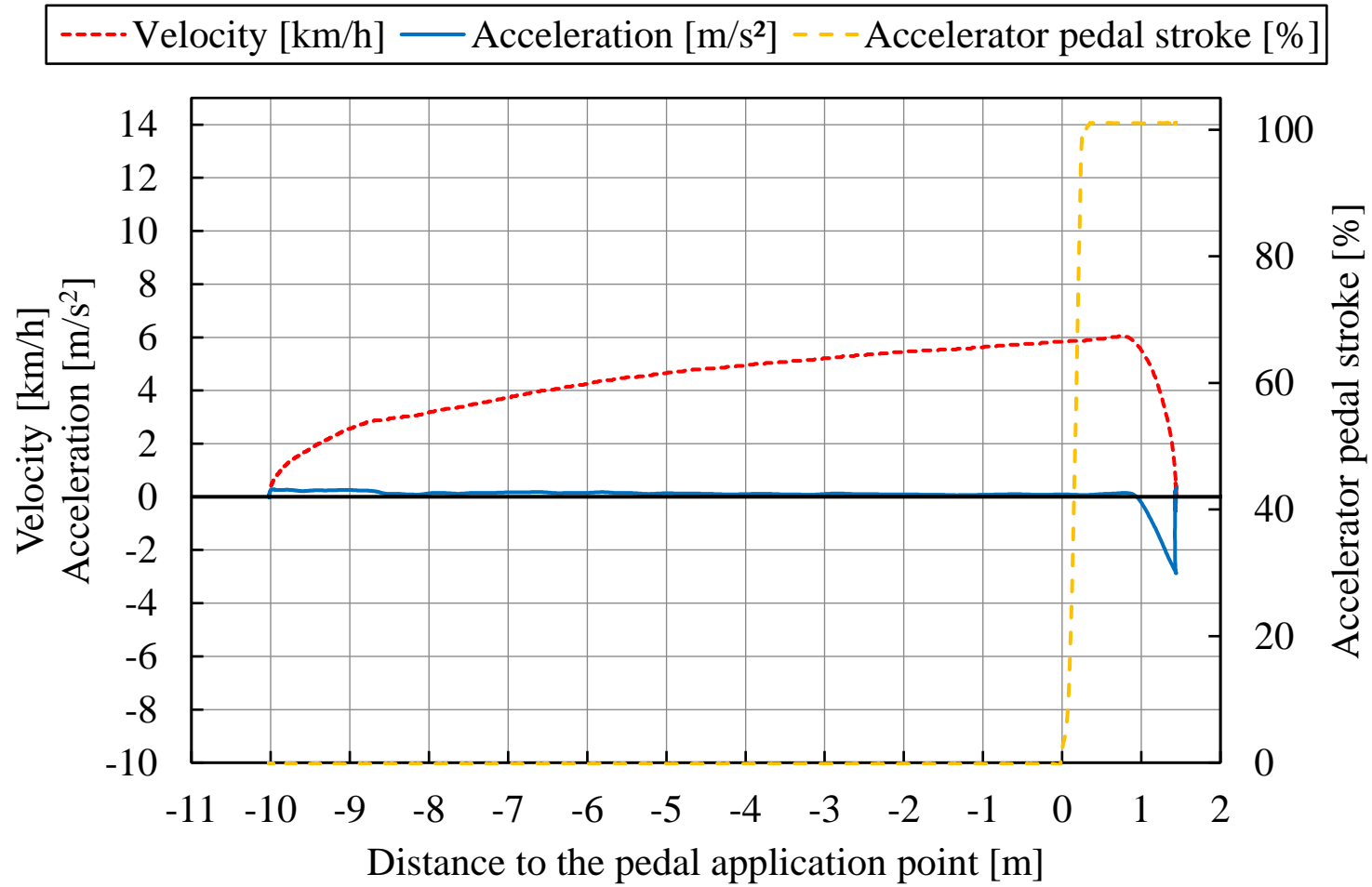
### Forward\_Vehicle\_3m\_No.1



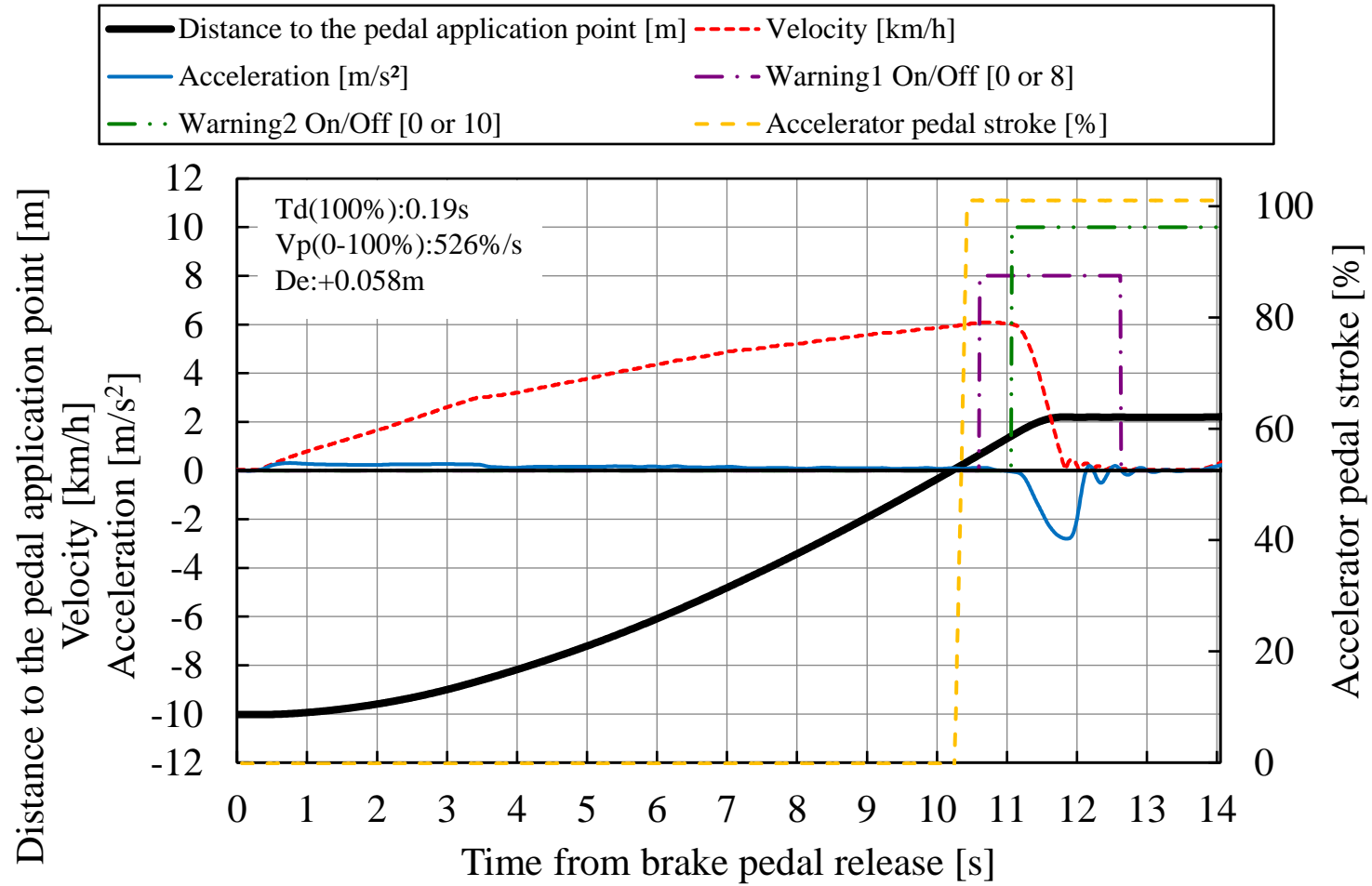
### Forward\_Adult\_2m\_No.1



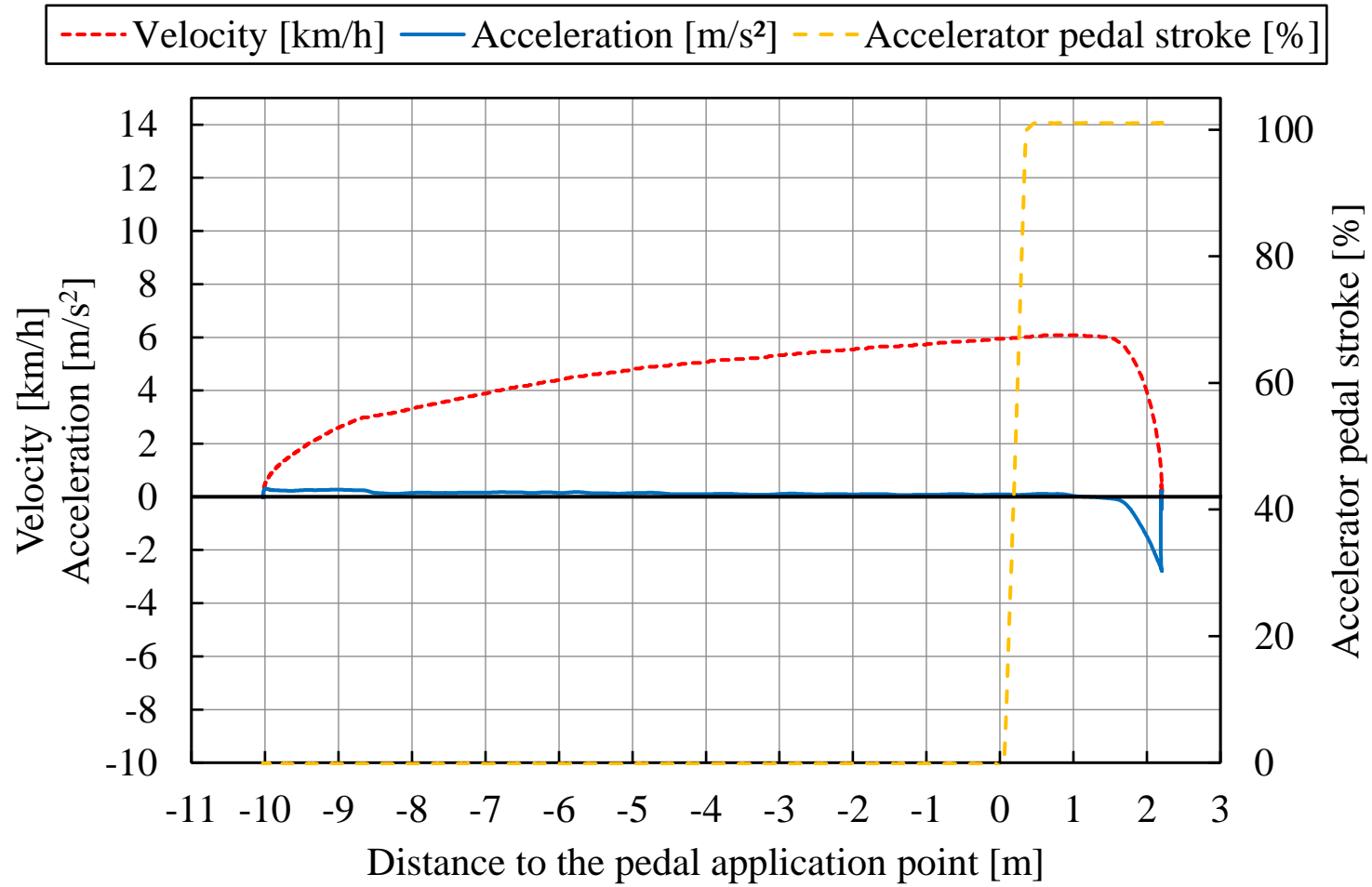
