VISIBILITY OF TEXT INFORMATION FUNCTIONING AS URBAN DISASTER PREVENTION
-The Visibility of Emergency Signs in the Daegu Subway Fire, Korea -

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ABSTRACT

It is considered that cities are increasingly vulnerable against disaster because of complex urban structure, more strangers in the city, and advent of the super-aging society. Therefore, tools to assist evacuation on one's own judgment are called for in the event of a disaster. The evacuation takes the following three steps: First, we seek for an understanding of present situation. Next, we seek for refuge area. And finally, we evacuate to safer places. Text Information is very important at every step of the evacuation. This report shows the effectiveness of Text Information from the perspective of disaster prevention. First, "Visibility Model" is presented. The model is adapted for disaster situation like in the event of a fire. Then it shows a case study in which the model is applied to a real disaster: the widely known subway fire in the Daegu City.

KEY WORDS: Visibility Model, Text Information, Smoke Density, Age, and Daegu Subway Fire

1. INTRODUCTION

It is considered that contemporary urban life is increasingly vulnerable against Disaster. There are three reasons for the city vulnerability: (1) Increasingly complex urban structure, congestion, and multistory buildings. (2) More strangers across the city border. (3) Advent of the super-aging society. Under this circumstance, some tools to assist to evacuate on one's own judgment are called for in the event of a disaster.

The evacuation takes the following three steps. First, we try to understand the present location, assess the situation and decide whether to evacuate or stay. And next, we seek for safe area for refuge (Emergency Exit etc.). Finally, we evacuate to safer places once we find the routes for evacuation. Text Information is crucial to these processes.

There are many kinds of signs useful for evacuation. One is "Name of Place" sign for understanding of present location. Another is "Location Map" sign for seeking for the escape routes. Other is "Directional Route" sign for leading to the refuge area. In order for Text Information to properly function for evacuation, we need to ensure signs' visibility. For the visibility of Text Information, we have to consider not only sign's design but also affecting factors of environmental conditions surrounding signs.

This paper, first demonstrates "Visibility Model in Steady State" established in our previous studies[1)2)3)5)]. Next, by referring to past researches, the Transmission Model is developed in order to calculate changes of luminance under smoking-fire environment including the smoke density (Cs). The Transmission Model is validated by comparing the observed value in the experiment and the values predicted by the Model. Then by combining the Transmission Model and Visibility Model in Steady State, a new Visibility Model in Fire Situation is formulated. Finally, the Visibility Model in Fire Situation is applied to the subway incident in Daegu for assessing the visibility of the evacuation signs.

2. VISIBILITY MODEL IN A STEADY STATE [1)2)3)5)]

Generally speaking, three factors are important to properly design visual environment. Those three factors are environmental conditions, visual object's conditions and human visual ability. The former two factors define visual stimulus, and the latter one defines visual sensitivity. Human visual ability consists of many functions like field of view and color sensitivity and so on, but usually the most important is visual acuity. Visual response evaluation, namely visibility depends on both visual stimulus and visual sensitivity.

Visual stimulus is represented by 4 elements, namely size of a visual target, background luminance, contrast between the visual target and background luminance, and viewing time. If the viewing time is more than 100ms, the visibility becomes stable regardless of time[4)]. There is a significant difference of visual acuity not only among age groups (Young / Aged) but also among individuals. However, it has been found that the environmental conditions at which maximum visual acuity (MVA) is attained are the same despite of differences of MVA[1)-3)]. Therefore MVA can be an index for measuring human visual sensitivity.

