Estimation of Traffic Fatality Reduction by Automated Driving Systems

Yasushi NISHIDA and Makoto SHIOTA

Institute for Traffic Accident Research and Data Analysis, Japan

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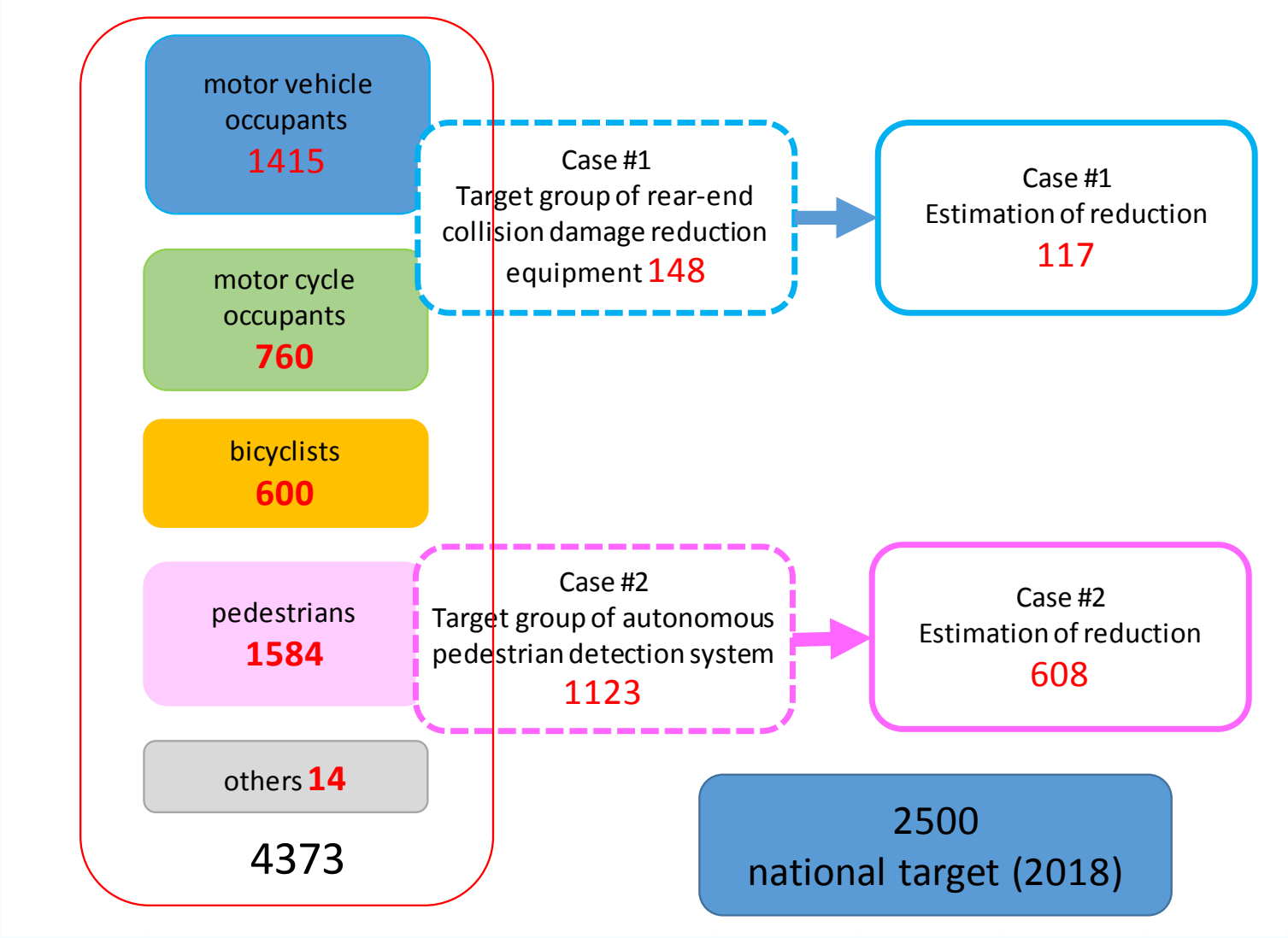
Traffic fatalities by type of road user in 2013



