Study about Audible Warning system effects for VRU safety

JAPAN

Test Methods

Participants: Total 24 drivers
Average 38.5±11.7 years old (20's, 30's, 40's, 50's x male/female x 3)

Test condition
- Audible warning timing
  5 cases of timing, every participants experienced each conditions 5 trials (randomized order)

	Positions of audible warning indication
Case 1	0.0m reversing (just after R-range selected)
Case 2	0.5m reversing
Case 3	1.0m reversing
Case 4	2.5m reversing
Case 5	No warning

Measurements
- GPS for vehicle motion and camera for driver behavior equipped for test vehicle.

Measurements		Device	Accuracy
Vehicle motion	Position (reversing distance) Speed (reversing speed) Audible warning output Gear position (Reverse range)	VBOX3i SL-RTK VBOX3i SL-RTK VBOX3i SL-RTK VBOX3i SL-RTK	0.01m (100Hz) 0.01km/h (100Hz) 0.1mV (100Hz) ON/OFF (100Hz)
Driver behavior	Pedal operation Eye sight direction	Small camera Small camera	(30Hz) (30Hz)

Test Methods

Instructions for participants
- Reversing to parking lot about 10m behind.
- In case of aware audible warning, braking for decelerate vehicle and stop as soon as possible.
- Carefully drive imagining being at a parking lot of typical commercial facilities where people and cars come and go.

Before driving,
- Participants confirm the difference between audible warning and information sound for “reverse gear”.
- Participants confirm not to easy to see small child (about 1m height) behind the vehicle by direct or indirect vision from the driver’s seat.
- Participants exercised velocity, acceleration feel and braking feelings of test vehicle beforehand.

Instructions for audible waring and rear vision

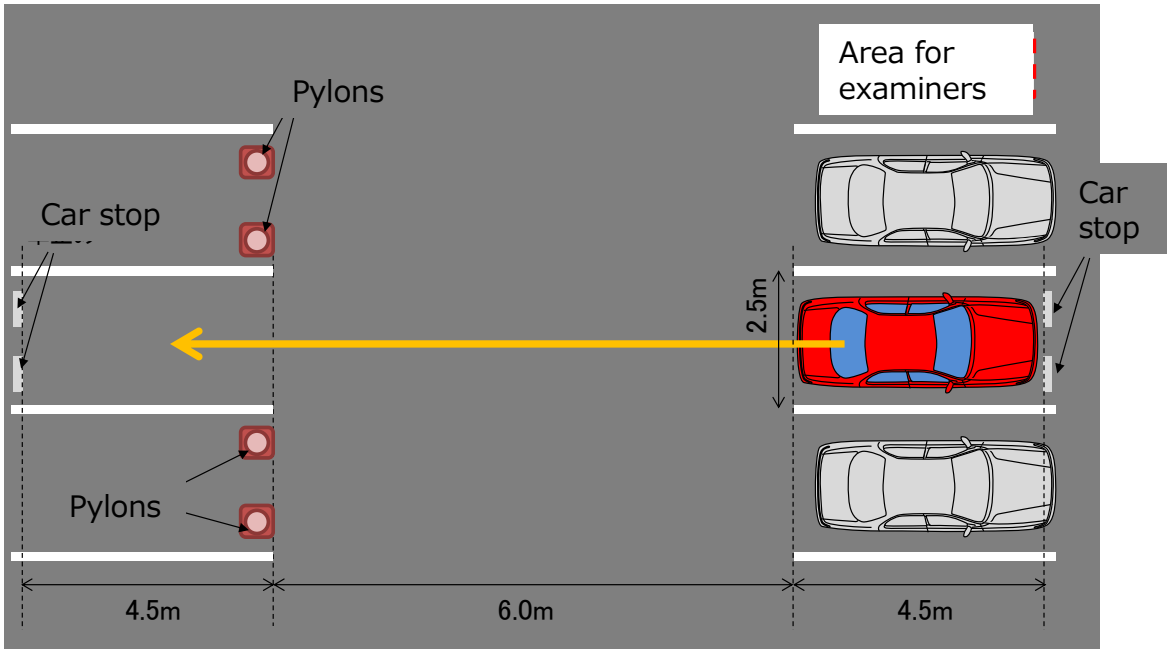
Exercise of reversing of test vehicle

Image of a parking lot of typical commercial facilities

Test Methods

Methods for driving

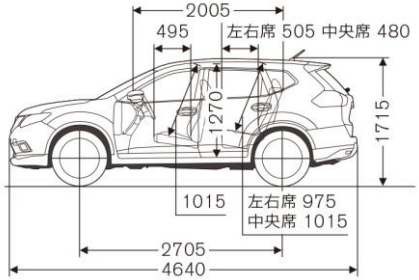
- Environments imitating public parking space set at proving ground (JARI)
- Task
  1) Reversing to parking lot about 10m behind
  2) In case of audible warning indication (buzzer), braking, decelerate and stop the vehicle.
- Audible warning was made for any timing indication.
- No obstacles located behind the vehicle.

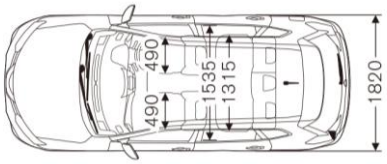


Test Methods

Test vehicle
- SUV (Nissan X-trail) used.
- Audible warning provided small speaker located upper-side of cluster.

