

A STUDY ON THE ANALYSIS OF DRIVER'S VISUAL BEHAVIOR CHARACTER AT HIGHWAY CURVE SECTION

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Abstract: Generally, to grip driver's visual action character is very important because 90% of all information about driving is acquired by it. Especially curve-section was establish delineator to secure drive ability and increase traffic safety and was located to provide for driver forward situation. Therefore first of all delineator must review establishment standard, effectiveness point of view driver's visual character.

In this paper first subject observe driver's visual behavior and grasp the character by the focus recorder at highway line number 34(JIN-CHUN IC. from BYUK AM RI to IP JANG MYON, spot where traffic accidents occur frequently). And then, as a result, second subject is that use foundation data to review establishment standard to consideration visual behavior a point of view of delineator.

Key Words: Traffic safety, Visual behavior, Curve-section, Delineator

1. INTRODUCTION

Establishment of delineator's has for object that road condition give information and safety drive's environment to driver. Curve-section must need function strengthen and facilities to increase traffic safety. Because lethal-rate high double curve-section than noncurve-section by the existing traffic accident statistical data) Therefore advance countermove is important about traffic safety

While it is important that grasping visual action character of driver's first primary because first, outside information of being drive depend on driver's sight and action(over 90%), second, these information get accomplished through process of recognition-judgment-action.

Especially delineator facilities must need to review (establishment standard, utility etc. a point of view of driver's visual action character

Therefore, in this paper first subject observe driver's visual behavior and grasp the character by the focus recorder at highway line number 34(JIN-CHUN IC. from BYUK AM RI to IP JANG MYON, spot where traffic accidents occur frequently). And then, as a result, second subject is that use foundation data to review establishment standard to consideration visual behavior a point of view of delineator

These have to do observe driver's visual behavior and review considerations thing from now on by the kind of three characters. The kind of three characters are different between place #1 and place #2, visual character at day and night and visual character curve-section before, curve-section and pass a curve-section.

2. TRAFFIC ACCIDENT CHARACTER STUDY ON HIGHWAY

2. 1. Traffic accident situation on highway

Every road length 100km/every 1 millions vehicle per accident was indicated that highway and a [municipal road is 0.46 and 0.43. Accordingly Risk rate high comparatively (Expressway 0.33, Each road total average 0.24) The rate of traffic accident is 9.2% and 90.8% at curve-section and noncurve-section If it were consideration that length of curve-section than straight-section absolutely short, many traffic accidents are able to happen at

curve-section. It is indicated very highly lethal-rate that is dangerous level of traffic accident at curve-section and noncurve-section<Figure1> Therefore highway curve-section is very dangerous and must provide for traffic safety facilities.

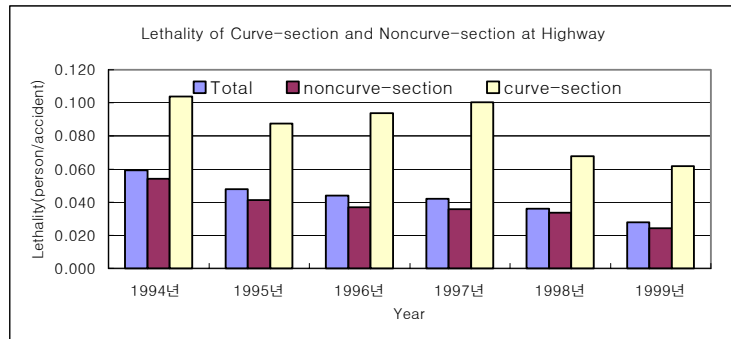


Figure 1. Lethality of curve-section and noncurve-section at Highway

2. 2. A field study

In this paper, examination section was selected on highway line number 34(JIN-CHUN IC. from BYUK AM RI to IP JANG MYON). The place occurrence traffic accident frequency and was assign with spot where traffic accidents occur frequently. In addition to, it is satisfy follow conditions and can prove different from visual behavior by radius. Therefore, it was choose place that radius is Max($R=500m$) and Min($R=130m$) in examination section.

- Curve-section of forward were not confirmed directly to obtain road condition from delineator at straight-section.
- Curve length is over the settle level for grasp the driver's visual behavior at curve-section.
- The place is visual or etc. obstacle is rarely for grasp the driver's visual behavior at curve-section.

