3．4．8　交通安全施設に関する研究

Paper

A Research on Interrelation between Illuminance at Intersections and Reduction in Traffic Accidents

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ABSTRACT

One recently apparent trend in increasing traffic accidents in Japan is the increase in nighttime accidents. To address this problem, various traffic safety measures have been introduced aiming at safer road traffic environments. Among these measures, road lighting, in particular 'local lighting' has been introduced in an increasing number as a countermeasure against nighttime accidents. However, in terms of number of fatal accidents by road profile, the 'at intersection' accounts for the largest portion of the fatalities. Therefore, a more effective intersection lighting measure must be studied.

This paper discusses the illuminance levels expected for intersection lighting from the viewpoint of traffic accident reduction effect and reports the review result. The means used in reviewing were accident data before and after introduction of accident countermeasure and statistical analysis. It was learned from the result of these review works that an average road surface illuminance at intersections maintained at 20 lx or higher, as a level expected for intersection lighting, can provide the effect of accident countermeasure, and that an average road surface illuminance of 30 lx can further positively develop a statistically significant result as to reduction in traffic accidents.

KEYWORDS : road lighting, traffic accident, intersection

1. Introduction

In 1999, the annual traffic accidents fatalities in Japan was 9,005, which marks a continued decrease in traffic fatalities over four years in succession since 1996. However, in the year 1999, the number of the injured persons due to traffic accidents exceeded one million for the first time and the total of traffic accidents involving death and/or injury topped 850,000, resulting in an increase over seven running years.

One significant trend in recent traffic accident statistics is the increase in nighttime traffic accidents. The nighttime traffic accidents often result in severe outcome, and the fatality ratio with nighttime accidents is approximately three times[1] as high as that with daytime accidents. Therefore, the reduction of nighttime traffic accidents is posing a greater challenge in promoting safe traffic programs.

In addressing such a challenge, various safe traffic facilities have been introduced to improve safety in road traffic environments. In particular, since 'at intersection' account for a very large percentage in nighttime traffic accidents by road profile[2], lighting on intersections has been one of the potential countermeasures against nighttime traffic accidents. However, it has not yet been clarified whether effectively introduced lighting into intersections can decrease traffic accidents and which level of illuminance positively develops the effect of lighting at intersections.

Focusing on 'intersection lighting' as a promising accident countermeasure to reduce nighttime traffic accidents, this paper reports the result of our investigation into the illuminance level needed for intersection lighting, by survey of traffic accidents both before and after introduction of the countermeasure, and by statistical

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*One of the authors, Hiroshi Oya, belonged to Public Works Research Institute from April 1999 to March 2000. (On April 1, 2000, the Public Works Research Institute was restructured into the National Institute for Land and Infrastructure Management.)

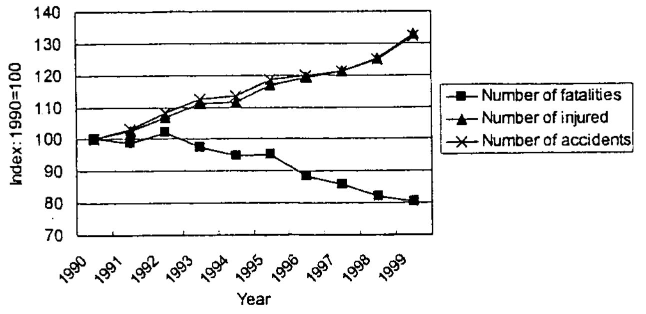


Fig. 1 Trends in number of traffic accidents and number of fatalities and injured

analysis technique.

2. Unique Characteristics of Nighttime Traffic Accidents

2.1 Recent Trends in Traffic Accidents in Japan

Fig. 1 summarizes the recent trends in traffic accidents resulting in death or injury as well as number of fatalities and injuries. The plotting in this diagram represents the trends in the numbers of traffic accidents, fatalities and injured relative to the numbers in 1990 that are taken as 100.

Although the fatalities has been decreasing since 1992, the number of traffic accidents resulting in death or injury, as well as number of injured, has been steadily increasing during the same period.

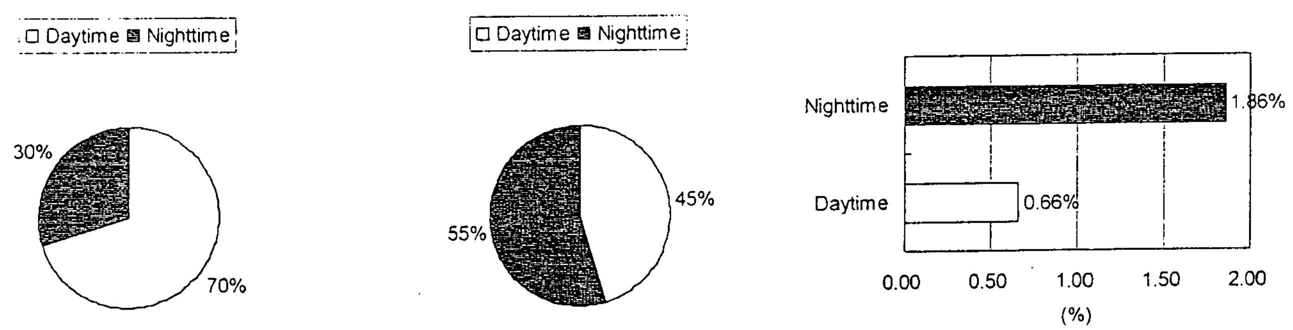
2.2 Occurrences of Traffic Accidents in Night and Day

Fig. 2 provides the 1999 data for both daytime and nighttime accidents resulting in death or injury (a), number of fatal accidents (b), and fatal accident ratio (number of fatal accidents divided by number of accidents resulting in death or injury) (c). Although the number of daytime accidents resulting death or injury account for 70%, the absolute number of nighttime fatal accidents is greater than that of daytime fatal accidents. The proportion of fatal accidents to total traffic accidents can be indicated as a fatal accident ratio such as the one given in Fig. 2(c), where the ratio is 0.66% for daytime and 1.86% for nighttime (that is, approximately three times as high as daytime). These trends have remained unchanged since 1992.

2.3 Trends in Nighttime Traffic Accidents

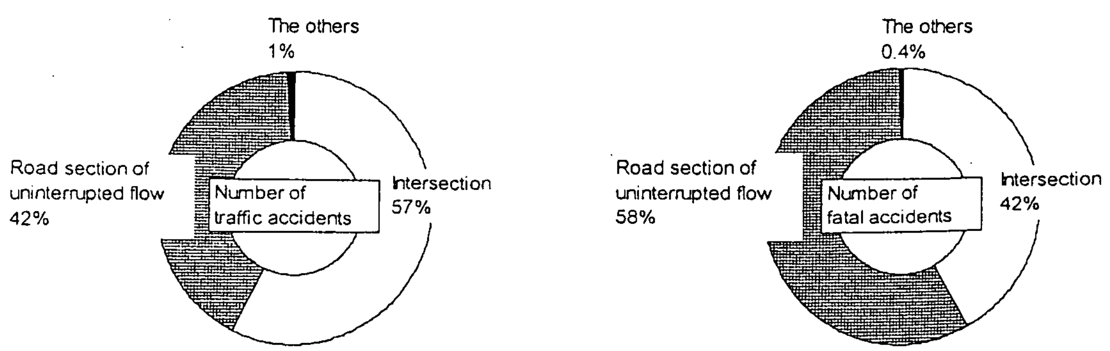
Fig. 3 illustrates the number of 1999 nighttime traffic accidents resulting in death or injury by road profile (a) and number of fatal accidents by road profile (b).

The accidents at intersections resulting in death or injury account for 57%, and the fatal accidents also exhibit a greater percentage.



(a) Percentages of traffic accidents (b) Percentages of fatal accidents (c) Fatality ratio

Fig.2 Traffic accident occurrences for daytime and nighttime (as of 1999)



(a) Percentages of traffic accidents (b) Percentages of fatal accidents

Fig. 3 Percentages of nighttime traffic accidents by road profile

2.4 Characteristics of Nighttime Traffic Accidents and Possible Countermeasure

The nighttime traffic accidents can be characterized in that:

- Nighttime traffic accidents often lead to severe result.
- Nighttime accidents at intersections account for a relatively large portion of whole nighttime traffic accidents.

Reflecting these findings, the efforts of our study were focused on the intersection lighting as an accident countermeasure by road illumination for reducing nighttime traffic accidents, thereby the current situation was reviewed and more positive measures in the coming future were evaluated.

3. Overview of Guidelines for Illuminance at Intersections

3.1 Roles of Intersection Lighting

By intersection lighting, an obstacle on a road surface can be identified as a darker silhouette against a lighter background that is illuminated with luminaires. Therefore, the luminaires must be situated so that the resultant luminance pattern can provide a good background for an obstacle. Once such a luminance pattern is established, intersection lighting provides illumination for a particular region at intersection not illuminated by the headlamps on a car that is switching over lanes. When adequately installed, a lighting arrangement in an intersection allows the driver of a car approaching that intersection to readily identify a pedestrian, obstacle or other car possibly present in the intersection.

3.2 Overview of Guidelines for Intersection Lighting

According to the installation guideline in Japan for road lighting facilities, the lighting installation system is roughly categorized into continuous lighting and local lighting. Local lighting is installed on intersections or pedestrian crossings in order to help a driver (or a road user) clearly identify traffic situation or road conditions at a location where traffic flows and road lanes are locally complicated. An available guideline for intersection lighting offers example luminaire layouts by purposes of local lighting. Although not specifically defining necessary road surface illuminance contributable to local lighting, this guideline sets forth the luminaire layout examples which when followed correctly can provide required illuminance. This scheme is valid also in other nations.

International standards that clearly define illuminance needed at intersections as numerical guideline include a CIE recommendation[3]. The result of calculation of illuminance with luminaire layout specified in the installation guideline in Japan for road lighting facilities was found to be virtually equivalent to the illuminance level defined in that recommendation. The recommendation additionally defines lighting categories based on road types, complication status and other factors, and specifies the minimum level requirement of average illuminance by the categories. For example, the minimum level requirement of average illuminance for 'intersection in important city route' is set to 20 lx.

4. Before and After Study About Road Lighting Introduction

In our present study, the effect of road lighting in reducing traffic accidents was evaluated through investigation into traffic accidents both before and after introduction of lighting facilities. To select intersections subjected to investigation, the result of investigation into achievement from a separately undergone road traffic safety program (hereinafter referred to as 'investigation into road traffic safety programs') was used. At the same time, the road traffic accident data both before and after introduction of road lighting were taken from the Comprehensive Database for Traffic Accident. The investigation performed is outlined below. Incidentally each road traffic safety program was investigated as to the site for executing the program (route number, distance from the starting point), scope and schedule.

4.1 Overview of the Comprehensive Database for Traffic Accident

The Comprehensive Database for Traffic Accident was constructed by integrating the traffic accident information derived from the traffic accident statistics data collected by the National Police Agency of Japan and the road structure/traffic status information derived from the Road Traffic Census data collected by the Ministry of Land, Infrastructure and Transport of Japan into one database by way of matching data.

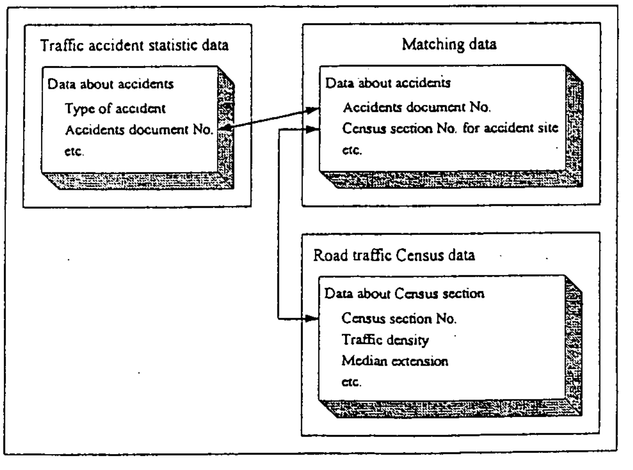


Fig. 4 Scheme of the Comprehensive Database for Traffic Accident

Note that this matching data includes the site information about the site of each traffic accident occurrence (route number and distance from the starting point). The concept of the Comprehensive Database for Traffic Accident is schematically illustrated in Fig. 4. This database covers the roads that are included in the Road Traffic Census (that is, national highways, prefectural highways and municipal roads in ordinance-designated cities), not the national expressways administered by expressway public corporations.

