Development of a Sustainable Crime and Disaster Prevention Lighting System that Contributes to the Safety and Security of Communities

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ABSTRACT

This study describes an LED lighting system that does not affect crops and is sustainably developed to ensure the safety and security of residents and students. Prior to the installation, the authors conducted a questionnaire survey of students, faculty and staff and local residents regarding the acceptability of blue LED lights. Then, a bright blue colour was adopted to ensure visibility and installed a blue LED security light with a high-definition security camera that can catch suspicious persons. Prior to installation, the device was converted from a commercial power source to one that uses renewable solar energy, thus increasing the significance of its installation in relation to one of the SDG initiatives for carbon neutrality. In this way, the installation of this device considered its impact on crops, and the device proved useful not only for crime prevention but also for disaster prevention.

Keywords: Security Light with Video Camera, LED Lighting System, Disaster Prevention, Powered by Solar and Battery, Measures against Light Pollution

Ⅰ. Introduction

The existence of street lights has important significance for residents to ensure safety at night and to live in the community with peace of mind. However, the installation of such systems may adversely affect the growth of crops; thus, selecting a method that poses fewer problems for both farmers and residents has become an important issue. Residents think that it is essential to install street lights on children's school routes and on community roads. On the one hand, it is generally difficult to install them on roads leading to houses near paddy fields and fields out of consideration for agricultural businesses in these areas. On the other hand, universities have the responsibility to protect students from suspicious persons when leaving school at night, among others, and to maintain and operate a campus where they can study with peace of mind by ensuring safety. However, in consideration of the impact on agricultural crops, Shikoku University,(i.e. the authors' school), has not been able to install street lights on some school routes.

This is because in recent years, many farmlands have been converted into residential lands, and the remaining farmlands are scattered among residential areas. The same is true for the back side of the university (north side) and the rice fields adjacent to the city road

that is part of the school route (Fig. 1). As rice is a short-day plant, under long-day conditions, such as in the case of street lights, road lights and advertising lights, the delay in heading leads to reduced yields and poor quality [1]. The number of days of delayed heading that does not affect the harvest of rice is 3 days or less [1]. Therefore, we clarified the installation conditions of street lights that satisfy the conditions and then designed and installed them.

Meanwhile, it has been reported that the colour blue has a calming effect, and many blue streetlights are installed across the country [2,3]. However, its effect is not clear [4,5]. Therefore, when installing blue LED security lights with security cameras, it is necessary to clarify the necessity of installation and the use of this colour. The authors showed that the selection of blue LED lighting was appropriate by reviewing the literature, after which we described the results of a questionnaire survey to residents and students. We also reported on the installation of the blue LED security/disaster prevention light with a camera (hereafter referred to as 'this device').

Ⅱ. Effects of blue LED lighting on rice cultivation

In this study, we reviewed the literature for conditions that do not affect the yield of rice, specifically, those conditions that can limit the number of days to delay heading to within 3 days. These include the installation location (the distance from the rice plant to the light source), the installation angle of the light source, as well as the type, colour and wavelength of the light source.

To reduce the delay of heading within 3 days, it was necessary to control the light distribution with LED lights of 5 lx or less at a field height of 20 cm [6]. Furthermore, we found that by using blue light LEDs, the heading started and completed on almost the same schedule as when there was no night-time lighting [7].

Harada et al. reported that near-ultraviolet (UV), white, yellow and red LED light sources significantly delayed the emergence of rice [8]. In the case of white and blue/green LED light sources, the delays are reported to be 13 days and less than 3 days, respectively [9]. Meanwhile, in the case of light emission control, the delay in heading is reported to be 1 day [10]. Based on these results, we decided to adopt a blue LED light source for this study.