The experimental person was selected satisfying that drive record is 3year any more, visual action is no problem, owner driver and 4 persons. Because the vehicles are load various truck and passenger car mainly at highway. The kind of experimental vehicle is recreation vehicle (Trajet XG model, The lowest height is 160cm) RV is the middle class of truck and passenger car. The focus recorder used Takei corporation product. Wireless communication possible the cause that visual action is able to measure firsthand. Experimental observe angular to

measurement firsthand visual behavior. A focus area was divided X(horizontal) and Y(vertical)angular, measured with day and night. Therefore it is possible to estimation of a point of view various. Visual character was grasped the visual speed of the apple of the eye, the rate of space of sight etc.



Figure 2. Panoramic photograph of curve-section at research place
(Left : Place #1, Right : Place #2)

2. 3. Establishment standard of delineator

The facilities for securing driver's safety are delineator, the gull sign, road guide cap by Ministry of Construction and Transportation guide 『Ministry of Construction and Transportation a rule explanation and guide about road's structure/facilities standard』 .

The setting place is provided section that a fan shape change section without warning. But establishment place and high can establish flexibility with field conditions.

To increase effect of facilities, driver's visual behavior must consider. The facilities depend on driver's visual the cause.

Table 1. Standard of setting on delineator

Division	Detail content
Definition	- Delineator is facility guiding vehicles smoothly one of the facility road's second that inform road's a fan shape or changing geometric condition of the forward
Setting Location	- Design speed 50km/h over - Road's a fan shape change rapidly - Lane or wide of lane change rapidly. In case of road's illuminator ellipsis
Setting Place	- Set the outermost of shoulder, generally from shoulder to 0~200m point such a geometric - Standard setting supposes 0.5m from outermost of shoulder, unavoidable set on 0.5m nearly moderately
Setting High	- Set 90cm from pavement to the central point

Table 2. The present condition of facility at place #1 (R=500m)

Kind of facility	Present condition	Standard of setting
Delineator	Inside of curve	Non
	Outside of curve	White & new style 9EA, Non fixed, High: 1.2m fixed
Chevron Sign	Inside of curve	Non
	Outside of curve	General style 4EA, Non fixed, High: 1.2m fixed
Road guide cap	It was buried under the overlay	
Etc.	Warning sing 1EA, High: 2m	

Table 3. The present condition of facility at place #2 (Radius=130m)

Kind of facility	Present condition	Standard of setting
Delineator	Inside of curve	White & new style 14EA, Non fixed, High: 1.15m fixed
	Outside of curve	White & new style 16EA, Fixed, High: 1.2m fixed
Chevron Sign	Inside of curve	Non
	Outside of curve	General style 9EA, Non fixed, High: 1.2m fixed
Road guide cap	It was buried under the overlay	
Etc.	Warning sing 2EA, High: 2m	

3. DRIVER'S VISUAL BEHAVIOR CHARACTER

3. 1. Visual behavior character at lace #1(Radius=500m)

3. 1. 1 Territory of sight at day

The experimental test was beginning satisfying that drive record is 3years, visual action is no problem, owner driver and 4 persons at spot where traffic accidents occur frequently.

As a result, driver's visual is Max $-19.8^{\circ}\sim 19.0^{\circ}$, Min $-15.9^{\circ}\sim 14.8^{\circ}$. It is indicated that generally activity visual character at place #1(R=500m, L=218m). The place #1 spot where traffic accidents occur frequently spot where traffic accidents occur frequently (but right and left is different to each person character standard with median at curve-section)

And up and down territory of sight is observed that Max range is $-6.8^{\circ}\sim 12.4^{\circ}$, Min range is $-1.8^{\circ}\sim 12.1^{\circ}$. Therefore driver's watch carefully conditions of forward and keep up long distance frequently from visual-distance point of view. But driver's visual behavior is confirmed that Max range is $16.3^{\circ}\sim -2.7^{\circ}$ (Min range is $-16.5^{\circ}\sim -9.3^{\circ}$) by standard with median. That is to say, visual behavior is limited, reduced and concentrated with the center of a sphere. As a result, if visual action rate (about visual action widen) were 1.0 at straight-section, visual action rate is $0.54\sim 0.69$. That is, visual action is reduced at curve-section. For all that visual character of this place is concentrated with the center of a sphere. But delineator estimated the outside of driveway at with establishment standard. Therefore delineator escape driver's visual action range, so that it is need to consideration to increase effect of facilities. While, visual behavior is very activity like straight-section with right and left, up and down. Such a visual behavior is a common character for all the experimental person