Audible warning
・Continuous 1,220Hz
・70db at headrest

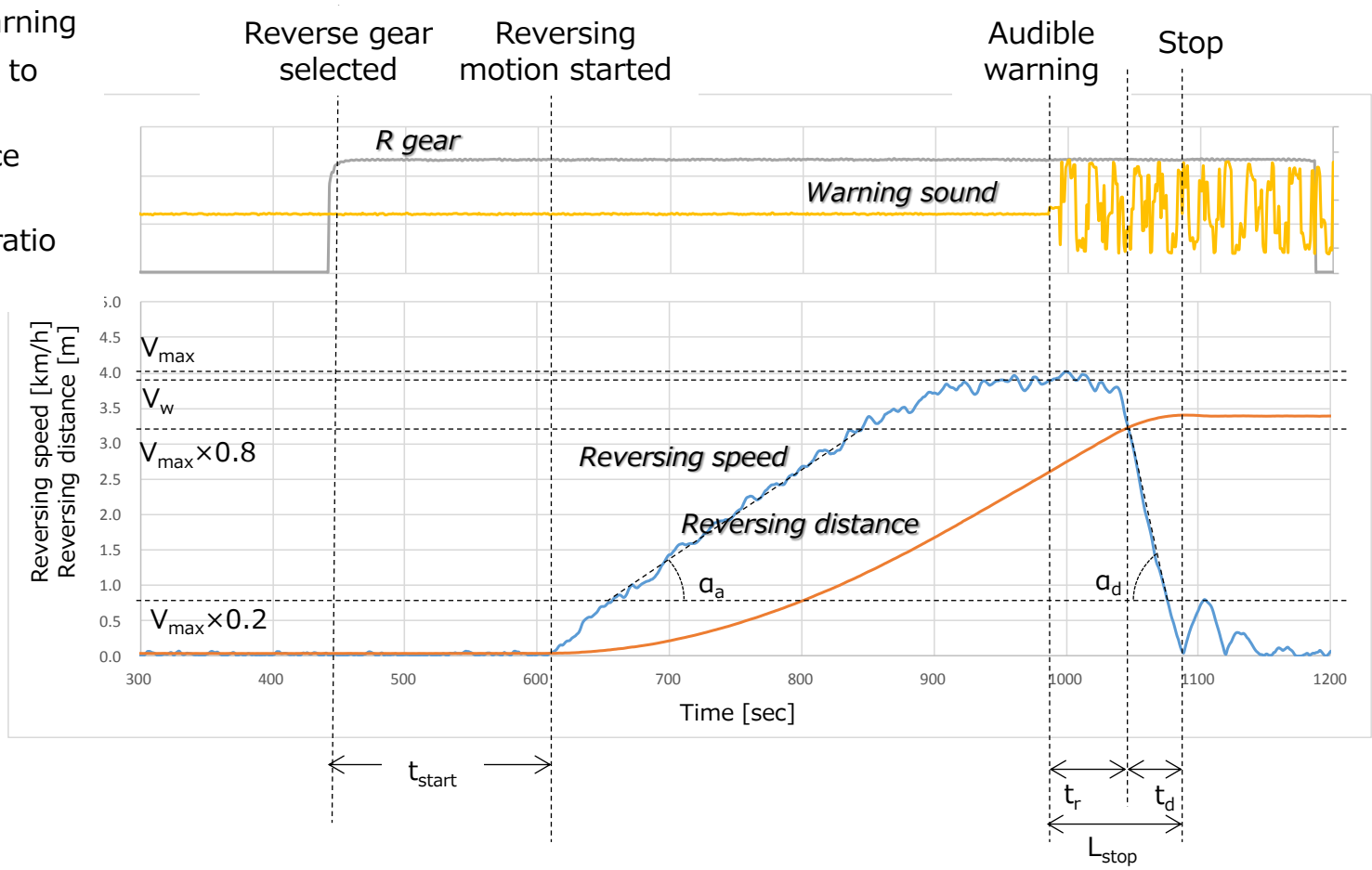




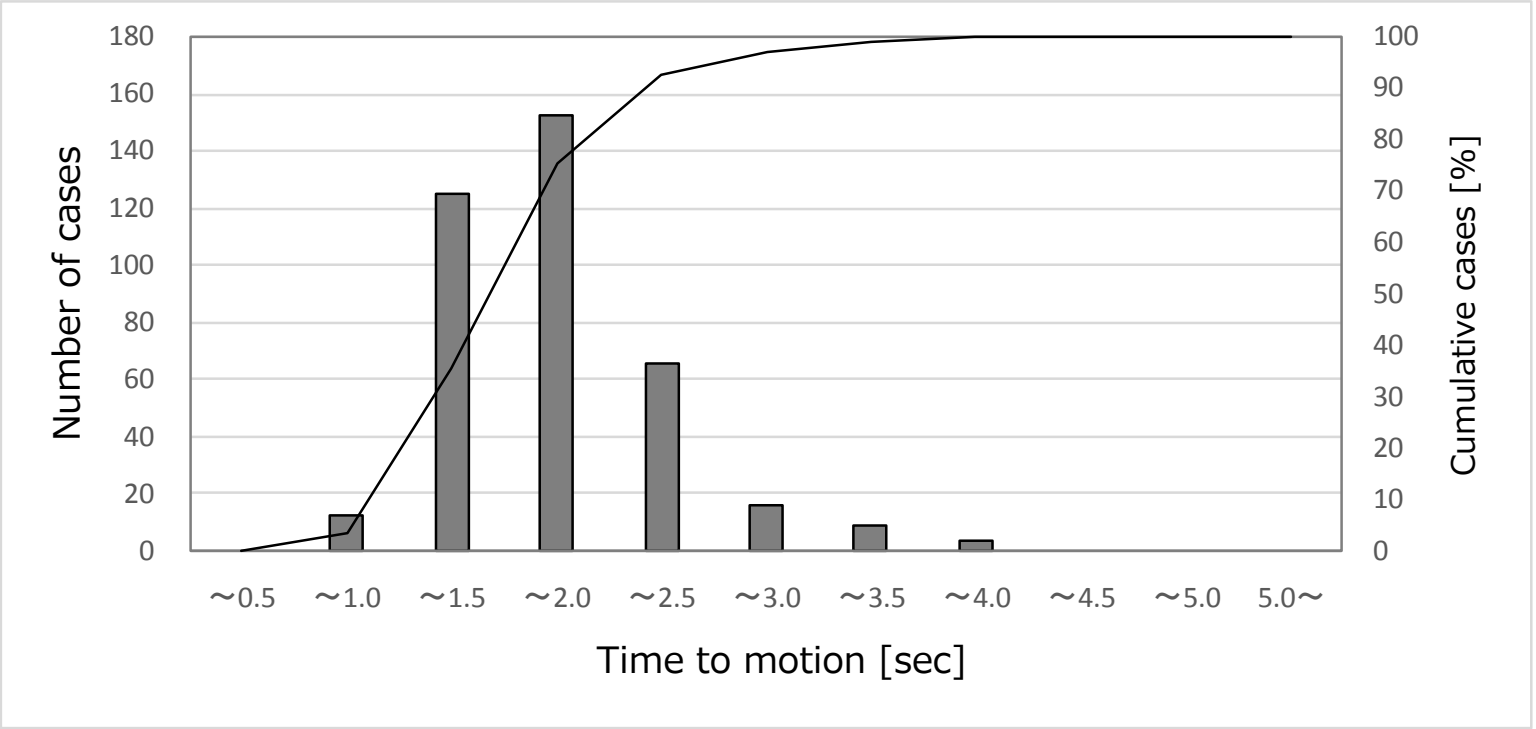
(http://history.nissan.co.jp/X-TRAIL/T32/1312/spec_dimensions.html)

Acquired data

1) t_{start} Time to vehicle move
2) a_a Acceleration