Based on the results in Ref. [5], Visibility Model of Text Information at steady state (the viewing time exceeding 100ms) can be constructed by five elements: character size (S), luminance contrast (C), background luminance (L_b), maximum visual acuity (MVA) and legibility of character sentence. Equation 1 shows the Visibility Model of Text Information[5)].

$$\left.\begin{aligned} S \times {L_b}^{0.23} \times C = MVA^{-1} \times 10^{0.75\alpha'} \times 30 \\ C = \frac{|L_b - L_t|}{\max(L_b, L_t)} \end{aligned}\right\} \qquad (1)$$

where S is character size (minute), L_b is adaptation background luminance and L_t is character luminance (cd/m^2), C is luminance contrast, MVA is Maximum Visual Acuity. α' shows the rate to get more “Normal” legibility within the same MVA group, and we call this Visibility Level. The effective areas of Equation 1 are $10 \le S \le 100$, $0.35 < L_b < 1400$, $0.52 \le C \le 0.93$, $MVA \ge 0.1$, and $0.05 \le \alpha' \le 0.95$.

This Visibility Model was derived based on the experimental results which were carried out for 86 subjects under various visual stimulus conditions. The visual target was a monochromatic Japanese sentence typed in Ming font. Whichever value of L_b and L_t is higher legibility did not change[6)].

Equation 2 treats the effects of other visual stimuli on visibility by replacing the effects with the equivalent size of character. If the luminance contrast C of sign’s character is over 0.5, the color doesn’t affect the visibility. Gothic font is thicker than Ming font, so the visibility of Gothic character is higher than that of Ming character under the visual condition that character size s is small and/or observer's MVA is low.

$$S_{color} = S_{mono} (C > 0.5)$$
$$\left. \begin{aligned} S_{Gothic} &= 1.27 \times S_{Ming} (S \times MVA < 40) \\ S_{Gothic} &= S_{Ming} (S \times MVA \geq 40) \end{aligned} \right\} \tag{2}$$

3. OPTICAL TRANSMISSION MODEL THROUGH SCATTERING MEDIUM

In real situations, we have to consider two kinds of factors affecting visibility; one is routine factors like weather, sun's altitude, light's on/off and deterioration by weather stain, and the other is non-routine factors like power failure, obscuration by smoke and damage that is caused by disasters like fire, earthquake and so on. In order for Text Information to function properly for evacuation, we need to secure the visibility under such affecting factors. For the application of Visibility Model's to a real situation, it is necessary to consider both routine and non-routine factors in terms of luminance and/or contrast.

Under a fire, we have to treat the effects of absorption and scattering of smoke on the background and target luminance. Luminance contrast will change in smoke, too. So, they need to be incorporated into the calculation of Visibility Model.

3.1 Basic Model of Optical Transmission Through Scattering Medium7)8)

In this section, we construct the basic model of optical transmission through scattering medium as referring the reports of Chandrasekhar7) and Matsuura8). Equation 3 is the well known law of Lanbert-Beer7):

$$I_s = I_o \times e^{-CsV} \tag{3}$$

$$\left. \begin{aligned} Cs &= \sigma_s + \sigma_{ab} \\ k &= \frac{\sigma_s}{Cs} \end{aligned} \right\} \tag{4}$$

where I_o is the incident light flux, I_s is the transmitted light flux, V (unit: m) is the distance between I_o and I_s, and C_s is the optical smoke density. Furthermore, C_s consists of scattering coefficient σ_s and absorption coefficient σ_{ab}. Generally speaking, the value of k of black smoke from a flaming fire is about 0.5, and that of white smoke from a smoldering fire is 1.09).

Fig.1 shows the concept of the luminance $L(s;\theta_s,\phi_s)$ at an arbitrary point S in the direction of (θ_s,ϕ_s). We rearrange the basic model of optical transmission through scattering and absorbing based on Chandrasekhar's equations7)8) as follows:

$$\frac{dL(s;\theta,\varphi)}{ds} = -CsL(s;\theta,\varphi) + \frac{kCs}{4\pi} \int_0^{4\pi} P(\theta,\varphi : \theta_s,\varphi_s) L(s;\theta_s,\varphi_s) d\omega_s \tag{5}$$

$$\frac{1}{4\pi}\int_0^{4\pi} P(\theta,\varphi:\theta_s,\varphi_s)d\omega_s = 1 \quad (6)$$

where $P(\theta,\varphi:\theta_s,\varphi_s)$ is the scattering function, (θ_s,ϕ_s) denotes an incident angle, and (θ,ϕ) shows a reflection (and/or scattering) angle. $d\omega_s$ is an infinitesimal solid angle in the direction of (θ_s,ϕ_s).