4.2 Selection of Intersections Subjected to Investigation

From the result of the research into traffic safety programs, the intersections subjected to our investigation were selected.

Many traffic safety programs involve a plurality of safety measures in one intersection. Since the objective of our study was to investigate the effect of road lighting onto reduction in traffic accidents, the intersections incorporating only road lighting as a traffic safety measure were selected. The procedure for selection was as follows:

Step 1:

The intersections incorporating road lighting were selected from the traffic safety program survey data according to the criteria below:

- Prefectures covered: Tochigi, Gumma, Ibaraki, Saitama, Chiba, Tokyo, Kanagawa
- Roads covered: national highways administered by Ministry of Land, Infrastructure and Transport of Japan.
- Year of executing safety measure: Fiscal 1991

Consequently, 113 sites were selected.

Step 2:

As to the intersections having incorporated road lighting and selected in step 1, the accident data associated with the site information in the data of these intersections were selected based on the site information within the Comprehensive Database for Traffic Accident (More specifically, an error of 100 m was allowed to accommodate the limited precision in site data within both site information sets.)

Step 3:

From the intersections selected in step 2, those not experiencing nighttime accidents during fiscal 1990 (a previous year before the road lighting was incorporated) were excluded. Consequently, 18 intersections were selected. Each intersection selected was within a major trunk line (ordinary national highway) and had a daily traffic volume of 10,000 vehicles or greater.

Table 2 Percentage reduction in accidents at intersections having lighting (Overall average)

Percentage reduction in nighttime accidents(%)	43
Percentage reduction in accidents(%)	41
Percentage reduction in daytime	3

4.3 Summation of Traffic Accidents

For the selected intersections, the number of traffic accidents both before and after the introduction of road lighting were tabulated. The fiscal years covered in the summation were as follows:

- Before: fiscal 1990
- After: fiscal 1992 – 1995

The reasons for why the period for summation of "Before" was limited only to one fiscal year are that the traffic safety program survey was intended for the safety measure executed in fiscal 1991 and that the accident data in the Comprehensive Database for Traffic Accident became fully available in fiscal 1990.

For summation of traffic accidents, not only nighttime accidents but also daytime accidents were included.

The data for "before" (resultant summation for fiscal 1990 alone) was compared with that for "after" (the average for summations of four years from fiscal 1992 to 1995).

4.4 Investigation into Illumination Levels

Survey by interview was performed with administrators of the roads that involved the selected intersections. The items investigated were as follows:

- Size of intersection (profile of intersection, road width, type of road surface, etc.)
- Situation for installing road lighting (locations and number of luminaires, types of luminaire and light source, height of poles, overhang, etc.)

The investigation into illumination level, which was a major objective of our survey, was achieved by calculation based on the luminaire arrangement diagrams maintained

Table 1 Investigation results for intersections having incorporated lighting (nighttime average)

Judgment for accident reduction effect	Item	Before	After	Difference
O	Road surface illuminance (lx)	12.8	28.9	16.1
(9 sites)	Number of accidents (accidents/year)	2.7	0.9	−1.8
×	Road surface illuminance (lx)	4.3	20.1	15.8
(9 sites)	Nuber of accidents (accidents/year)	1.2	1.3	0.8
Total	Road surface illuminance (lx)	8.5	24.5	16.0
(18 sites)	Number of accidents (accidents/year)	1.9	1.1	−0.8

by road administrators as well as the previously mentioned survey result. As a criterion for illumination level, the average road surface illuminance was used since with certain intersections, the number of installed luminaires per intersection or the area being illuminated could be small.

Table 1 shows the tabulated information about the averages obtained from the results of our investigation. In this study, the threshold for judging whether or not a measure is effective in reducing traffic accidents was set to 30% by considering the technical report from CIE[4]. Additionally, Table 2 summarizes the information about the percent reduction in nighttime accidents; overall percent accident reduction reflecting percent reduction in daytime accidents; and for a comparison purpose, the percent reduction in daytime accidents. For calculating these factors, the formulas below were used:

- Percent reduction in nighttime accidents
  $=\{1-(N_a/N_b)\}\times 100$ (%)
- Percent reduction in daytime accidents
  $=\{1-(D_a/D_b)\}\times 100$ (%)
- Percent reduction in accidents
  $=[1-\{(N_a/N_b)/(D_a/D_b)\}]\times 100$ (%)

where, N_a: number of nighttime accidents after introduction of road lighting, N_b: number of nighttime accidents before introduction of road lighting, D_a: number of daytime accidents after introduction of road lighting, D_b: number of daytime accidents before introduction of road lighting.

As can be understood from the knowledge obtained from our investigation, the traffic accident reduction measure by lighting helped reduce nighttime traffic accidents by 40%. This understanding is supported by a fact that the percent daytime accident reduction in the same intersections remained virtually unchanged. The average road surface illuminance in the whole investigated intersections increased from approximately 9 lx "before" the improvement at intersection lighting to approximately 25 lx "after" the improvement in intersection lighting. Furthermore, after introduction of road lighting, the average road surface illuminance reached approximately 30 lx on the intersections that were judged to exhibit accident prevention effect.

5. Statistical Analysis

5.1 Analysis Technique

Based on the results of investigation into the "before" and "after", the interrelation between illuminance and nighttime traffic accidents was further evaluated by statistical analysis technique. The illuminance class of the intersections subjected to our analysis was essentially 20lx, which is common to both the illuminance guideline in Japan and CIE recommendation.

Taking 30lx (the average of illuminance values in the intersections that showed reduction in accidents) as a threshold, these intersections were classified into three illuminance groups—20lx to 30lx, 30lx and greater, and less than 20lx. Then, for each illuminance group, the statistical significance in the accident percentages with "before" and "after" was analyzed. The number of intersections analyzed was five with "20lx or less" group, seven with "20lx to 30lx" group and six with "30lx or greater" group.

Incidentally, the term "accident ratio" means the number of accidents per traffic volume.

5.2 Results of Analysis

The results of analysis are summarized in Table 3, where the nighttime accident ratios are indicated as annual averages, and the nighttime traffic volume for the route on each site is also reflected.

As a result of the analysis, the "30lx or greater" group was judged to have a significant difference of 1%. Although "20lx to 30lx" group failed to exhibit a significant difference, comparison between the "before" and "after" within this group suggests the effect of accident reduction measure. "20lx or less" group did not show any sign of the effect of accident reduction measure. For this reason, from expected variation in accident reduction effect due to the difference in average road surface illuminance, the road surface illuminance of 20lx or greater by incorporation of road lighting as accident reduction arrangement can reduce the possibility of accidents at intersections, and the illuminance of 30lx or greater will positively reduce the accidents at intersections. This coincides with the finding obtained from the survey for "before" and "after" (that the average road surface illuminance at the sites that showed positive accident reduction effect is 30lx).

6. Level of Lighting at Intersections

6.1 Preferable Illuminance Level at Intersections

The lighting at intersections not only provides ordinary road lighting but also allows the driver of a car approaching an intersection to identify the intersection and clearly judge

Table 3 Analysis of effect by average road surface illuminance groups

Average road surface illuminance (lx)	Night accident ratio (accidents/100 million cars/year)			Significant difference judgment for before and after	Number of sites
	Before	After	Difference		n
20 or less	12,071	15,797	3,726	—	5
20 to 30	15,602	9,485	-6,117	—	7
30 or greater	20,180	5,098	-15,082	1% significant difference	6

the situation in roads around the intersection. For example, if a lighting arrangement is incorporated into an intersection in the road whose surface is brightly illuminated with a continuous lighting arrangement, it will be necessary to make the intersection conspicuous by rearranging the layout of lighting facilities in it so that the illuminance in the intersection is greater than that in the road section illuminated with continuous lighting.

As described previously, the guideline in Japan for installing road lighting facilities does not mention the road illuminance with intersection lighting and only describes the typical arrangements for luminaires at intersections. By installing the luminaires according to the example layout in this guideline, the illuminance at intersections will be approximately 1.5 times as high as that with continuously illuminated sections.

Incidentally, in urban areas, adaptation luminance of driver's eyes increase owing to illuminance around the driver, possibly causing the visibility at intersections to drop. The illuminance level in an intersection, even when that intersection is illuminated with local lighting rather than with continuous lighting, should be determined by considering the surrounding luminous environment.

6.2 Recommended Illuminance Level at Intersections

The effectiveness of lighting in reducing traffic accidents in the previously selected intersections was evaluated by analytical method. As a result, it was found that an average road surface illuminance of 20 lx or greater can help attain the effect of accident countermeasure. This value coincides with the value in guideline in Japan for installing road lighting facilities or CIE recommendation. Also, an average road surface illuminance of 30 lx or greater resulted in more positive effect of the accident countermeasure by lighting. Based on these facts, the following illuminance levels expected for intersection lighting have been determined:

[Illuminance level expected for intersection lighting]

- Basic level: average road surface illuminance 20 lx
- Recommended level: average road surface illuminance 30 lx

Note, however, that the values above are intended for major trunk roads such as national highways (intersections associated with lighting category C2 per CIE recommendation).

7. Conclusion

From the viewpoint of effectiveness in traffic accident reduction, the levels expected for intersection lighting were investigated. Generally, the number of traffic accidents occurring in one intersection is very small, and, at the same time, many mutually affecting factors are contributing to these accidents. Therefore, in this study, sites having only road lighting as an accident countermeasure were selected and subjected to investigation. First, the numbers of accidents both before and after introduction of an accident countermeasure were surveyed. Then, the effect of installed lighting facilities was statistically analyzed.

From the result of these review works, it was learned that an average road surface illuminance at intersections maintained at 20 lx or higher, as a level expected for intersection lighting, can provide the effect of accident countermeasure, and that an average road surface illuminance of 30 lx can further positively develop the effect of accident countermeasure. However, other measures will be needed for sites where a hazardous situation can be expected or accidents have been frequently occurring, or where heavy traffic and complex environment can lead to complicated illumination requirements.

In this study, the authors believe to have successfully demonstrated the effectiveness of traffic accident countermeasure at intersections that have adequately bright lighting facilities. Thus, when providing intersection lighting, the lighting facility must be at least capable of providing the illuminance that is needed according to the road lighting installation guideline currently in effect in Japan.

As the importance of project assessment in executing public works is increasingly recognized, it will be increasingly necessary to construct traffic safety facilities, attempting to provide more efficient traffic safety programs. The authors hope that this report can contribute to improved safety in road traffic.

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264 標識等の情報量・形態と判読時間に関する実験

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An Experiment on Interpretation Time of Traffic Sign Information

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Public information for road users are presented by traffic signs and variable message sign boards on roads. It has not been argued fully until now about the amount/form of information for those facilities. In this study, an experiment and analysis on the amount/form of information were conducted using interpretation time of information as an index of understanding degree of information. The results of the study indicate that interpretation times of familiar information were shorter than unfamiliar information and road signs are understood as pattern and there are few influence of colors.