3) V_{max} Maximum velocity
4) V_w Velocity at warning
5) t_r Reaction time to warning
6) t_d Time to reduce speed
7) a_d Deceleration ratio
8) L_{stop} Stop distance



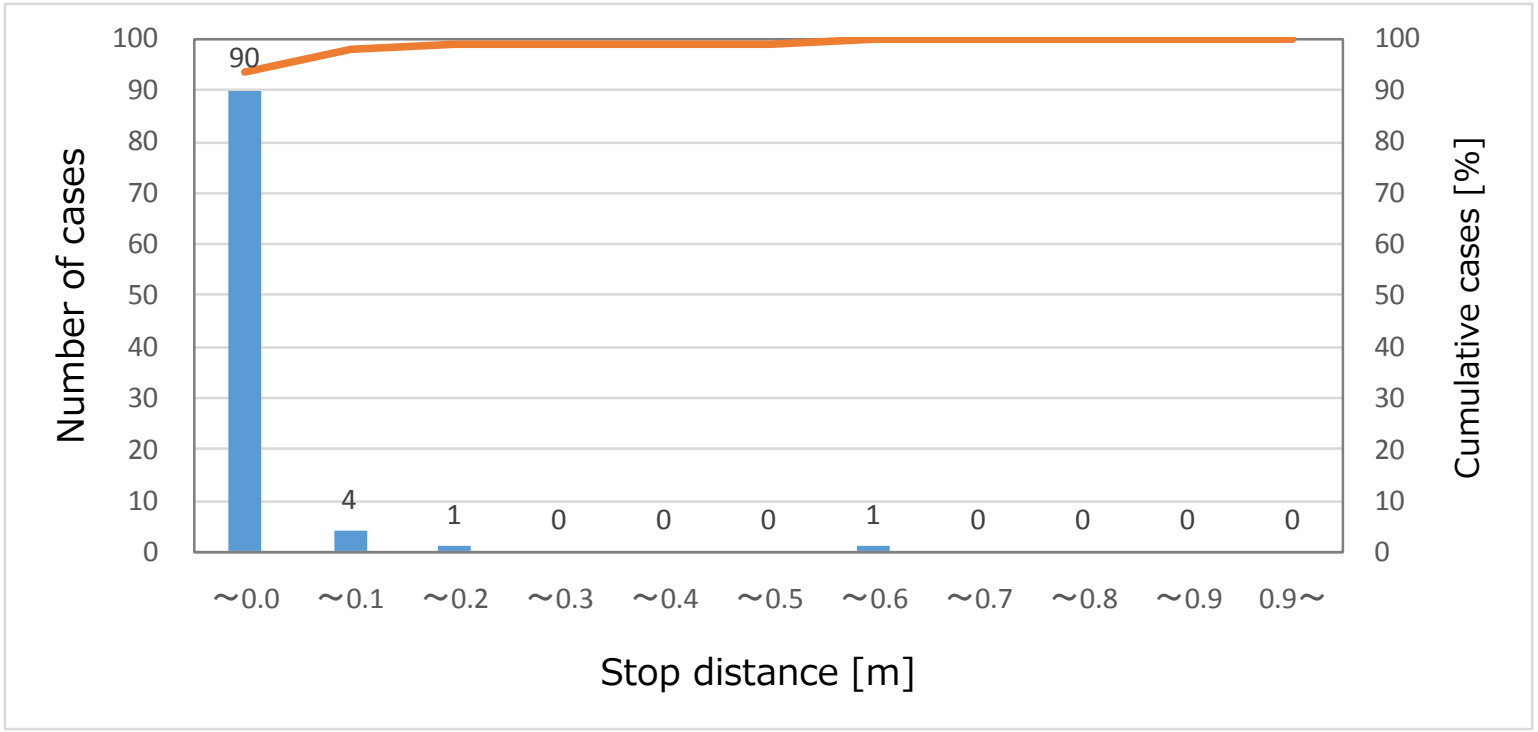
Results



Time to motion from reverse gear selected
(2~5 trial at Condition 2~5, N=384)