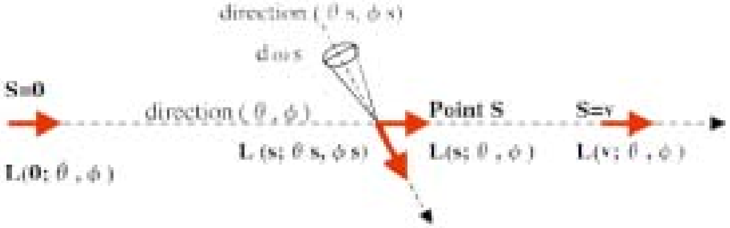

Fig.1 Concept of the luminance L(s; θ , φ) of an arbitrary point S.[8]

Integrating Equation (5) for s=0-v, the luminance $L(v;\theta,\phi)$ of point v is expressed by Equation (7). The first term in the right-hand side of Equation (7) means the extinction of the luminance $L(0;\theta,\phi)$ by traveling to the point v. The second term in the right-hand side shows the sum of scattering luminance $L(s;\theta_s,\phi_s)$ from s=0 to s=v.

$$L(v;\theta,\varphi) = L(0;\theta,\varphi)e^{-Csv} + \int_0^v \frac{kCs}{4\pi}\int_0^{4\pi} P(\theta,\varphi:\theta_s,\varphi_s)L(s;\theta_s,\varphi_s)d\omega_s e^{-Cs(v-s)}ds \qquad (7)$$

Substituting Equation (6) into Equation (7), the basic model of the optical transmission through a scattering medium is finally expressed as follows:

$$\begin{aligned} &L(v;\theta,\varphi) = L(0;\theta,\varphi)e^{-Csv} + \int_0^v kCsL(s;\theta_s,\varphi_s)e^{-Cs(v-s)}ds \\ &\therefore L(v;\theta,\varphi) = L(0;\theta,\varphi)e^{-Csv} + kL(s;\theta_s,\varphi_s)(1-e^{-Csv}) \end{aligned} \qquad (8)$$

3.2. Approximation of the Optical Transmission Model[8]

If the reflection luminance of a wall surface Li is constant and luminance distribution of scattering medium Lc is uniform, Lc is constant at any position and in any direction, so we can treat Lc the same as Li. $Ld(x;\theta,\phi)$ means the emitting luminance for itself. Then we can derive the approximate optical transmission model (9) as follows:

$$\begin{aligned} &L(v;\theta,\varphi) = Ld(x;\theta,\varphi)e^{-Csr(x,v)} + Lie^{-Csr(x,v)} + kLc(1-e^{-Csr(x,v)}) \\ &Li = Lc \\ &\therefore L(v;\theta,\varphi) = Ld(x;\theta,\varphi)e^{-Csr(x,v)} + Li\left\{e^{-Csr(x,v)} + k(1-e^{-Csr(x,v)})\right\} \end{aligned} \qquad (9)$$

In particular, if the medium is scattering only like smoldering smoke, the value of k is almost equal 1.0. Equation (9) is reduced to Equation (10). In both Equation (9) and (10), it is not necessary to treat an incidence angle and so on.

$$L(v;\theta,\varphi) = Ld(x;\theta,\varphi)e^{-Csr(x,v)} + Li \qquad (10)$$

3.3. Calculation of Reflection Luminance of Wall Surface Li

If there are some light sources diffusing completely in the closed space, Li is calculated by Equation (11).

$$Li = \frac{F_{sum} \times \rho_{ave}}{\pi \times A_{sum}} \tag{11}$$

where F_{sum} is the sum of illuminance intensity in the space, ρ_{ave} is medium reflectance surface of the space, and A_{sum} is the sum of surface area of the space.