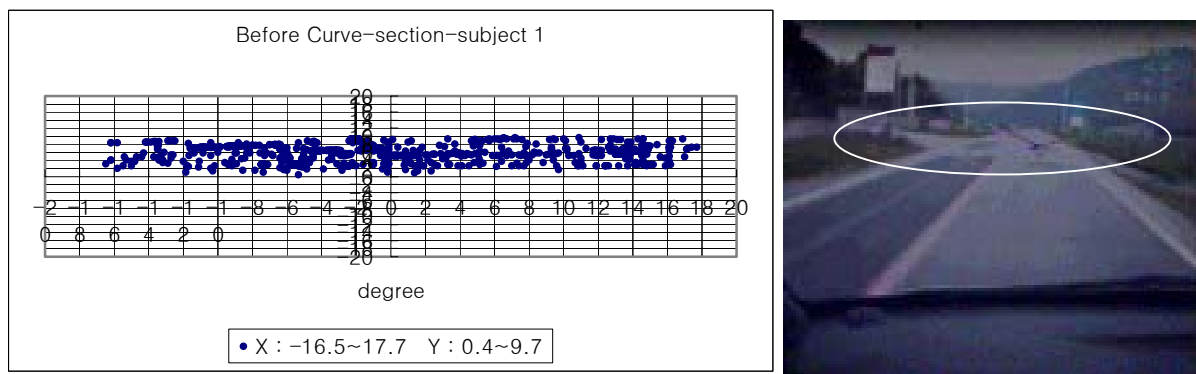


Figure 3. Driver's Visual Behavior at Strait-section 1(Daytime, Subject 1)

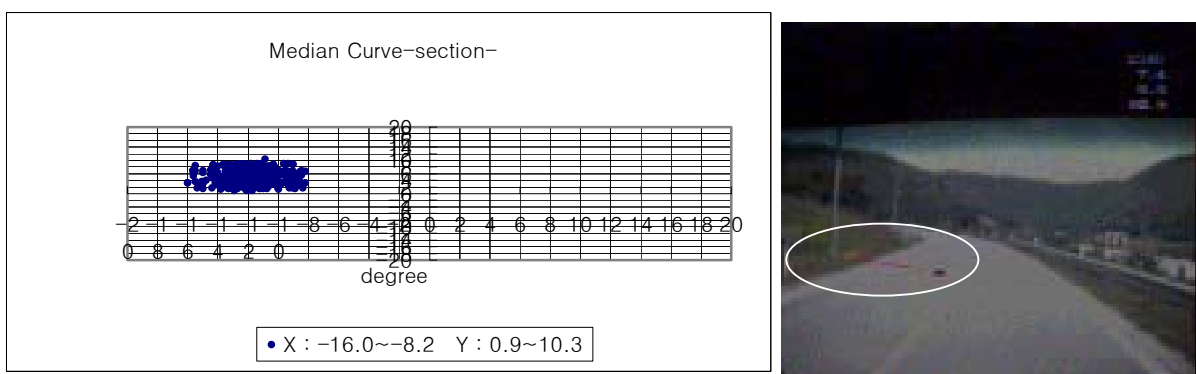


Figure 4. Driver's Visual Behavior at Curve-section(Daytime, Subject 1)

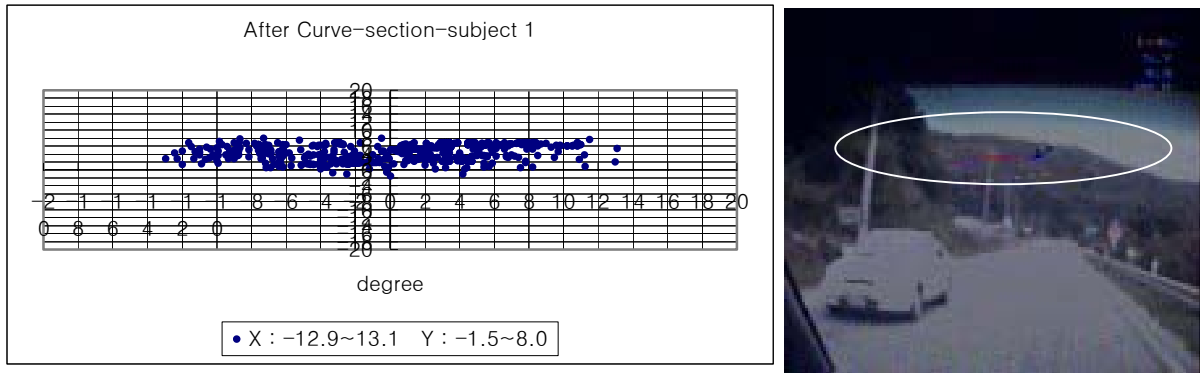


Figure 5. Driver's Visual Behavior at Strait-section 2(Daytime, Subject 1)

Table 4. As a Section Sight Area at Place #1(R=500m, Day)

