Functional Improvements to Expand the Application Range of the Crime and Disaster Prevention Lighting System

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ABSTRACT

Blue light-emitting diode（LED）security lights that do not affect crops were installed on the city road north of the university campus. This installation along with built-in security cameras assisted in crime prevention. The original commercial power supply specifications of the device were modified such that it used sunlight as the power source. This was one of the sustainable development goals toward carbon neutrality. This joint research project was conducted with the device manufacturers, during which several such devices were installed across regions and environments. Over the past year, we improved the performance of solar battery and changed the current control of the lighting system to adjust the lighting duration. We also conducted experiments to investigate the effects of these lighting systems on crops and their performance in detecting passerby and suspicious activities. We are also aiming to use this system to assist in resolving various local issues, such as searching for people lost in the mountains, watching over children on their way to and from school, and detecting elderly people wandering around.

Keywords: Security Light with Video Camera, LED Lighting System, Disaster Prevention, Powered by Solar and Battery, Anomaly detection of passers-by

Ⅰ. Introduction

Street light installation is prohibited near farmlands, making the daily commute through the area difficult at night. In addition to issues such as declining birthrate and aging population, the farmlands in rural areas are converted to residential lands due to the shortage of farm successors. Therefore, residential lands surrounded by farmlands are often sold, and there are even areas where it is essential for children to be dropped off and picked up by their parents on their way home. In March 2022, we installed six blue light-emitting diode（LED）security lighting systems on city roads with similar regional characteristics［1］used by students to commute to and from apartments and drive to and from the student parking lot. These roads are narrow without any lanes（4.8- and 5.8-m wide）but commuter vehicles and school shuttle buses operate here. Thus, pedestrians may almost hit the fence on the side of the road whenever

a vehicle passes by and some suspicious activities were also reported. However, because these roads are adjacent to rice fields, lighting systems have not been installed therein. Such systems ensure the safety and security of students and passerby without affecting the crop growth.

This security lighting system is more than just a street light and has various installation conditions, locations, and uses. Thus, its specifications must be periodically improved to address the issues in a region. Therefore, a scheme is under consideration wherein the light system can be used as an experimental device, and its specifications can be improved based on various conditions. Moreover, we will conduct demonstration experiments using the device and implement it to solve social issues. In subsequent sections, the results of using the light system since its development have been discussed along with the social issues that will be addressed in the future using the said system.

Ⅱ. Role of lighting and security lights in town development

Urban lighting is vital for urban development as it can impact the quality of tourism, events, and landscapes and prevent crimes and disasters. In subsequent sections, the background of the study and related research on blue security lights are discussed. Part of this chapter is published in the third issue of the annual report; herein, the research background is discussed detail and some issues are addressed.

1. Historical background of blue security lights

Blue security lights were introduced in Japan [2] motivated by the reports that blue security lights installed on Buchanan Street in Glasgow, Scotland's largest city, may help reduce crimes. The related effects and possibilities of blue security lights were verified in several studies. Ikemoto et al. [3] conducted a demonstration experiment of installing blue LED security lights in Tokushima Prefecture, interviewed road users about the visibility, impressions, and psychological effects of the installed device and investigated the current situation and possibilities. Taira [4] examined the current status of blue LED security light installation in Japan, its use in crime prevention, and its psychological effects. Moreover, the characteristics of blue and white composite LED lighting were determined. Mizokami [5] discussed the blue street lights installed in residential areas and blue suicide-prevention lights installed at railway stations and railroad crossings and verified their effectiveness, particularly in the railway sector, using a questionnaire. Ohno et al. [6] believed that blue lighting and the color itself were perceived differently in various countries and environments and further investigated these points using a questionnaire by particularly targeting students in Kansai and Glasgow. Additionally, differences based on whether or not people have seen such blue lighting system were discussed herein.