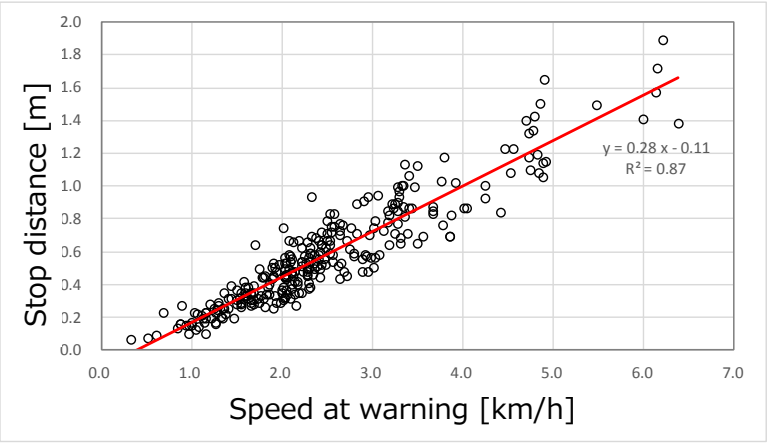
Results

※Total 6 time were not stopped. It was composed by 3 of 24 drivers.

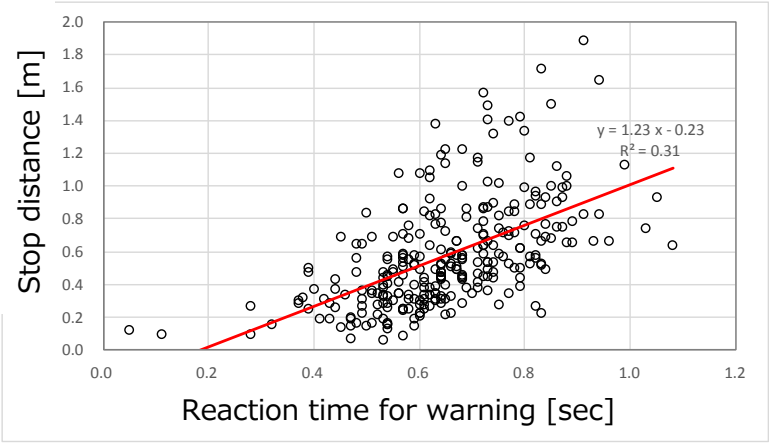


Stop distance just after reverse gear selected
(2~5 trial at Condition 1, N=384)

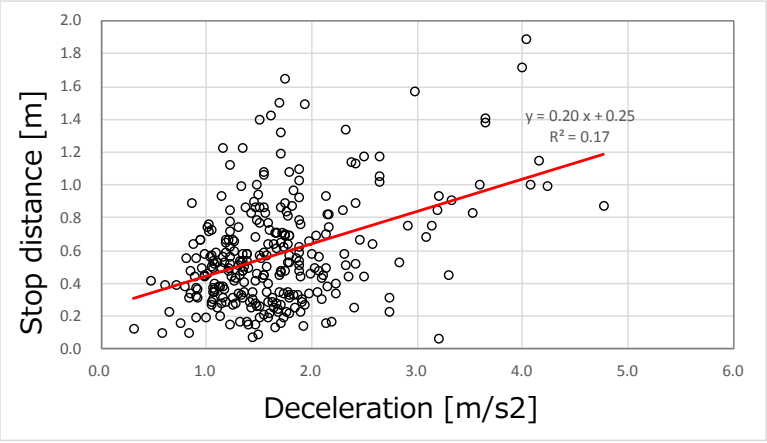
Results



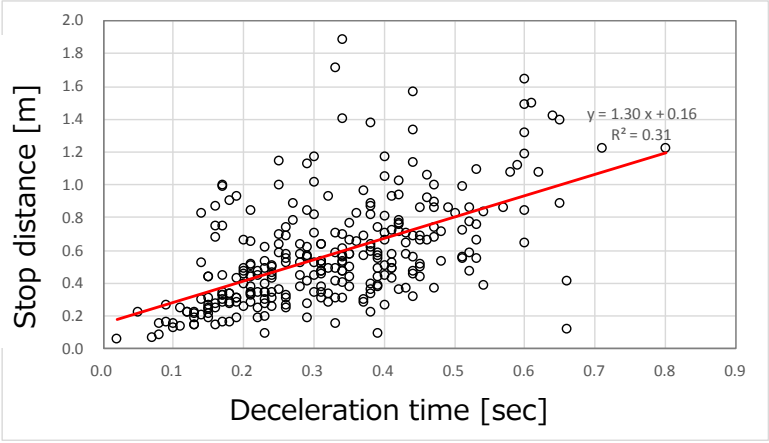
Speed at warning and stop distance
(2~5 trials at condition 2~4, N=384)



Reaction time for warning and stop distance
(2~5 trials at condition 2~4, N=384)



Deceleration and stop distance
(2~5 trials at condition 2~4, N=384)