Place #1(Day)		Left & Right Area	Up & Down Area
R=500m, L=218m		(degree/sec)	(degree/sec)
Subject 1	Strait section1	-19.8 ~ 19.0	-0.8 ~ 12.1
	Curve-section	-16.5 ~ -9.3	-1.6 ~ 11.0
	Strait section2	-15.1 ~ 14.7	-4.6 ~ 10.3
Subject 2	Strait section1	-17.6 ~ 17.3	-3.2 ~ 13.4
	Curve-section	-16.3 ~ -2.7	-6.8 ~ 10.9
	Strait section2	-15.3 ~ 13.3	-2.3 ~ 11.9
Subject 3	Strait section1	-15.9 ~ 14.8	-6.8 ~ 12.4
	Curve-section	-13.7 ~ -4.8	-5.4 ~ 11.4
	Strait section2	-15.3 ~ 17.3	-10.7 ~ 8.4
Subject 4	Strait section1	-18.8 ~ 17.5	-0.1 ~ 17.3
	Curve-section	-18.4 ~ -7.0	4.4 ~ 12.3
	Strait section2	-15.1 ~ 12.5	-9.6 ~ 8.7

3. 1. 2. Territory of sight at night

In driver's visual behavior(The experimental three persons) analysis driver's visual behavior character is indicated reducing trend of focus distribution(right and left, up and down) at night. While Max range is $-12.8^{\circ} \sim 10.0^{\circ}$ at straight-section, Min range is $-13.0^{\circ} \sim -2.1^{\circ}$ at curve-section by standard with median. At curve-section visual character is indicated reducing of visual action, at night, too.

In addition to, if Range of territory of sight(average) be established to be set a standard, right and left direction is 0.34, up and down direction is 0.73, so that the physical function slow to recognition. Therefore it is need to reviewing of delineator that is located the outside of the road. These trends of range of territory of sight are similar case at curve-section (Figure6, 7, 8, Table 5). Visual area of right and left and up and down is 0.52 and 0.63. Accordingly Visual area trend indicated a similar case at place #2, too.

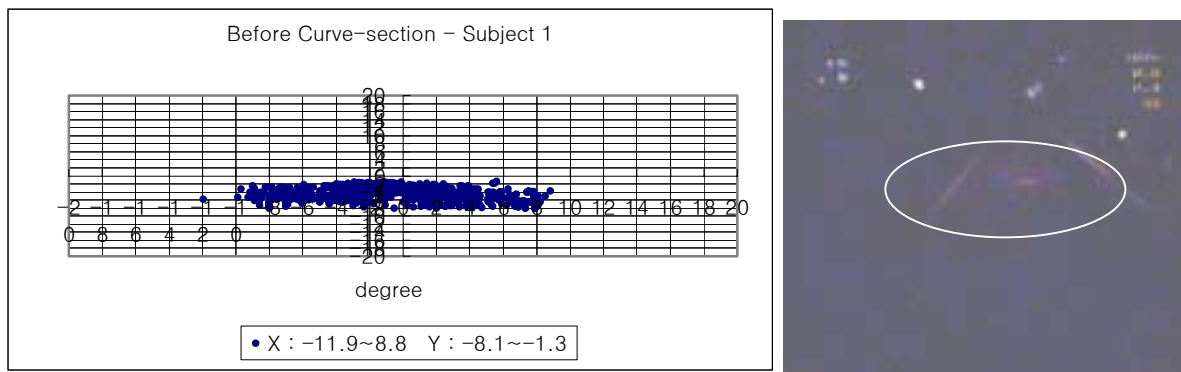


Figure 6. Driver's Visual Behavior at Strait-section 1(Nighttime, Subject 1)