1. Grand Plan (Activities of ITARDA and other groups)

Macro-data

Accident Data 2013
- fatalities : 4373
- Serious : 44547
- Slight : 736947

Accident Data 2014
- fatalities : 4113
- serious : 41657
- Slight : 669717

pattern -ization

Grouping of pattern sheets

Car vs Car

	CTC01	CTC02	CTC03			CTC04
		SCA01			SCA02	SCA03

count

Accident pattern sheets

Pattern sheet #nnn

Pattern sheet #002

Pattern sheet #001 (CTC-01)

	fatal	serious	slight	total
ACCIDNT				
CASUALTY				

2014

analysis

2015

analysis

Detail Accident Analysis Sheet

2016

Braking

▲70 fat.

Estimation of Reduction of Fatalities by Automated Driving Systems

analysis

▲600 fat.

2. Topics of the Presentation

- ○ Patternization of Traffic Accidents
- ○ Accident Pattern Sheets
- ○ Trial Estimation of Traffic Fatality Reduction by Automated Driving Systems
- ○ Topics for Discussion

3. Accident Data Items for Patternization

Primary Party	Road Category	Collision Type	Road Type	Maneuver of Primary Party	Direction of Secondary Party
vehicle motorcycle bicycle pedestrian **Secondary Party** vehicle motorcycle bicycle pedestrian	Public road (non-expressway /non-motorway)	Pedestrian-Vehicle *facing vehicle *back to vehicle *crossing the road ・・・・・・ Vehicle-Vehicle *head-on collision *rear-end collision *angle collision *col. while turning left *col. while turning right ・・・・・・ Single Vehicle *col. with structures *col. with parked vehicle *running off the road ・・・・・・	signalized intersection non-signalized intersection vicinity of intersection non-intersection * tunnel/bridge * curve or bend * other other (not road)	starting up/ going forward changing lane turning left turning right U-turning going backward crossing other	<vehicle> coming from *opposite *left *right going the same direction standing/parking <pedestrian> facing/back *left side *right side crossing from *left *right other
	Expressway /motorway	Pedestrian-Vehicle Vehicle-Vehicle *rear-end collision *other collision *other Single Vehicle *col. with structures *col. with parked vehicle *running off the road ・・・・・・			

Total : 31500 patterns

To select patterns
with more than 3 fatalities

4. Patternization of Accident Types

ITARDA Macro Data

Accident Data 2013

Fatalities：4373
Serious Injuries：44547
Slight Injuries：736947

Matters considered for Patternization

1. Useful for the impact assessment of safety devices
2. Suitable size of database
3. Easy to understand the context of the concerned accident

Patternization

255 patterns

Grouping of Pattern Sheets

	CTC01	CTC02	CTC03			CTC04
		SCA01			SCA02	SCA03

n=3500 fatalities

Count for each sheet

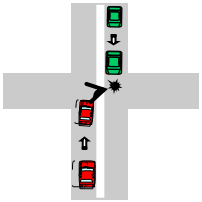
...

Accident Pattern Sheet #XXX

Accident Pattern Sheet #002

Accident Pattern Sheet #001 (CTC-01)

	fatal	serious	slight	total
Accidents				
Casualties				



Each cell(accident pattern) has more than 3 fatalities.

3500 fatalities (80% of 4373 fatalities) are involved in the selected 255 patterns.

5. Summary of Accident Patterns

255 patterns are selected from 31500 patterns, and 3500 fatalities (80% of 4373 fatalities) are involved in these patterns.

Road category	Collision Type	Primary party	Secondary party	the number of fatalities	Selected Patterns		Cover ratio
					the number of patterns	the number of fatalities	
Public road (non-expressway /motorway)	Vehicle-vehicle	Vehicle	Vehicle	636	28	583	91.7%
		Vehicle	Motorcycle	283	22	211	74.6%
		Vehicle	Bicycle	359	28	300	83.6%
		Motorcycle	Vehicle	204	13	140	68.6%
		Motorcycle	Motorcycle	13	1	3	23.1%
		Motorcycle	Bicycle	8	1	3	37.5%
		Bicycle	Vehicle	132	7	89	67.4%
		Bicycle	Motorcycle	5	0	0	0.0%
	Single vehicle	Vehicle	-	650	47	552	84.9%
		Motorcycle	-	214	23	163	76.2%
	Pedestrian-vehicle	Vehicle	Pedestrian	1297	50	1173	90.4%
		Motorcycle	Pedestrian	37	4	26	70.3%
		Pedestrian	Vehicle	126	10	106	84.1%
		Pedestrian	Motorcycle	6	0	0	0.0%
Expressway /motorway	Vehicle-vehicle	Vehicle	Vehicle	95	8	72	75.8%
		Vehicle	Motorcycle	7	1	3	42.9%
		Motorcycle	Vehicle	7	0	0	0.0%
		Motorcycle	Motorcycle	0	0	0	–
	Single vehicle	Vehicle	-	82	10	69	84.1%
		Motorcycle	-	18	1	4	22.2%
	Pedestrian-vehicle	Vehicle	Pedestrian	14	1	3	21.4%
		Motorcycle	Pedestrian	0	0	0	–
Total				4193	**255**	**3500**	**80.0%**