Key Words: visibility, road, /Amount of information, Chinese character, traffic sign

1. はじめに

道路標識や道路情報板に表示される情報は、道路標識については'道路標識設置基準[1)]'、道路情報板では'道路情報表示の規格について*'などで標準的な表示形態が示されている。しかし、現在の設置状況を見ると、一つの板に表示される情報量が多くなる傾向にあり、運転者が安全に理解できる情報の量や形態を把握し、運転者にとってわかりやすい情報提供を行っていくことが道路管理者に求められている。本研究は、標識や情報板に対する運転者の理解度を把握するための基礎的研究として、パソコン画面上に提示された情報を判読する時間を計測し、情報量(文字数)や情報形態(文字情報、図形情報等)と判読する時間との関係を実験・解析したものである。

2. 実験目的

漢字を組み合わせた地名、案内標識、情報板表示、図形、など各情報の判読性および理解度を、情報をパソコン画面上に表示してから運転者が判読するまでの時間(以下判読時間という。)により検討する。

3. 実験方法

3. 1 実験情報の製作

実験に用いる情報として、Table.1に示す情報をパソコン上で表示できるように製作した。

ここで、漢字の使用頻度の判断は、新聞における出現頻

*建設省道路局企画課長発道企発第52号、昭和47年9月

Table.1 Contents of Information Used in the Experiment

Kind	Form	Content
Character	Chinese character	High use frequency : 5 strokes(玉、兄)、10 strokes (梅、夏) 、15 strokes (横、箱)
		Low use frequency : 5 strokes (処、末) 、10 strokes (俵、桑) 、15 strokes (輝、盤)
	Place Name	Familiar name : 柏(Kashiwa)、土浦(Tsuchiura)、水海道(Mitsukaido)、常陸太田(Hitachi-Ohta)
		Unfamiliar name : 牧(Maki)、三瀬(Mitsuse)、大多喜(Ohtaki)、宇治田原(Uji-tawara)
Sign	Regulate Warning	Stop (led background-black letter, led background-white letter), Under construction (black background-orange pictograph, yellow background-black pictograph), Admit approach to directions pointed out only (black background-orange allow, blue background-white allow)
Variable Message Sign Board	Text	1 : 強風(Strong wind)、 2 : 事故・冠水(Accident・Covered with water)、 3 a : 落石・通行止・迂回路有 (Falling of rocks・Road closed・There is a detour)* * meaning combination of words 3 b : 越波・凍結・渋滞(Covered with waves・Freeze・Congestion)** ** meaningless combination of words
Graphic	Symbol	Snowman(Snow fall) (black background-orange figure, blue background-white figure)

度などを基に調査を行っている事例[2]もあるが、ここでは漢字単体のなじみの程度として、常用漢字で、小学校までに習得する漢字であり文字単体で意味をなすものと、漢字単体ではあまり用いられないもので区分した。表示地名のなじみの有無は、被験者が居住している地域に近い地名をなじみあり、遠方の地名をなじみなしとした。また情報板文字は、通常情報板に使われている文字情報を単語として組み合わせるものとし、一連の意味づけを行った組み合わせ、単語相互間に一連の意味を持たない組み合わせの２種類について行った。図形情報は、標識令で定められた図案および、情報板などで一般的に見受けられる模擬図案をそれぞれ採用した。

３．２　実験方法

（１）　被験者

実験における被験者は、年齢、性別等でなるべく偏りが生じないように選定した。年齢は非高齢者として50歳代までとした。また、地名理解度について統一性を持たせるため、被験者は全て茨城県または近県在住者とした。視力条件は、矯正可で両眼視力0.7以上とし、普通免許を保有するものとした。

（２）実験環境

実験条件を統一するために、屋外光を完全に遮断可能な室内で実施した。

・使用パソコン及びディスプレイ：DELL Optiplex GX 1、17インチ液晶モニタ（画面解像度1024×768ピクセル）

・ディスプレイ－被験者間の距離：250 ㎝に固定（標識文字高 40cm を約 50m 手前から視認した場合を想定）

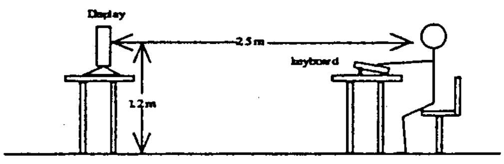


Figure.1　Experimental Condition

・室内はできるだけ太陽光が入らないように、黒いブラインドで遮断し室内照明を点けて行った。

(３)実験方法・手順

室内に設置したパソコンの前に着席させる。被験者は、実験情報が提示された後内容を理解した時点で被験者の前に設置されたキーボードのエンターキーを打鍵する。打鍵により表示画面は消え、表示開始時点から打鍵までに要した時間が画面上に1/1000秒単位で表示される。計測員は、画面上の秒数を判読時間として記録する。また計測員は、表示された情報の意味を被験者に対してヒヤリングし、理解度として記録する。

このとき解析に用いた判読時間は、計測された判読時間からキーを押す時間（反応時間）を引いた時間とし、反応時間は、別途計測した（Figure.2）。

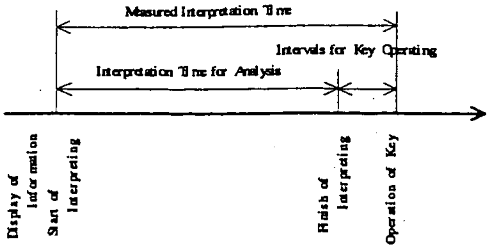


Figure 2.　Flow of Interpreting of Information

なお、理解度の正誤を判定するチェック項目については実験による回答方法が異なるため、別途定めた。これに関し、地名や文字情報は知識による個人差があるため、実験で使用した地名や文字についてどの程度の認識しているのかヒアリングを行い、認識の程度を確認した。

実験情報の提示順序としては、実験の順番を決める場合、比較的簡単な文字情報から始めると早押し実験と思われてしまう恐れがあるため、標識図形から始めることとした。また、順序効果を排除するため、被験者を３群に分類し、群毎に実験毎の提示順序をランダム化して配置した。各実験パターン毎に最初のものについては、２回目以降より時間がかかることが予想され、順序効果の有無について確認するため、各実験要素毎に、一番最初に提示した群の平均値と２回目以降に提示群の平均値に有意な差がないかをｔ検定した。

判読時間の計測結果には、特定の被験者のみの固有の要因（読み方を知らなかった等）が作用していると思われるデータを異常値とし、異常値を除いた正常データについて分析を行うこととした。なお、各ケースにおける全データの標準偏差(SD)で±2SD 以上となったもの異常値とした。

４．実験結果

実験結果についてｔ検定を行った結果では、順序効果に有意差はみられなかった。

実験結果では、情報に対するなじみの程度によって判読時間に差が生じた。実験では、漢字については比較的接する機会の多いと考えられるものとそうでないもの、地名については被験者が居住している地域で比較的多く見かける地名をなじみのある地名として選定している。以下では、これら状況を踏まえ、漢字の使用頻度の多寡や地名のなじみの程度などを総じて‘なじみ度’とする。

４．１　異常値

基準に従って異常値を判定すると、漢字については‘なじみのない地名の回答について悩んだ’、図形では‘意味がよくわからなかった’等の理由で異常値が抽出された。被験者毎にみると異常値の割合が全体の２割以上を占めた被験者は４名おり、特定の被験者が抽出されている反面、計測中1回でも異常と判断された被験者は約５割に上り、情報になじみがなければ、だれでも判読時間が大きくなる

可能性があることがわかった。

4．2　判読時間の計測結果

各情報における平均値、標準偏差（±SD）を求めるとともに、母平均の有意差検定(有意水準0.05)で有意差がないとされた情報についてグループ分けを行った。以下ではそれらの結果を示す。

4．2．1　漢字1字の比較

漢字1字の計測結果は、Figure.3のとおりとなった。

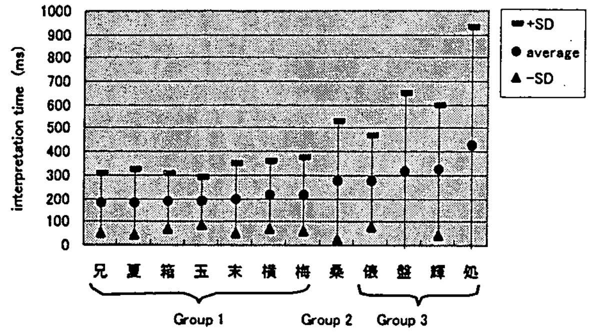
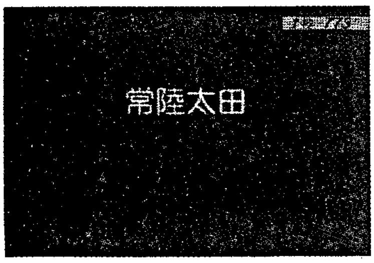


Figure.3　Interpretation Times of 1 Chinese Characters

実験に用いた漢字の選定は、なじみ度の高いもの（兄、夏、箱、玉、横、梅）となじみ度の低いもの（末、桑、俵、盤、輝、処）に分けて行ったが、グループ毎の特徴を見ると、なじみ度が高い、あるいは画数が少ないものがグループ1に、なじみ度が低く画数が多いとして設定された漢字がグループ3に区分されており、グループ1とグループ3では150ms程度の差が現れている。



(Text ; White,　Background ; Blue)

Figure.4　An Example of Display of Place Names

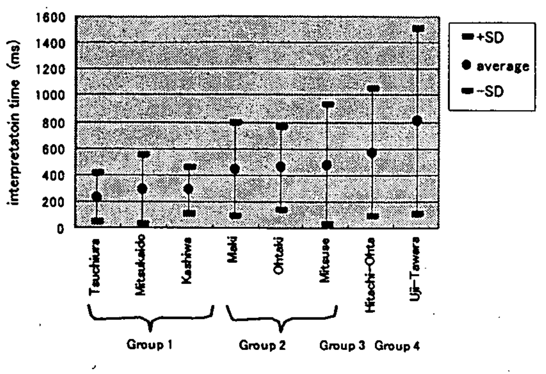


Figure.5　Interpretation Times of Place Names

4．2．2　表示地名

実験に用いた漢字の表示形態はFigure.4のとおりである。

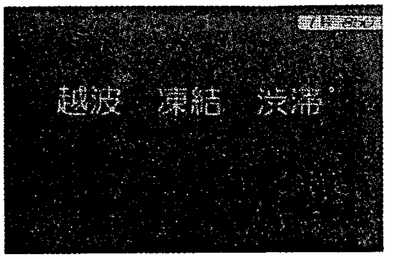
また、地名情報数と判読時間との関係をFigure.5に示す。

漢字1字の‘柏’が、平均値で300ms程度あり、Figure.3の漢字1字に比べて50ms秒程度長くなっているが、これが単なる漢字としての表示と地名としての表示による差であるかどうかは不明である。図をみると、地名数3文字程度までであれば、地名の漢字数に係わらず、なじみ度の高い地名は判読時間が短く、なじみ度が低いと平均的に200ms程度長くなっている。またなじみのある地名でも4文字地名の場合、実験に用いた地名は2文字ずつに分けて読むことができることから、2地名分を読むこととなり1地名読む場合の約2倍の時間を要している。例えば、地名としてなじみのある‘常陸太田’は‘常陸’と‘太田’に分けられ、‘常陸太田’の判読時間570msは、‘柏’の280msの2倍にほぼ等しい。また、‘宇治田原’は被験者にとってそれほどなじみのある地名ではないことから、判読時間は810msであるが、これは同じくなじみのない地名‘牧’の判読時間450msの2倍に近い。

4．2．3　文字情報の情報数による比較

情報板に表示されている各種の文字による警報情報を想定し、情報数による判読時間の差を比較したものがFigure.7である。

図によれば、1情報は500ms、2情報は1,000ms、3情報では2,500msと、情報数に比例して判読時間は長くなり、情報数の違いによって有意水準1％で有意な差があったが、3情報の‘落石通行止迂回路有’(3a)と‘越波凍結渋滞’(3b)には有意差がなかった。



(Text ; Orange,　Background ; Black)

Figure.6　An Example of Display of Texts

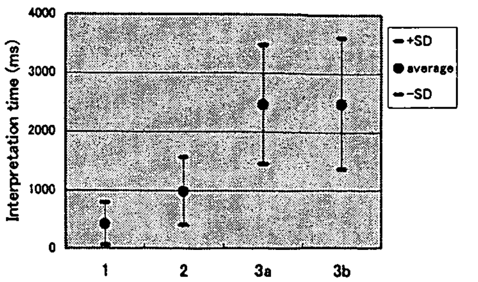
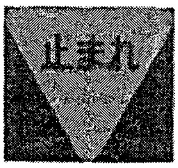
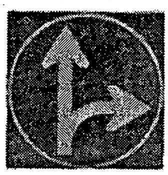
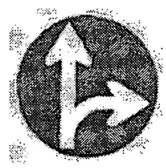
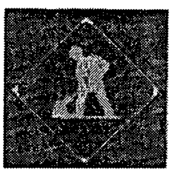