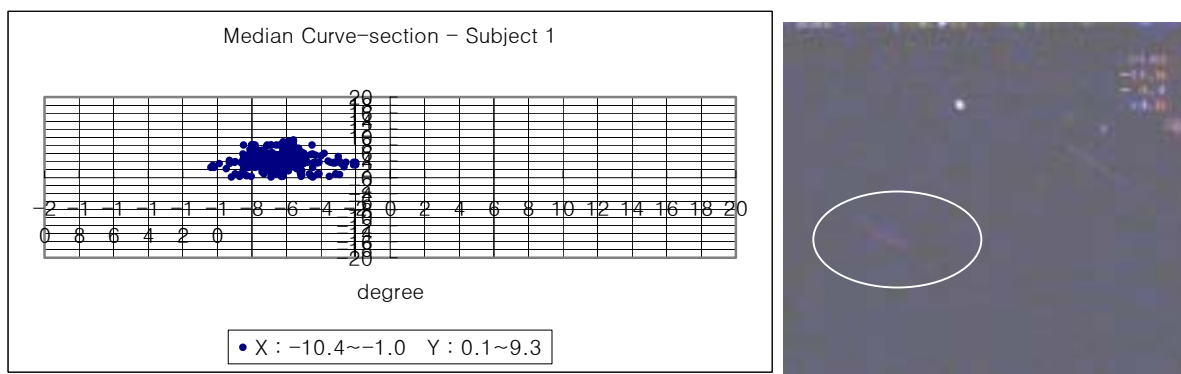


Figure 7. Driver's Visual Behavior at Curve-section(Nighttime, Subject 1)

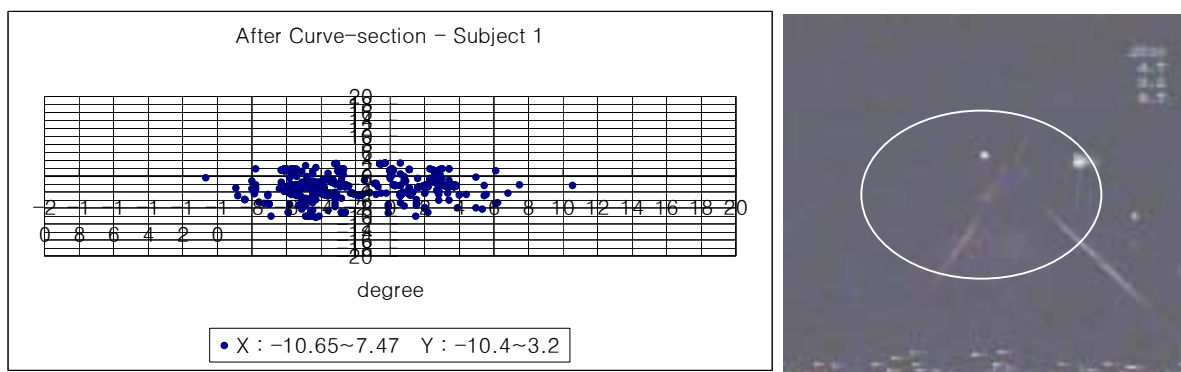


Figure 8. Driver's Visual Behavior at Strait-section 2(Nighttime, Subject 1)

Table 5. As a Section Sight Area at Place #1(R=500m, Night)

Place #1(Night)		Left & Right Area	Up & Down Area
R=500m, L=218m		(degree/sec)	(degree/sec)
Subject 1	Strait section1	-12.8 ~ 10.0	-8.5 ~ 0.3
	Curve-section	-11.6 ~ -1.2	-0.7 ~ 11.6
	Strait section2	-13.0 ~ 7.7	-13.7 ~ 4.0
Subject 2	Strait section1	-13.3 ~ 5.3	-8.7 ~ 9.3
	Curve-section	-13.0 ~ -2.1	-2.6 ~ 10.4
	Strait section2	-9.8 ~ 10.0	-10.4 ~ 6.6
Subject 3	Strait section1	-10.7 ~ 7.2	-8.9 ~ 5.8
	Curve-section	-12.4 ~ -0.9	-3.7 ~ 9.1
	Strait section2	-11.5 ~ 9.1	-7.4 ~ 3.4

3. 2. Visual behavior character at place #2(Radius=130m)

3. 2. 1. Territory of sight at day

From experimental section Min radius place #2(R=130m, L=207m) is indicated different of visual behavior of between straight-section and curve-section, too. Especially, visual behavior act very activity behavior at curve-section that can't be confirmed road's condition of forward. That is to say, when road's condition of forward do not be confirmed driver recognize aggressively to obtain information for road's safety.

In addition to, straight-section of curve-section after is indicated same behavior at straight-section of curve-section before. Therefore situation of concentrating of driver's focus on inside of curve is able to general visual character.