4. VERIFICATION OF APPROXIMATED TRANSMISSION MODEL

We measured light intensity change under various Cs levels in an experimental laboratory, and examined the validity of the Approximated Transmission Model. The size of laboratory is $W7.5m \times D10.0m \times H4.0m$, and the reflectance of its surface is 0.038. All of lights in the laboratory were turned off during the experiment. The luminous target, which is a luminous circle of 14 centimeters in diameter and the height luminous circle center is 1.35 meters about the room floor, is centrally located in the laboratory. The light source of the target is an incandescent lamp (100 W, 1500 lm).

A luminance meter (MINOLTA LS-110) is set on the center line of the luminance circle of the target ($(\theta,\varphi)=(0,0)$) 1.0 meter apart. And we put one illuminance meter (MINOLTA T-10) at the same position of the luminance meter, and put another illuminance meter on the floor just beneath of the target.

We use two kinds of smoke in the experiments; one is a black smoke generated by smoke candles (Koa-Kako SL-135B, whose major component are Hexachloroethane, Anthracene and Magnesium coating) as a substitute of smoke under the flaming fire. The other is a white smoke by inflaming cotton wicks as a substitute of smoke under the smoldering fire.

In the experiment, we first smoked up the room until its Cs reaches the maximum intensity. And then we measured the light intensity and Cs continuously, while the smoke is diluted slowly till Cs=0 by a mechanical ventilation. The smoke in the room was stirred all times by a fun so the Cs distribution was kept uniform. Cs is measured by four smoke density meters that are set at both side of the target at two different heights. The results of these meters were almost the same, so we regarded the mean value of the four Cs data as the representative data.

4.1. Verification of Scattering Ratio “k”

If Cs distribution is uniform in the laboratory, the total light intensity of scattering by smoke can be measured by the illuminance meter. In Equation (4), k is defined of the ratio of scattering coefficient σ_s to smoke density Cs. Under high concentration of Cs, the illuminance value may decrease by absorption, but it does not increase by scattering more than the illuminance value under Cs=0. Moreover, if Cs consists of only σ_s, k is equal 1.0.

Fig. 2 shows the relationship between illuminance and Cs for grasping the scattering ratio k for two different smokes. The front illuminance is higher than the floor illuminance because of the different intensity of luminous flux entering the illuminance meter. However, the relative relationship between illuminance and Cs is constant regardless the value difference between the front illuminance and the floor illuminance. Therefore, we can confirm the homogeneous distribution of Cs in the laboratory. In the case of white smoke (by cotton wick), illuminance value is constant despite the increase of Cs, which implies that Cs of white smoke consists of only σ_s ($\therefore k = 1.0$). In the case of black smoke (by smoke candle), illuminance value E_{black} decreases with the increase of Cs, it is seen that the relationship between Cs and $\log_e E_{black}$ is linear, i.e.

$$\log_e E_{black} = a \times Cs + b \tag{12}$$

The coefficient a of Equation (12) is almost 0.5 in the both result of the front illuminance and floor illuminance, which shows that Cs of black smoke consists of equal parts of σ_s and σ_{ab} ($\therefore k = 0.5$). These results are the same as Jin's report9).

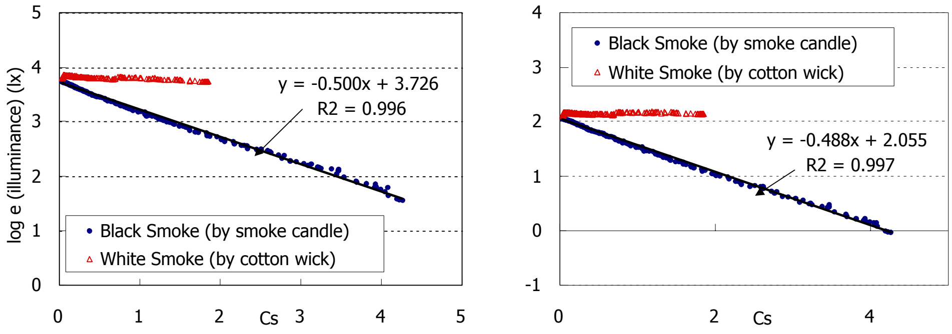

Fig.2-1 Front Illuminance **Fig.2-2 Floor Illuminance**

Fig.2 Relationship between illuminance and Cs for grasping the scattering ratio "k" at two different smokes