2. Role and position of security lights

This section overviews the role and position of lighting and security lights in urban development and explores their possibilities. The current role of lighting role in the urban development in Glasgow, which motivated the introduction of blue security lights in Japan, were explored based on the urban development plan of the city council. Blue security lights were installed in Glasgow as part of the city's lighting strategy introduced in 2005 during the Radiance, Glasgow Festival of Light, to differentiate streets. The "Glasgow City Center Strategy and Action Plan 2014–19 [7]" states that the benefits of the city center must be promoted to tourists and residents via campaigns, branding, and events. To this end, four strategies were proposed to change the appearance of the downtown area: the City of Light Strategy, a high-quality public space program wherein 162 km of white streetlights are installed, two Radiance Light Festivals, and development of the city by installing lighting systems. The Glasgow City Council Strategic Plan 2017–2022 [8] has proposed "Improve the efficiency of services through the

development of smart technologies, including garbage collection and street lighting" to realize urban development and sustainable cities. The universal design of lighting and colors for urban development have been extensively researched. Ishida [9] proposed to consider various visual situations and sensibilities when installing artificial light designs in public spaces. He pointed out that there is a need to consider minorities, not just their ideas. Kubota et al. [10] developed a color universal design support system for walking spaces by focusing on differences in color identification and color vision characteristics in walking spaces; the use of online systems were experimentally validated. Yamamoto [11] presented a method of evaluating comfort, particularly in public spaces, clarified impressions, and explored the possibility of reflection in future lighting design. Several strategies for crime prevention on streets at night have been proposed. Yanase et al. [12] conducted a survey to understand the expectations of pedestrians from streets at night and clarify the current state of the light environment that affects route selection. Thus, the impression and visibility achieved by manipulating the spacing of street lights at two locations with different sidewalk widths were investigated herein. Yabuki et al. [13] developed a lighting system that used a wireless sensor network and lights from a private property as the lighting source to prevent crimes via territoriality and surveillance in residential areas at night. Inspired by this, wireless sensor–linked lighting and wireless sensor pseudo leakage light were used herein, and an impression evaluation experiment was conducted via 3DCG animation. The importance of lighting from a landscape perspective and the diverse roles of lighting and security lights in urban development were also investigated [14].

3. Possibility of installing blue security lights

The impressions and psychological effects of installing blue security lights were analyzed by conducting multiple demonstration experiments. However, the impressions of installing blue security lights must be analyzed by considering technological advances and innovations along with the impact of environments in which they are installed. Furthermore, from the perspective of the role of lighting in urban development, we will examine ways to use lighting and light from various perspectives and verify their effectiveness as they can influence the impression of a region or spot and can characterize that region. The ideal form of security lights must be considered with an eye toward the realization of smart cities. Awareness regarding the use of blue for crime prevention is spreading as blue revolving lights are installed on voluntary security patrol vehicles. Additionally, residents of Tokushima Prefecture, which was the first in the world to commercialize high-brightness blue LEDs and has considerably higher global share of LED production, are likely familiar with blue LEDs. Therefore, such factors will also be considered during analysis.

Ⅲ. Questionnaire survey on this device after installing a blue LED security light with a security camera

After device installation, we conducted an awareness survey using a questionnaire to understand the students' and local residents' perception regarding this device and its necessity.

1. Purpose

After installing the blue LED security light with a security camera, we specify the use of security camera, the blue image, and the necessity of installing the device.

2. Method

1) Recruitment of research collaborators

Research collaborators were the residents of the local government/self-governing association where the device was installed and users of the university campus. An approval for recruiting collaborators was obtained in advance from the Shikoku University Research Ethics Review Committee of the institution to which the author

belongs (approval number 2021005). Then, written explanations were handed over to the local residents, verbally explaining the research purpose, their free will to cooperate, that refusal would not be a disadvantage, and that the results would not be used for purposes other than research. Survey forms and self-addressed stamped return envelopes were distributed and requested the participants to take the survey and post their responses. For university students, information about research cooperation was provided on the portal, and similar explanations were given to those who made requests; they were also asked to post their responses in the designated drop boxes.

2) Survey period

The study was conducted from November to December 2023.

3) Data collection Method

An anonymous, self-administered questionnaire was created based on the findings from the literature and used for the research herein. The items on the questionnaire were scored based on a five-point Likert scale, where 5 indicated "strongly agree " and 1 indicated "not at all." The questions were related to the installation of street lights with security cameras (10 items) and their perception about the blue color from blue LED security lights with cameras (10 items), as shown in Table 1 [1].