Figure.7　Interpretation Times of Texts

4．2．4　規制・警戒標識、シンボルマーク等の比較

実験に用いた情報をTable.2に示す。

Table.2　Design of Graphic Information

	Dummy (D)	Formal (F)
「Stop」	Text;Black, Sign figure;Red 	Text;White, Sign figure;Red 
「Admit Approach to Directions Pointed out Only」(A.D.)	Figure;Orange, Background;Black 	Figure;White, Background:Blue 
「Under Const-ruction」(U.C.)	Figure;Orange, Background;Black 	Figure;Black, Background;Yellow 
「Snow Fall」	Figure;Orange, Background;Black 	Figure;White, Background;Blue 

一時停止、指定方向外進入禁止および道路工事中の規制・警戒標識と、雪だるまのシンボルマークについて、従来の情報板で提供されている情報形態を模擬した図案と、正規・正常な色彩を使った正規図案により比較を行った結果をFigure.8に示す。

図によれば、標識図案では他の色彩を使って模擬的に表示された図案と正規の色彩で表示された図案に、大きな差はみられないが、雪だるまのシンボルマークのように雪を白く表示した正常の図案では、雪だるまを橙色で表示した模擬図案より判読時間は短くなっている。

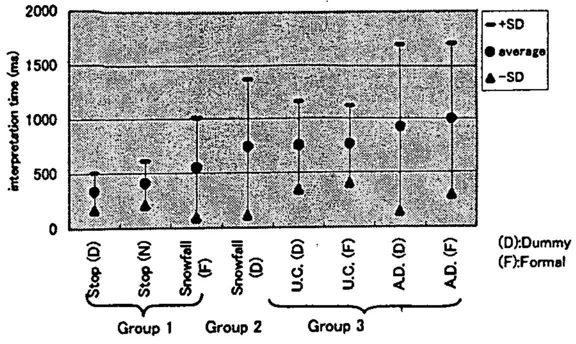


Figure. 8　Interpretation Time of Graphic Information

グループ1は、一旦停止標識であり、図案内に止まれの文字が表示され、このため、判読時間、標準偏差ともに小さくなっているものと思われる。グループ2の雪だるまは見慣れた図案であり、グループ3の情報より200〜400ms程度判読時間は短くなっている。被験者間の判読時間のばらつきは大きい。

グループ3は、ばらつきが非常に大きく、情報に見慣れている、情報の意味を知っている被験者とそうでない被験者間等で判読時間に大きな差が生じることが推測される。

4．2　実験結果のまとめ

判読時間の分析結果をまとめると以下のとおりである。

① なじんだ情報は判読に要する時間が少ない。

② 文字情報は3文字程度までであれば文字数に関係なく判読するのに300〜500ms程度要する。

③ 文字情報は2情報になると1情報の倍（1秒）程度の判読時間となる、また3情報になると判読時間は大きく増加し2,000〜3,000ms程度必要となる。

④ 複数の文字情報を全て理解するには、全てを読むことになるので短い時間では判読できない

⑤ 情報が多くなるほど被験者毎による判読時間の差は顕著になり、特に図形標識でその傾向が著しい

理解度では、文字表示の場合3情報になると内容が完全に理解できない被験者が現れた。情報を増やす場合は、繰り返し表示あるいは情報の補完（情報板と音声情報との組合せなど）が必要と考えられる。また、シンボル情報などでは、標識のように運転者の認知が十分でないことから、適切な色彩を用いることが必要であると考えられる。

5．あとがき

実験結果から、情報量が増えるに従い判読時間が延びる結果となった。また、見慣れた情報の方が判読が早いという傾向がみられた。これらを考えると、判読時間を文字や図形の基本的な情報に対する判読時間およびなじみ度を因子とする関数として、定量化できる可能性があると思われる。判読時間の定量化が可能になれば、標識や情報板の情報内容の設計が適正かつ容易に行えるようになる。今後の課題である。

（参考文献）

1)、日本道路協会；道路標識設置基準・同解説、昭和63年1月

2)、王、椎名；単語認知における単語要素の視認性と使用頻度の効果、人間工学 Vol.37,No.6, 2001

128. 歩道路面の明るさと視線距離に関する一考察

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1. はじめに

夜間に歩行者や自転車は、どの程度先を見ながら通行しているのかを、試験走路内に設定した仮設歩道に歩行者及び自転車を通行させ、通行後のヒアリングにより調査したので報告する。

2. 実験概要

国土技術政策総合研究所内の試験走路に約 50mの仮設歩道を設置し、設定した照度レベル毎に仮設歩道を被験者に通常の速度で歩行させ、通過後、歩行中何メートル先を視認しているかについてヒアリングを行った（以下、被験者から視認位置までの距離を視線距離という)。仮設歩道では、表 1 に示す実験条件を設定し、被験者の目の順応状態を考慮し低い照度レベルから順に通行させた。また周辺環境は、仮設歩道近傍には道路照明を点灯し、模擬的に歩道周辺の光環境の有無を設定した。

表 1 実験条件

歩道幅員	4m(第 4 種第 2 級の道路)
照度設定	1.5／3／5／10／20（l x)、均斉度 0.2 10／20 （l x）は周辺環境有り
灯具配置	片側配列（8 灯)、高さ 5.2m、取付ｽﾊﾟﾝ 26m
光源	蛍光水銀ランプ HF200X
被験者	65 歳以上の高齢者 10 名、非高齢者 10 名 車椅子利用者 7 名
歩道上障害物	模擬的に段差及び障害物を数箇所設置
実験項目	非高齢者：歩行状態と自転車乗車状態 高齢者：歩行状態 車椅子利用者：車椅子での通行状態

設定した照度レベルは JIS の 4 段階と、諸外国の基準値で最も低く設定されている CIE の 1.5Lx を合わせ 5 段階とした。非高齢者は歩行状態と自転車乗車状態で、高齢者は歩行状態のみで実験を行った。実験では、実際に下肢不自由者で車椅子を利用している被験者についても、照度レベル 1.5Lx を除く条件で測定した。なお各照度レベルの設定値に対して、実際の照度は±10%程度の変動があった。

3. 実験結果

図 1 に実験結果を示す。

- 照度が高くなるに従って視線距離が延びている。この傾向は、どの被験者においても同様である。
- 非高齢の歩行者は、照度レベル 20Lx で昼間と同程度の視線距離になっている。高齢者では 20Lx でも昼間の視線距離にまでは達しない。
- 自転車は、照度レベル 10Lx 以上になると、昼間よりも遠方を視認している。
- 歩行者等と比べて車椅子利用者の視線距離は短く、その差は約 10〜15m程度であった。

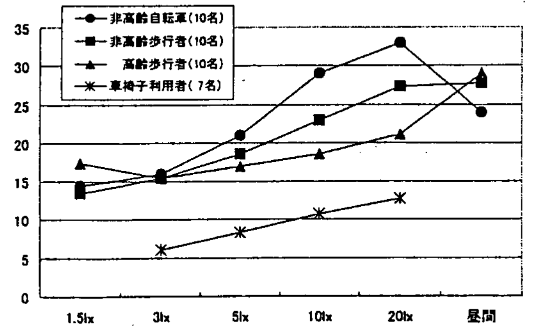

図 1 照度レベルと視線距離の関係

4. 考察とまとめ

路面の明るさが少なくなると、視認可能範囲が狭くなることでまず足下を気にして視線距離が短くなっている。一方、照度レベルが 20Lx になると非高齢者であれば昼間と同様の視線距離になっている。歩行者照明として、どの程度の明るさが必要かは十分議論を要するが、20Lx 程度あれば満足できるレベルであると判断される。

ただし、高齢者においては今回の実験では視線距離の最大値が明確になっていない。また、自転車、車椅子利用者については、視線距離が歩行者とは異なるものであることが明らかになった。周辺の視認可能範囲、移動速度、移動形態（例えば、車椅子利用者は車輪を廻すたびに前傾姿勢をとる）等が影響していることが考えられるので、これらについてさらに検討が必要である。

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2) Publication CIE No.136-2000 : "Guide to the lighting of urban areas"

An Experimental Study on Brightness of Sidewalk Surface and Sight Distance
Kazuhiko ANDO, Nozomu MORI and Kentaro HAYASHI

119. 歩行者用照明の必要照度に関する研究

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1. はじめに

我が国においては、諸外国に例をみないほどの急速な高齢化の進展により、本格的な高齢社会が到来しつつある。近年の交通事故の特徴をみれば、夜間における高齢歩行者の死亡事故件数が増加傾向にあり、これも高齢化進展の現れのひとつといえる。これらを踏まえ、高齢者や身体障害者等が自立した日常生活や社会生活を営むことができる環境を整備することを目的に通称「交通バリアフリー法」が制定され、多様な道路利用者を考慮した歩道等の整備が求められている。しかし、現在のところ、これら多様な道路利用者を想定した歩行者用照明の明るさや設置方法等は明確でなく、適切な歩行者用照明の整備手法を確立することが緊急の課題となっている。

本研究は、多様な道路利用者（ここでは特に、非高齢者・高齢者と車椅子利用者に着目）にとって安全・快適な歩道照明環境を提供することを目的に、視認性評価実験によって歩道に必要とされる照度について検討を行ったものである。

2. 実験概要

国土技術政策総合研究所内の試験走路に仮設した歩道に、電線ゴムカバーや三角コーンを段差や障害物として模擬的に設置した。所定の照度に設定された仮設歩道の障害物ゾーンとすれ違いゾーンの一連の区間を、被験者は通常の歩行速度で通行し、通過後に各評価項目（路面や障害物の見え方、すれ違う通行者の危険感および顔の見え方、路面の明るさのムラ、歩道照明環境の眩しさ）についてヒアリング形式でアンケートに回答した。実験順序としては、被験者の目の順応状態を考慮し低い照度レベルから実験を開始した。仮設歩道近傍には道路照明を点灯し模擬的に歩道周辺の光環境の有無を設定して実験を行った。写真 1 に仮設歩道風景、図 1 に実験概要図を示す。

写真 1　仮設歩道風景

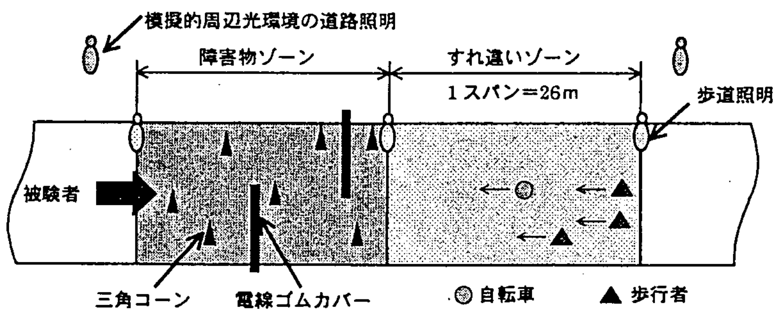

図 1　実験概要図

3. 視認性評価実験

3.1 実験条件

実験条件を表 1 に示す。照度レベルは JIS の 4 段階と諸外国の基準値の中で最低照度レベルであった CIE の 1.5Lx を含む 5 段階とした。各照度レベルは照明器具前面にフィルターを介することによって調整した。非高齢者は歩行状態と自転車乗車状態（ライト点灯）で、高齢者は歩行状態のみで実験を行った。車椅子利用被験者は下肢不自由者で、最低照度レベル 1.5Lx での評価は行っていない。なお、設定した各照度レベルが得られているかは、実験前に照度測定を行って確認した。