### Forward\_Adult\_2m\_No.1



### Forward\_Adult\_3m\_No.1

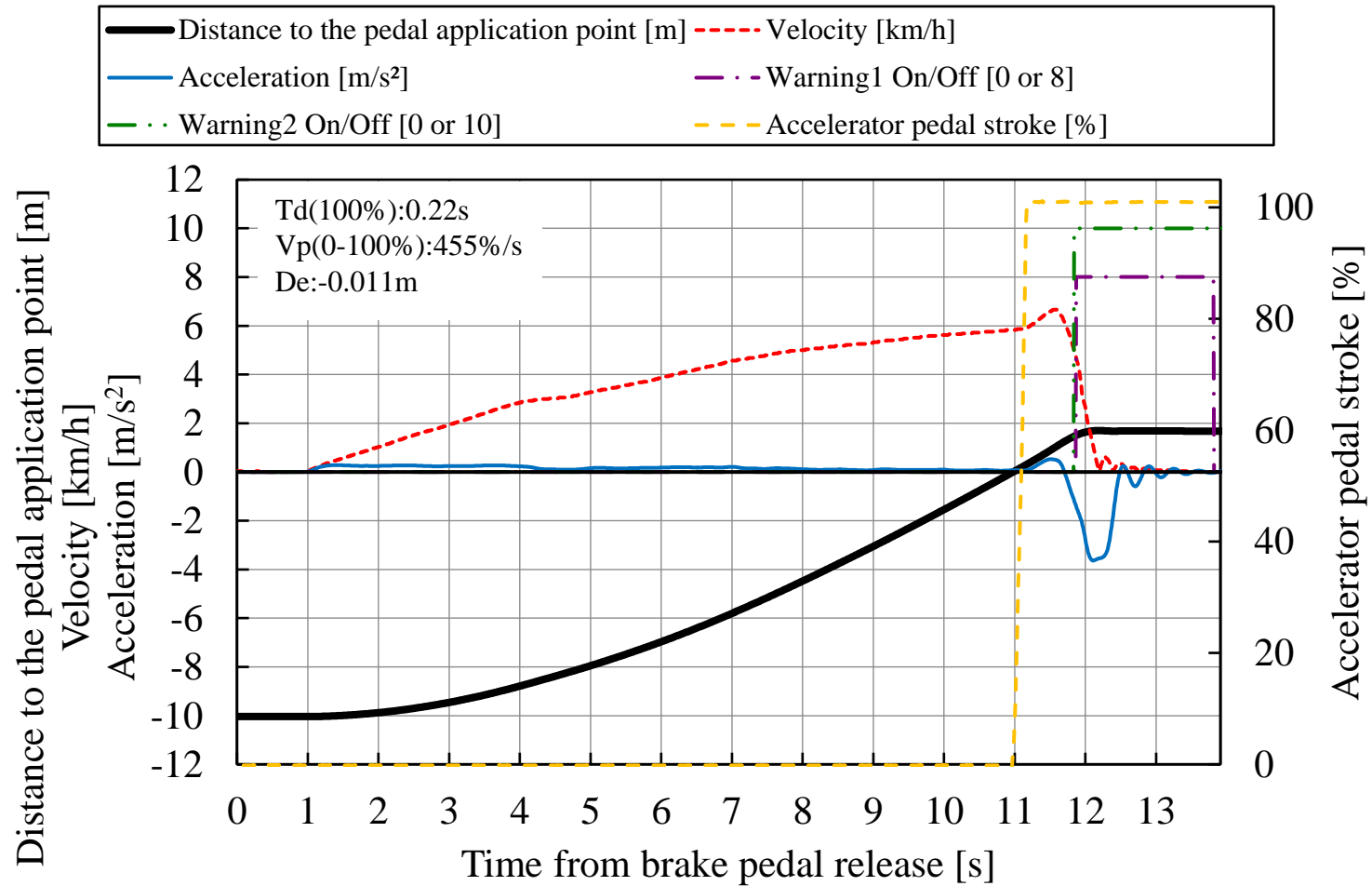


### Forward\_Adult\_3m\_No.1

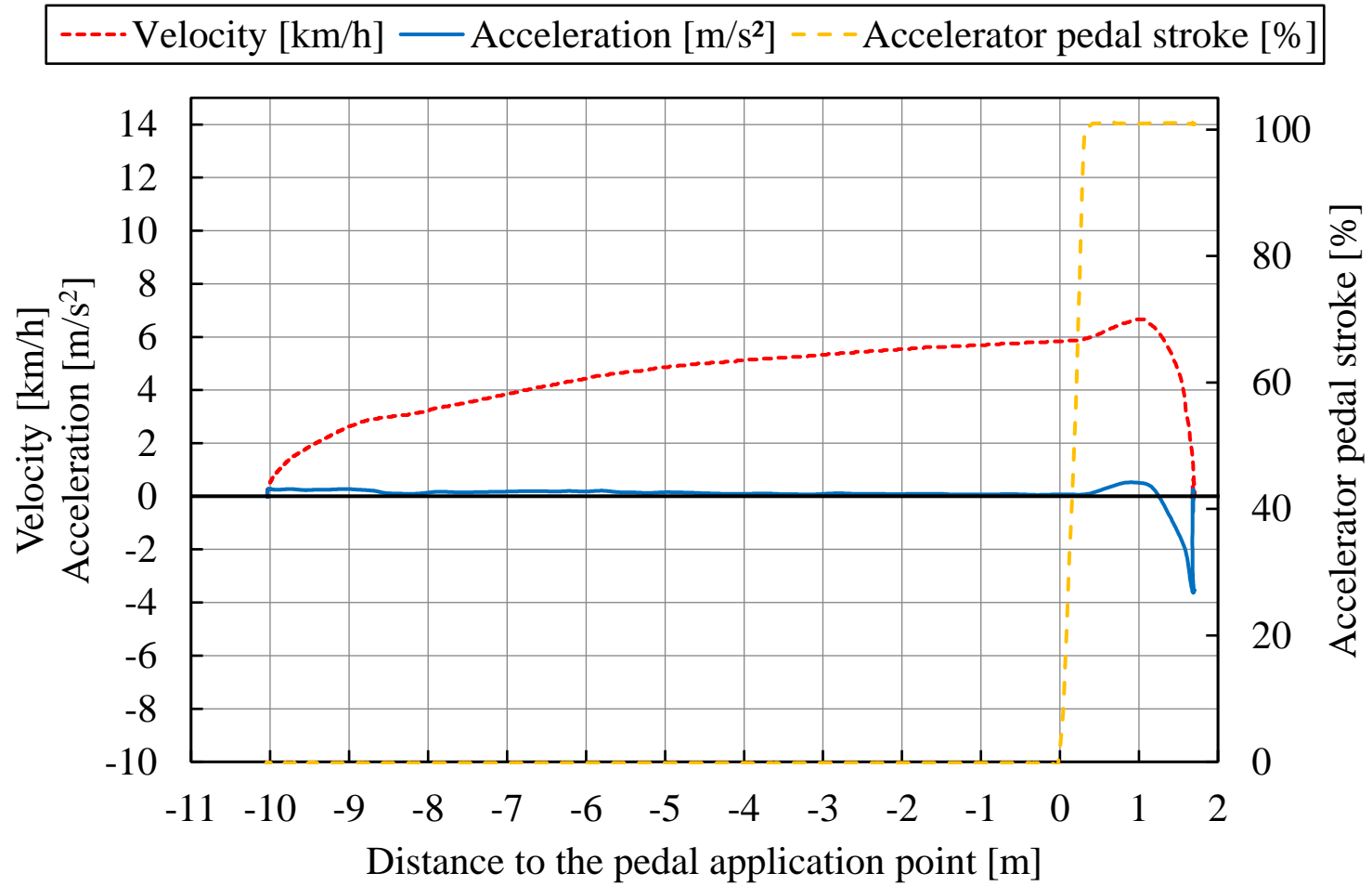