We investigated the necessity of installing the system in 10 locations: "A plaza where young people gather," "On the bridge," "Front door of homes," "Rivers and coastlines," "Streets in the neighborhood," "Near railroad crossings," "Everywhere in town," "Park/children's play area," "Near the school gate," and "Children's school route." 'The survey was conducted using "Need 1, Unnecessary 0." We asked them to freely describe any other areas that required system installations.

4) Analysis method

After tabulating each question, we checked for

Table 1 Questionnaire used in the survey [1]

What are your thoughts on the installation of street lights with cameras?	
question no.	Question content
1	Having a security camera will give you peace of mind.
2	Security cameras can prevent incidents from happening.
3	With security cameras, you can walk, go out, or commute to work or school with peace of mind.
4	It is safer to have it in a place where an unspecified number of people come and go.
5	It will serve as evidence when an incident or accident occurs.
6	You can rest assured that you will not be inadvertently suspected.
7	I get nervous when I think that I am being filmed by a security camera.
8	I feel cramped in my life when I am being filmed by security cameras.
9	There is no sense of incongruity even if you see a security camera in your everyday life.
10	Security cameras are not particularly effective.

What do you think about the blue color of the blue LED security light with camera?	
question no.	Question content
1	Blue has a calming effect.
2	Blue is a deterrent to crime.
3	If there is blue lighting, it can be expected that crime prevention activities will be enhanced.
4	Blue lighting makes the landscape look beautiful.
5	Blue lighting makes the landscape look lonely.
6	Streetlights other than those with security cameras should also be blue.
7	Blue streetlights are better than white streetlights.
8	Blue is not evidence of a crime because the color of your complexion and clothes looks different.
9	Blue is good in summer, but feels cold in winter.
10	There is no need to install a camera if the blue light has a crime-prevention effect.

any differences in how people perceived the device after it was installed depending on whether they had seen it or not. To this end, non-normality was confirmed using the Shapiro–Wilk test and the statistical software SPSSVer29 ($p = 0.000$ for all items, and data distribution showed non-normality at $p < 0.01$ for all items). Then, the Mann–Whitney U test (significance level: 5%) was performed.

3. Results

1) Overview of research collaborators

A total of 232 research collaborators participated in the survey: 87 men, 143 women, and 2 who did not fill in the information. The age breakdown, data collection location, and occupation are shown in Table 2.

Table 2 Overview of research collaborators

Gender	Males	87
	Females	143
	unfilled persons	2
Age	10's	62
	20's	141
	30's	9
	40's	5
	50's	8
	Over 60s	5
	unfilled persons	2
Profession	student	202
	company employee	15
	Civil servants/group employees	6
	teaching staff	7
	self-employed	0
	part-time job	0
	others	2
		n=232

Additionally, 126 people (54%) had seen the device installed on the north side of the university, whereas 106 people (46%) had never seen it (Fig. 1).

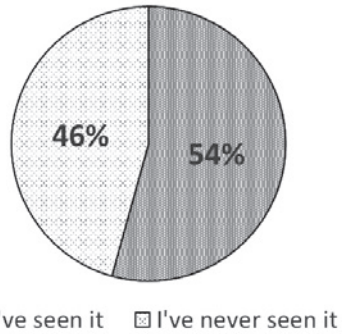

Fig. 1 Chart showing the results for whether or not the installed equipment was seen

2) What are your thoughts on the installation of street lights with cameras? (10 questions)

Table 3 shows the results of the survey conducted for people's perception about the installation of security cameras. Among the 10 questions on security cameras, a significant difference was observed between these questions: "I feel cramped in my life when I am being filmed by security cameras" and "Security cameras are not particularly effective." The participants who did not see the security camera felt cramped and thought it did not help prevent crimes. However, the scores were low for both set of questions, indicating that they generally

Table 3 Results for the question on the installation of street lights with cameras

question no.	I've seen it n=126		I've never seen it n=106		
	Avg.	SD	Avg.	SD	p
1	4.54	0.691	4.35	0.856	0.081
2	4.35	0.779	4.25	0.977	0.835
3	4.31	0.860	4.29	0.855	0.823
4	4.67	0.671	4.55	0.762	0.184
5	4.75	0.633	4.66	0.705	0.252
6	4.50	0.793	4.56	0.735	0.585
7	2.98	1.361	3.22	1.407	0.197
8	2.67	1.263	3.07	1.345	0.029 *
9	4.15	0.865	4.12	0.998	0.868
10	1.81	1.095	2.23	1.159	0.001 **

Mann–Whitney U test *p<0.05. **p<0.01. n=Data count

viewed the installation positively.