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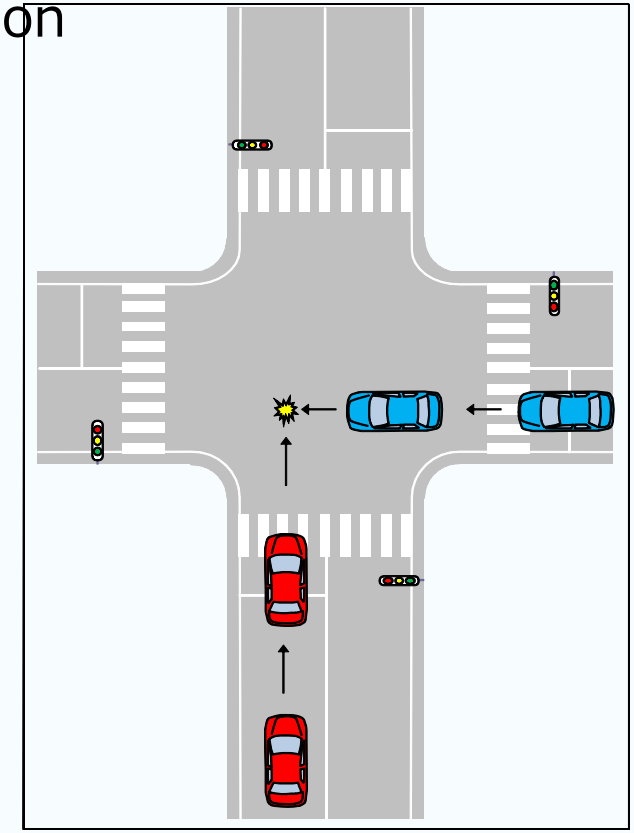
6. Example of Accidental Pattern Sheet

Vehicle vs. vehicle at a signalized intersection

Pattern No.	CTC-01
Road	Public road, Expressway,
Road design	At intersection, Near intersection, Uninterrupted road section,
Type of primary party	Vehicle, Motorcycle, Bicycle Pedestrian,
Type of secondary party	Vehicle, Motorcycle, Bicycle Pedestrian,
Movement of primary party	Starting up/Go straight, Turning left, Turning Right,
Traveling direction of secondary party	Opposite, Left, Right, Same, Others,
Collision type	Head-on collision, Rear-end collision, Crossing collision, collision while turning right, collision while turning right,



	Fatal	Serious injury	Sight injury
Accident	18	274	4,665
Casualty	19	316	7,081

All Japan

	Fatal	Serious injury	Sight injury
Accident	4,278	42,361	582,382
Casualty	4,373	44,547	736,947

7. Example of Detail Accident Analysis Sheet

Table: Detail Accident Analysis Sheet for Vehicle to Vehicle Collision

Day/Night	%
dawn	
daytime	
twilight	
night-time	

Day/night

Weather	%
clear	
cloudy	
rainy	
misty	
snowy	

Weather

Road surface	%
dry	
wet	
freezed/sn	
unpaved	

Road surface

Central divider	%
Reserve/m	
Marking	
none	
other(not r	

Central divider

Road class	%
National hig	
major local r	
local road	

Road class

Traffic violation (Primary party)			%
Disregarding traffic signal			
Road or lane infringement			
Speeding			
Improper crossing or turning around			
Driving too close to vehicle ahead			
Improper changing lane			
Improper overtaking			
Improper right turn			
Improper left turn			
Impeding priority traffic			
Improper driving at intersection	*vehicles crossir		
	*vehicle turning		
	*pedestrians		
	*other		
Impeding pedestrians			
Impeding bicyclists			
Failure to slow down			
Failure to stop			
Failure to drive safely	*Improper steering and/or braking		
	*Distracted driving		
	*Failure to confirm traffic movement		
	*Failure to make safety check		
	*other		
others			
unknown/none			

