RESEARCH AND RULE-MAKING ACTIVITIES ON PEDESTRIAN PROTECTION IN KOREA

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ABSTRACT

Pedestrian safety is one of the most demanding topics in vehicle safety in Korea. Although the total numbers of deaths and injuries have continuously decreased year by year, the pedestrian is still a major source of traffic victims. Among 240,832 cases (total traffic accidents), 37% (89,443) was pedestrian involved accidents in 2003. Last year, 50% (3,594 fatalities) of all traffic accidents that related fatality (total 7,212) was vehicle-pedestrian type accident in Korea. Among them, numbers of deaths in pedestrian age under 6 were 142 with 13,528 injured children.

In 1999, Korean government, Ministry of Construction and Transportation, launched a research project to develop a proper solution on pedestrian protections from vehicle related accidents. The project also included the evaluations of current existing test methods, i.e. EEVC type test and IHRA type test, and the possibility of harmonization with these test methods.

The main objective of the presented method is to develop the adequate dynamic test procedure and injury assessment criteria. The current all existing passenger vehicles of the front shape were measured and categorized into three groups according to IHRA recommendation, and the effect of vehicle shape on pedestrian kinematics was investigated to define the head impact speed, head impact angle and WAD with the various impact speeds and walking postures as the test procedures. In this paper, JARI pedestrian computer model, TNO MADYMO computer model and FEM H-model were used to configure and compare the pedestrian dynamic behaviors during the various impact events. With head impact tests and simulations, the design feasibility, lead times for auto industry and suitable injury criteria were investigated.

Based on the research, Korean government will extend the KNCAP on new vehicle's pedestrian impact test to evaluate how vehicle front structure is pedestrian friendly. With careful study on the results of NCAP, after that pedestrian regulation will come into effect within 2 or 3 years later.

ASSESSMENT OF PEDESTIRAN RELATED TRAFFIC ACCIDENTS IN KOREA

Late 80's when Korea rapidly increases of use the automotive as a personal transportation means, the traffic related accidents were inevitable. Early '90, over the 13,000 valuable lives killed by the vehicle related accidents. Until 1997, the number of persons killed each year in the traffic accidents is about 10,000 and more than 300,000 peoples were injured though it has shown a decreasing trend. Casualties who were involved with vehicle to pedestrian related accidents were approximately up to 50% of the total traffic related death in 2003 and unfortunately the rate is still increasing year after year.

Based on the police reports, total traffic accident fatality was 7,212 and vehicle to pedestrian type accident's fatality was 3,595 including fatality of occupants on vehicles. In terms of pure pedestrian, the death was 2,896. It is 40.2% of all traffic accident fatality. The injured pedestrian was 53,069 while total traffic injured person was 376,503. The pedestrian injured rate was 14.1%. The main reason why the fatality is so higher than injured rate is that the pedestrian is relatively weak compared with the stiffness of vehicle outer structure surfaces. In order to reduce the number of victims from traffic accidents, the Ministry of Construction and Transportation (MOCT) has been investigated adoption of regulation for pedestrian protections from vehicles. During last 3 years of research works, studied characteristics of domestic environments of pedestrian along with pedestrian related traffic accidents investigations.

Trends of Traffic Accidents Patterns

Since 1990, 48% of all accumulated police reported fatality accident data (1990-2003) was a vehicle-pedestrian crash type accident as shown in Table 1 and Fig. 1. Each year's data is shown in Fig. 2. This is the largest accident type cause the death during the accidents. The total reported data exceed 3 million accidents. In fatality, the second accident type was a vehicle-pedestrian accident. It was about 36% of total accidents while the total case of accidents is the largest. The remaining 4% of total accidents was vehicle only involved accident and vehicle only accident's fatality is about 15%.

Table 1. Trends of Traffic Accidents Periods of 1990 – 2003 in Korea

	Vehicle-vehicle		Vehicle-person		Vehicle only		Vehicle-train		Total	
	Accidents	Deaths	Accidents	Deaths	Accidents	Deaths	Accidents	Deaths	Accidents	Deaths
1990	110,513	4,442	133,282	6,441	11,395	1,376	113	66	255,303	12,325
1991	118,897	4,805	136,941	6,952	10,036	1,609	90	63	265,964	13,429
1992	125,006	4,455	122,951	5,802	91,39	1,321	98	62	257,194	11,640
1993	133,587	3,947	117,431	5,241	97,98	1,159	105	55	260,921	10,402
1994	149,899	4,204	105,261	4,641	10,859	1,194	88	48	266,107	10,087
1995	146,783	4,315	91,395	4,564	10,603	1,378	84	66	248,865	10,323
1996	166,677	5,390	87,292	5,070	11,037	2,160	46	33	265,052	12,653
1997	162,085	4,981	74,144	4,458	10,192	2,134	31	30	246,452	11,603
1998	158,732	3,593	70,631	3,495	10,318	1,949	40	20	239,721	9,057
1999	190,437	3,788	74,527	3,692	10,943	1,855	31	18	275,938	9,353
2000	206,971	4,208	72,932	3,890	10,569	2,135	9	3	290,481	10,236
2001	185,207	3,258	65,898	3,243	9,466	1,590	8	6	260,579	8,097
2002	164,334	2,808	59,271	3,201	7,411	1,207	10	6	231,026	7,222
2003	**141,841**	**2,197**	**89.443**	**3,595**	**9,531**	**1,416**	**17**	**4**	**240,832**	**7,212**