Other items, such as being able to live with peace of mind and being able to prevent accidents, were both scored highly without any significant differences, indicating that respondents viewed them positively.

3) What do you think about the color blue from the blue LED security light with camera? (10 questions)

Table 4 shows the results of a survey on what people thought about the blue color of the device. There were significant differences in 7 of the 10 questions.

The participants who saw blue security lights scored higher on the four questions: "Blue has a calming effect," "Blue is a deterrent to crime," "If there is blue lighting, crime prevention can be expected to be enhanced," Blue lighting makes the landscape appear beautiful," indicating that they perceived them to have a calming and crime-preventing effect.

In contrast, for three questions "Blue lighting makes the landscape look lonely" and "Blue is not evidence of a crime because the color of your complexion and clothes look different," "There is no need to install a camera if the blue light has a crime-prevention effect" ; those who had seen blue security lights scored lower. In other words, the survey results showed that this device can improve the scenery and prevent crimes and requires a camera.

The results of the survey conducted after installing the device showed that people who had seen

Table 4 Results for the questions about the blue color from the blue LED security light with camera

question no.	I've seen it n=126		I've never seen it n=106		
	Avg.	SD	Avg.	SD	p
1	4.16	0.853	3.63	1.043	0.000 **
2	3.40	1.118	3.12	1.008	0.042 *
3	3.65	0.992	3.25	0.977	0.001 **
4	4.00	1.064	3.61	0.952	0.001 **
5	2.49	1.297	3.10	1.015	0.000 **
6	2.72	1.186	2.97	1.052	0.056
7	2.99	1.238	3.07	1.078	0.739
8	2.55	1.150	2.92	0.926	0.014 *
9	2.77	1.464	3.21	1.080	0.055
10	1.88	1.116	2.65	1.194	0.000 **

Mann–Whitney U test *p<0.05. **p<0.01. n=Data count

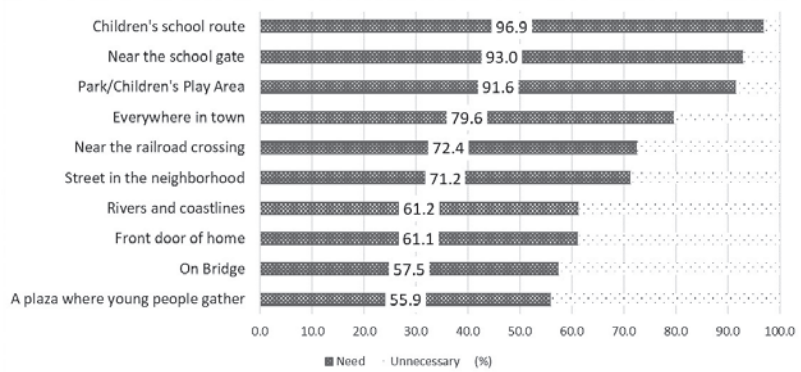

Fig. 2 Results of an awareness survey for each question regarding the location of device conducted after its installation

the device had a more positive view of it.

4) Where should the blue LED security light with camera be installed? (10 choices)

We investigated the necessity of installing the device in 10 locations: "A plaza where young people gather," "On the bridge," "Front door of a home," "Rivers and coastlines," "Streets in the neighborhood," "Near the railroad crossing," "Everywhere in town," "Park/children's play area," "Near the school gate," and "Children's school route." The results are shown in Fig. 2.

More than 90% of respondents answered that "Children's school route (96.9%)," "Near the school gate (93%)," and "Park/children's play area (91.6%)" required these systems. In addition, more than 50% of respondents said that it should be installed in all the 10 locations.

We asked the participants to write down any other areas they thought were necessary, and the following were listed: "Near the entrance to the restroom," "Locker rooms," "Dark streets with no street lights," ' and "Parking/bicycle parking." In particular, there was a request for "more streetlights to be installed on the road to the second north parking lot." We installed the device along the road to the second north parking lot, but it was found that there were still not enough users and that there was a desire to install more devices.