Table 6. As a Section Sight Area at Place #2(R=130m, Day)

Place #2(Day)		Left & Right Area	Up & Down Area
R=130m, L=207m		(degree/sec)	(degree/sec)
Subject 1	Strait section1	-19.8 ~ 19.0	-0.8 ~ 12.1
	Curve-section	-16.5 ~ -9.3	-1.6 ~ 11.0
	Strait section2	-15.1 ~ 14.7	-4.6 ~ 10.3
Subject 2	Strait section1	-17.6 ~ 17.3	-3.2 ~ 13.4
	Curve-section	-16.3 ~ -2.7	-6.8 ~ 10.9
	Strait section2	-15.3 ~ 13.3	-2.3 ~ 11.9

Subject 3	Strait section1	-15.9 ~ 14.8	-6.8 ~ 12.4
	Curve-section	-13.7 ~ -4.8	-5.4 ~ 11.4
	Strait section2	-15.3 ~ 17.3	-10.7 ~ 8.4
Subject 4	Strait section1	-18.8 ~ 17.5	-0.1 ~ 17.3
	Curve-section	-18.4 ~ -7.0	4.4 ~ 12.3
	Strait section2	-15.1 ~ 12.5	-9.6 ~ 8.7

3. 2. 2. Territory of sight at night

As compared with day and night, driver's visual action can grip decreasing phenomenon generally such a place #1. Almost right and left direction, as standard of straight-section, is about 36% at curve-section, at up and down direction is about 46% at place #1. (Table 9).

Table 7. As a Section Sight Area at Place #2(R=130m, Night)

Place #2(Night) R=130m, L=207m		Left & Right Area (degree/sec)	Up & Down Area (degree/sec)
Subject 1	Strait section1	-9.4 ~ 8.7	-5.3 ~ 9.0
	Curve-section	1.0 ~ 8.6	-1.2 ~ 7.0
	Strait section2	-10.4 ~ 3.0	-4.4 ~ 8.9
Subject 2	Strait section1	-8.2 ~ 8.4	-1.3 ~ 9.9
	Curve-section	0.6 ~ 9.8	2.0 ~ 9.5
	Strait section2	-8.6 ~ 8.4	-5.2 ~ 8.8
Subject 3	Strait section1	-9.5 ~ 7.2	-6.5 ~ 8.6
	Curve-section	6.0 ~ 14.5	-3.7 ~ 7.9
	Strait section2	-7.8 ~ 8.3	-7.4 ~ 10.7

Table 8. Average Sight Area place #1 & #2 at Day

Division	Left & Right Area		Up & Down Area		
	Sight Area	%	Sight Area	%	
Place #1	Strait section1	-15.5 ~ 15.0	1.0	-3.8 ~ 11.6	1.0
	Curve-section	-14.7 ~ -4.4	0.34	-0.8 ~ 10.4	0.73
	Strait section2	-13.0 ~ 12.5	0.85	-5.0 ~ 8.1	0.85
Place #2	Strait section1	-11.1 ~ 12.6	1.0	-3.9 ~ 11.4	1.0
	Curve-section	-1.2 ~ 14.0	0.52	-1.3 ~ 8.4	0.63
	Strait section2	-11.6 ~ 11.4	0.93	-5.0 ~ 9.4	0.94

Table 9. Average Sight Area place #1 & #2 at Night

Division	Left & Right Area		Up & Down Area		
	Sight Area	%	Sight Area	%	
Place #1	Strait section1	-10.6 ~ 7.2	1.00	-3.8 ~ 11.6	1.00
	Curve-section	-10.9 ~ -3.3	0.43	-0.8 ~ 10.4	0.91
	Strait section2	- 9.6 ~ 8.8	1.03	-5.0 ~ 8.1	0.89
Place #2	Strait section1	-6.4 ~ 9.3	1.00	-5.7 ~ 7.5	1.00
	Curve-section	4.2 ~ 9.8	0.36	0.9 ~ 7.0	0.46
	Strait section2	-6.7 ~ 4.3	0.70	-3.8 ~ 7.3	0.84

4. DRIVER'S VISUAL BEHAVIOR CHARACTER BY VISUAL SPEED

4. 1. Visual speed change at place #1

Driver's visual speed is indexed to representing level of driver's visual action. In case of visual speed is fast, driver's visual speed indicate aggressive action. As an action, it means situation that driver easy to recognition to surrounding road's condition. By means of these, in spite of different of each section and experimental person, at place #1, visual speed indicate 69.3~91.2degree/sec at straight-section 1, 18.8~23.3degree/sec at curve-section, 54.8~78.1degree/sec at straight-section 2. Therefore visual action at curve-section is able to level of 1/3 of it at straight-section.

Therefore driver's visual action range and visual function become low at the same time, so that it confirm to greatly becoming low cope with ability for safety driving. Especially, when it were considered driver's character such a lethality of a large of damage of traffic accident at curve-section that become low visual behavior and speed, complement at a point of view facilities means that it need to make up for and overcome bad condition. (for four person's average visual speed : straight-section 81.2degree/sec, curve-section 21.5degree/sec). In addition to, average visual speed is 63.2~69.5degree/sec at straight-section, 19.7~25.5degree/sec at curve-section at night. (for three person's average visual speed : straight-section 66.3degree/sec, curve-section 21.7degree/sec)

At night, average visual speed is 3/4 of level daytime at straight-section, but nighttime do not different. So that visual speed of curve-section at night is the lowest level of speed.