4.2. Verification of Approximated Transmission Model

In this experiment conditions, we verify the approximated transmission model of Case 2. The light source in the laboratory is only the luminous target, so we can calculate Li by using Equation (11) as follows:

$$Li = \frac{F_{sum} \times \rho_{ave}}{\pi \times A_{sum}} = \frac{1500 \times 0.038}{\pi \times \{2 \times (7.5 \times 10 + 10 \times 4 + 4 \times 7.5)\}} = 0.062$$

Ld is the luminance under the condition of Cs=0.The distance $r(x,v)$ between target equipment and luminance meter is 1.0 meter. We use the value of k from the results of the previous section 5.1. When these values are substituted for Equation (9), the predicted values of luminance Lv are determined.

The relationship between the observed value and the predicted value is shown in Fig.3. In the case of black smoke, the predicted value of luminance is 15 % higher than the observed value, and the difference between the observed value and the predicted value increases as luminance increases. In the case of white smoke, the predicted value of luminance is 11 % lower than the observed value. Therefore we are able to consider that the approximated transmission model can be applied within an acceptable limit of error.

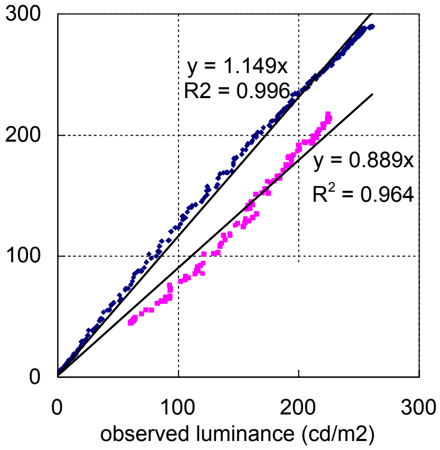

Fig.3 Relationship between observed luminance and predicted luminance at two different smokes

5. VISIBILITY MODEL IN FIRE SITUATION

In this chapter, we construct the Visibility Model in Fire Situation combining the Visibility Model in Steady State (chapter 2) and the Optical Transmission Model through scattering medium (chapter 3).

5.1. Visibility Model in Fire Situation for Luminance Target

If the target emits light ($Ld > 0$) like emergency exit sign lighting, the Visibility Model in Fire Situation is shown in the simultaneous Equations (13) that includes smoke density (Cs) and scattering coefficient (k).

$$\left.\begin{aligned} &S \times (L_{bf})^{0.23} \times C_f = MVA^{-1} \times 10^{0.75\alpha'} \times 30 \\ &L_{bf} = L_b \times e^{-CsV} + Li \times k(1-e^{-CsV}) = Li \times \left\{\rho_b \times e^{-CsV} + k(1-e^{-CsV})\right\} \\ &L_{tf} = Ld \times e^{-CsV} + Li \times \left\{e^{-CsV} + k(1-e^{-CsV})\right\} \\ &C_f = \left|L_{bf} - L_{tf}\right| / \left\{\max(L_{bf}, L_{tf})\right\} \end{aligned}\right\} \qquad (13)$$

where L_{bf} and L_{tf} are the adaptation background and target luminance in fire smoke respectively, L_b is background luminance without smoke (cd/m^2), ρ_b is background reflectance, and V is the visual distance between the target and the observer.