Traffic violation (Primary party)

Human error (Primary party)					%
Recognition error	*Distracted driving	*mental			
		*physical	*dropping object		
			*watching traffic sign, etc.		
			*watching landscape, structures, etc.		
			*watching other veh. Etc.		
			*other		
	*Failure to make safety check	*completely			
		*not sufficient			
Decision error	*Failure to confirm other's movement	*expected other party's avoidance			
		*other			
	*Improper forecast	*speed, dustabnce, etc.			
		*exp			
		*othe			
	*misunderstanding of the e				
Performance error	*Improper performance	*ope			
		*insu			
		*abrupt braking			
		*improper steering			
		*steering while braking			
		*other			
unknown/none					

Human error (Primary party)

Danger Perception Speed	(Primary party) %	(Secondary party) %		
10km/h or slower than				
20km/h or slower than				
30km/h or slower than				
40km/h or slower than				
50km/h or slower than				
60km/h or slower than				
80km/h or slower than				
100km/h or slower than				
faster than 100km/h				
unknown				

Danger perception speed

Age of driver	(Primary party) %	(Secondary party) %
6 yrs. or younger		
7-15 yrs.		
16-24 yrs.		
25-49 yrs.		
50-54 yrs.		
55-64 yrs.		
65-74 yrs.		
75 yrs. and over		

Age of driver

The number of fatalities are very small for most of the patterns.

Therefore , it is practical to analyze injury accidents or casualties.

8. Impact Assessment for Rear-end Collision

Reduction of fatalities is expected by the spread of the rear-end collision damage reduction equipment on public road.

Vehicle-vehicle(Public road)			Primary party	Starting up or go Straight					・・・
			Secondary party	Same	Opposite	Right	Left	stopping	・・・
Primary party	Secondary party	Road types	Type of collision						
Vehicle	Vehicle	Near intersection	Rear-end collision	11				22	
Vehicle	Vehicle	Tunnel/Bridge	Rear-end collision	3					
Vehicle	Vehicle	Straight line	Rear-end collision	13				17	
Vehicle	Motorcycle	Straight line	Rear-end collision	4				3	
Vehicle	Vehicle	intersection	Rear-end collision	4					
Vehicle	Bicycle	Near intersection	Rear-end collision	13					
Vehicle	Bicycle	Tunnel/Bridge	Rear-end collision	3					
Vehicle	Bicycle	Curve	Rear-end collision	3					
Vehicle	Bicycle	Straight line	Rear-end collision	44					
Motorcycle	Vehicle	Straight line	Rear-end collision					8	

Applicable patterns：13, Applicable total fatalities：148

But the reduction of 148 fatalities by the system is not practical.