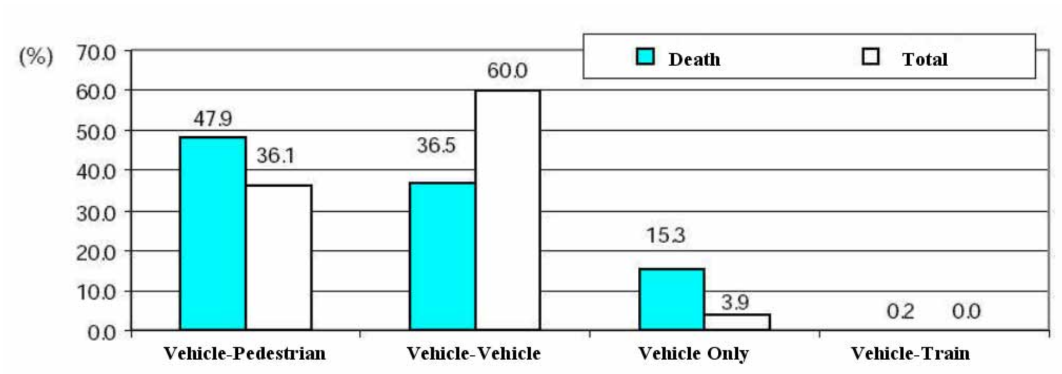


Figure 1. Accumulated accident type distribution of fatalities in Korea

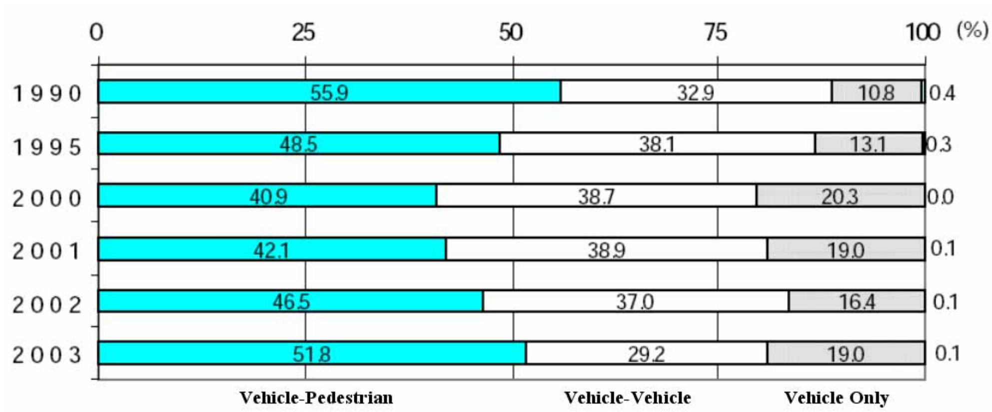


Figure 2. Accident type distribution of fatalities in Korea

Pedestrian Accident Patterns by Age Group

As shown in Table 2, 44.6% of pedestrian death is over 61 years and older people. Their total death is 1,291. Among them, 724 deaths are over 71 and years older elderly peoples. The statistics of casualties standardized by population distribution by age or those of fatalities by age indicate that the rate of meeting with accidents or being killed in such accidents increases among pedestrians at age 61 and over. Fatality of child (less than 14 years old) is 9.5% (274 death). However in terms of injured case, 24.8% (13,181 injured child) of all pedestrian injured cases is less than 14 years old child. Elderly people's injured rates are less than 10% (61-70 years old: 9.8%, over 71 years and older: 6.6%). It may be due to the different characteristics of biomechanics behaviors during crash.

As shown in Figure 3, pedestrian casualty (both death and injured) per 10,000 populations, injured over 61 years and older is the largest group with 158.6 persons. The ratio is more than 2 times of those of 20 years old age group. Fatality ration of elder people is 24.3 persons per 10,000 populations while 21 – 30 years old group's ration is less than 1.8 persons. This indicates killed rate of elder pedestrian is more than 13 times of those of 21 – 30 years old group. This indicates that, the more elderly peoples in near future, the more pedestrians are likely to meet with accidents.