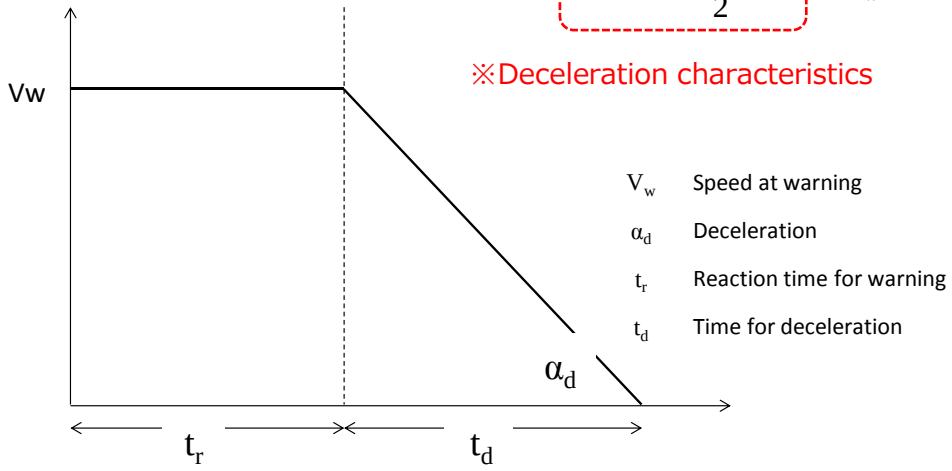


Deceleration time and stop distance
(2~5 trials at condition 2~4, N=384)

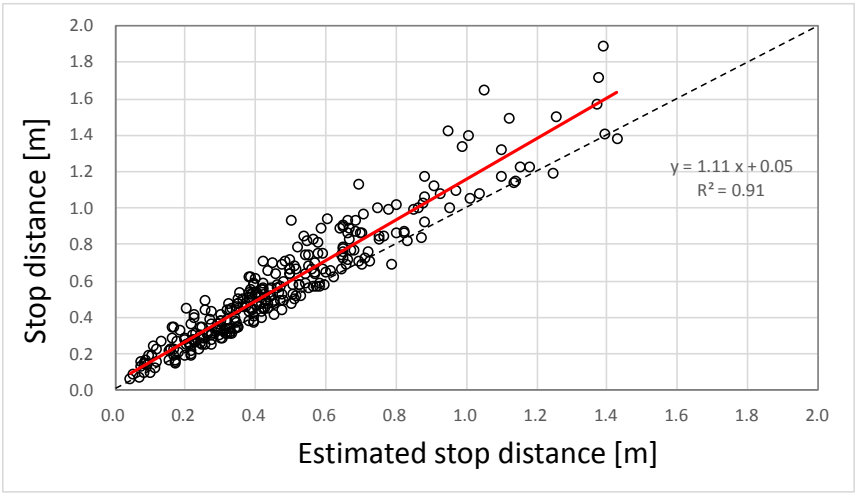
Modeling of reversing behavior for warning

Estimated stop distance $= \left(t_r + \frac{t_d}{2} \right) \times V_w$

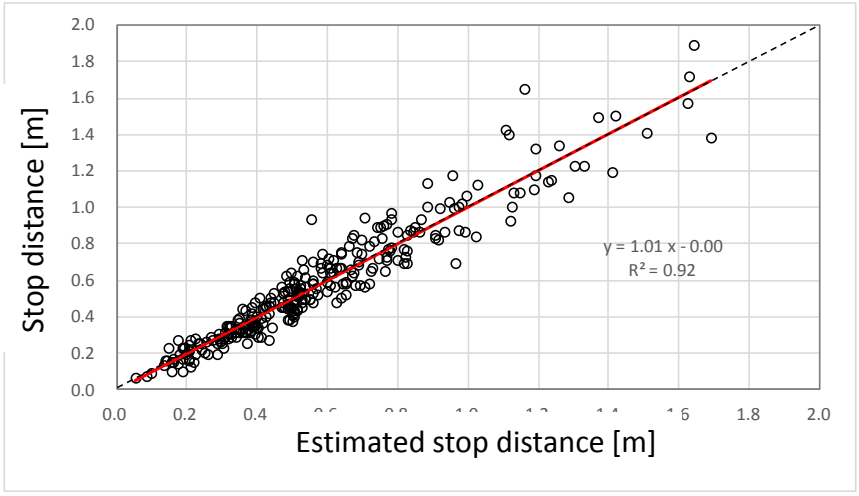
※Deceleration characteristics



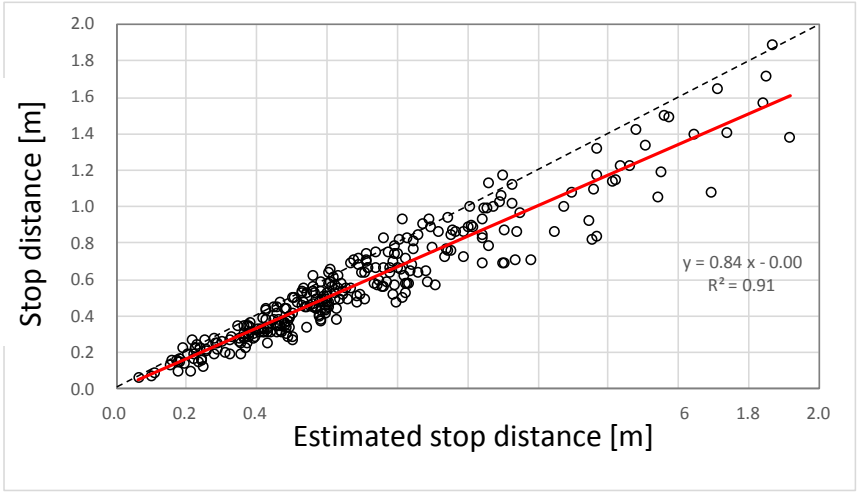
V_w	Speed at warning
α_d	Deceleration
t_r	Reaction time for warning
t_d	Time for deceleration