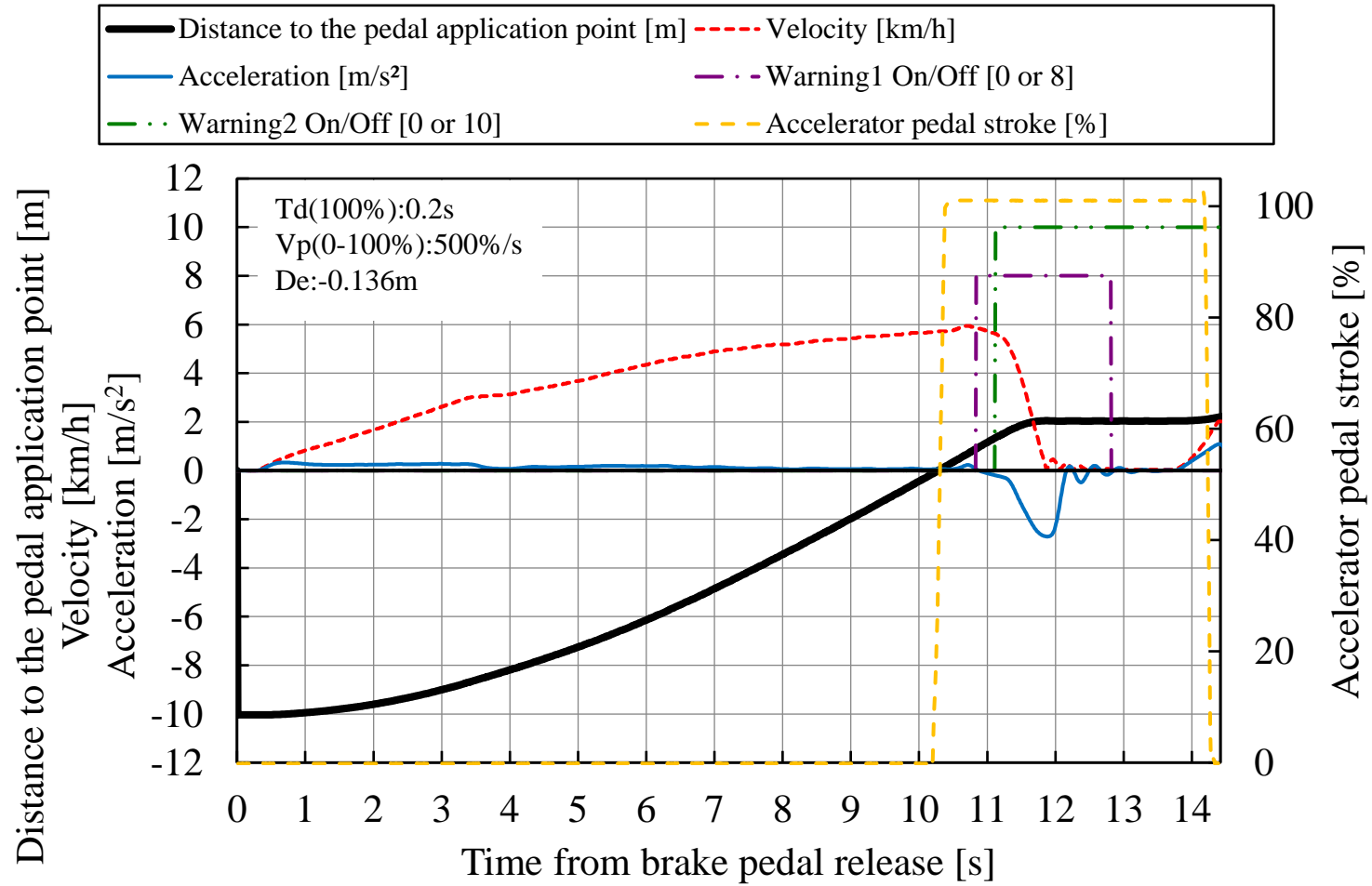
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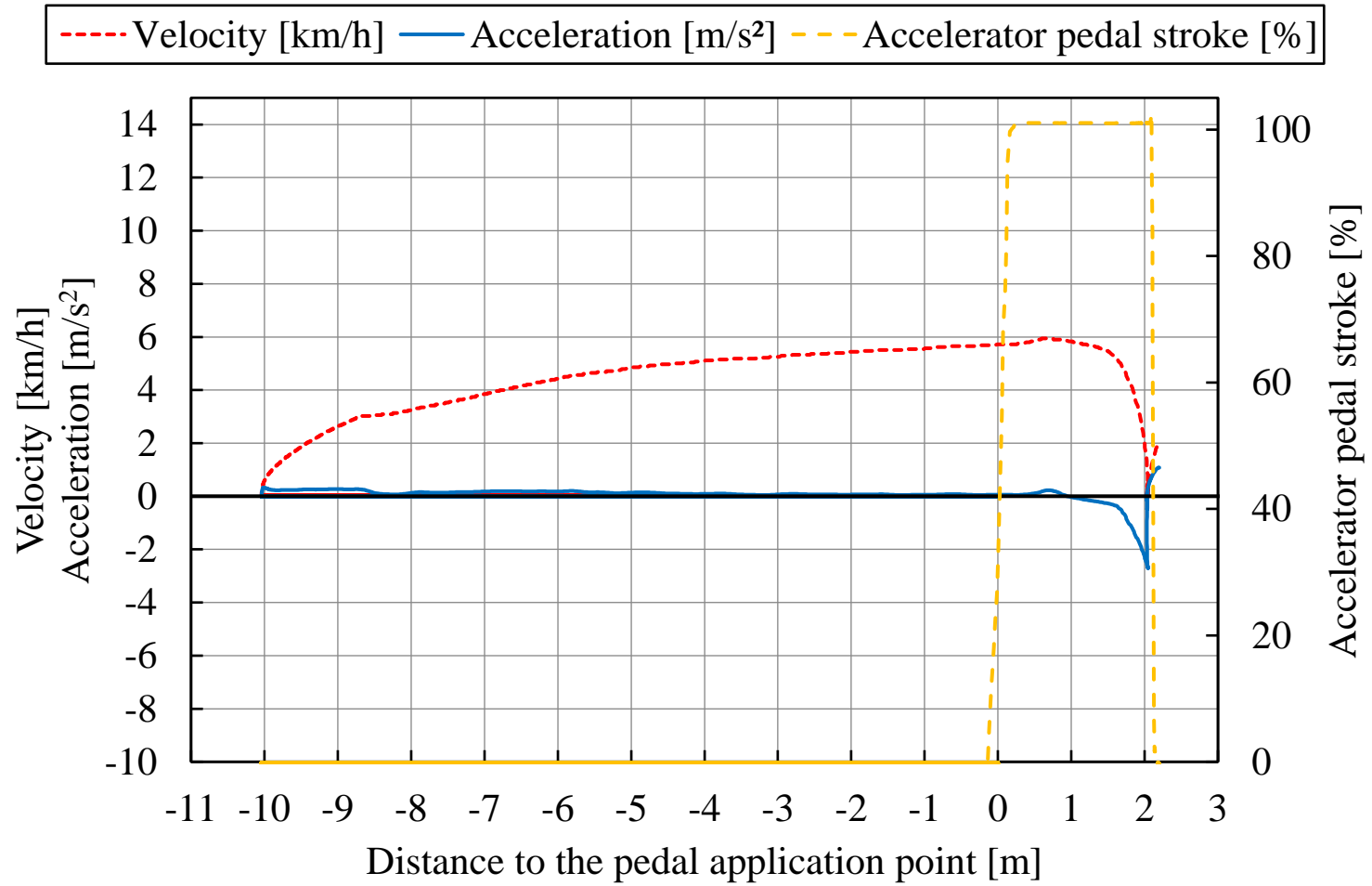
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