Ⅳ. Impact of the device on agricultural crops

We conducted a survey and analysis to determine the effects of the device on plant growth. Night lighting negatively impacts the crops, delaying the emergence of rice grains and increasing the number of insect pests. To mitigate this issue, light distribution control has been proposed [15]. However, a board reflector used for this purpose reduces the light intensity but consumes more power, which is not desirable from the perspective of energy cost performance. Therefore, blue LEDs and high-speed flash are considered effective countermeasures [16]. The proposed lighting system uses blue LEDs as the lighting module, and its impact on agricultural crops must be determine for its practical applicability. To this end, experiments were conducted in 2022 and 2023 on rice and broccoli. The growth status of both crops was visually confirmed with and without LED projection.

Figure 3 shows the experimental environment of rice, wherein a blue LED was projected directly onto the right stock group. Experiments were also conducted under conditions wherein the left plant group was irradiated with indirect light. A comparison of the heading time of both groups revealed that the plants irradiated with direct LED light were longer but the heading time delayed. Contrastingly, no such effect was observed in the plants subjected to indirect irradiation. The illuminance and other aspects of the proposed lighting system have been designed assuming that it will be installed at a height of around 4 m, and the impact on rice crops will be minimal at such an installation height.

Fig. 3 Blue LED projection experiment on rice

Figure 4 shows the effect of blue LED projection on the growth of broccoli. For the group that was not irradiated with blue light, growth was inhibited due to insect feeding damage, whereas less damage was observed in the group irradiated with blue light. The pest-repellent effect of blue LED projection was also previously reported [17]. Blue light irradiation may be beneficial for the growth of certain crops.

Fig. 4 Effect of blue LED projection on the growth of broccoli (Left: without irradiation, Right: with irradiation)

The following conclusions can be drawn regarding blue LEDs and plant growth.

(1) Irradiation from a close range promotes germination and growth. However, the irradiation distance of the proposed system did not considerably impact the crop growth. This will be quantitatively verification in future studies.

(2) Blue light had a pest-repellent effect on broccoli. The effective irradiation distance will be quantitatively determined in future studies.

Ⅴ. Anomaly detection of passerby

The proposed device was also used for anomaly detection by installing it on street lamps at a height of ~4 m relative to the ground along with a camera unit that was built into the same body (Fig. 5). The experiments were conducted to recognize the passerby and their behavior.

Fig. 5 Suggested security camera system (Blue light-emitting area in the upper center of the image)

Joint body models were previously used to classify the behavior of passersby [18], and facial recognition [19] was used to identify the individuals. However, as the models were installed at a height and consumed more power, low-resolution images were captured. Herein, as the camera unit of the proposed device was installed at a height of 4 m, images of passersby were captured directly from above or diagonally (Fig. 6). Therefore, it is difficult to obtain joint body models and face recognition.

We will be using gait recognition, which is an identification method used to recognize individuals based on their gait. This approach has garnered considerable attention because it can be used even at low resolution and performs passive authentication. It is also used in various fields including forensic investigations [20]. Gait recognition can be performed when sufficient data are captured by the camera system of the device.

To perform gait recognition, individuals were detected using the object detection algorithm, YOLO, owing to its ability to detect objects at a high speed [21]. As shown in Figure 6, two individuals were detected in the video (marked in green). However, the detection

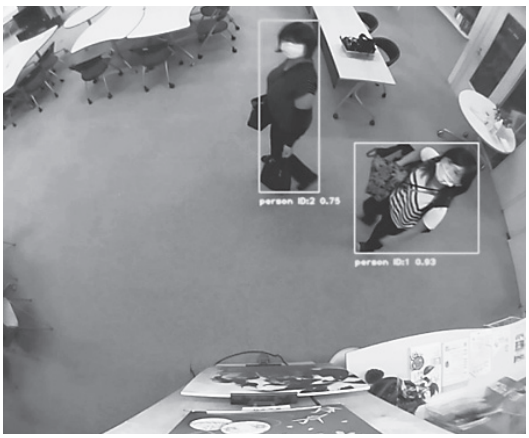

Fig. 6 Photographed image

accuracy considerably decreases when three or more individuals are detected. In the future, we will balance high speed and detection accuracy in gait recognition.