表 1　実験条件

歩道幅員	4m（第 4 種第 2 級の道路）
照度設定	1.5／3／5／10／20（lx）、均斉度 0.2 10／20（lx）は周辺環境有り
灯具配置	片側配列（8 灯）、高さ 5.2m、取付ｽﾊﾟﾝ 26m
光源	蛍光水銀ランプ HF200X
被験者	65 歳以上の高齢者 10 名、非高齢者 10 名 車椅子利用者 7 名
歩道上障害物	模擬的に段差及び障害物を数箇所設置
実験項目	非高齢者：歩行状態と自転車乗車状態 高齢者：歩行状態 車椅子利用者：車椅子での通行状態

A Study of the Required Illuminances of the Lighting for Pedestrians
Kentaro HAYASHI, Nozomu MORI and Kazuhiko ANDO

3.2 実験結果

図２に各照度レベル別、被験者別の視認性評価結果を示す。支持率とは通行のしやすさについて肯定的な回答をした被験者の割合（例えば、路面が見えて歩きやすかった、障害物が認識できたと回答した人）を示している。1.5、3 Lx の低い照度レベルはどの被験者においても「路面が見えて歩きやすい」「すれ違う歩行者・自転車の顔が見える」とする評価の支持率が 40％以下と低い。車椅子利用者は照度レベル 5Lx でも「すれ違う歩行者・自転車の顔が見える」とする評価の支持率が過半数を下回っている。また、非高齢者の自転車乗車状態において 1.5Lx は「危険を感じない（対人、対自転車）」とする評価の支持率が 40％と低い。その他の評価項目においては概ね高い支持率を得ている。

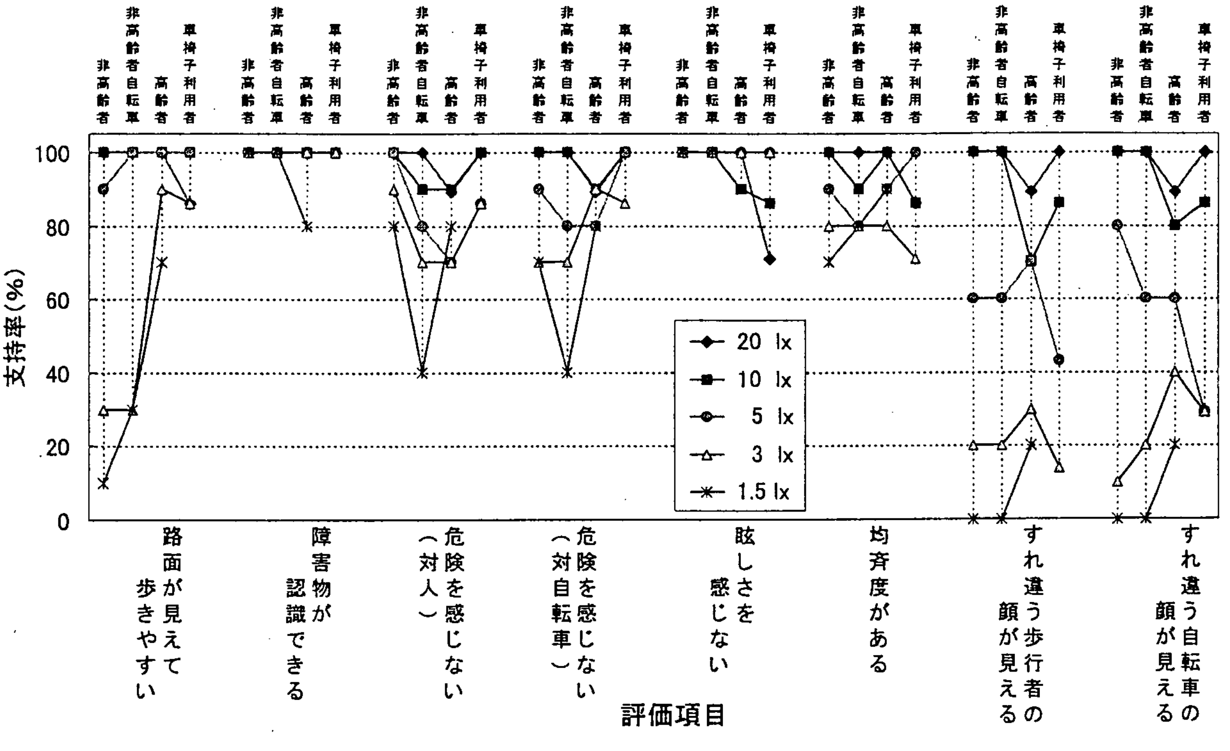

図２ 視認性評価実験結果

4. 考 察

歩行者用照明の最も基本的な要件として路面の見やすさに着目すると、照度レベル 1.5Lx および 3Lx では半数以上被験者が満足していない。また全項目で半数以上の支持を得ている照度は、10Lx 以上である。このことから、多様な道路利用者を考慮した歩行者用照明に必要な照度は、最低限 5Lx は必要であり、障害者等を考慮する場合は 10Lx 以上が必要であると思われる。

5. まとめと今後の課題

視認性評価実験より、多様な道路利用者にとって安全・快適に通行できる歩道の照度レベルを把握することができた。今後は、照明の明るさ以外の要件として、グレアの問題、光源による色温度や演色性等について、歩道空間の快適な利用の面からの検討が必要であると考える。

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3) Publication CIE No.136-2000 : "Guide to the lighting of urban areas"

◈ 特集：道路の機能向上に資する技術開発 ◈

夜間雨天時における区画線の視認性向上対策

安藤和彦* 森　望**

1. はじめに

雨天時は道路の視環境が極端に悪化し、運転者は運転にかなりの注意を払わなければならなくなります。この原因のひとつとして、路面が濡れて区画線が見えにくくなることが挙げられます。特に夜間は、区画線はほとんど見えなくなり、自分の走行位置や進行方向の確認が難しくなります。

これに対し、高視認性区画線が夜間雨天時の区画線の視認性を高める方法として採用されています。通常の区画線と高視認性区画線の構造を簡単に比較すると図-1のとおりとなります。一般に区画線にはガラスビーズが含まれ、このガラスビーズが夜間に車両の前照灯の光を再帰反射して、これを運転者は区画線として視認することができます。しかし雨天時には、塗膜が平滑なためガラスビーズの上に水膜ができ前照灯の光は前方に反射してしまいます。このため、運転者に前照灯の光が戻ってこず、区画線を視認することができません。高視認性区画線は、ベースと凸部によって構成され、凸部が水膜上に露出して、区画線として視認できるようにしています。

また高視認性区画線は、凸部をタイヤが踏んだときに車体に振動が発生し、運転者に車線逸脱を警告する効果も有しています。

このように高視認性区画線は、夜間雨天時の視認性向上や車体振動による警告に優れた効果を発揮していますが、通常の区画線に比べて高価であることから、高速道路や、国道・主要地方道の曲線部等に利用が限られ、さらに普及させるには、より経済的で容易に利用できる方法の検討が必要になっています。

これらの状況から、比較的経済的でかつ容易に高視認性区画線と同等の夜間の視認性向上が図られる方法として、現在のベースと凸部が一体で施工される高視認性区画線に対して、既存の区画線上に凸部を付加する新たな方策について実験検討しましたので、その結果についてご紹介します。

2. 実験の内容

2.1 実験の目的

既に設置されている通常の区画線の視認性を向上させる方法として、既設区画線のベース上に高視認性画線と同様の凸部を付加した場合、高認性区画線と同程度の視認性が確保できるかどうかを確認するものとしました。

実験は、現行高視認性区画線として一般的に用いられている凸部の仕様について、高さ 4mm、

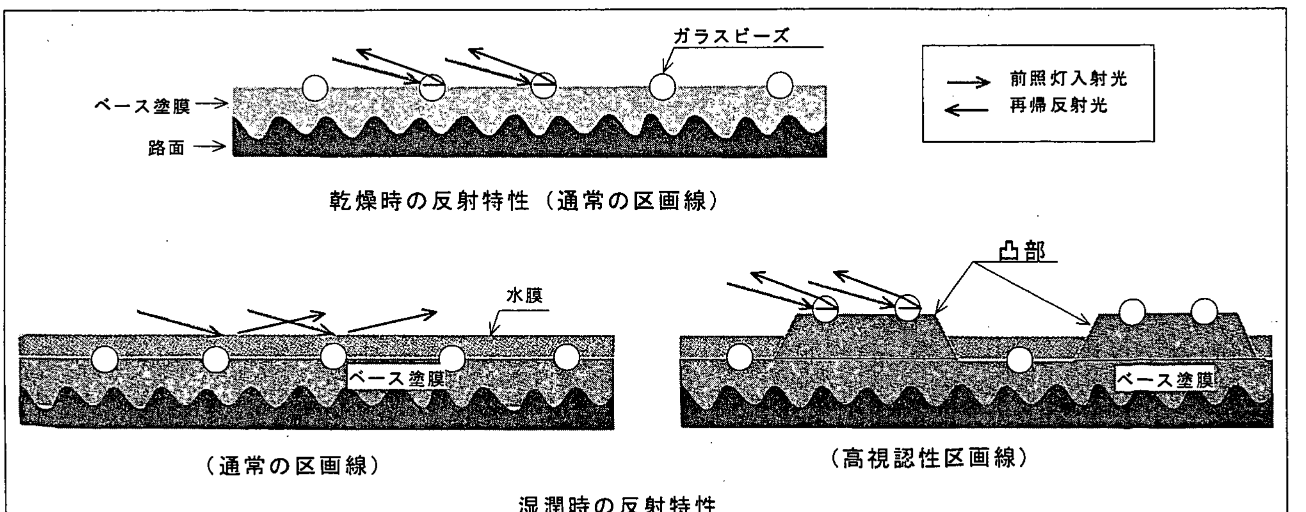


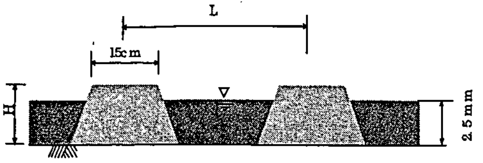
図-1 区画線の前照灯反射特性

A Visibility Improvement Measure at Road Marking at Rainy Night

表-1 凸部の間隔 L と高さ H との関係

設置間隔 L(cm)		30	50	100	150	備考
高さ H (mm)	見え方評価	4,7	4,7	4,7	4,7	
	振動評価	4,7	4	4	4,7	
	騒音・路面振動測定	4	—	4	4,7	平坦路面追加

注)L=30cm,H=4mm：標準的高視認性区画線の仕様



幅 15cm、設置間隔 30cm を基本として、凸部の設置間隔、凸部の高さを変えた場合の、視認性や振動特性の効果や、騒音・路面振動の発生状況を評価・計測するものとしました。

2.2 実験方法

実験では、現在道路で使われている様々な高視認性区画線の凸部形状のうち、設置間隔を実験条件として設定しやすい矩形断面 (表-1 図参照) を用いました。凸部の設置間隔と高さの組み合わせは表-1 に示すとおりです。なお、騒音・路面振動測定では、比較のため凸部を設置していない路面についても測定しました。

(1) 湿潤時の見え方評価

国土技術政策総合研究所の試験走路内に設置されている散水装置を使い、湿潤路面を設定しました。また、視認性の評価は図-2 に示す位置関係で行いました。視認性を評価するモニターは、運転席に座り、車両の前照灯をすれ違いビーム状態で照射し、表-2 に示す 5 段階で凸部の視認性を評価しました。このときモニターは、非高齢者 13 名、高齢者 5 名の計 18 名とし、視力は 0.7 以上 (矯正可) としました。