5.2. Visibility Model in Fire Situation for Reflecting Target

If the target does not emits light ($Ld = 0$) like road signs or location map, the Visibility Model in Fire Situation is shown in the simultaneous Equations (14). L_t is the target luminance without fire smoke(cd/m^2), and ρ_t is the reflectance of target surface.

$$\left.\begin{array}{l} S \times (L_{bf})^{0.23} \times C_f = MVA^{-1} \times 10^{0.75\alpha'} \times 30 \\ L_{bf} = L_b \times e^{-CsV} + Li \times k(1 - e^{-CsV}) = Li \times \{\rho_b \times e^{-CsV} + k(1 - e^{-CsV})\} \\ L_{tf} = L_t \times e^{-CsV} + Li \times k(1 - e^{-CsV}) = Li \times \{\rho_t \times e^{-CsV} + k(1 - e^{-CsV})\} \\ C_f = \left| L_{bf} - L_{tf} \right| / \{\max(L_{bf}, L_{tf})\} \end{array}\right\} \tag{14}$$

Here the necessary level of visibility in disaster situations is assumed to be $\alpha' \geq 0.80$. In fire situation, we should set two kinds of risk indices: smoke density and the value of MVA. The average MVA of the aged is about 0.9, and that of the young is about 1.9$^{7)}$.

6. THE VISIBILITY OF EVACUATION SIGNS IN THE DAEGU SUBWAY FIRE

6.1. Problem of Visibility in the Daegu Subway Fire

Here, a case study applying our models to a fire situation is shown: The widely known subway fire in the Daegu City. It happened on February 18th, 2003. Nearly 200 people have been reported dead, and remarkably, as many as 142 persons in the train. The death toll in the train (No.1080), which came into the opposite platform, was bigger than that in the train (No.1079) in which the fire was started. One of the main causes of the tragedy was that there was no escape route for passengers in No.1080. Driver cut the power off, closed all doors without checking the remaining passengers and left the train. Few knew how to operate the emergency cocks, the only tool to open doors under any condition (even without power). If they had been able to open the door by operating emergency cocks, many lives might have been saved. For a while after the arrival of No.1080, the passengers could see their surroundings. With good visibility of the Text Information of emergency cock, many passengers would have been able to read it, operate emergency cock, open the door and make an escape route.

In the station yard, the death toll was big, too. It was considered that the victims could not see the lighting of Emergency Exit Sign and lost escape routes under the dense smoke. It is necessary to quantify the effectiveness of the light under the fire.

6.2. Calculation of Visible Distance as Characteristic of the Target

We quantify the visibility of Emergency Signs to convert it into a Visible Distance D at which an observer can read the Text Information of Signs easily. Fig.4 shows the physical characteristics for which calculation of D is needed. Visible Distance is computed by the simultaneous Equations (15) based upon the Visibility Model in the Steady State. This Visible Distance represents the characteristic of the target and is given by.

$$\left.\begin{array}{l} D = \sqrt{V^2 + (H - h)^2} \\ V = \cos\delta \times (S'/2) / [tan\{S/(2 \times 60)\}] \\ \cos\delta = D/V \\ S = 10^{0.75\alpha'} \times 30 / \{MVA \times L_b{}^{0.23} \times C\} \end{array}\right\} \tag{15}$$

where V (m) is the distance between target (i.e. character of Text Information) and observer's eyes. H (m) is the height of the sign's character and h (m) is the height of the observer's eye. In the survey report$^{7)}$ on physical measurement of Japanese people, the average h of the aged is about 1.49, and that of the young is about 1.58. δ (degree) is the angle of center of the character and vertical direction. S' is the original size of character.