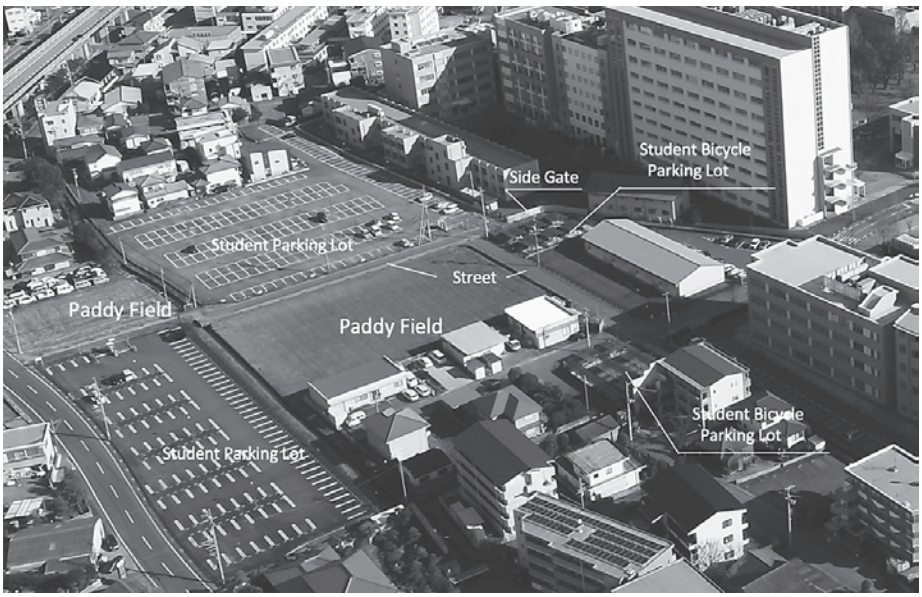

Fig. 1 Back area of Shikoku University (north side)

Table 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.

Table 2. What do you think about the blue colour of the 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.

Ⅲ. Necessity of the Installation of Blue Street Lights and the Participants' Impressions

1. Purpose

Regarding the installation of blue LED security lights with cameras, we will clarify the necessity of installation and the use of the blue colour.

2. Method

a. Recruitment of research collaborators

Research collaborators included residents of the local government/self-governing association where the device was installed, as well as users of the university campus. Approval was obtained in advance from the Shikoku University Research Ethics Review Committee of the institution to which the author belongs(approval number 2021005). Afterwards, we provided written explanations to the local residents. We explained both in writing and verbally the purpose of the research, the voluntary nature of their participation, that refusal would not be a disadvantage, and that the results would not be used for purposes other than this research. Then, we distributed survey forms and self-addressed stamped return envelopes on the spot and asked those who could cooperate with the survey to put the results of their responses in the post and post them. For all university students, information about research cooperation was provided on the portal, and similar explanations were given to those who made requests. They were then asked to post in the designated drop-boxes.

b. Survey period

The survey was conducted from June 2021 to August 2021.

c. Data collection method

The survey used an anonymous self-administered questionnaire. The items on the questionnaire are five-point Likert scales, ranging from 5(‘strongly agree’) to 1(‘not at all’). Tables 1 and 2 show the contents of the questionnaire.

d. Analysis method

The statistical software in the analysis was SPSS Ver26. First, we performed a simple tally. Then, we checked whether there was a difference in

interpretation depending on gender, students and working status. After confirming non-normality with the Shapiro–Wilk test, we performed Mann–Whitney U test, in which the significance level set at 5%.

3. Results

a. Overview of research collaborators (Table 3)

The summary of the research participants is as follows: 85 males, 192 females and 2 individuals who did not identify their genders for a total of 279 persons. See Table 3 for age breakdown, data collection location and occupation.

b, 'What are your thoughts on the installation of street lights with cameras?'

The participants had positive views about the

Table 3. Overview of research participants

Gender	Males	85
	Females	192
	unfilled persons	2
Age	10's	76
	20's	98
	30's	20
	40's	21
	50's	28
	Over 60s	36
Survey location	outside the university	61
	on campus	218
Profession	student	151
	company employee	39
	Civil servants/group employees	27
	teaching staff	20
	self-employed	2
	part-time job	17
	others	23

n=279

Table 4. Results of the awareness survey on the installation of street lights with security cameras

question no.	n=277 Males Avg.	Males SD	Females Avg.	Females SD	p	n=279 on campus Avg.	on campus SD	outside the university Avg.	outside the university SD	p
1	4.25	0.853	4.34	0.750	0.585	4.35	0.768	4.29	0.799	0.530
2	4.20	0.894	4.27	0.729	0.953	4.33	0.709	4.14	0.855	0.088
3	4.01	0.969	4.26	0.740	0.091	4.26	0.770	4.08	0.873	0.110
4	4.50	0.829	4.56	0.644	0.958	4.56	0.628	4.52	0.785	0.996
5	4.77	0.499	4.72	0.514	0.351	4.72	0.521	4.76	0.495	0.369
6	4.06	1.023	4.41	0.725	0.011 *	4.49	0.729	4.08	0.903	0.000 **
7	3.37	1.247	3.19	1.171	0.250	3.23	1.221	3.28	1.168	0.794
8	3.28	1.193	2.97	1.111	0.039 *	2.97	1.219	3.20	1.043	0.122
9	3.75	1.080	3.95	0.925	0.241	3.95	1.041	3.82	0.889	0.108
10	1.93	0.954	2.09	1.022	0.193	2.14	1.059	1.94	0.937	0.138