Table 2. Pedestrian fatality and injury by age group in 2003

	Total	14 less	15-20	21-30	31-40	41-50	51-60	61-70	71 over	N/A
Death	2,896	274 (9.5%)	54 1.9%)	141 (4.9%)	279 (9.6%)	429 (14.8%)	400 (13.8%)	567 (19.6%)	724 (25.0%)	28 (1.0%)
Injured	53,069	13,181 (24.8%)	3,528 (6.6%)	6,768 (12.8%)	6,729 (12.7%)	7,850 (14.8%)	5,618 (10.6%)	5,202 (9.8%)	3,527 (6.6%)	666 (1.3%)

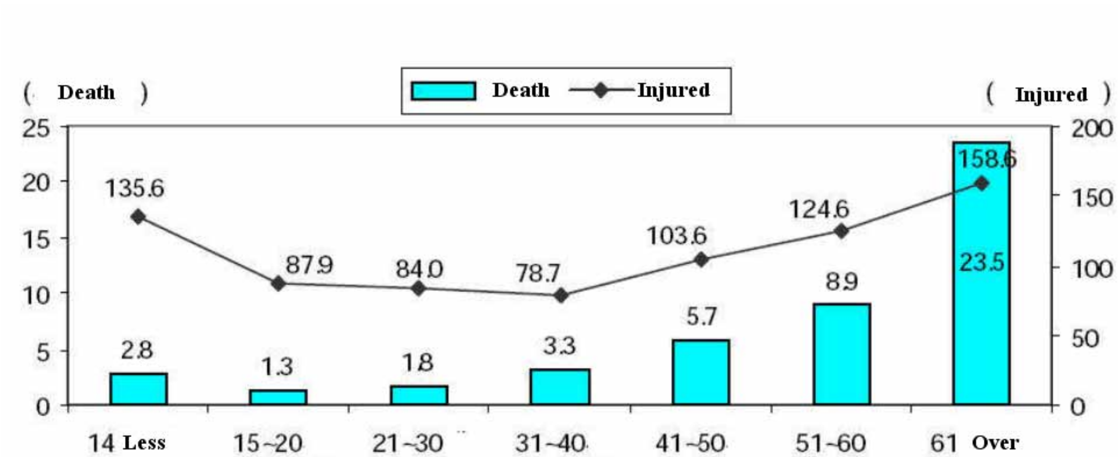


Fig. 3. Age group pedestrian death and injured rates per 10,000 populations in 2003

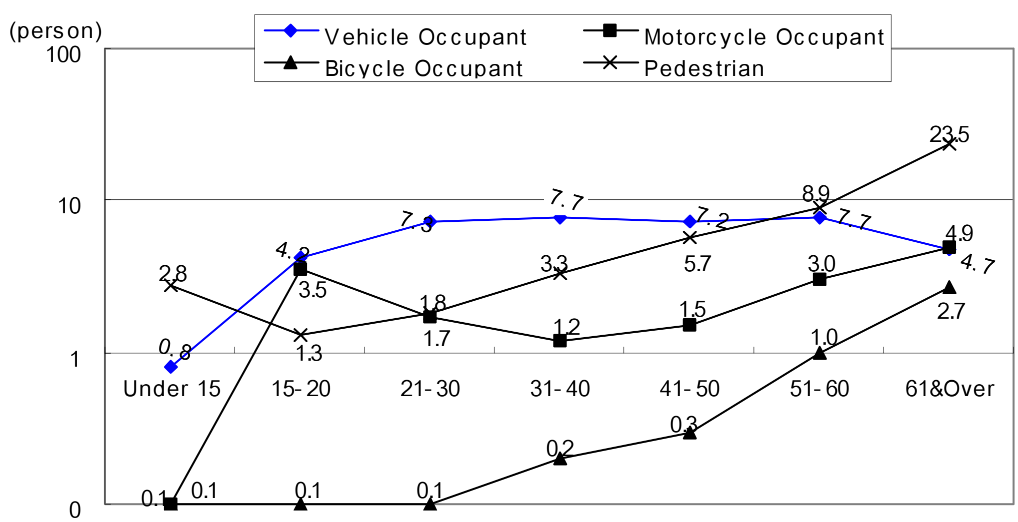


Fig. 4. Age group accident type death rate per 10,000 populations in 2003

Figure 5 show that the percentage of injured parts of traffic accidents involved persons who had experienced at least hospitalized 2 or 3 days. Up to serious injured cases, the incidence of injury is the most frequently observed in the lower leg and necks, followed by head.

In the fatal accidents, injury to the head is the major cause of death (64%), followed by lower legs (11%) and neck (9%). The body of injured occupant in the vehicle is shown in Figure 5.