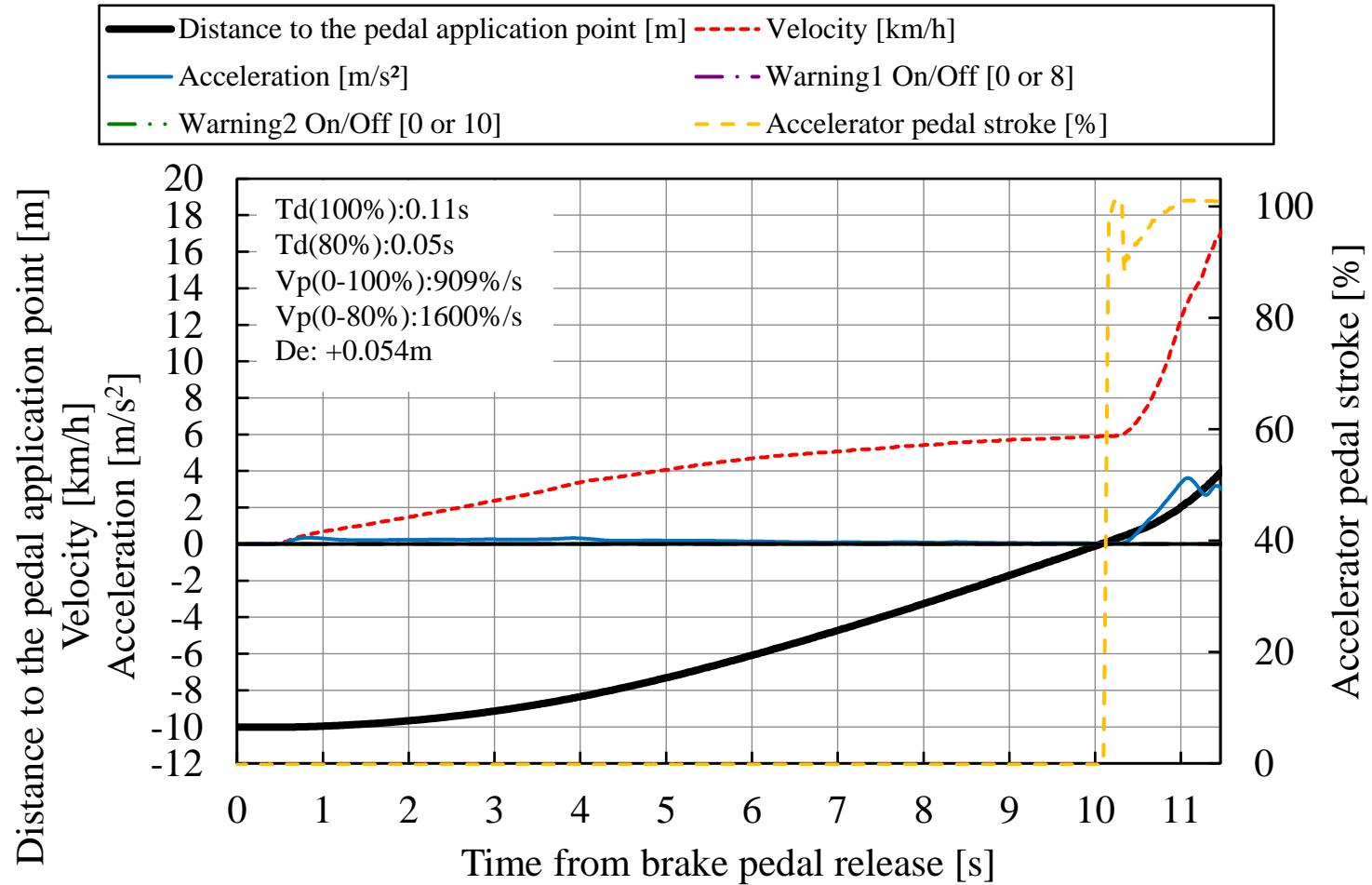
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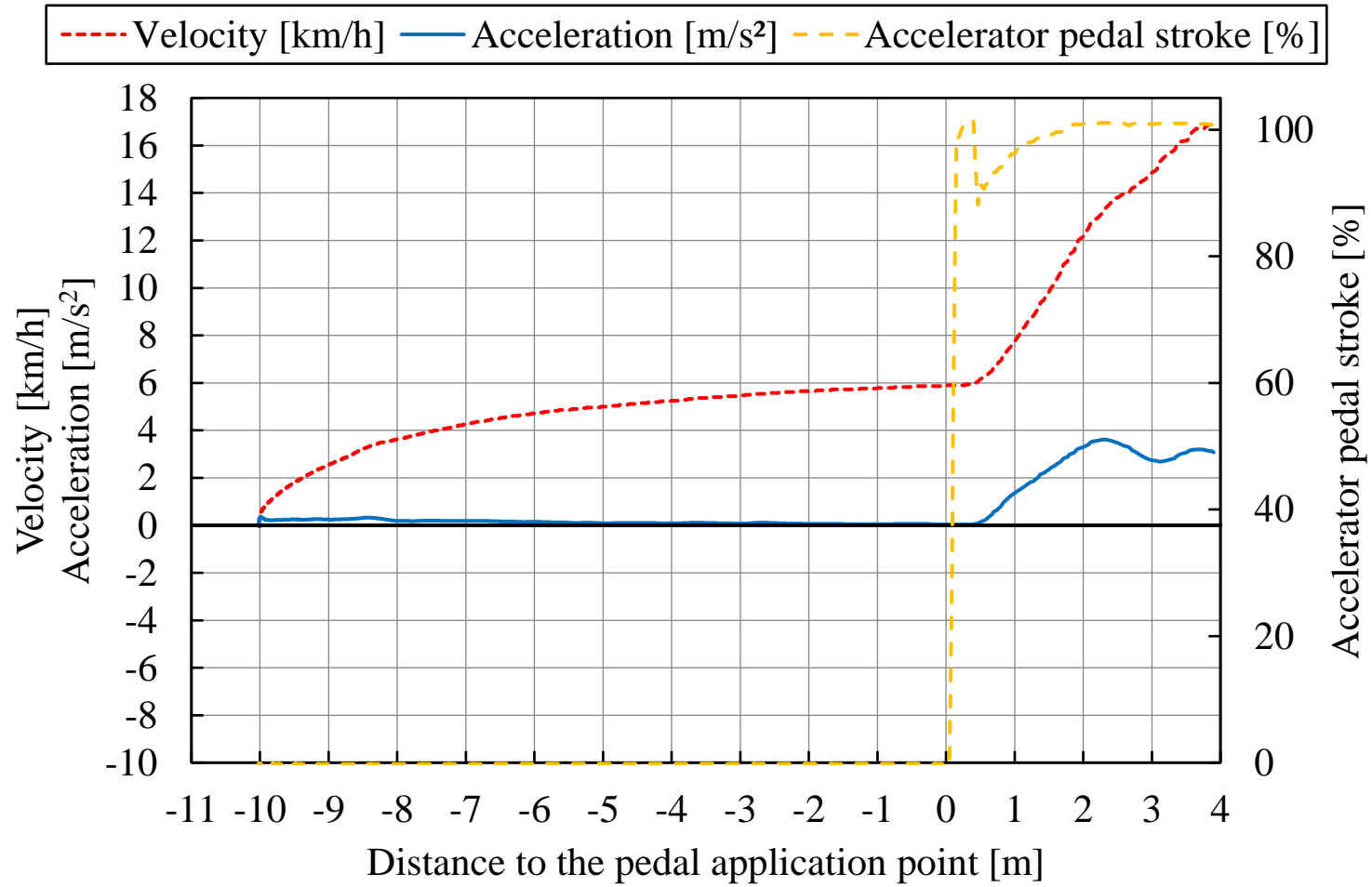
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