Ⅵ. Expansion of systems for searching and detecting victims

The proposed device was effectively used to address various local issues besides crime prevention. The camera module has Full HD resolution, with 6223A-SRD WiFi + Bluetooth module, display control application processor with H.264 Codec, and N32926U4DN video processor. N32926U4DN is a system-on-chip（SoC）obtained from Taiwan's Nuvoton, and the CPU is equipped with an ARM926EJ-S, a video processor specialized for camera and video processing, including video codec. We prioritized on the functions of camera, wireless communication, video storage, GPS（current location/time）, and security light. Considering that the security light was a separate circuit, It can be reproduced using a Raspberry Pi+ camera module + GPS module. Therefore, we installed the device in which the main board was replaced with a Raspberry Pi + camera module in U302 and verified its operation.

First, we confirmed that Raspberry Pi could be remotely connected to the classroom LAN via wireless LAN to view videos from other laboratories. RTSP and H.264 formats were used for video distribution. Furthermore, on the receiving side, AI was used to detect objects and people. We also tested the process of saving only frames where a person was detected and confirmed that although the HDD was full, videos could be recorded. YOLO v8 was used for object detection. The proposed device should operate independently during emergencies such as disasters in mountainous or urban areas. Therefore, an independent network was built. The contents of the study, including experiments and surveys, are shown below.

To meet sustainable development goals, sustainable systems must be used not only during disasters but also during normal times. Therefore, wireless systems that consume less power must be developed. To this end, we considered Private LoRa; however, its communication speed was considerably slower to handle images and videos. WiFi HaLow［22］and Wi-SUN FAN［23］are also being considered. Although WiFi HaLow is not a mesh-type network, it can transmit images at a high speed. Wi-SUN FAN has a lower range and distance than WiFi HaLow, but it can transmit images and has a mesh network.

By making it a battery-powered + mesh network terminal, it could be used to find, contact, and understand the situation of people in distress and disaster victims. The device can become an effective infrastructure for saving lives during disaster.

Ⅶ. Conclusions

The proposed device has a simple structure with blue LED lighting system and a built-in security camera. It can be used for disaster and crime prevention. In the future, we will equip drones with mesh network terminals and disperse them around sites where disaster victims and survivors may be present. We will also contact and exchange information with disaster victims and people in distress via the mesh network built using the proposed device.

Conflict of interest

There are no conflicts of interest to disclose regarding this article.

Acknowledgments

We would like to express our deep gratitude to all the subjects who cooperated in this study. This research result was obtained as a result of research activities at the Society 5.0 Study Group, Shikoku University Interdisciplinary Research Institute.

References

1）Y. Ikemoto, E. Yokozeki, Y. Hosokawa, S. Tsujioka, N. Suzuki, A. Kondo, K. Kida, Y. Amano, and K.

Yamamoto：“Development of a Sustainable Crime and Disaster Prevention Lighting System that Contributes to the Safety and Security of Communities”, Annual Bulletin of the Research Institute of Interdisciplinary Research, Shikoku University Vol.3, pp.55-62, (2023).

2) S. Sudani, “The introduction background and nationwide actual conditions report of the blue lighting”, Journal of the Illuminating Engineering Institute of Japan, Vol.92, No.9, pp.631-636, (2008) (in Japanese).

3) Y. Ikemoto, A. Kondo, K. Mino, and K. Yamamoto, “Installation Effects and Possibility of Blue LED Lights for Crime Prevention”, Annual Bulletin of the Research Institute of Management and Information Science, Shikoku University, Vol.14, pp.95-106, (2009) (in Japanese).

4) S. Taira: “*Aoirobouhanntou niyoru Bouhannkouka toAoiro･SIroirohukugou LED Syoumei no Kaihatu*”, Bulletin of Counseling Room for Mental Health, Vol.4, pp.67-74, (2010).

5) Y. Mizokami: “Psychological Effects of Blue Light and Illumination: Lighting for the Prevention of Crime and Suicide (Psychological / Physiological Effect and Evaluation of Blue Light)”, Journal of the Illuminating Engineering Institute of Japan, Vol.97, No.9, pp.632-637, (2013).