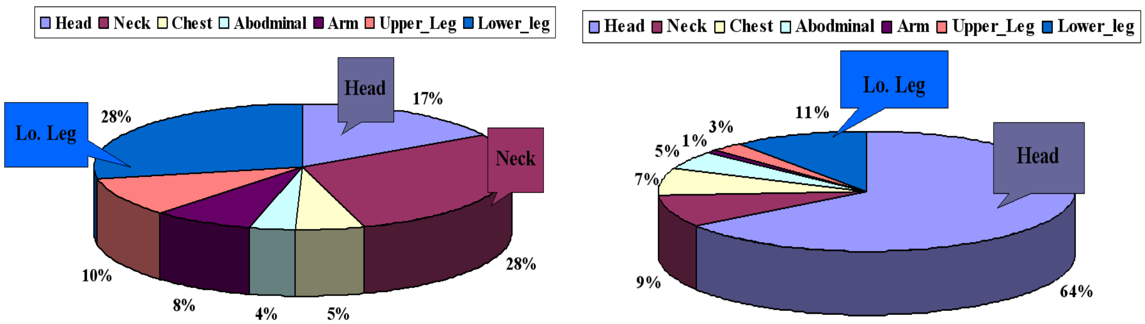


Fig. 5. Injured body parts and Fatality caused main severely injured body parts in pedestrian

RESEARCH AND RULE MAKING ACTIVITIES

This accidents data analysis indicates that significant improvement of vehicle safety performances are needed to protect the pedestrians during the accidents. In order to reduce number of fatalities, especially from the vehicle, the Ministry of Construction and Transportation (MOCT) has been seriously considered adoption of pedestrian protection regulations. Recently MOCT of Korea launched special task team for pedestrian researches. This research group studied the patterns of Korean pedestrian accident, and injury as well as survey of existing test methods for feasibilities and international harmonization as shown in Figure 7.

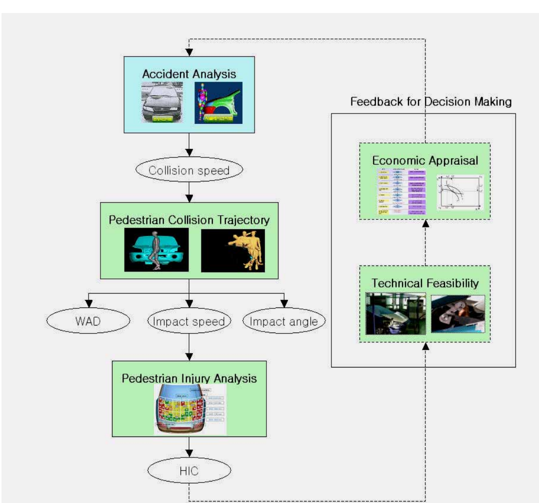


Fig. 7. Scheme of research procedures

Pedestrian Kinematics During Vehicle Impacts

Figure 7 shows two pedestrian models currently used for the simulation study. These are JARI, and TNO pedestrian models that already validated by TNO and IHRA (JARI) with comparing results from their computer simulations and published PMHS (Post Mortem Human Subject) tests.

According to IHRS recommended simulation procedures, a parameter study was conducted to understand the influence of pedestrian size, waling position, vehicle shape, vehicle stiffness, and vehicle impact speed onto the pedestrian impact condition such as head impact velocity, head impact angle, and head impact location (Wrap Around Distance: WAD). IHRA's three walking position WP1, WP2, and WP3 were used for the parameter study as well as a standing position with 40kph vehicle impact speed.

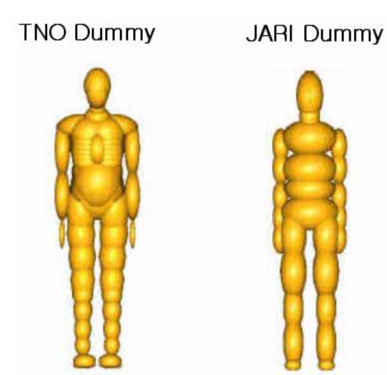
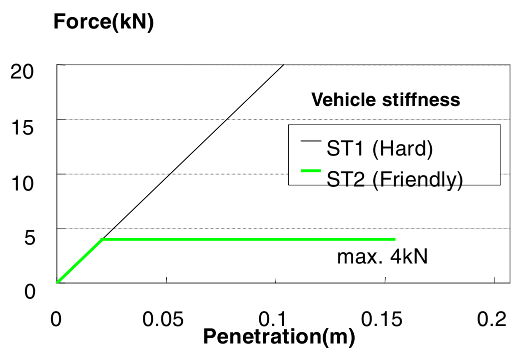
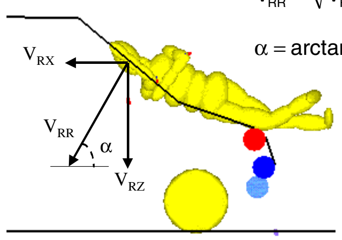


Fig. 7. Pedestrian Models (AM50)

Two different vehicle stiffness, IHRA's hard and friendly, was used, and the definition of the head impact velocity and the head impact angle and the definition of the head impact velocity and the head impact angle are illustrated in Figure 8. .





$$V_{RR} = \sqrt{V_{RX}^2 + V_{RZ}^2}$$

$$\alpha = \arctan\left(\frac{V_{RZ}}{V_{RX}}\right)$$

V_{RX} : Relative head velocity against vehicle (X)
V_{RZ} : Relative head velocity against vehicle (Z)
V_{RR} : Head Impact Speed
- Resultant of relative head velocity against vehicle -
α : Head Impact Angle
- Obtain from V_{RX} and V_{RZ} ratio -