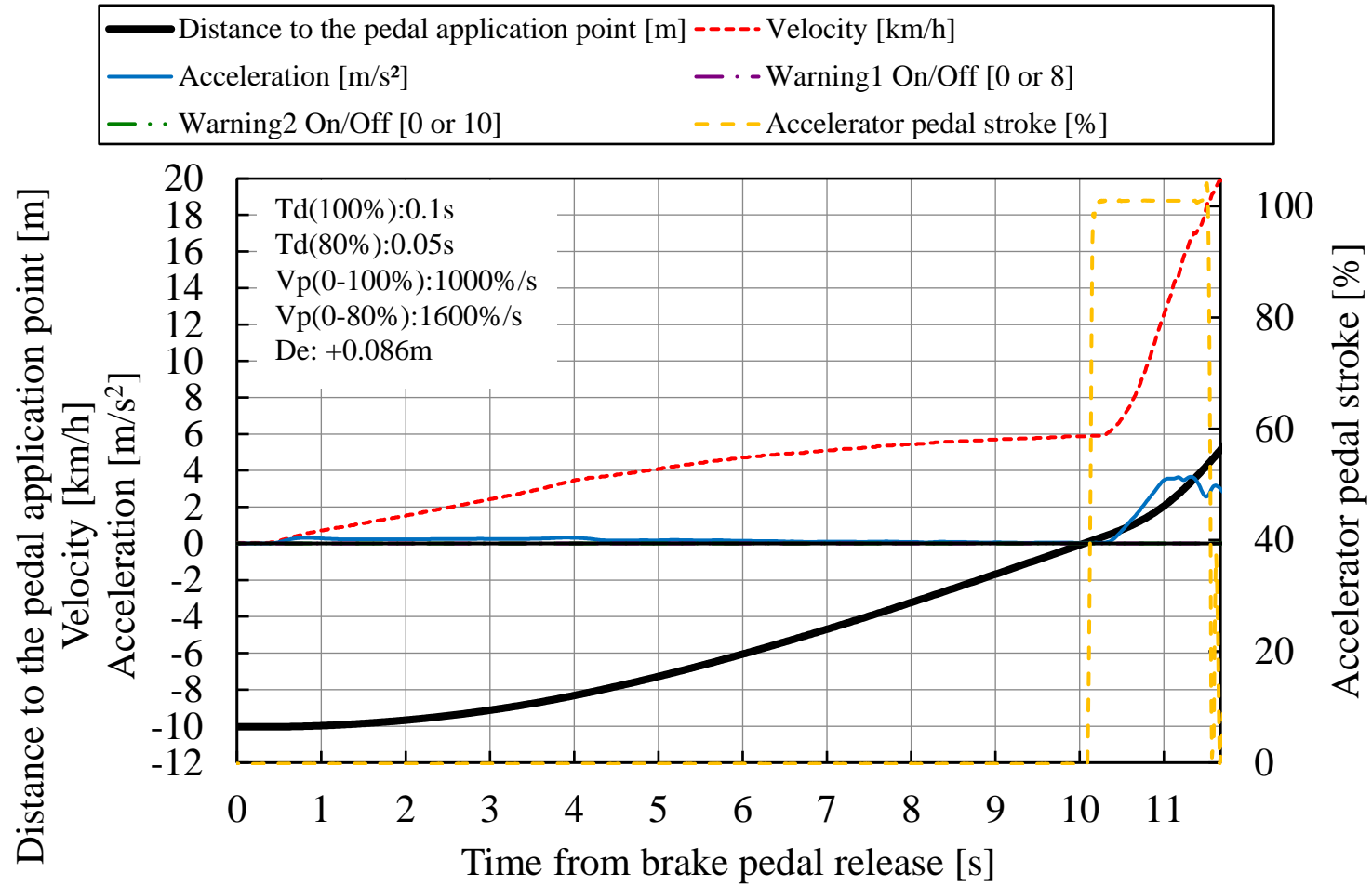
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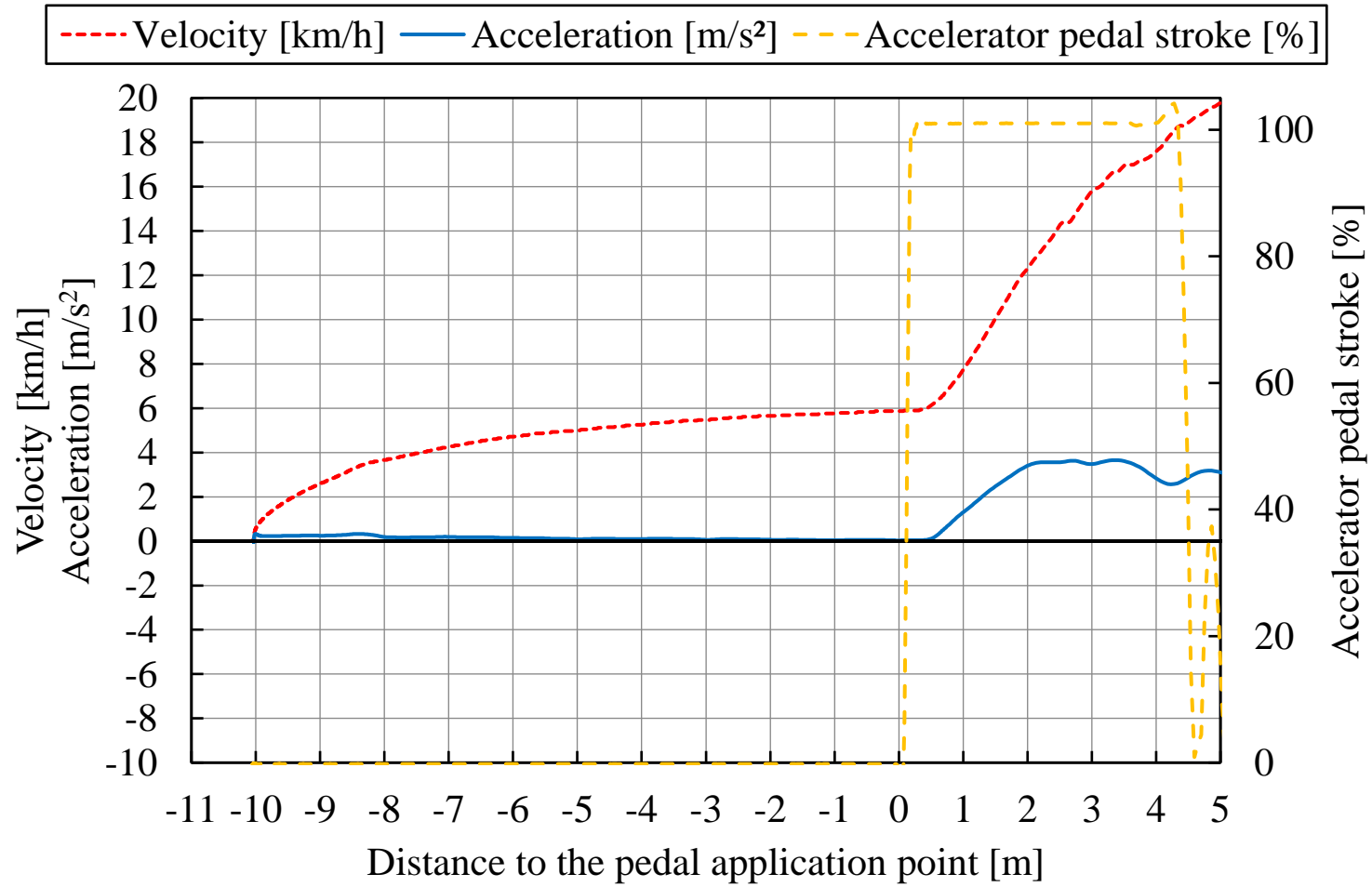
### Backward\_Vehicle\_2m\_No.1