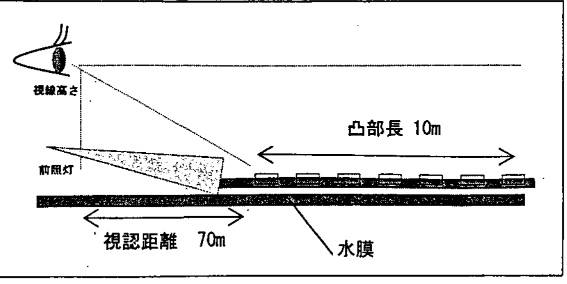


図-2 凸部仕様と見え方評価方法

表-2 視認性の 5 段階評価

5. 非常によく見える　4. よく見える　3. 見える
2. 見えにくい　1. 見えない

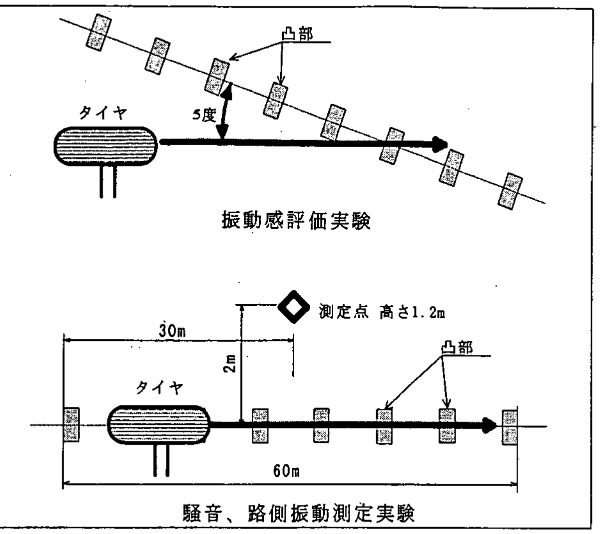


図-3 振動感・騒音・路面振動測定時の走行条件

(2) 凸部による振動感の評価

凸部を踏みつけたときの車体の振動を運転者が知覚できるかどうか確認するための実験を行いました。実験は，比較的振動を感じにくい条件として、曲線部などで車輪が凸部を 1 度踏み越える場合を想定しました (図-3 上図)。このとき通過する速度は 60km/h とし、通過する角度は曲線部での凸部の踏みつけ角度を検討し、5 度としました。

(3) 踏みつけ時の騒音、路面振動の測定

高視認性区画線上をタイヤが踏みつけるとき、騒音および振動が発生するので、凸部の形状寸法によってどの程度の騒音、振動が発生するのかを、設置区間長 60m の中央 (30m 位置) で、凸部より 2m 離れた地点で測定しました。タイヤは設置区間 (60m 長) 上を 40km/h、または 60km/h の速度で連続的に通過するものとしました (図-3 下図)。

3. 実験結果

(1) 凸部の間隔が 50cm までであれば大多数の運転者は視認できる

一般的に用いられている凸部の高 4mm について、凸部の間隔を変えた場合の見え方を比較したものが図-4 です。

'よく見える' 以上に着目すると、凸部間隔が長くなるほど割合が減少しているのが分かります。しかし '見える' 以上では設置間隔 50cm が最も多く、50cm 程度までであれば基本仕様 (設置間隔 30cm、凸部の高さ 4mm) と同程度の視認性となっています。これが、100cm になると、'見える' 割合は半数以下になり、視認性がかなり低下しています。ただし、通常の区画線が湿潤時に全く

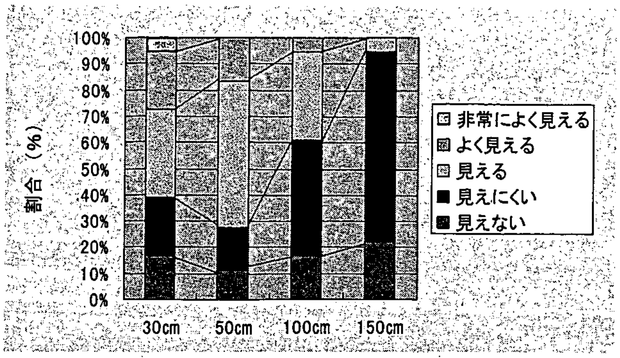


図-4 凸部の設置間隔と視認性との関係
(凸部の高さ 4mm)

見えなくなってしまうこと考えれば、100cm の設置間隔でも 8 割程度が 75m 先の凸部を視認 (‘見えにくい’ 以上) できており、間隔を広げて設置してもある程度の視認効果は得られていると考えられます。

(2) 凸部を高くすると視認性は高まる

凸部の高さを 4mm と 7mm で比較したものが図-5 です。凸部を高くすることで凸部の視認性が向上していることがわかります。特に凸部の間隔が開いたときに効果が見られます。従って湿潤時には、凸部の間隔が広がると前後の凸部が重なることなく独立して見えることになり、このため高くすることによる視認面積の拡大が視認性を高めることになります。

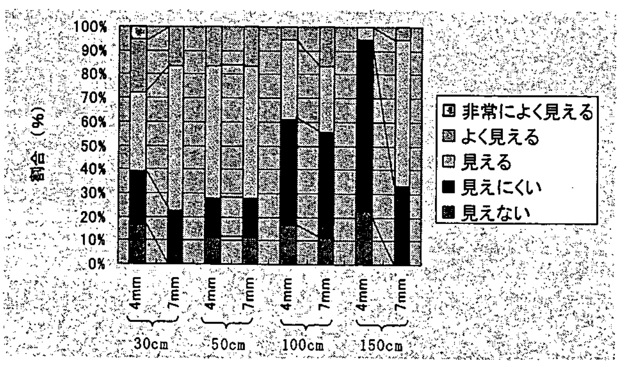


図-5 凸部の高さと視認性との関係

(3) 設置間隔が短ければ高齢者は非高齢者と同等以上の視認性があるが、設置間隔が開くと視認性が急激に低下する傾向にある

高齢者、非高齢者について、高さ 4mm の凸部の視認性評価結果を割合で示したものが図-6 です。モニターの数が異なるので一概に比較することはできませんが、設置間隔 100cm までは高齢者は非高齢者と同等以上に凸部が視認できると評価しており、通常いわれている高齢者の視機能の低下が評価結果には現れていません。ただし

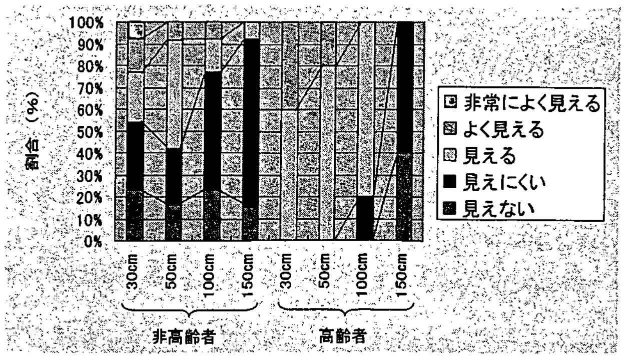


図-6 高齢者・非高齢者による視認性の差異

高齢者の場合設置間隔が 150cm になると、評価は急激に下がっています。この原因については今のところ明らかでなく、静止視力と動態視力との関係なども含め、さらに検討が必要と考えます。

(4) 凸部を踏み越えるとき、設置間隔 150cm でも運転者は振動を感じている

凸部には、視認性を高める効果の他に、運転者に振動感を与え、区画線上を通過したことを認知させる効果があります。今回の実験でこの効果について調査した結果は、図-7 のとおりです。

凸部が運転者に与える振動感は、凸部の間隔が短いほど、また凸部が高いほど強くなっています。ただし、今回の実験条件で最も振動を感じにくいと考えられる、高さ 4mm-設置間隔 150cm でもほとんどの運転者は振動を感じていることから、いずれの条件でも振動効果を有していると考えられます。

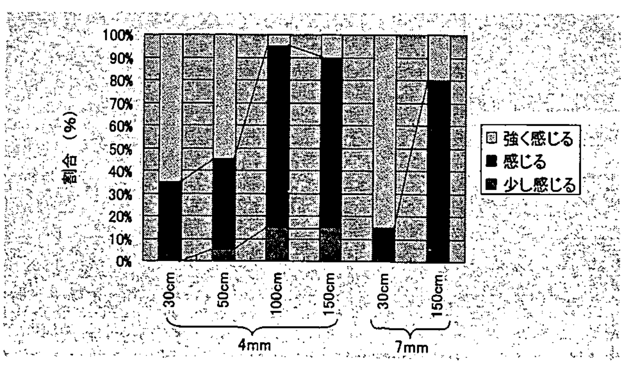


図-7 凸部条件と振動感との関係

(5) 凸部を踏み付ける騒音レベルは、交通流の速度が高いと問題がある

凸部間隔および高さと騒音レベルとの関係をみたものが、図-8 です。

騒音は、凸部間隔が短くなるほど、凸部の高さが高くなるほど大きくなっており、4mm-30cm の組み合わせでは平坦の路面より 5dB 程度増加し

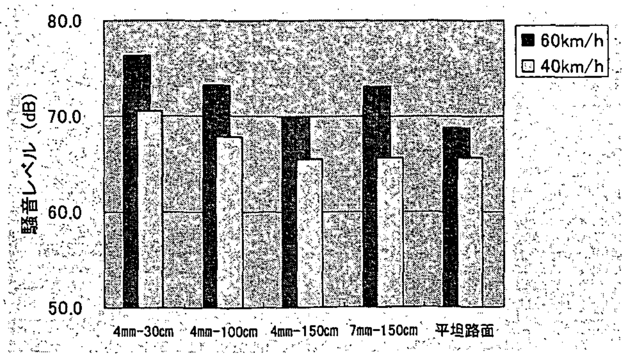


図-8 凸部条件と騒音レベルとの関係

ています。また、計測された値は65dB～75dB程度に分布し、比較的交通量のある道路に面する居住系の地域では多少問題になる騒音になっています[1)]。従って、人家が隣接する幹線道路等で交通流の速度が比較的高い道路では、凸部の設置は避けることが望ましいと考えられます。

凸部の高さは、4mmでも視認性は十分確保できかつ振動感も得られており、騒音への影響を考慮すると特に7mmを用いる必要はないと思われます。

(6) 路面の振動は、路面自体の凹凸の影響が大きく、凸部による影響は小さい

路面の振動を測定した結果では、振動レベルは45dB～65dB程度に分布し速度による差はみられませんでした。また路面自体の凹凸によって振動は大きく変化し、凸部の付加による振動の明確な増加はみられなかったことから、特に凸部の付加によって路面振動が問題になることはないと考えられます。

4. 実用的な凸部仕様と適用箇所

以上の実験結果等から、実用的な凸部仕様と適用箇所についてまとめると以下のとおりです。

① 既設の平滑な区画線上に凸部を付加することは、夜間雨天時の視認性向上に効果的である。

② 凸部を設置する個所は、運転者が自分の位置や進行方向が分かりにくい状況として、曲線部あるいは多車線道路の車線境界線などへの利用が効果的である。

③ 凸部の仕様は、高さ4mm、幅15cm、設置間隔50cmあれば視認性、振動感による踏み越え等の認知が十分可能となる。

④ 設置間隔100cmは、設置間隔50cmに比べて視認性が低下するのもの8割以上の運転者が視認できていることから、人家が連担する地域や車両が踏む多車線道路の車線境界線で騒音等の問題がある場合に設置するのが効果的である。

⑤ 凸部の設置間隔が100cm以内の場合、高さを4mmから7mmにする視認効果は少ない。

⑥ 凸部の設置間隔150cmでは高さ7mmにすることで視認性は向上する。

⑦ 高さ7mmの車体振動による注意喚起効果を期待して設置する場合、沿道に人家がある道路での利用は適さない。

5. あとがき

現在のところ、費用等の関係でベースと凸部を一括して施工する高視認性区画線の設置区間は、規格の高い道路の危険箇所等を中心に利用されて、規格の低い道路等にまでは十分行き渡っていない状況です。

道路の曲線部等に設置されている既存の区画線をベースとして、本稿で述べた凸部を付加することで、比較的安価に夜間雨天時の視認性を向上することができ、また区画線の輝度が高まるので雨天時以外の夜間でもより見えやすくなります。曲線部以外には、多車線道路の車線境界線も夜間雨天時の視認性確保は重要な安全対策となりますので、凸部を設置する効果は高いと考えられます。今後安全対策を実施するために、ぜひ参考にしていただきたいと思います。

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Research on the Interrelation between Illuminance at Intersections and the Reduction in Traffic Accidents

by Hiroshi Oya, Kazuhiko Ando and Hideyuki Kanoshima

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Abstract

One recent apparent trend in increasing traffic accidents in Japan is the increase in night-time accidents. To address this problem, various traffic safety measures have been introduced aimed at safer road traffic environments. Among these measures, road lighting, in particular 'local lighting', has been introduced in increasing numbers as a counter-measure against night-time accidents. However, in terms of the number of fatal accidents by road profile, the 'at intersection' accounts for the largest portion of the fatalities. Therefore, more effective intersection lighting measures must be studied.