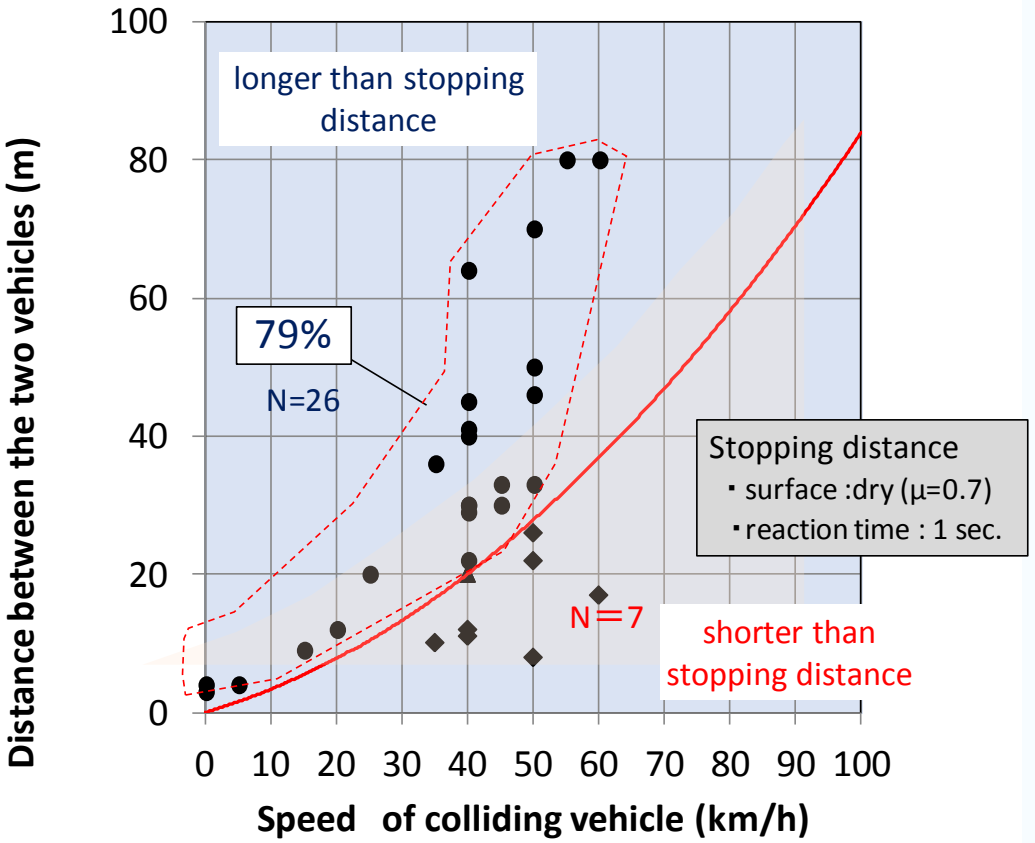
It is required to study the context of accident and the performance of the concerned device for the impact assessment.

9. Reference for Estimation of reduction of rear-end col.

79% of drivers who caused rear-end collisions **noticed** the collided vehicle under the condition **where they had enough space to stop safely**.

Warning System might reduce 117 fatalities in rear-end collisions.

148 × 0.79 ＝117



Relation between **the speed of the colliding vehicle** and **the distance of the collided vehicle and the colliding vehicle** at the moment when the driver of the colliding vehicle noticed the collided vehicle (N=33)

M.Nakano :Reduction of Injuries involved in rear-end collisions, Report for 18th Symposium of ITARDA, 2015

10. Impact Assessment for Pedestrian Accident

Reduction of Pedestrian fatalities is also expected by the safety device using **autonomous** pedestrian detection system(camera or radar).

Pedestrian-vehicle accident			Primary party	Starting up or go Straight					Turning left		Turning right			Reversing	
			Secondary party	Neer Side	Foreside	Right	Left	Other	Right	Left	Right	Left	Other	Left	Other
Primary party	Secondary party	Road types	Type of collision												
Vehicle	Pedestrian	Intersection with signal	Pedestrian crossing			27	21		5	9	36	44	3		
Vehicle	Pedestrian	Intersection with signal	Other crossing			13	6					3			
Vehicle	Pedestrian	Intersection with signal	On road					3							
Vehicle	Pedestrian	Intersection	while walking parallel to vehicle	4											
Vehicle	Pedestrian	Intersection	Pedestrian crossing			56	19				3	6			
Vehicle	Pedestrian	Intersection	Other crossing			112	40			3	13	6			
Vehicle	Pedestrian	Intersection	On road					5					5		
Vehicle	Pedestrian	Near intersection	while walking parallel to vehicle	14											
Vehicle	Pedestrian	Near intersection	Pedestrian crossing				6								
Vehicle	Pedestrian	Near intersection	Other crossing			84	39					8			
Vehicle	Pedestrian	Near intersection	On road				4	34					3		
Vehicle	Pedestrian	Tunnel/Bridge	On road					4							
Vehicle	Pedestrian	Curve	while walking parallel to vehicle	7											
Vehicle	Pedestrian	Curve	Other crossing			17	9								
Vehicle	Pedestrian	Curve	On road					8							
Vehicle	Pedestrian	Straight line	while walking parallel to vehicle	76	16										
Vehicle	Pedestrian	Straight line	Pedestrian crossing			12	7								
Vehicle	Pedestrian	Straight line	Other crossing			205	85								
Vehicle	Pedestrian	Straight line	On road				4	59							3
Vehicle	Pedestrian	Straight line	Other	3			9	9							3
Vehicle	Pedestrian	Other	Other											3	
Motorcycle	Pedestrian	Intersection	Other crossing			4									
Motorcycle	Pedestrian	Straight line	while walking parallel to vehicle	3											
Motorcycle	Pedestrian	Straight line	Other crossing			12	7								
Pedestrian	Vehicle	Intersection with signal	Pedestrian crossing			36	20								
Pedestrian	Vehicle	Intersection with signal	Other crossing			15	3								
Pedestrian	Vehicle	Near intersection	Other crossing			6	4								
Pedestrian	Vehicle	Straight line	while walking parallel to vehicle	3											
Pedestrian	Vehicle	Straight line	Other crossing			4	9								
Pedestrian	Vehicle	Straight line	On road					6							