### Backward\_Vehicle\_3m\_No.1

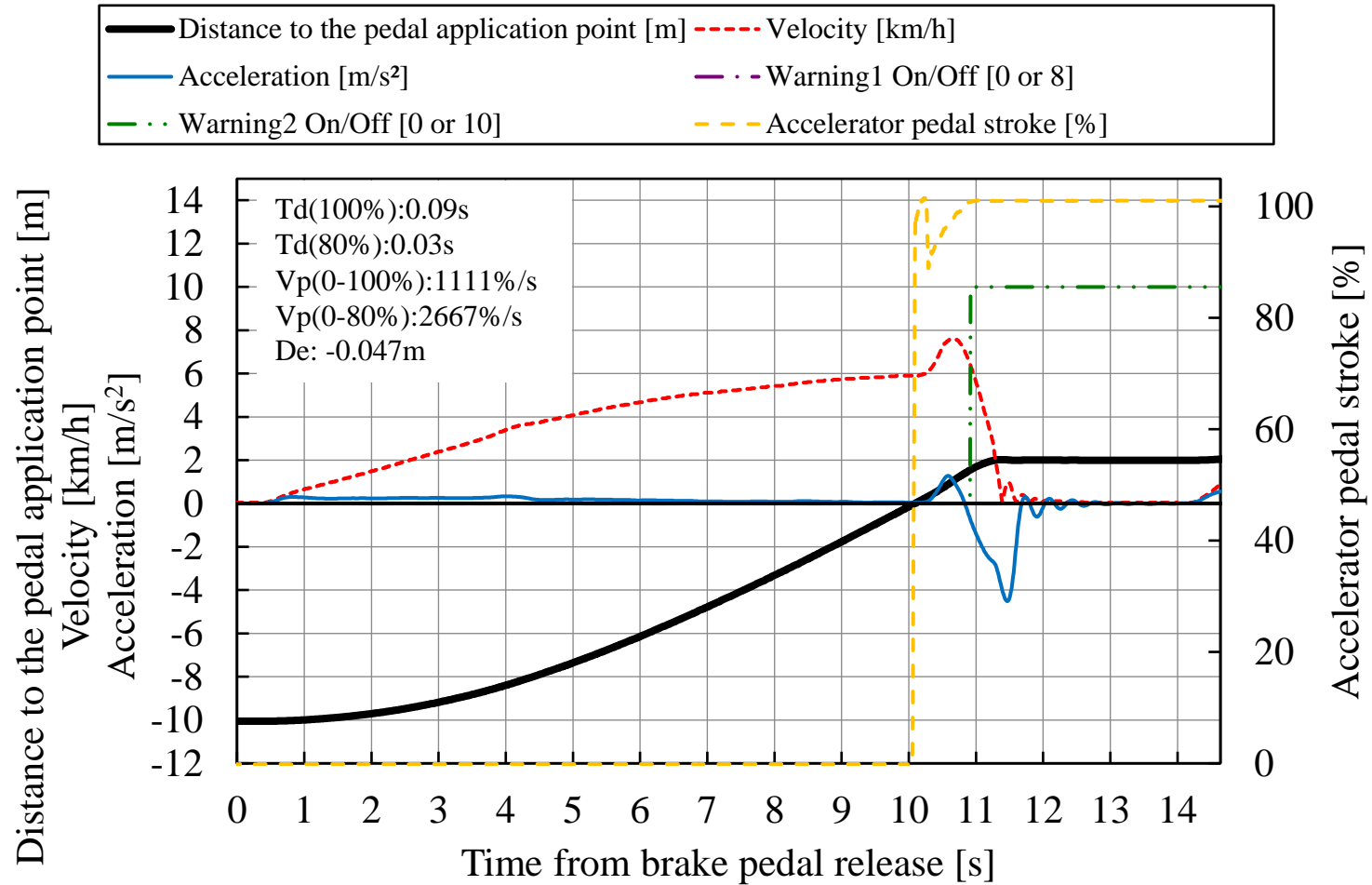


### Backward\_Vehicle\_3m\_No.1

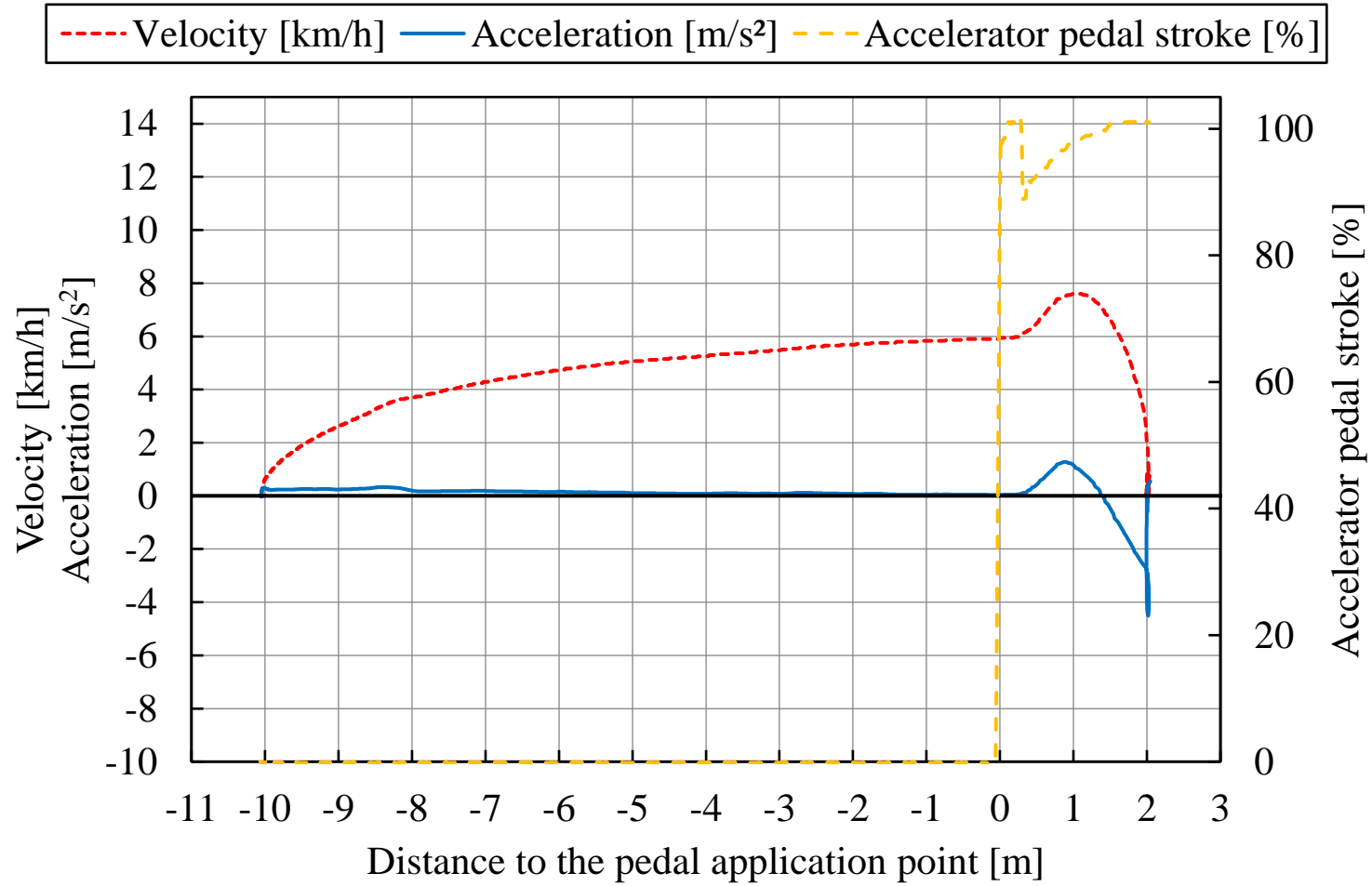