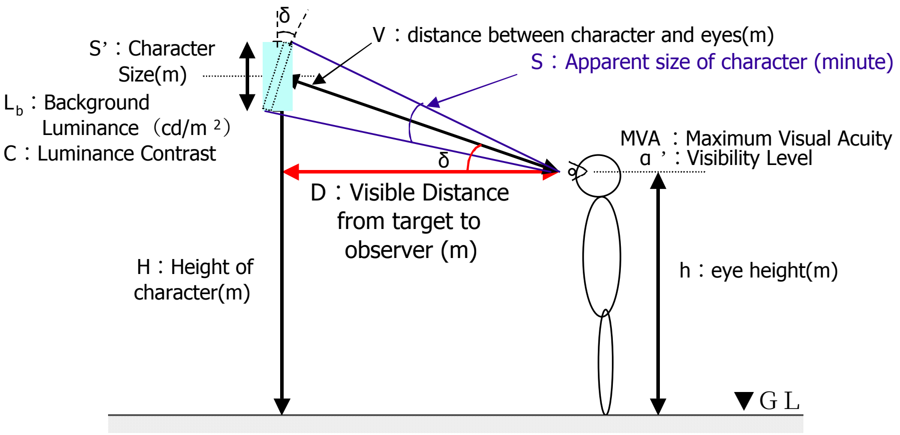

Fig.4 Physical Characteristics to need Calculation of Visible Distance (D)

If an observer cannot read target's characters easily because the visual stimulus of the characters is in bad conditions: the character size is very small and their contrast is low, then we cannot calculate Visible Distance of it.

6.3. The Visibility of Evacuation Signs in the Daegu Subway Fire

We measured the visual stimulus and the position of the operating manual sign of emergency cock at the site of the fire. Fig 5 shows the sign and Tab.1 shows the visual stimulus of the sign.

Tab.1 Visual Stimulus of Operating Manual Sign

Center Height of Installation Position	1.65m
Illumiinance of Target Surface	450lx
Size of Taget	H 0.151m×W0.095m

		Headline	Description	Supplement
Number of characters		8	52	37
Charactere Size	Height	1.20	0.60	0.54
	Width	0.78	0.48	0.42
Reflectance	Character	0.468	0.103	0.103
	Background	0.208	0.468	0.468
Contrast		0.555	0.780	0.780
Color Combination(C/B)		White/Red	Black/White	Black/White

Fig.5 Operating Manual Sign of Emergency Cock at the fire

First, we compute Visible Distance (in the smokeless situation) of the sign's characters to operationalize visibility based upon the Visibility Model. Under the disaster situation, sign's characters have to be legible, so we set Visibility Level at $\alpha' = 0.8$. Visible Distance of the sign's headline is very small: the one for the young is 79 cm and that for the aged is 29 cm. Especially for the aged, the sign's characters are hard to read even in the normal conditions of the car, it is ineffective whenever a disaster occurs.

In smoke, background/target luminance and contrast changes with the increase of smoke density Cs. Therefore, secondly we calculate the adaptation luminance L_{bf}, L_{tf} and contrast C_f at observer's eye position based on the Visible Distance. We use the Equations (14), because the sign does not emit light, and show the results in Fig.6-1. As increasing Cs, two kinds of luminance at eye position increase and contrast decreases by adding the scattering luminance.

And then, we calculate the necessary size of the characters S'_{need} to keep the same visibility with increasing Cs by Equation (16).

$$S'_{need} = \frac{10^{0.75 \times 0.8} \times 30}{MVA \times L_{bf}^{\;0.23} \times C_f} \tag{16}$$

The relationship between S'_{need} of the target's headline and Cs is shown in Fig.6-2. In the figure, S'_{need} increases as Cs increases. And S'_{need} of the young (its Visible Distance is longer than the one of the aged) is bigger than that of the aged under the same Cs. In the case of the young, S'_{need} is about four times size of the original in the thick smoke like $Cs = 2.0$ under the condition of Visible Distance $D = 79cm$.

All of the evacuation signs were quickly improved after the fire. We measured visual stimulus of the new operating manual sign of emergency cock, too. Fig 7 shows the sign and Tab.2 shows the visual stimulus of the sign.