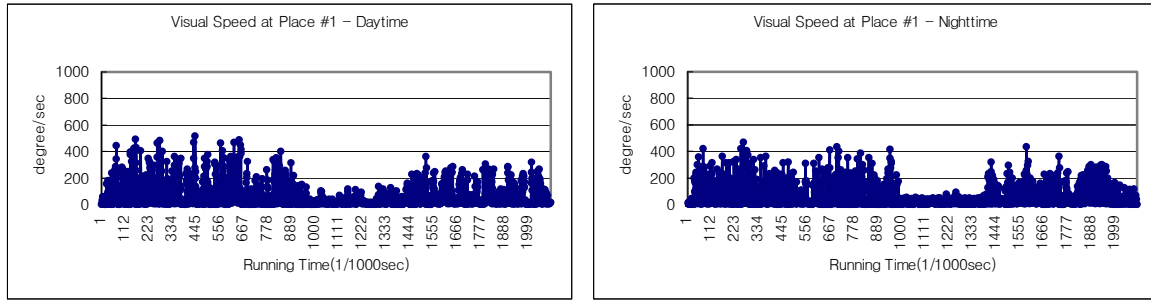


Figure 9. Visual speed at Place #1 (Left: Daytime, Right: Nighttime, Subject 1)

Table 10. Driver's Visual Speed Changing at Place #1

Place #1((Day & Night) R=500m, L=218m		Average Visual Speed (degree/sec)			
		Day	Night	Day	Night
Subject 1	Strait section1	84.4	66.1	515.6	470.1
	Curve-section	23.3	16.7	133.1	94.2
	Strait section2	62.9	63.3	363.0	435.0
Subject 2	Strait section1	79.7	69.5	455.5	447.0
	Curve-section	22.0	25.5	134.3	139.0
	Strait section2	78.1	69.5	459.0	420.4
Subject 3	Strait section1	69.3	63.2	412.0	422.0
	Curve-section	18.8	19.9	130.1	153.6
	Strait section2	54.8	57.0	435.0	288.0
Subject 4	Strait section1	91.2	-	546.0	-
	Curve-section	21.9	-	143.1	-
	Strait section2	66.7	-	313.0	-
Average	Strait section1	81.1	66.3	482.3	446.3
	Curve-section	21.5	20.7	135.2	128.9
	Strait section2	65.6	63.3	392.5	381.0

4. 2. Visual speed change at place #2

Driver's visual speed at place #2 same result at place #2. at day The four experimental person's average visual speed is about 111.6degree/sec at straight-section and about 21.5degree/sec at curve-section And ,at night, visual speed is observed average 77.5degree/sec at straight-section, 17.1degree/sec at curve-section. Curve-section have level about 1/5 of straight-section.

As a result, driver's visual behavior indicate activity watching carefully action at before curve-section, visual action reduce and was concentrate with inside of cure at curve-section, curve-section. Especially at night, cause visual action reduce because of reducing visual action and an evaporating situation and effect on beam of the opposite side vehicles, it need to consider driver's visual behavior on establishment standard at night.

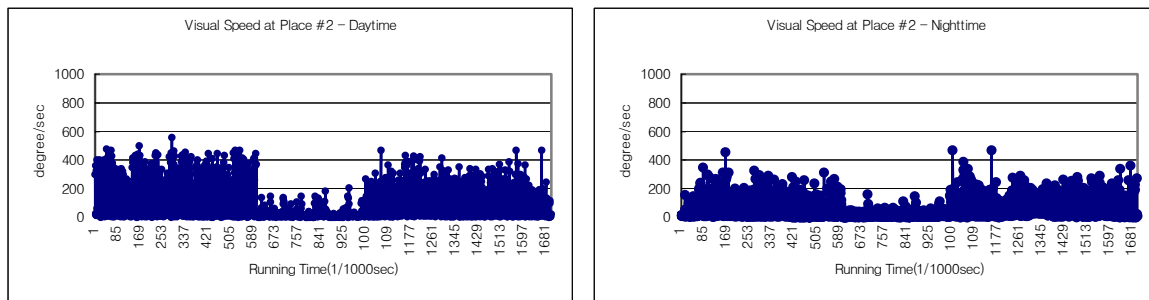


Figure 10. Visual speed at Place #2 (Left: Daytime, Right: Nighttime, Subject 1)