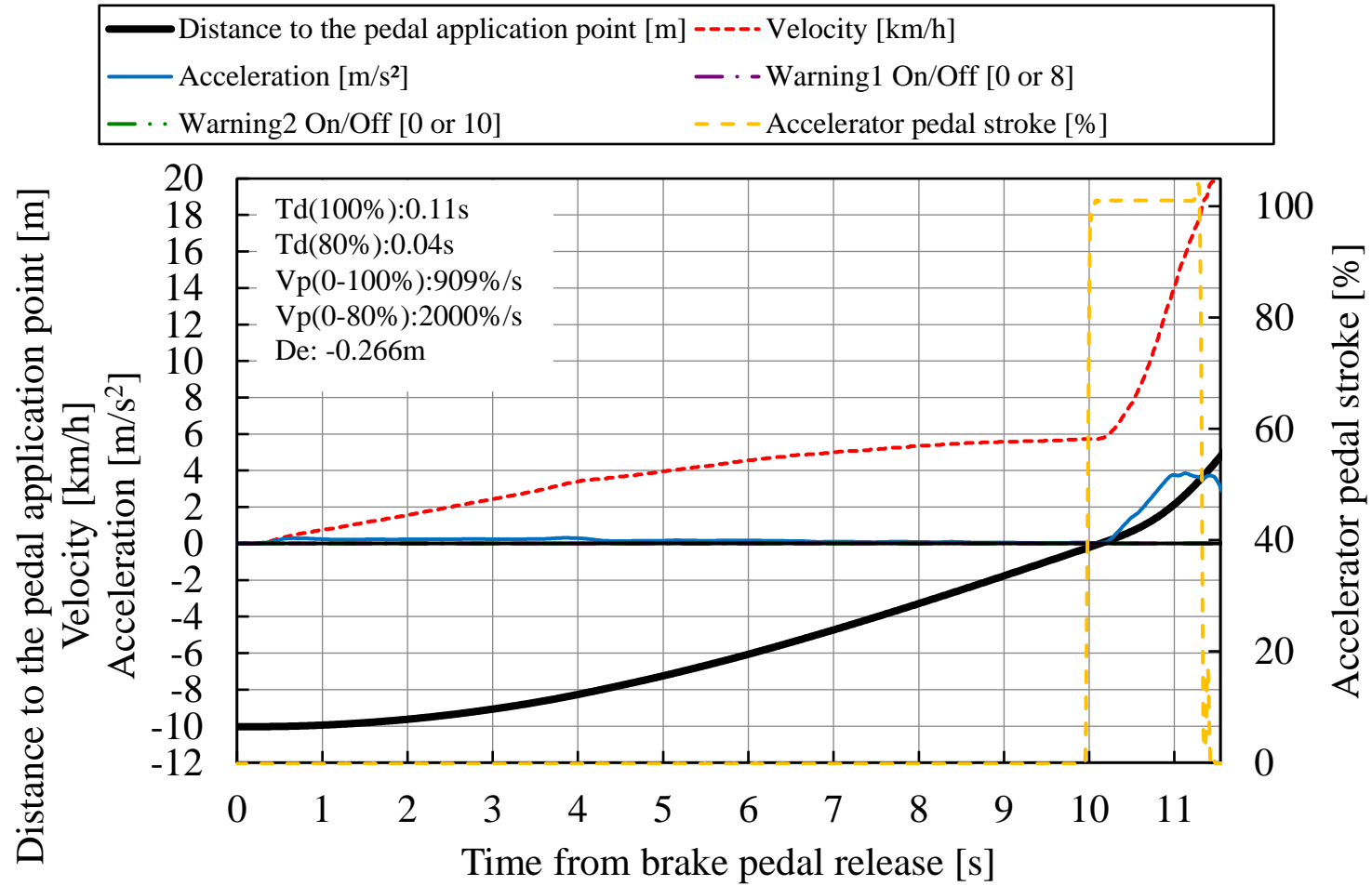
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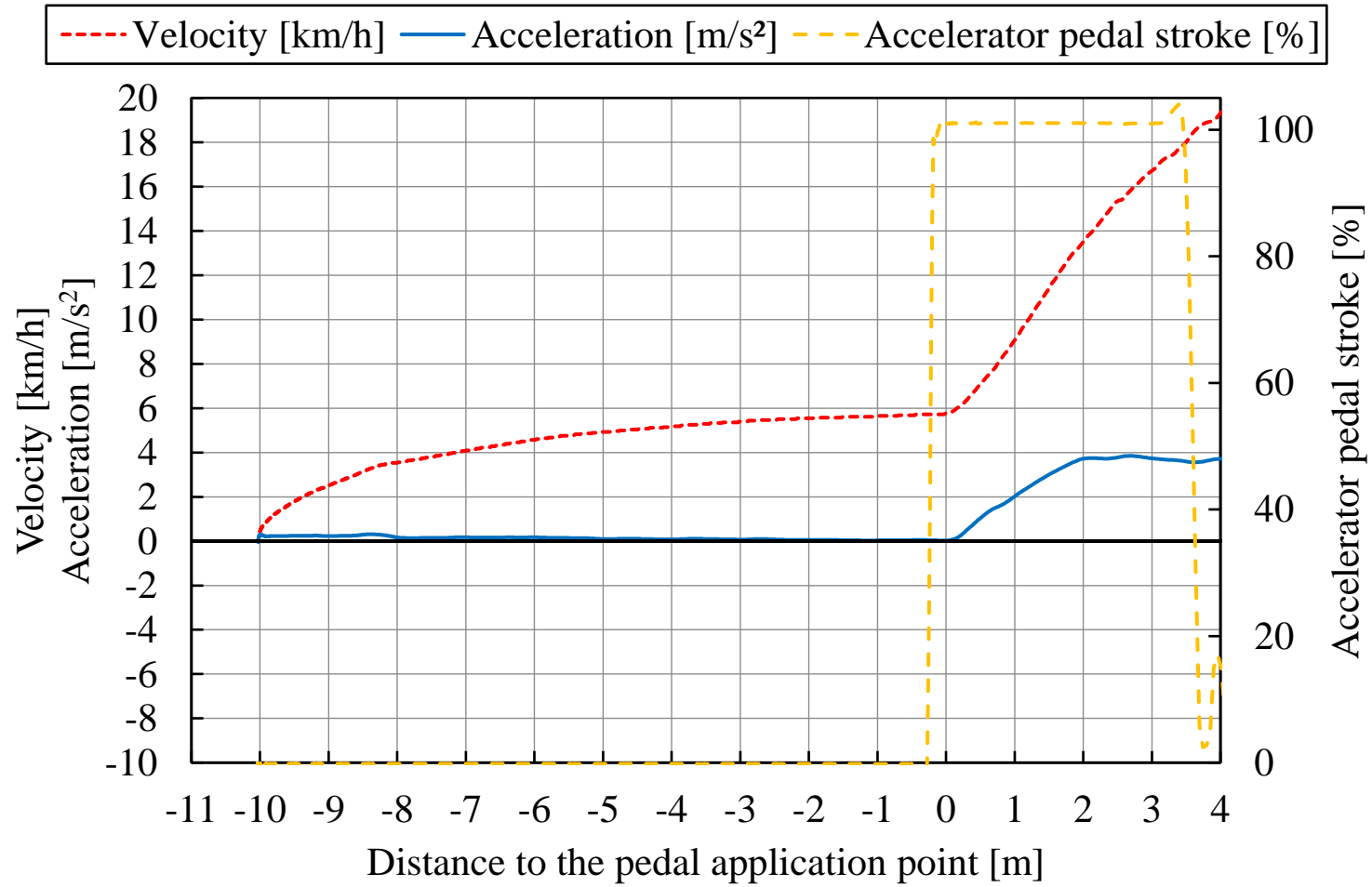
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