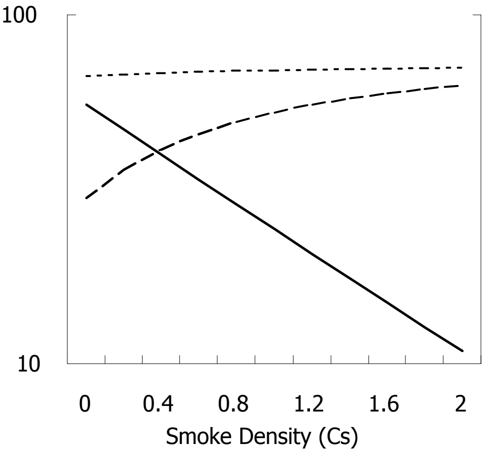

Fig.6-1 Change of Visual Stimulus in smoke **Fig.6-2 Relationship between Cs and S'$_{need}$**

Fig.6 Visibility of Target's Headline in the fire smoke

Tab.2 Visual Stimulus of New Sign

Center Height of Installation Position	1.06m
Illumiinance of Target Surface	127lx
Size of Taget	H 0.217m×W0.283m

		Headline	Description	
Number of characters		10	52	6
Charactere Size	Height	3.60	2.13	2.13
	Width	2.36	1.61	1.61
Reflectance	Character	0.757	0.158	0.362
	Background	0.362	0.757	0.757
Contrast		0.522	0.791	0.522
Color Combination(C/B)		White/Red	Black/White	Red/White

Fig.7 New Operating Manual Sign after the fire

Before the fire, only the passengers in the close neighborhood of the door could recognize the sign. But since the improvement, the passengers at wide-ranging distance from the door can get necessary Text Information. Fig.8 shows the difference of Visible Area between two operating manual sign before/after the fire. Visible Distance of the new sign's headline is longer than the old one: D for the young is 175cm and the one for the aged is 57cm. Visible Distance of the new sign increases about twice than before.

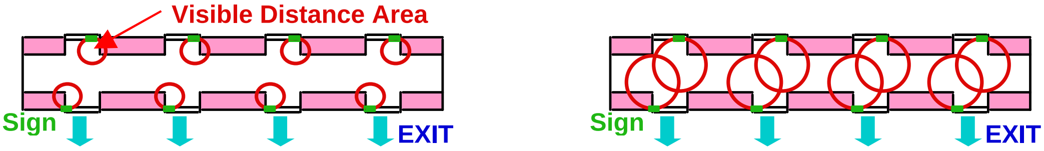

Fig.8-1 Old Sign Before the Fire **Fig.8-2 New Sign After the Fire**

Fig.8 Visible Area of Headline of Operating Manual Sign (for the young)

Fig.9 shows the comparison of the old sign with the new sign about the relationship between Cs and S'_{need} to keep the same visibility in the smoke. We calculate S'_{need} of the new sign if the observer sees it from the Visible Distance of the old sign ($D = 79cm$). The headline characters of the new sign can be read under a thin smoke like $Cs = 0.8$. It is considered that the new sign is much more effective in the fire situation.

Fig.9 Comparison of S'$_{need}$ for the young

It means the chance of survival increases significantly. This is a good example demonstrating the importance of Text Information for disaster prevention. In addition, these operating manual signs of emergency cock are reflecting targets, so we cannot see them if there is no ambient light as blackout.

7. CONCLUSION

In designing signs, consideration for visibility is important. Also in non-routine time, like emergency and reconstruction, Text Information is useful as a means of communication in disasters. So visibility should be secured even for temporary signs. We formulate a Visibility Model in fire situation by introducing the Visibility Model in Steady State and the Transmission Model. And then, we calculated the visibility of emergency signs in the Daegu subway fire. In this report, we demonstrated the effectiveness of new operating manual sign of emergency cock improved after the fire for visibility. After the fire, Daegu Metropolitan Subway Authority put up the educational poster in noticeable places in the station yard. This is a very important measure to reduce the risk and damage of next disaster.

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