Case: Estimated using minimum data from subjects



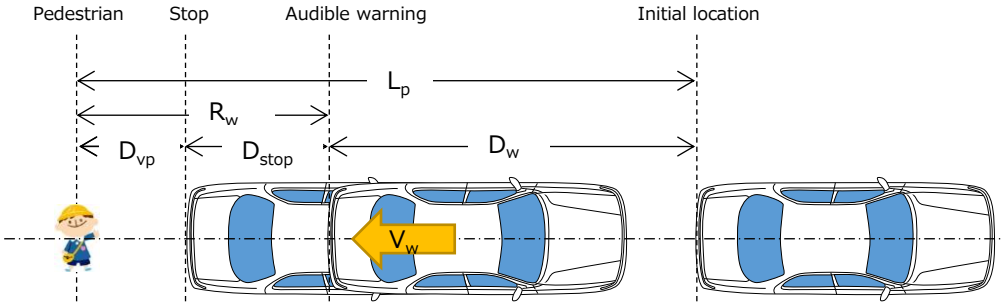
Case: Estimated using mean data from subjects



Case: Estimated using maximum data from subjects

Methods for numerical simulation

Calculate Stop distance (D_{vp}) for all combinations (total 31,104 cases) of Warning distance(R_w), Pedestrian distance (L_p) and drivers (ID01~ID24).



Choice of Range of audible warning (R_W)
※0.1m step from 0.0～3.5m (total 36 cases)

↓

Choice of Pedestrian distance (L_P)
※0.1m step from 0.0～3.5m (total 36 cases)

↓

Choice of driver
※ID01~ID24 (total 24 cases)

↓

Indicate waring before reversing motion ($L_P \leqq R_w$)

YES → Estimate Stop distance (D_{stop}) $D_{stop} = D_{dbsw}$

NO ↓

Calculate Speed at audible warning (V_W)

$$V_w \begin{cases} = \sqrt{2(L_p - Rw)\alpha_a} & (\sqrt{2(L_p - Rw)\alpha_a} \leq V_{max}) \\ = V_{max} & (V_{max} > \sqrt{2(L_p - Rw)\alpha_a}) \end{cases}$$

↓

Estimate Stop distance (D_{stop})
$D_{stop} = T_{cv} \cdot V_w$

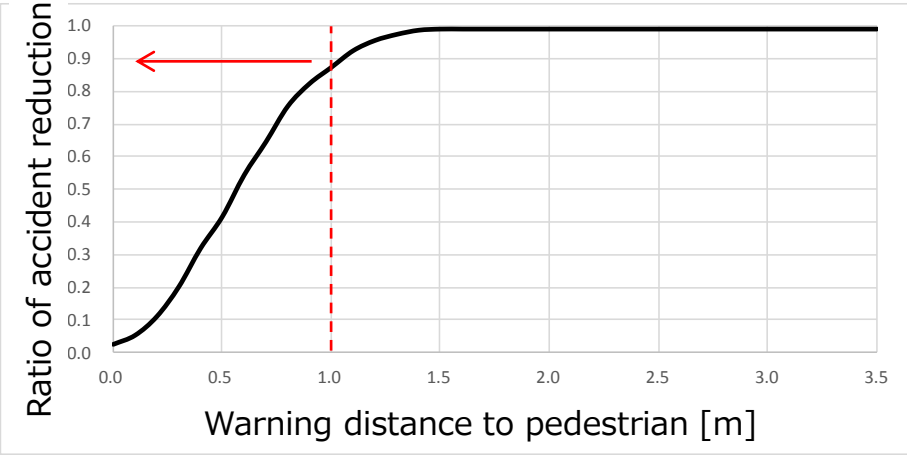
↓

Calculate Stop distance to pedestrian (D_{vp})
$D_{vp} = R_w - D_{stop}$

Conditions	R_w	Range of audible warning (0.0~3.5m)
	L_p	Pedestrian distance（0.0m～3.5m）
	D_{dbsw}	Stop distance in case of warning indicated before reversing motion (ID01~ID24) -> Maximum for each participants (condition 1)
	α_a	Reversing acceleration (ID01~ID24) -> Maximum for each participants (condition 5)
	V_{max}	Maximum of reversing speed (ID01~ID24) -> Maximum for each participants (condition 5)
	T_{cv}	Deceleration characteristics (ID01~ID24) -> Mean for each participants (condition 2~4)
Calculated data	D_w	Reversing distance for audible waring
	V_w	Speed at audible warning
	D_{stop}	Estimated stop distance
	D_{vp}	Stop distance to pedestrian