6) H. Ono, and R. Tokunga: “Evaluation of Blue Light and Blue Color in Terms of Safety and Security: A Comparative Study Between Japanese and Scottish Students”, Otemae University Otemae, Journal, Vol.11, pp.43-66, (2010).

7) Glasgow City Council, “Getting Ahead of Change Glasgow City Centre Strategy and Action Plan 2014-19”, pp.1-44, (2014).

8) Glasgow City Council, “Glasgow City Council Strategic Plan 2017 to 2022”, pp.1-24, (2017).

9) S. Ishida: “*Hukushi no Machidukuri × Syoumeidezain*”, Hukushi no Machidukuri, Vol.20, No.3, pp.93-96, (2018).

10) S. Kubota, H. Seki, T. Kariya, and A. Abe: “Development and Application of Color Universal Design Support System for Pedestrian Space”, IPSJ journal, Vol.52, No.1, pp.140-152, (2011).

11) K. Yamamoto: “Ideas and effects of lighting design in urban public space”, Journal of the Illuminating Engineering Institute of Japan, Vol.74, No.3, pp.137-142, (1990).

12) R. Yanase, and F. Sakai: “The Influence of Interval Between the Street Lights on Impression and Cognitive Distance of the Nighttime Street”, Journal of Architecture and Planning, Vol.71, No.601, pp.139-144, (2006).

13) N. Yabuki, T. Hukuda, and Y. Yoshida: “Development of Lighting Method or Strengthening Surveillance and Territory in Residential Areas”, Journal of Environmental Engineering, Vol.75, No.650, pp.321-329, (2010).

14) K. Takahara, K. Kana, and Y. Sakuma: “A Study on the Characteristics of Urban Nightscape in Nakanoshima, Osaka -Focusing on the relation between the recognition of visitors and illumination ratios”, Journal of Architecture and Planning, Vol.77, No.672, pp.403-408, (2012).

15) Ministry of the Environment: “*Chiki Syoumei Kannkyou Keikaku Sakutei Manyuaru*”, 〈https://www.env.go.jp/content/900400151.pdf〉, pp.26-30, (2000), Accessed Jan 7, 2024.

16) Y. Sonoyama, K. Iwaya, and H. Yamamoto: “Light pollution latest phenomenon and trends of crops”, The Journal of the Institute of Electrical Installation Engineers of Japan, Vol.36, No.1, pp.33-36, (2016) (in Japanese).

17) M. Hori: “Lethal effect of blue light on insects and its application to pest control”, Japanese Journal of Pesticide Science, Vol.43, No.2, pp.109-116, (2018) (in Japanese).

18) T. Mori, and H. Kikuchi: “*Shindosennsa niyoru Hoyoutokutyouryou wo motiita Kozinnshikibetu･Tuisekihousiki no Teiann*”, Computer Security

Symposium 2017, Vol.2017, No.2, pp.972-979, (2017).

19) K. Onodera, T. Suzuki, and Y. Kiyohara: *"Kaoninsyoudousa no Tokutyou wo motiita Smart phone no Kaninnsyousyuhou"*, Proceedings of the **th National Convention of IPSJ, Vol.2022 , No.1, pp.395-396, (2022).

20) Y. Makihara, D. Muramatsu, and Y. yagi: "Gait Recognition and Its Applications to Forensics", IEICE Fundamentals Review, Vol.14, No.4, pp.318-328, (2021) (in Japanese).

21) G. Tannno, H. Inoue, Y. Umehara, S. Tanaka, R. Imai, D. Kamiya, and M. Nakahata, "Kennsetugennba no Zinnbutuninnsiki no tameno YOLO no Tokuseibunseki ni kannsuru Kennkyuu, Proceedings of the **th National Convention of IPSJ, Vol.2021, No.1, pp.73-74 (2021).

22) Contec e-shop HP 〈https://www.contec.com/jp/products-services/daq-control/ flexlan-iot/media-converter/rp-wah-sr1/price/〉, Accessed Jan 7, 2024.

23) ROHM User's Guide 〈https://fscdn.rohm.com/jp/products/databook/applinote/ module/wireless/bp35c5-t01_evaluati onboard_ug-j.pdf〉, Accessed Jan 7, 2024.