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

Table 5. Results of the awareness survey on the blue colour of camera-equipped security lights

question no.	n=277 Males Avg.	Males SD	Females Avg.	Females SD	p	n=279 on campus Avg.	on campus SD	outside the university Avg.	outside the university SD	p
1	3.78	0.925	3.97	0.693	0.195	3.99	0.798	3.81	0.732	0.033 *
2	3.23	0.821	3.38	0.771	0.164	3.33	0.860	3.32	0.722	0.904
3	3.28	0.855	3.44	0.772	0.188	3.44	0.841	3.34	0.742	0.583
4	3.49	0.861	3.57	0.853	0.432	3.69	0.843	3.37	0.834	0.002 **
5	3.31	0.974	3.33	0.869	0.834	3.40	0.934	3.24	0.849	0.121
6	2.83	1.135	2.97	0.899	0.324	3.05	1.038	2.79	0.879	0.049 *
7	2.84	1.048	2.95	0.933	0.587	3.05	0.988	2.76	0.915	0.015 *
8	3.01	0.956	3.02	0.761	0.640	3.16	0.893	2.86	0.698	0.002 **
9	3.53	1.130	3.27	0.907	0.030 *	3.37	1.019	3.31	0.940	0.643
10	2.39	1.113	2.58	1.062	0.086	2.68	1.122	2.35	1.020	0.005 **

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

installation of street lights with security cameras and thought that the installation provided them with peace of mind. Related to Question 6, many people felt safe because they would not be inadvertently suspected. Furthermore, the results statistically showed that more students than working adults and more women than men think this way. Women also felt more secure, whilst men felt more restricted (Table 4).

c. Impression on the blue colour of the camera-equipped security lights

The results showed that men tended to feel colder than the blue colour of the blue LED security light with camera. In addition, a large percentage of the students thought that the scenery with blue lighting was beautiful and had a calming effect. As these results are strictly based on individual senses, it is necessary to verify them using physiological testing methods, such as electroencephalograms and heart rate monitors, in the future Table 5.

Ⅳ. Installation of Blue LED Street Lights with Security Cameras

For the security camera-equipped blue LED security lights, we adopted 'ACTIKLE', whose performance is shown in Table 6 and is sold by Amano Corporation. Designed by Amano Corporation (a joint research team of the authors), the ACTIKLE can be

Fig. 2 State of construction during the device installation

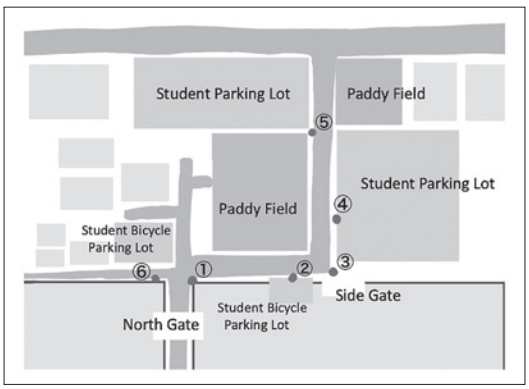

Fig. 3 Location of the installed device and the immediate surroundings

Table 6. Specifications of the ACTIKLEs used in this study

<Main Body>	
Sise	355×153×124
Weight	2.5Kg
Power Consumption	15W (3W)
Maximum Input Current	0.31A
Operating Environment Temperature	0~45° C
Waterproof Performance	IPX5
<Lighting Section>	
Luminous Flux	600lm
Color Temperature	15000K
Average Color Rendering Index	>60
Power Consumption	12W
<Camera Section>	
Image Sensor	1/2.7 CMOS
Video Compression Method	H.264
Resolution	FHD 1920×1080
Recording Bitrate	1Mbps
Frame Rate	15fps
Recording Days	11 days
Time Correction	GPS
Recoding Media	Micro SD card 128GB

Table 7. Power specifications for the installed device

<Solar Panel>	
(Standard Condition: Module Temperature 25°C, AM1.5, Irradiance 1kW/m2)	
Type	Monocrystalline Solar Module
Sise	580×343
Weight	3 kg
Nominal Maximum Output	28 W
Nominal Maximum Output Operating Current	1.95 A
Nominal Maximum Output Operating Voltage	14.7 V
Nominal Short-Circuit Current	2.05 A
Nominal Open Voltage	17.7 V
<Battery>	
Sealed Lead-Acid Battery	36 Ah
Lithium Ion Battery	100Ah

operated with a commercial AC power supply and is sold commercially. Based on this device, we modified it to run on solar power and batteries. Table 7 shows the specifications of the solar panel and the battery we used in this study.