Fig. 8. Pedestrian simulation conditions

Vehicle Shapes in Different Categories

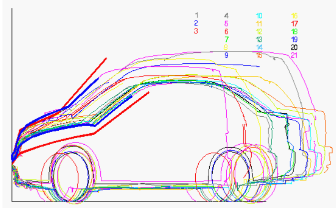
Based on the IHRA and WP29 W/G studies, front shape of passenger car was investigated and categorized into three groups, Sedan, SUV and 1-Box, so that the effect of vehicle front shape on the pedestrian impact was studied with computer simulations focusing on the head impact velocity, head impact angle, WAD (Wrap Around Distance) and head effective mass.

Figure 8 shows the car front shape corridors for the three groups obtained from current Korean production cars with overplots of IHRA's results. The measured corridors of domestic vehicles are fall into the results of IHRA measures. However the hood angle of one 1-BOX vehicle is less than 30 degree. This means that even though intended design and purpose of vehicle was 1-BOX vehicle, the test procedure will be followed by SUV vehicle category. It will mislead the government's pedestrian protection policy and the level of protections.

Comparison of Sedan Corridor

■ IHRA/Japan Definition
Sedan: Bon. Angle < 30 ˚ & LEH < 835mm

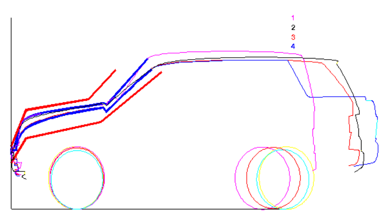
Classification	Korea		IHRA/Japan	
	Lower	Upper	Lower	Upper
BL(mm)	122	175	127	127
BCH(mm)	431	479	435	516
LEH(mm)	656	849	565	839
Bon. Length(mm)	1099	895	1200	635
Bon. Angle(˚)	13	19	11	18
Win. Angle(˚)	29	32	29	40



Comparison of SUV Corridor

■ IHRA/Japan Definition
SUV: Bon. Angle < 30 ˚ & LEH > 835mm

Classification	Korea		IHRA/Japan	
	Lower	Upper	Lower	Upper
BL(mm)	182	165	195	195
BCH(mm)	640	647	544	736
LEH(mm)	939	1050	832	1168
Bon. Length(mm)	1077	1132	1023	844
Bon. Angle(˚)	14	9	11	8.5
Win. Angle(˚)	39	51	36	43



Comparison of 1 BOX Corridor

■ IHRA/Japan Definition
1 Box: Bonnet Angle > 30 ˚

Classification	Korea		IHRA/Japan	
	Lower	Upper	Lower	Upper
BL(mm)	166	189	188	188
BCH(mm)	521	601	448	704
LEH(mm)	970	989	864	1144
Bon. Length(mm)	521	129	361	157
Bon. Angle(˚)	28	47	40	40
Win. Angle(˚)	32	43	30	46

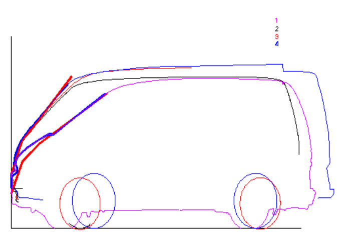


Fig. 8. Three vehicle categories 2-D front shape corridors from domestic vehicles

Pedestrian Trajectory Simulation Results

As shown in Figure 9, it is clear that the pedestrian size and the vehicle category affects to the head impact condition, especially for the head impact location, angle, and head velocity.

Compared with JARI and TNO model, however the simulations were influenced by pedestrian–vehicle contact locations, contact characteristics, and upper arms interference with vehicle and body parts of dummy.

In general, the head contact locations, WAD are similar, but impact velocity and angle are shown some discrepancy for adult pedestrian model. In 6 years old child model case, JARI and TNO model show the consistent results both in speeds and angles. This is due to the relatively small body that contact with striking vehicle with initial stage of crash.

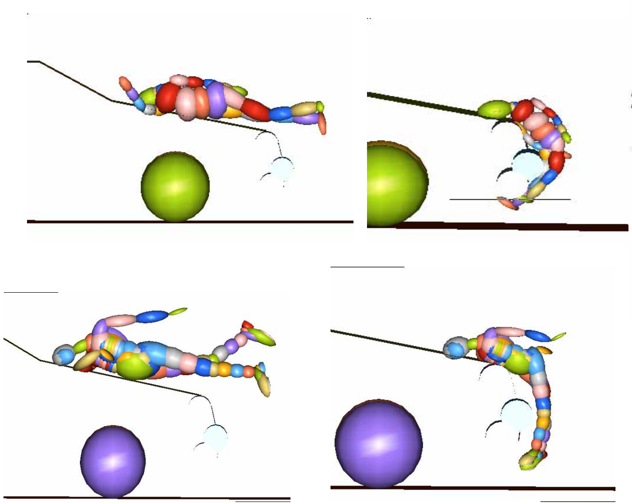


Fig. 9. Sedan type vehicle simulation results with JARI and TNO models(A50 and 6Y)