This paper discusses the illuminance levels expected for intersection lighting from the viewpoint of traffic accident reduction and reports the results. The means used were a review of accident data and statistical analysis before and after the introduction of accident counter-measures. It was learned that an average road surface illuminance at intersections maintained at 20 lux or higher, can provide an effective accident countermeasure, and that an average road surface illuminance of 30 lux can further develop a statistically significant reduction in traffic accidents.

1. Introduction

In 1999, the annual traffic accidents fatalities in Japan was 9,005, which marks a continued decrease in traffic fatalities over four successive years since 1996. However, in the year 1999, the number of the injured persons due to traffic accidents exceeded one million for the first time and the total of traffic accidents involving death and/or injury topped 850,000, resulting in an increase over seven years.

One significant trend in recent traffic accident statistics is the increase in night-time traffic accidents. Night-time traffic accidents often result in severe outcomes, and the fatality ratio with night-time accidents is approximately three times[1] as high as that with daytime accidents. Therefore, the reduction of night-time traffic accidents poses a greater challenge in promoting safe traffic programmes.

In addressing such a challenge, various traffic safety facilities have been introduced to improve safety in road traffic environments. In particular, since 'at intersection' accidents account for a very large percentage of night-time traffic accidents by road profile[2], lighting for intersections has been one of the potential counter-measures against night-time traffic accidents. However, it has not yet been clarified whether effectively introduced lighting at intersections can decrease traffic accidents – and which levels of illuminance positively develop the effect of lighting at intersections.

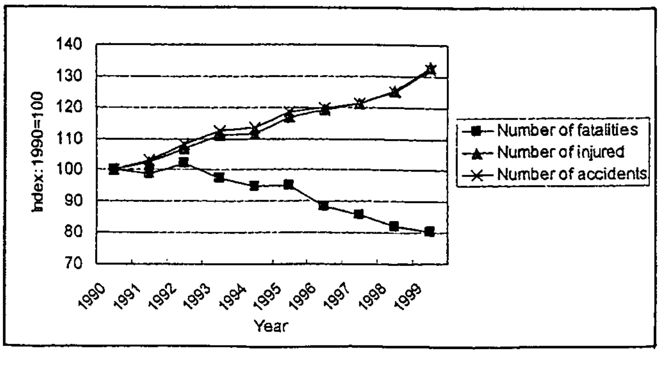
Focusing on 'intersection lighting' as a promising accident counter-measure to reduce nighttime traffic accidents, this paper reports the result of our investigation into the illuminance levels needed for intersection lighting, through a survey of traffic accidents both before and after the introduction of the counter-measure, and through statistical analysis.

2. Unique Characteristics of Night-time Traffic Accidents

2.1 Recent Trends in Traffic Accidents in Japan

Fig. 1 summarises the recent trends in traffic accidents resulting in death or injury, as well as number of fatalities and injuries. The plotting in this diagram represents the trend in the numbers of traffic accidents, fatalities and injured, relative to the numbers in 1990 (taken as 100).

Fig 1: Trends in the number of traffic accidents and number of traffic fatalities and injuries



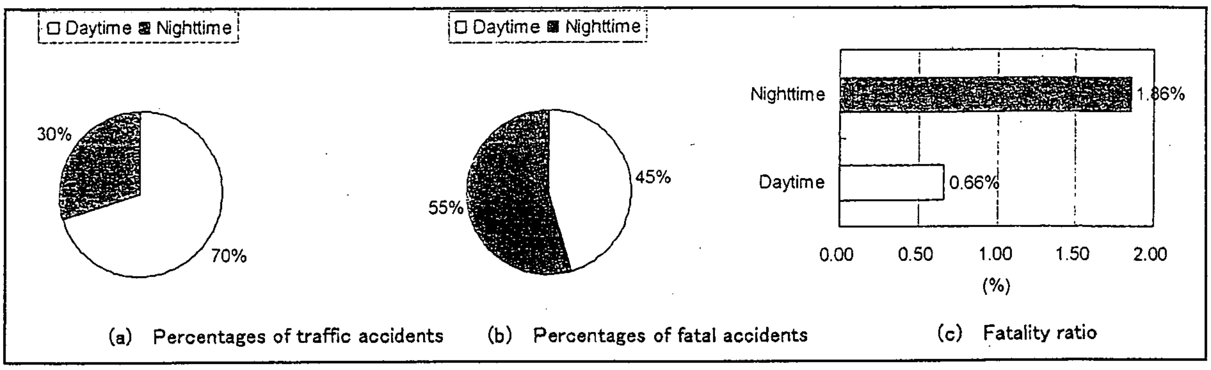


Fig 2: Traffic accident occurrences for daytime and night-time (as of 1999)

Although the fatalities have been decreasing since 1992, the number of traffic accidents resulting in death or injury, as well as number of injured, has steadily increased during the same period.

2.2 Occurrences of Traffic Accidents by Night and Day

Fig.* 2** provides the 1999 data for both daytime and night-time accidents resulting in death or injury ***(a), number of fatal accidents ***(b)***, and the fatal accident ratio (number of fatal accidents divided by number of accidents resulting in death or injury) ***(c)***. Although the number of daytime accidents resulting in death or injury accounts for 70 per cent, the absolute number of night-time fatal accidents is greater than that of daytime fatal accidents. The proportion of fatal accidents to total traffic accidents can be indicated as a fatal accident ratio such as the one given in ***Fig. 2(c)***, where the ratio is 0.66 per cent for daytime and 1.86 per cent for night-time (that is, approximately three times as high as daytime). These trends have remained unchanged since 1992.

2.3 Trends in Night-time Traffic Accidents

Fig. 3 illustrates the number of 1999 night-time traffic accidents resulting in death or injury by road profile ***(a)*** and number of fatal accidents by road profile ***(b)***. The accidents at intersections resulting in death or injury account for 57 per cent, and the fatal accidents also exhibit a greater percentage.

2.4 Characteristics of Night-time Traffic Accidents and Possible Countermeasures

Night-time traffic accidents can be characterised as follows:

- Night-time traffic accidents often lead to severe results.
- Night-time accidents at intersections account for a relatively large proportion of all night-time traffic accidents.

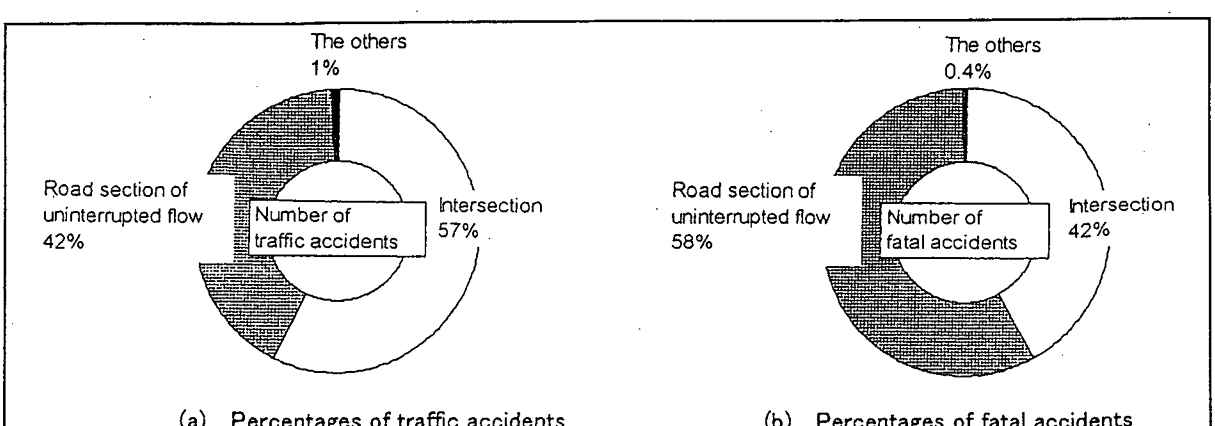
Reflecting these findings, the efforts of our study were focused on intersection lighting as a counter-measure to reduce night-time traffic accidents.

3. Overview of Guidelines for Illuminance at Intersections

3.1 Roles of Intersection Lighting

By intersection lighting, an obstacle on a road surface can be identified as a darker silhouette against a lighter background that is illuminated by luminaires. Therefore, the luminaires must be situated so that the resultant luminance pattern can provide a good background for an obstacle. Once such a luminance pattern is established, intersection lighting provides illumination for a particular region of

Fig 3: Percentages of night-time accidents by road profile



an intersection not illuminated by the headlamps of a car that is switching lanes. When adequately installed, a lighting arrangement at an intersection allows the driver of a car approaching that intersection to readily identify a pedestrian, obstacle or other car present at the intersection.

3.2 Overview of Guidelines for Intersection Lighting

According to the installation guidelines in Japan for road lighting facilities, the lighting installation system is roughly classified into continuous lighting and local lighting. Local lighting is installed on intersections or pedestrian crossings in order to help a driver (or road user) clearly identify the traffic situation or road conditions at a location where traffic flows and road lanes are complicated. An available guideline for intersection lighting offers sample luminaire layouts for the purpose of local lighting. Although not specifically defining the necessary road surface illuminance contributed by local lighting, this guideline sets forth luminaire layout examples, which when followed correctly, can provide the required illuminance. This scheme is also valid in other countries.

International standards that clearly define the illuminance needed at intersections as numerical guidelines include a CIE recommendation[3]. The result of calculating the illuminance with the luminaire layout specified in the installation guideline in Japan, was found to be virtually equivalent to the illuminance level defined in that recommendation. The recommendation additionally defines lighting categories based on road types, complication status and other factors – and specifies the minimum average illuminance according to those categories. For example, the minimum level requirement of average illuminance for 'intersection on important city route' is set to 20 lux.

4. 'Before' and 'After' Study of Road Lighting

Introduction

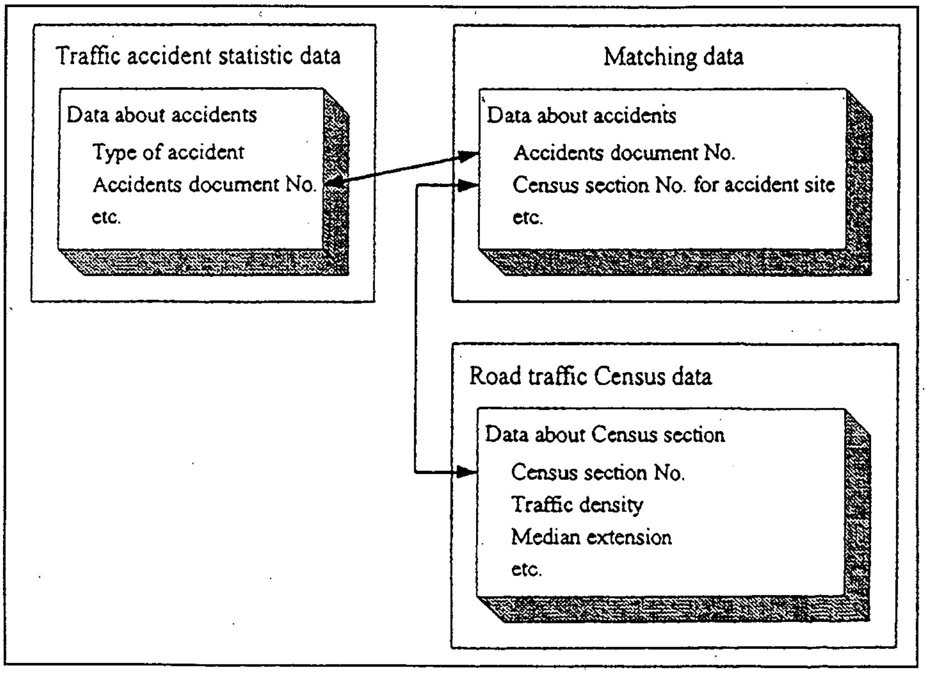
In our present study, the effect of road lighting in reducing traffic accidents was evaluated through investigation into traffic accidents, both before and after the introduction of lighting facilities. To select intersections for investigation, the results of investigations into separate road traffic safety programmes (hereafter referred to as 'investigation into road traffic safety programmes') was used. At the same time, road traffic accident data, both before and after the introduction of road lighting, was taken from the Comprehensive Database for Traffic Accidents. The investigation performed is outlined below. Incidentally each road traffic safety programme was investigated as to the site for executing the programme (route number, distance from the starting point), scope an schedule.