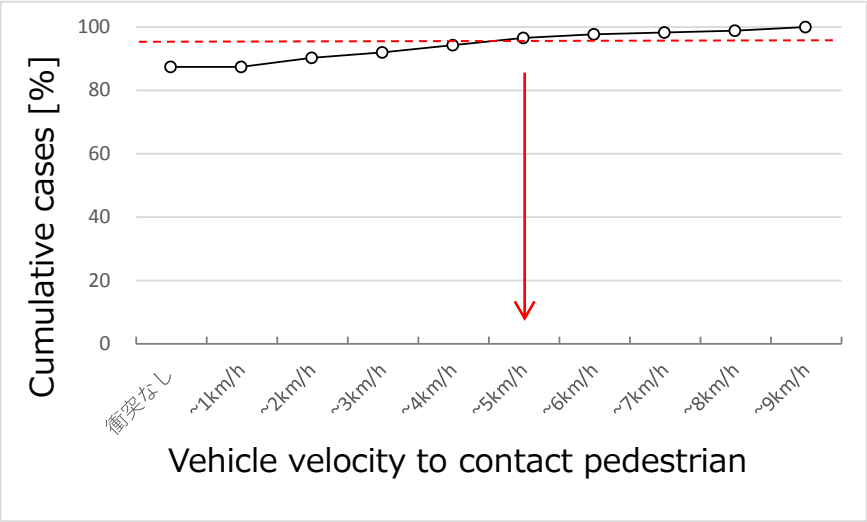
Calculations of the waring effects

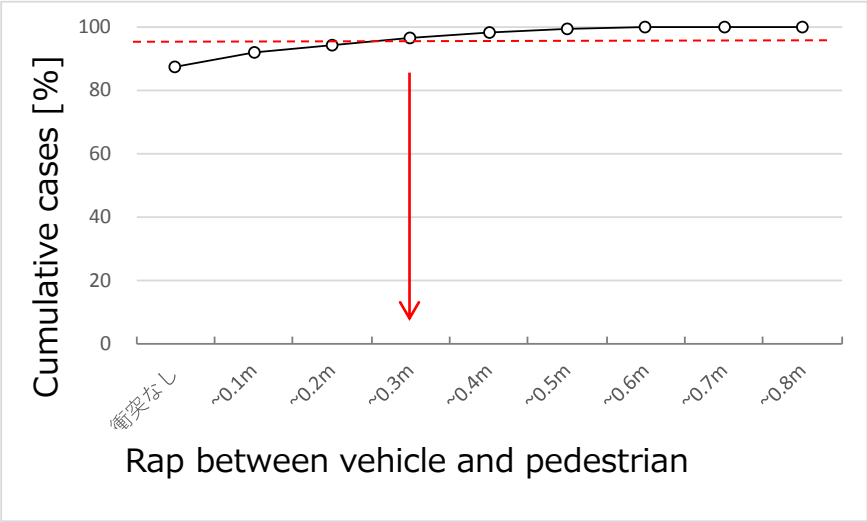
Percentage of “vehicle stop before reaching pedestrian (D_{vp}<0)“ were calculated as Ratio of accident reduction in each warning distance cases (total 864 cases).



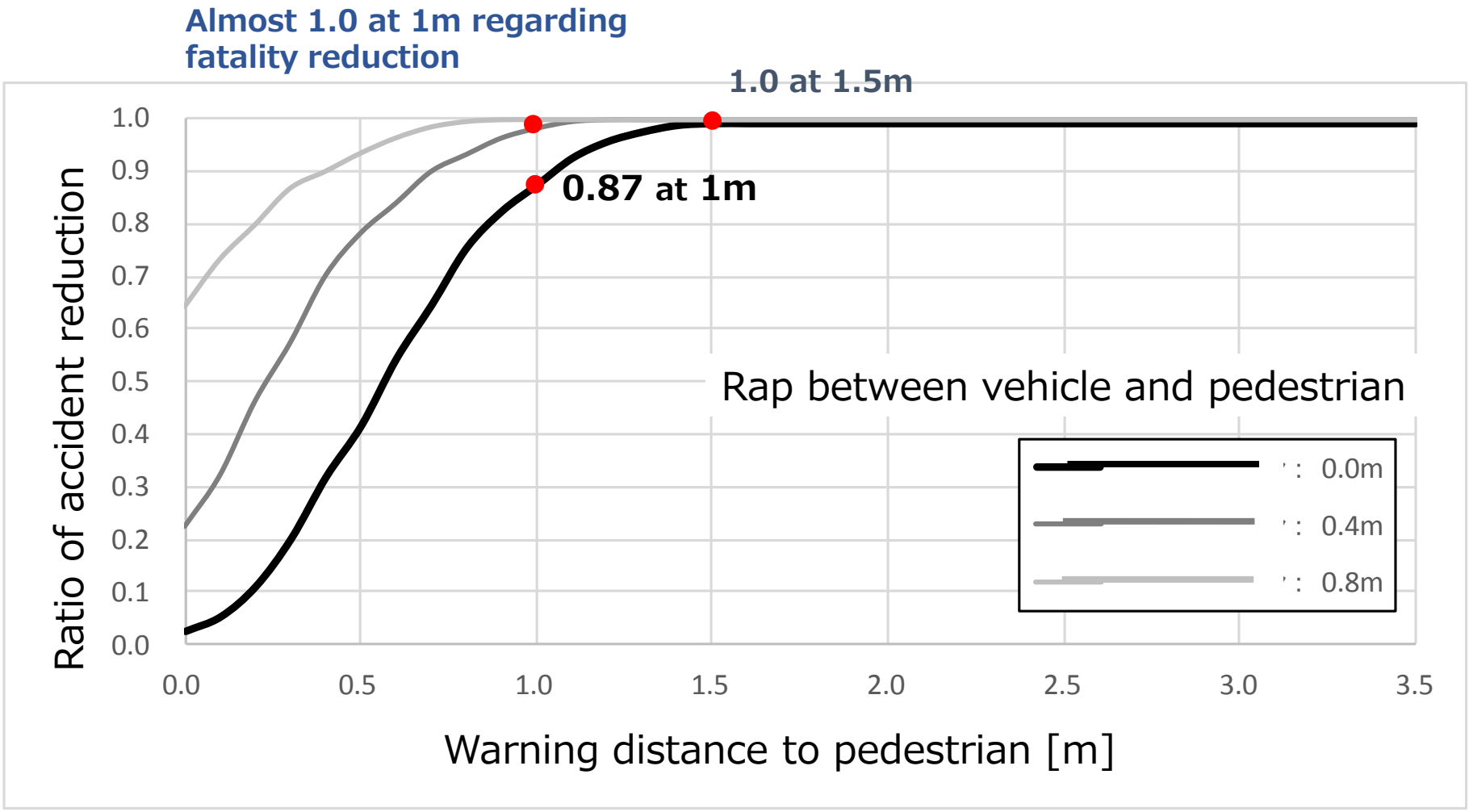
87% accident was reduced at 1m warning distance.