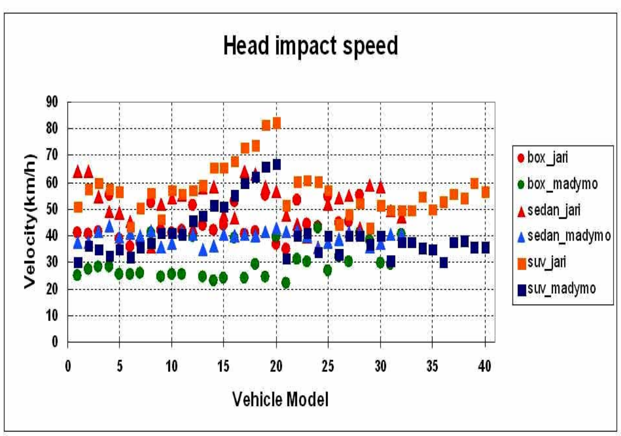


Fig. 10. Results of head impact speeds with JARI and TNO models(A50)

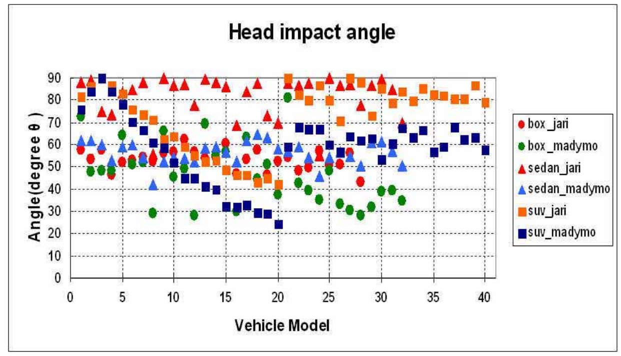


Fig. 11. Results of Head impact angle with JARI and TNO models(A50)

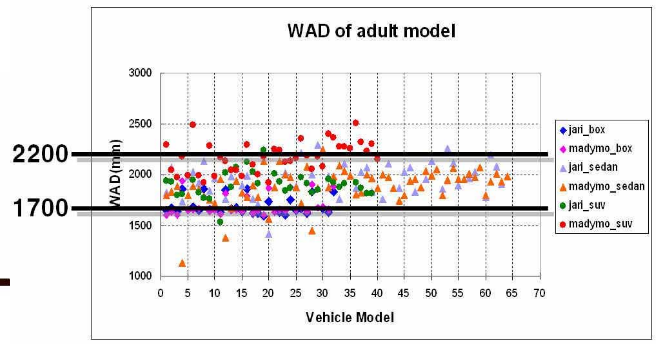


Fig. 12. Results of head impact WAD with JARI and TNO models(A50)

Evaluation of Existing Head Impact Test methods with Simple Hood Structure Model

The EEVC performed several studies and proposed various recommendations on test methods to assess pedestrian protection. The test methods should be based on sub-system tests, essentially to the bumper, bonnet leading edge and bonnet top surface. The test methods should be considered to evaluate the performance of each part of the vehicle structure with respect to both child and adult pedestrians, at car to pedestrian impact speed of 40 km/h with fixed impact angle for all applicable vehicles. (adult: 60 ° with 4.8 kg mass, child: 50 ° with 2.5 kg mass)

However, according to finds from IHRA study, Japan announced their new pedestrian regulation for head protection in both adult and child. IHRA approach is quite different that based on the observations from real world accidents. The starting point is different frontal shapes must influence the kinematics of occupant which leads specific head impact velocities and impact angles.

Japan's regulation based on the IHRA's results is same impact speed both child (mass: 3.5kg) and adult(mass:4.5kg) with 32kph. But the different vehicle categories have different head impact speeds. 65 ° / 90 ° / 50 ° (sedan/SUV/1-BOX) for adult, and f65 ° / 60 ° / 25 ° (sedan/SUV/1-BOX) for child.

UNECE/WP29 is under discussion for harmonization between EEVC and IHRA test method and injury criteria.

Meanwhile, NHTSA proposed the most sever head impact conditions. To maximum protections, the impact angle should be perpendicular to the bonnet surface that leads the maximum penetration of head into the bonnet surface.