4.1 Overview of the Comprehensive Database for Traffic Accidents

The Comprehensive Database for Traffic Accidents was constructed by integrating the traffic accident information, derived from the traffic accident statistics data collected by the National Police Agency of Japan, and the road structure/traffic status information derived from the Road Traffic Census data collected by the Ministry of Land, Infrastructure and Transport of Japan. This was put into one database by way of matching data.

Note that this matching data includes the information about the site of each traffic accident occurrence (route number and distance from the starting point). The concept of the Comprehensive Database for Traffic Accident is schematically illustrated in ***Fig. 4***. This covers the roads included in the Road Traffic Census (that is, national highways, prefectural highways and municipal roads in ordinance-designated cities) – but not national expressways administered by expressway public corporations.

Fig 4: scheme of the Comprehensive Database for Traffic Accidents



4.2 Selection of the Intersections Subject to Investigation

From the result of the research into traffic safety programmes, the intersections subjected to our investigation were selected. Many traffic safety programmes involve a plurality of safety measures at one intersection. Since the objective of our study was to investigate the effect of road lighting on the *reduction in traffic accidents*, intersections incorporating only road lighting as a traffic safety measure were selected. The procedure for selection was as follows:

Step 1:
The intersections incorporating road lighting were selected from the traffic safety program survey data according to the criteria below:

- Prefectures covered: Tochigi, Gumma, Ibaraki, Saitama, Chiba, Tokyo, Kanagawa
- Roads covered: national highways administered by the Ministry of Land, Infrastructure and Transport of Japan
- Year of executing safety measures -- Fiscal Year 1991

Consequently, 113 sites were selected.

Step 2:
For intersections having incorporated road lighting and selected in Step 1, the accident data associated with the site information was selected, based on the Comprehensive Database for Traffic Accidents (more specifically, an error of 100 metres was allowed to accommodate the limited precision in site data within both site information sets).

Step 3:
From the intersections selected in Step 2, those not experiencing night-time accidents during the fiscal year 1990 (a previous year before the road lighting was incorporated) were excluded. Consequently, 18 intersections were selected. Each intersection selected was within a major trunk line (ordinary national highway) and had a daily traffic volume of 10,000 vehicles or greater.

4.3 Summation of Traffic Accidents

For the selected intersections, the number of traffic accidents both before and after the introduction of road lighting was tabulated. The fiscal years covered in the summation were as follows:

- 'Before': fiscal year 1990
- 'After': fiscal years 1992-1995

The reasons for why the period for summation of 'before' was limited to one fiscal year are that the traffic safety programme survey was intended for safety measures executed in fiscal year 199; and the accident data in the Comprehensive Database for Traffic Accident became fully available in fiscal year 1990.

For the summation of traffic accidents, not only night-time accidents but also daytime accidents were included. The data for 'before' (resultant summation for fiscal year 1990 alone) was compared with that for 'after' (the average for summations of four fiscal years, 1992 to 1995).

4.4 Investigation into Illumination Levels

Surveys by interview were performed with administrators of the roads involving the selected intersections. The items investigated were:

- Size of intersection (profile of intersection, road width, type of road surface, etc.)
- The installation details of the road lighting (locations and number of luminaires, types of luminaire and light source, height of poles, overhang, etc.)

The investigation into illumination levels, which was a major objective of our survey, was achieved by calculation based on the luminaire arrangement diagrams maintained by road administrators, as well as the previously mentioned survey result. As a criterion for illumination level, the average road surface illuminance was used, since with certain intersections, the number of installed luminaires per intersection or the area being illuminated could be small.

Table 1: Investigation results for intersections having incorporated lighting (night-time average)

Judgment for accident reduction effect	Item	Before	After	Difference
O	Road surface illuminance (lx)	12.8	28.9	16.1
(9 sites)	Number of accidents (accidents/year)	2.7	0.9	-1.8
X	Road surface illuminance (lx)	4.3	20.1	15.8
(9 sites)	Number of accidents (accidents/year)	1.2	1.3	0.8
Total	Road surface illuminance (lx)	8.5	24.5	16.0
(18 sites)	Number of accidents (accidents/year)	1.9	1.1	-0.8

Percentage reduction in night time accidents (%)	43
Percentage reduction in accidents (%)	41
Percentage reduction in daytime	3

Table 2: Percentage reduction in accidents at intersections having lighting (overall average)

Table 1 shows the tabulated averages obtained from the results of our investigation. In this study, the threshold for judging whether or not a measure is effective in reducing traffic accidents was set at 30 per cent by considering the technical report from CIE[4]. Additionally, ***Table 2*** summarises the information about the percentage reduction in night-time accidents; the overall percentage accident reduction, reflecting the percentage reduction in daytime accidents; and for comparison, the percentage reduction in daytime accidents. For calculating these factors, the formulas below were used:

- Percentage reduction in night-time accidents: $= \{1-(Na/Nb)\}\times 100$ (%)
- Percentage reduction in daytime accidents: $= \{1-(Da/Db)\}\times 100$ (%)
- Percentage reduction in accidents: $= [1-\{(Na/Nb)/(Da \quad Db)\}]\times 100$ (%)

Note: *Na is the number of night-time accidents after the introduction of road lighting; Nb is the number of night-time accidents before the introduction of road lighting; Da is the number of daytime accidents after the introduction of road lighting; and Db is the number of daytime accidents before the introduction of road lighting.*

As can be understood from our investigation, lighting as a traffic accident reduction measure helped reduce night-time traffic accidents by 40 per cent. This understanding is supported by a fact that the percentage daytime accident reduction at the same intersections remained virtually unchanged. The average road surface illuminance at all the investigated intersections increased from approximately 9 lux 'before' the improvements to approximately 25 lux 'after' the improvements in intersection lighting. Furthermore, after the introduction of road lighting, the average road surface illuminance reached approximately 30 lux at the intersections that were judged to exhibit accident prevention effects.

5. Statistical Analysis

5.1 Analysis Technique

Based on the results of the 'before' and 'after' investigations, the interrelation between illuminance and night-time traffic accidents was further evaluated by statistical analysis. The illuminance class of the intersections subjected to our analysis was essentially 20 lux, which is common to both the illuminance guideline in Japan and the CIE recommendation.

Taking 30 lux (the average of illuminance values in the intersections that showed reductions in accidents) as a threshold, the intersections were classified into three illuminance groups: 20 lux to 30 lux; 30 lux and greater; and less than 20 lux. Then, for each illuminance group, the statistical significance of the accident percentages 'before' and 'after' was analysed. The number of intersections analysed was five in the '20 lux or less' group, seven in the '20 lux to 30 lux' group and six in the '30 lux or greater' group.

5.2 Results of the Analysis

The results of the analysis are summarised in ***Table 3***, where the night-time accident ratios are indicated as annual averages, and the night-time traffic volume for the route on each site is also reflected. The term 'accident ratio' refers to the number of accidents per traffic volume.

As a result of the analysis, the '30 lux or greater' group was judged to have a significant difference of one per cent. Although the '20 lux to 30 lux' group failed to exhibit a significant difference, comparison between 'before' and 'after' within this group suggests the effect of the accident reduction measure. The '20 lux or less' group did not show any sign of the effect of the accident reduction measure. For this reason, from the expected variation in accident reductions due to the difference in average road surface illuminance, a road surface illuminance of 20 lux or greater achieved by the incorporation of road lighting can reduce the possibility of accidents at intersections; and an illuminance of 30 lux or greater will positively reduce the accidents at intersections. This coincides with the findings obtained from 'before' and 'after' surveys – that 30 lux is the average road surface illuminance at the sites that showed a positive accident reduction effect.

Table 3: Analysis of effect by average road surface illuminance groups

Average road surface illuminance (lx)	Night accident ration (accidents/100 million cars/year			Significant difference judgment for before and after	Number of sites
	Before	After	Difference		n
20 or less	12,071	15,797	3,726	–	5
20 to 30	15,602	9,485	-6,117	–	7
30 or greater	20,180	5,098	-15,082	1% significant difference	6

6. Level of Lighting at Intersections

6.1 Preferable Illuminance Level at Intersections

The lighting at intersections not only provides ordinary road lighting, but also allows the driver of a car approaching an intersection to identify the intersection and clearly judge the situation in roads around the intersection. For example, if a lighting arrangement is incorporated into an intersection on a road whose surface is brightly illuminated with continuous lighting, it will be necessary to make the intersection conspicuous by rearranging the layout of its lighting facilities, so that the illuminance at the intersection is greater than that on the road section illuminated with continuous lighting.

As described previously, the guidelines in Japan for installing road lighting facilities does not mention road illuminance at intersections – it only describes typical arrangements for luminaires at intersections. By installing luminaires according to the sample layout in these guidelines, the illuminance at intersections will be approximately 1.5 times as high as that on continuously illuminated sections.

Incidentally, in urban areas, the adaptation luminance of driver's eyes will increase, owing to illuminance around the driver, which possibly causes the visibility at intersections to fall. The illuminance level at an intersection, even when that intersection is illuminated with local lighting rather than with continuous lighting, should be determined by considering the surrounding luminous environment.

6.2 Recommended Illuminance Levels at Intersections

The effectiveness of lighting in reducing traffic accidents in the previously selected intersections was evaluated by analytical method. As a result, it was found that an average road surface illuminance of 20 lux or greater can attain an accident counter-measure effect. This value coincides with the value of the guidelines in Japan for road lighting facilities, as well as the CIE recommendation. Also, an average road surface illuminance of 30 lux or greater resulted in more positive accident counter-measure effect. Based on these facts, the following illuminance levels expected for intersection lighting have been determined:

- Basic level: average road surface illuminance of 20 lux
- Recommended level: average road surface illuminance of 30 lux

Note, however, that the above values are intended for major trunk roads, such as national highways (intersections associated with lighting category C2 in the CIE recommendations).

7. Conclusion

From the viewpoint of the effectiveness of traffic accident reduction, the levels expected for intersection lighting were investigated. Generally, the number of traffic accidents occurring in one intersection is very small, and, at the same time, many mutually affecting factors contribute to these accidents. Therefore, in this study, sites having only road lighting as an accident counter-measure were selected and subjected to investigation. First, the numbers of accidents both before and after introduction of an accident counter-measure were surveyed. Then, the effect of installed lighting facilities was statistically analysed.

From the result of this review, it was learned that an average road surface illuminance at intersections maintained at 20 lux or higher, can provide the effect of an accident countermeasure; and that an average road surface illuminance of 30 lux can further positively develop the anti-accident effect. However, other measures will be needed for sites where a hazardous situation can be expected or where accidents have frequently occurred – or where heavy traffic and a complex environment can lead to complicated illumination requirements.

In this study, the authors have successfully demonstrated the effectiveness of adequately bright lighting facilities as a traffic accident countermeasure at intersections. Thus, when providing intersection lighting, the lighting facility must be at least capable of providing the illuminance that is needed according to the road lighting installation guideline currently in effect in Japan.

As the importance of project assessment in executing public works is increasingly recognised, it will be increasingly necessary to construct traffic safety facilities, in an attempt to provide more efficient traffic safety programmes. The authors hope that this report can contribute to improved safety in road traffic.

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