Table 11. Driver's Visual Speed Changing at Place #2

Place #2(Day & Night)		Average Visual Speed (degree/sec)			
		Day		Night	
R=130m, L=207m		Day	Night	Day	Night
Subject 1	Strait section1	124.1	81.4	558.0	455.5
	Curve-section	23.9	19.3	220.0	159.2
	Strait section2	105.3	81.9	466.7	466.7
Subject 2	Strait section1	120.0	72.7	469.7	435.0
	Curve-section	24.5	13.1	121.5	104.6
	Strait section2	102.0	70.4	337.9	362.0
Subject 3	Strait section1	105.5	78.5	549.0	364.0
	Curve-section	19.3	18.9	193.0	143.0
	Strait section2	101.5	75.5	466.7	485.0
Subject 4	Strait section1	96.7	-	524.9	-
	Curve-section	18.4	-	125.6	-
	Strait section2	104.6	-	524.9	-
Average	Strait section1	111.6	77.5	525.1	418.2
	Curve-section	21.5	17.1	165.0	135.6
	Strait section2	103.4	75.9	449.1	437.9

4. 3. The rate of visual space

As the rate of space of sight is defined rate of space that driver watch carefully in observation space (right and left, up and down each 40 degree) possible measuring with focus recorder using this paper, it means that the rate of space of sight the more high increase of visual activity.

By means of, the experimental person average rate of space of sight at place #1(R=500m) occupy 20.8% of total space at straight-section while 5.2% at curve-section, so average rate of space of sight at place #1 is level about 1/4, therefore we came to curve-section visual action restrictive and partial.

And then, after curve-section of the rate of space of sight increase 17.5%, so generally it happen to reduction of territory of sight, visual speed, the rate of space of sight at the same time at curve-section, it is difficult to recognizing of traffic information than straight-section by visual. Especially, in case of nighttime, the rate of space of sight is 10.6% at straight-section, 4.4% at curve-section, 11.3% at after curve-section, cause of lowest rate of space of sight and reduction of visual action than at daytime, therefore we know that curve-section inferior traffic environment

Table 12. Changing focus space each place

Division		Straight-section 1	Curve-section	Straight-section 2
Place #1 R=500m L=218m	Daytime	20.8 %	5.2 %	17.5 %
	Nighttime	10.6 %	4.4 %	11.3 %
Place #2 R=130m L=207m	Daytime	11.7 %	7.4 %	18.8 %
	Nighttime	8.0 %	2.7 %	7.3 %

4. 4. Visual character by the existence of the opposite side vehicles

In this paper, nighttime driving at curve-section, in case of the opposite side vehicles, as an until experimental result, as driver watch carefully continually beam of vehicle of the opposite side vehicles casually unlike general phenomenon that driver watch carefully inside of road, driver indicate commonly difficult or leave out behavior visual recognition of situation that driver is connection with traffic safety like pedestrian and/or confirming lane etc. at inside of curve-section.

To overcome these problem, it need to the facilities for light limiting of the opposite side vehicles partially, first of all, research on facilities establishing of guide eye to respect to driver's visual recognize action need.



Figure 11. As a Opposite Side Vehicle Concentrating Situation of The Focus
(Place #1, Left Curve)

5. RESULT AND FORWARD

In this paper, at curve-section traffic accident event rate and lethality higher than noncurve-section, this paper apply to highway line number 34, as foundation work to use delineator that was equipped to increase traffic safety, on straight-section and curve-section

But main visual behavior concentrating on inside of progress direction, visual action reduce than straight-section at curve-section. So we are need to forward review to increase effect of delineator.

While general visual behavior at night same at day, visual action of right and left, up and down direction more reduce. Especially up and down direction was limited visual action, so it is hard to recognize delineator.

It need to supplementation point of view driver's visual behavior to grip completely related matters for safety driving And while territory of sight of forward, the rate of space of sight that driver's indicate space watching carefully reduce from 20.8%, 11.7%(Daytime) at straight-section of each place #1, #2 to 5.2%, 7.4% at curve-section of each place #1, #2.

These were based on visual character, in case of the considering visual speed, territory of sight etc. it need that facility setting standard must be reviewed to increase traffic safety and

essential effect at curve-section. Especially, in case of the opposite side vehicles driving at night, driver indicate behavior watching carefully beam of the opposite side vehicles, so it need to countermove accompany to increase traffic safety cause limit forward of progress direction.

But in this paper, As set on the basis of the one-way, it need to research on different kinds of extend various lane, road's shape, radius and etc. to keeping up with recently highway extending trend.

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