In our study, three different test methods were evaluated using computer simulation with a hood of common passenger vehicle. To eliminate the interference of engine block structure, only hood was modeled with proper boundary conditions. As shown in Figure 13, 2.5kg or 3.5kg child head form was impacted center of hood with three different test conditions (EEC, IHRA and NHTSA)

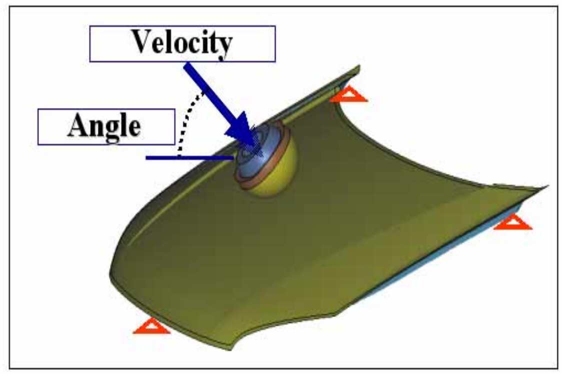
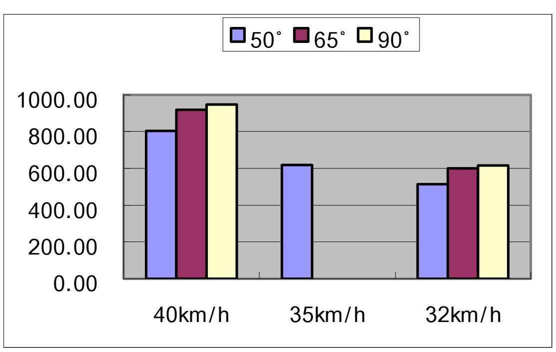


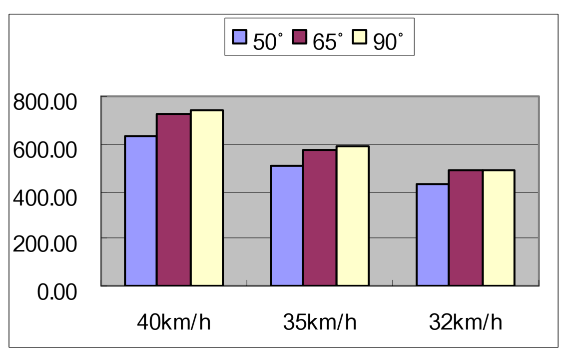
Fig. 13. Child head form impact model

Table 3 Comparison with three different child head impact test methods

	40km/h		35km/h		32km/h	
	2.5kg	3.5kg	2.5kg	3.5kg	2.5kg	3.5kg
50˚	1.00	0.79	0.77	0.63	0.64	0.53
65˚	1.14	0.90	0.90	0.72	0.75	0.60
90˚	1.18	0.92	0.91	0.73	0.77	0.61



a) 2.5kg



b) 3.5kg

Fig. 14. HIC of Child head form impact simulations

ECONOMIC APPRAISALS AND FUTURE PLANS

During the research, it must be make sure that the establishment of rule-making activities achieved proper number of lifesaving effects assuming that it is introduced and that all the vehicles concerned are replaced with vehicles complying to the regulation. Target Population is estimated for each of the age groups as following variables.

- Pedestrian head injury ratio (P_{ha})
- Death ratio of the head injury accidents (P_{dhk})
- Ratio of the pedestrian accidents under 40kph [PV_{d40}]
- Ratio of injury over HIC 1000 [$H_{1000,d}$]

Benefits are estimated using target population and social costs for the life savings and incident injury reduction. Social costs [C_{da}] are estimated using accident compensation cost for the car insurance. The benefits are calculated by the following equation.

$$B_{da} = C_{da} \cdot D_p \cdot p_{ha} \cdot p_{dha} \cdot pv_{d,40} \cdot H_{1000,d}$$

The estimate used the traffic statistics of 1999 and took into account passenger cars with 3500 kg or less in gross vehicle weight (the weight range of trucks being different from that of the regulation). The injury reference value was set to HIC 1,000.