Effects of waring for damage reduction are shown in deceleration.
Vehicle speed of contact pedestrian is about 4km/h, Rap between vehicle and pedestrian is about 0.2m in the most of cases (95%tile) at 1m waring .





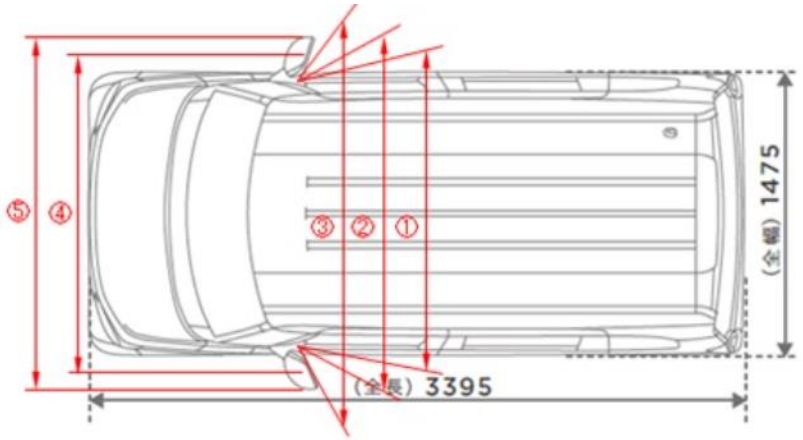
Simulation results

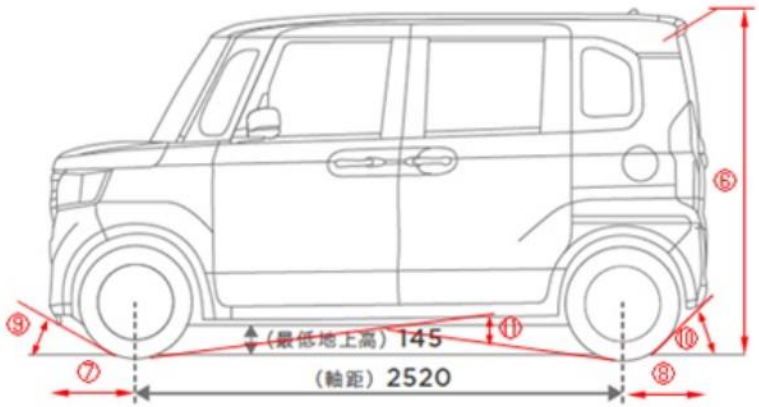


Cf. Small vehicle rear overhang short type : 0.43m

Appendix

Honda N-WAGON dimension





図の車両は、N-BOX G・Honda SENSING（FF）です。

数値表示箇所	状態			数値
①	両側フロントドアを開いた時の車幅	1段階目		2,495mm
②		2段階目		2,825mm
③		全開時		3,345mm
④	ドアミラーを含む車幅	ミラー閉時		1,650mm
⑤		ミラー開時		1,825mm
⑥	リアゲート全開時の全高	N-BOX N-BOX Custom（スロープ仕様除く）	FF	1,940mm
			4WD	1,960mm
		N-BOX（スロープ仕様）	FF	1,955mm
			4WD	1,975mm
		N-BOX Custom（スロープ仕様）	FF	1,965mm
			4WD	1,985mm
⑦	オーバーハング	フロント		445mm
⑧		リア		430mm
⑨	アプローチアングル	N-BOX	FF	24.5°
			4WD	26°
		N-BOX Custom	FF	25°
			4WD	23.5°
⑩	デパーチャーアングル	N-BOX（スロープ仕様除く）	FF	33°
			4WD	35°
		N-BOX Custom（スロープ仕様除く）	FF	32°
			4WD	34°
		N-BOX N-BOX Custom（スロープ仕様）	FF	31°
			4WD	33°
⑪	ランプブレークオーバーアングル	FF		15°
		4WD		16.5°

※記載数値は参考値であり、車両状態や測定方法などで異なります。

Honda HP
（https://customer.honda.co.jp/faq2/userqa.do?user=customer&faq=faq_auto_sp&id=69628&parent=60455）

Monitoring Range of Audible Warning System

Extracted from published material.

OEM	Vehicle Name	Monitoring Range (cm)				Comment
		Front Center	Front Corner	Rear Center	Rear Corner	
MALSO(ISO17386)		60	50	100	50	
TOYOTA	Crown:2018	100	60	150	60	
NISSAN	LEAF:2017	100	60	150	60	
HONDA	LEGEND:2018	×	60	110	60	
Mazda	CX-8:2017	100	55	150	55	
Mitsubishi	Eclipse-cross:2018	60	60	125	60	
Subaru	Levorg:2017	×	×	150	?	
Daihatsu	Thor:2017	100	60	150	60	
Daimler	C class:2014	100	60	120	80	
Daimler	A class:2018	30	?	100	?	@default setting
BMW	7 series:2016	70	60	150	60	
VW	Golf7:2013	120	60	160	60	
VW	Passat:2014	120	60	160	60	
Volvo	XC40 : 2018	80	?	150	?	
Tesla	Model S:2015	70※	?	90※	?	Measurement value