Subtotal :1017

Total :1123

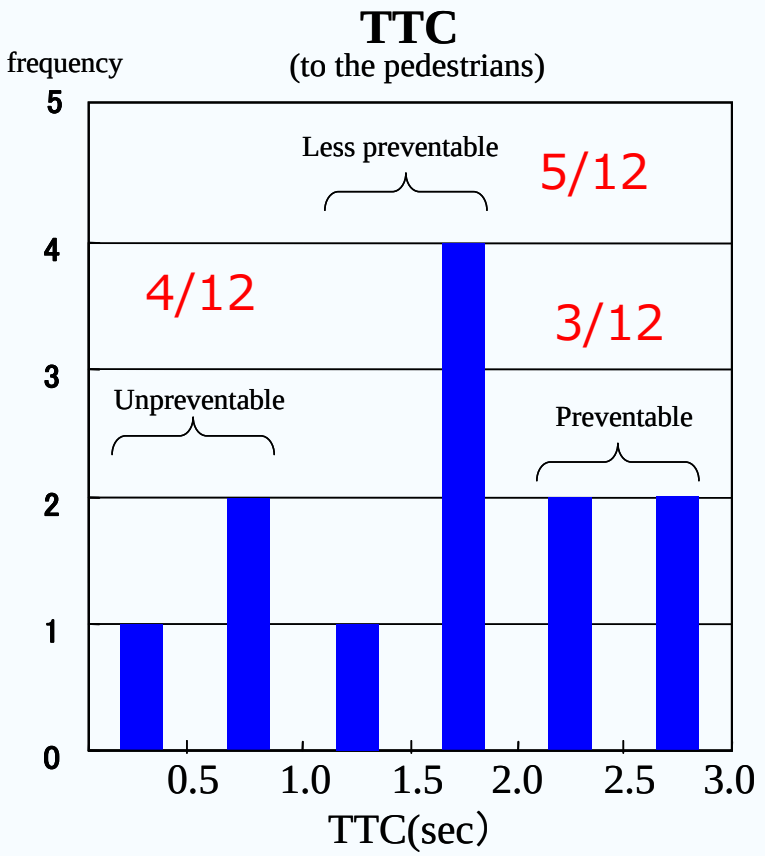
Subtotal :106

Applicable patterns : 43, Applicable fatalities : 1123

“1123” is very optimistic for the reduction by the system.

11. Reference: Distribution of TTC of Pedestrian Accidents

The performance of the safety device with pedestrian detection system is thought to be related with TTC.



The distribution of TTC (Time to Collision) on pedestrian accidents in the jurisdiction of Toyota Police Station shows; 25% for less than 1sec., 42% for 1-2sec. and 33% for 2-3sec. (N=12)

Source: M.Shiota, et al.:Study on fatality reduction based on analysis of traffic accidents occurred in the jurisdiction of Toyota Police Station, Presentation at JSAE Chuubu-Area Workshop 2010

12. Impact Assessment of Pedestrian Detection System

The reduction of pedestrian fatalities might be estimated considering the distribution of TTC(Time to collision) and survival ratio.