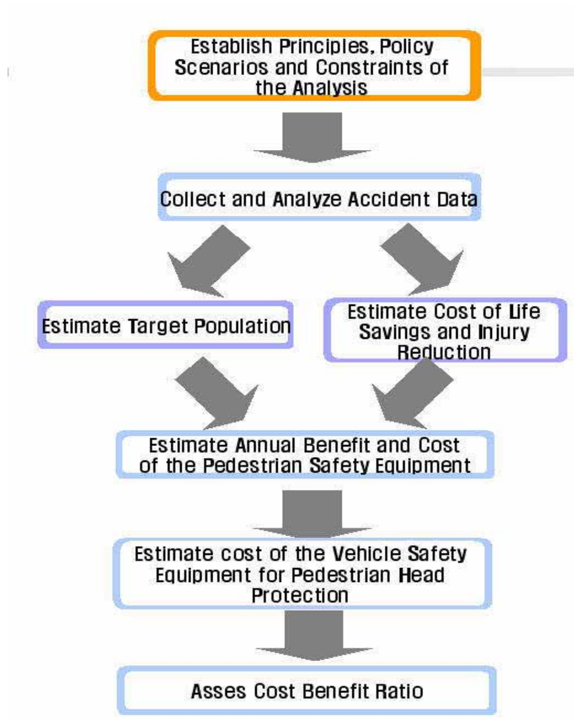


Fig. 15. Scheme of economic appraisals

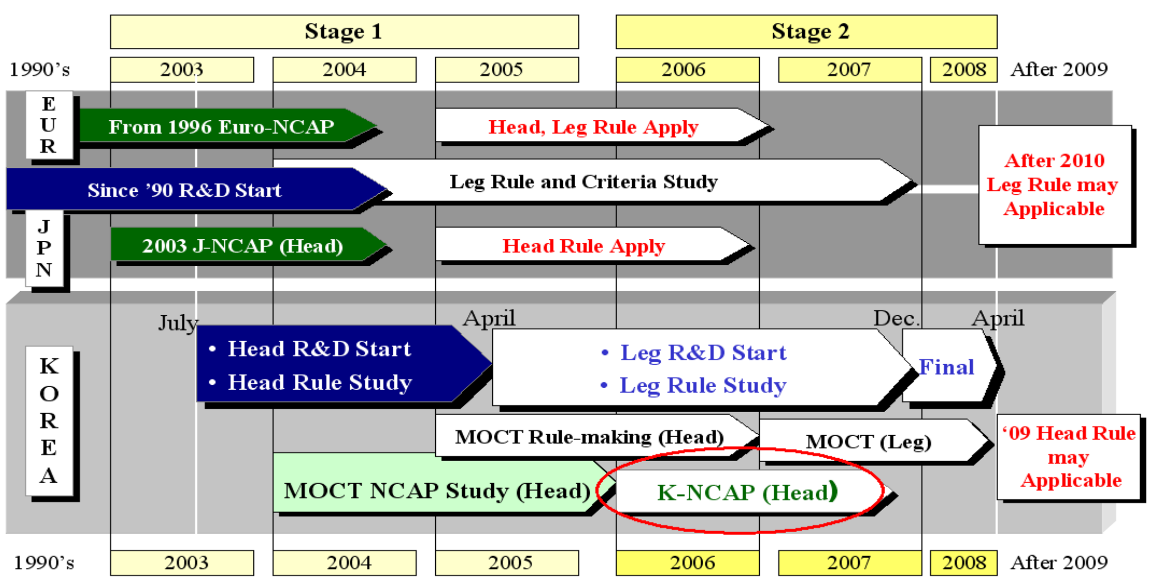


Fig. 16. Milestone of pedestrian protection rule-making activities

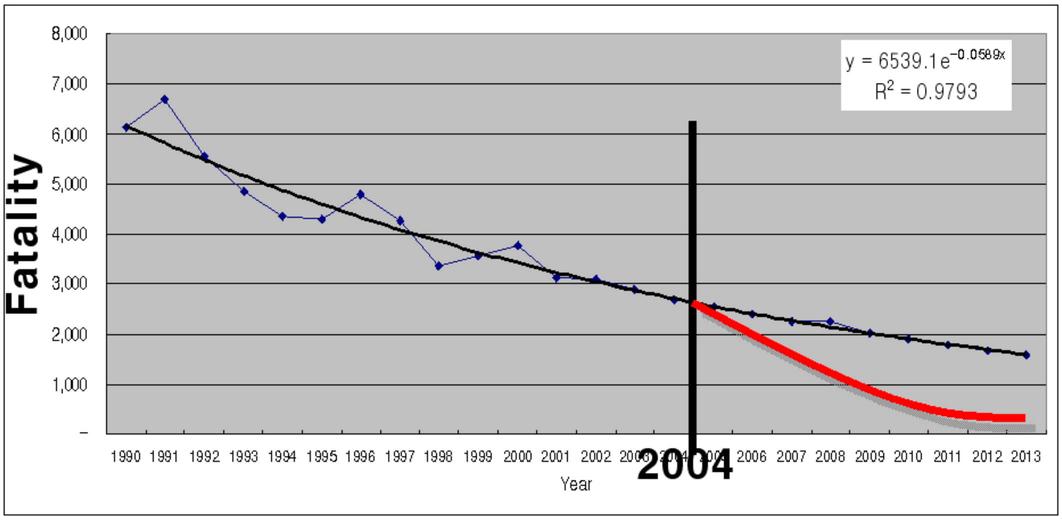


Fig. 17. Expected reduction of pedestrian related fatalities with enhanced rule-making activities

As a member of both on 1958 and 1998 agreements, Korea will continuously work for international harmonization. An informal group, GRSP/PS was organized under ECE/WP29/GRSP for establishing a Global Technical Regulation for pedestrian safety. According to its Terms of Reference, the informal group plans to finalize its written justification by the middle of 2005 and its complete and detailed recommendation by 2005 for a head protection regulation and a leg protection regulation.

Accordingly, Japan plans, respecting the discussion to be held in this Informal Group to the maximum, to introduce also a regulation for leg protection, while working for the harmonization of head protection regulations.

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