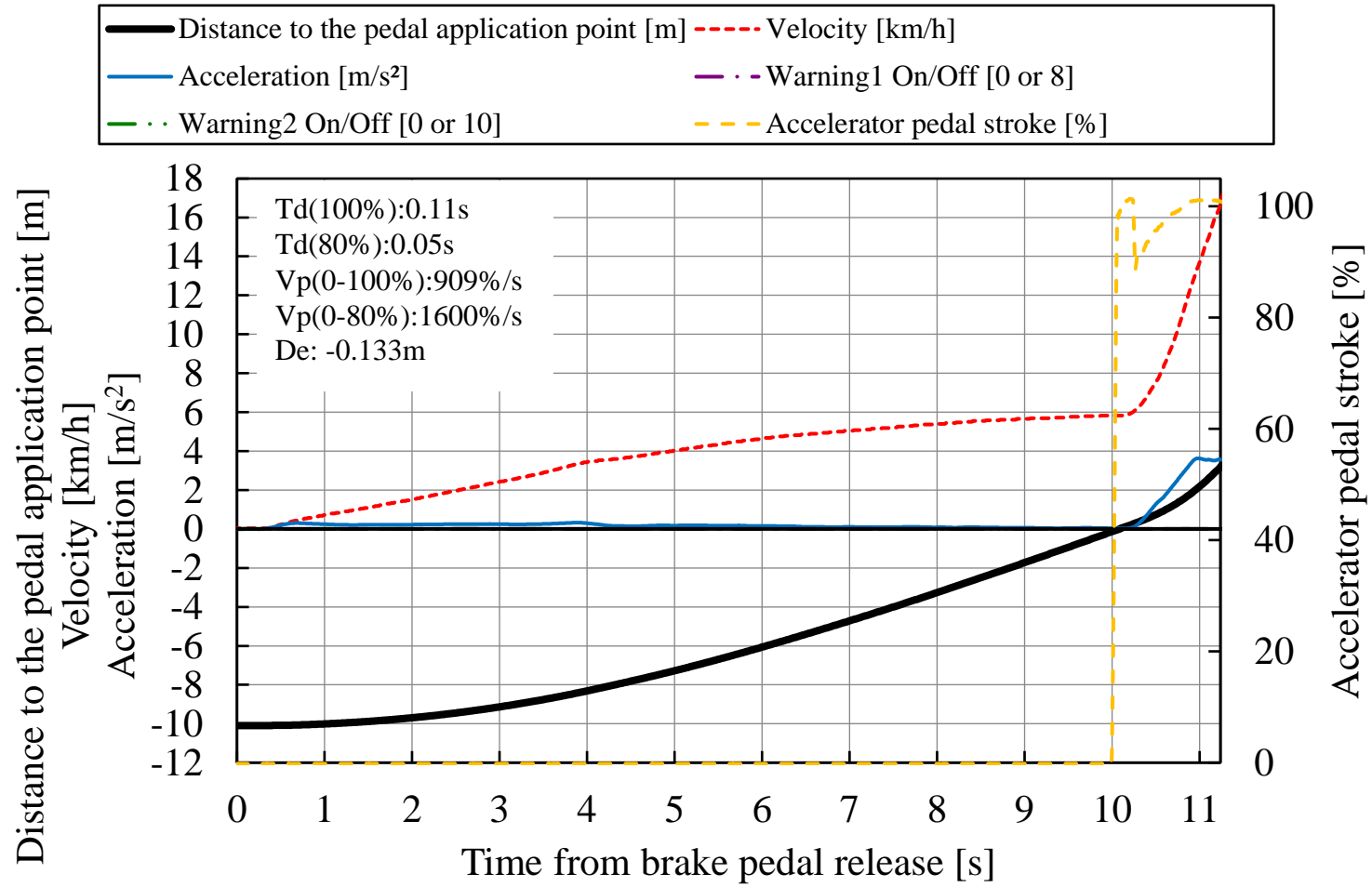
### Backward\_Adult\_3m\_No.1



### Backward\_Adult\_3m\_No.1



### Backward\_Child\_2m\_No.1



### Backward\_Child\_\_2m\_\_No.1