Table Impact Assessment of the pedestrian detection system with CCTV/Radar for fatal pedestrian accident

TTC <Time to collision>	(%) di	Target Group <real fatal occupants> (person) Q	Estimated distribution Qi=Q*di	Survival ratio (%) ri	Estimated survival occupants Distribution Si=Qi*ri	(person) S
0.0＜TTC≦1.0sec	25.0	1123	281	0	0	608
1.0＜TTC≦2.0sec	41.7		468	50	234	
2.0＜TTC≦3.0sec	33.3		374	100	374	

Reference

tentative

Source: M.Shiota, et al.:Study on fatality reduction based on analysis of traffic accidents occurred in the jurisdiction of Toyota Police Station, Presentation at JSAE Chuubu-Area Workshop 2010

13. Conclusion

(1) 4373 Traffic fatalities in 2013 are grouped by, 1) Combination of primary and secondary parties, 2) Road category, 3) Road design, 4) Collision type, and 5) maneuver/direction of movement, 255 patterns and several accident patterns with high frequency of fatalities are selected.

(2) 3500 fatalities (80% of 4373 fatalities) are involved in the selected 255 patterns.

(3) 255 accident pattern sheets with data; the number of fatalities, the seriously injured, the slightly injured, fatal accident, serious injury accident, and slight injury accident, and diagram showing the maneuver /direction of movement of the parties, are drawn.

13. Conclusion (continued)

(4) Detail accident analysis sheets are proposed for the impact assessment of safety techniques.

(5) Trial estimations are introduced;
117 (79%) fatalities out of 148 in rear-end collision on public road might be saved by rear-end collision damage reduction equipment.

608 pedestrian fatalities out of 1123 might be saved by the autonomous pedestrian detection system.

14. Next Subjects

Following topics should be discussed;

(1) Safety techniques for the unconsidered 873 fatalities (=4373-3500) and the impact assessment of those techniques

(2) Patternization for promising safety techniques and the impact assessment of those techniques.

(3) Transition stages from automated driving to manual driving and the distribution of transition stages,

considering distribution of recognition, decision and performance errors

Topic 1: Human Error and safety devices

Table: Distribution of Human Errors of Rear-end collisions(2014)

Human Errors	Details	%
Recognition error	*absent-minded driving, *distracted driving, *failure to perform a safety check, etc.	60
Decision error	*failure to confirm other's movement, *improper forecast, *misunderstanding the environment, etc.	25
Performance error	*improper braking/steering, *misuse of other devices, etc.	15

Warning System may reduce accidents by recognition errors.

Some drivers may make decision or operation error even if they are warned timely.

M.Nakano: Reduction of Injuries involved in rear-end collisions, Presentation of the 18th Symposium of ITARDA, 2015

Topic 2: Possible travel speed based on Vision Zero

Traffic control and road design may improve the effect of Automated Driving Systems.

Table 1. Possible long term maximum travel speeds related to the infrastructure, given best practice in vehicle design and 100% restraint use.

Type of infrastructure and traffic	Possible travel speed (km/h)
Locations with possible conflicts between pedestrians and cars	30
Intersections with possible side impacts between cars	50
Roads with possible frontal impacts between cars	70
Roads with no possibility of a side impact or frontal impact (only impact with the infrastructure)	100+

Source) Vision Zero - An ethical approach to safety and mobility：Claes Tingvall and Narelle Haworth:Monash University Accident Research Centre、the 6th ITE International Conference Road Safety & Traffic Enforcement: Beyond 2000, Melbourne, 6-7 September 1999.

Topic 3: Congestion and Accidents on Expressway

Reducing traffic congestion may reduce traffic accidents.

Table Accident fatalities and casualties by traffic incidents
On expressway/motorway in 2010-2014

Trouble	stopped vehicles	incidents	fatalities		casualties	
			daytime	night-time	daytime	night-time
yes	yes	accident*	8.0	**10.6**	6.0	**6.2**
		road working	**3.9**	2.3	**2.1**	1.5
		congestion*	**4.8**	0.8	**24.8**	15.8
		others	1.1	2.2	3.1	1.9
		subtotal	**17.8**	16.0	**35.9**	25.4
	no		**7.8**	11.1	**2.3**	4.1
no			74.3	**72.7**	61.6	**70.3**
unknown			0.0	0.2	0.1	0.2
total			100.0	100.0	100.0	100.0
		(n)	460	601	70,874	28,630

accident*: an accident occurred before the concerned accident.

congestion*: congestion caused by high traffic demand

END

Thank you for your attention!