In February 2022, pole installation work was carried out, and in March of the same year, six ACTIKLEs, which were improved to operate with solar power generation and batteries (this system is called this device), were installed.

The power supply voltage of the blue LED lighting section of this device must be 12V or higher, whilst the power supply voltage of the security camera section and the communication device section must be 5V or higher. Therefore, for the demonstration experiment, we decided to supply power with a combination of one solar panel (23W power generation) and one seal battery (12V output).

However, due to adverse weather conditions, such as rain and cloudiness as well as shadows of buildings, power may not be supplied as expected. Under such conditions, the numbers of days of battery-only operation were set as 2 days for the lighting unit and 7 days for the security camera.

1. Improving power supply capacity and power generation capacity

We further examined the amount of power generated by the solar system and the type and capacity of the storage battery. The battery has added lithium ion in addition to the sealed battery. Then, the lighting power supply was separated from that for the video camera and communication equipment. The lithium-ion (Li-ion) battery was used for lighting, and the sealed battery was used for the video camera and communication equipment. In addition, the number of solar panels was increased from one to four, enabling rapid charging with four times the amount of current. As a result, the lights remained on for at least 10 days even when there was insufficient sunlight, enabling 24-hour continuous recording. The types of solar panels and Li-ion batteries are the same as those shown in Table 7.

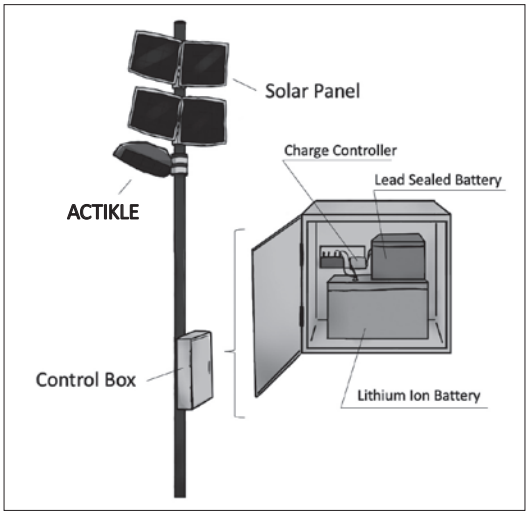

Fig. 4 Improved version of blue LED security light with security camera

V. Consideration

In this study, based on the results of literature

review and questionnaire survey, we determined the importance of installing the proposed device and obtained the consent of local residents and rice farmers to make such an installation. By installing this device, we prevented a decrease in yield due to delays in the emergence of rice, gain the consent of the surrounding farmers and secure the safety and security of the students and residents. However, to standardise this result and promote the safety and security of community roads near rice paddies nationwide in the same way, there are many more demonstration experiments that must be conducted whilst considering other factors. These factors include temperature, hours of sunshine, amount of precipitation and types of crops, among others. Therefore, it is necessary to continue investigating the various effects of blue LED light irradiation in future studies.

Overall, the residents' reaction to the device was positive. However, as there are differences in perceptions depending on gender and age, it is also necessary to scientifically investigate psychological changes among the participants after installation, especially when it comes to colour. Furthermore, even if there are psychological changes or changes in mood, it is not known whether these changes will be directly reflected in individuals' behaviours. Therefore, it is necessary to investigate physiological data as well.

In this study, we adopted solar power generation and batteries, which are renewable natural energies, instead of commercial products for the power supply needed for the device. As a result, the degree of freedom in the installation location increased, and it can be expected to function not only as a crime prevention light but also as a disaster prevention tool. According to a survey on the lives of residents affected by the Great East Japan Earthquake [11], health problems have emerged due to the disruption of lifelines such as gas. This shows that power supplies must be considered as well. Assuming that the proposed device will be installed in evacuation areas, preparations are currently being made so that certain devices, such as smartphones and radios, can be charged from the lighting battery in the event of a disaster.

Thus, in the future, we will continue further demonstration experiments, add functions as disaster prevention lights, add other necessary functions and make continuous improvements. In addition, we are currently considering systematisation from the viewpoint of crime prevention, such as making it possible to identify suspicious people using artificial intelligence-based automatic face recognition of security camera images. However, as the viewpoint of disaster prevention is also important, it is necessary to come up with a device that can prevent and deter accidents and incidents in the event of a disaster.

Adding the necessary value to this device in terms of both crime and disaster prevention and using it as a regional infrastructure will contribute to the creation of safe and secure cities. We would like to approach new value creation, in which local communities can work together from an academic standpoint.

Fig.5 Appearance after equipment installation

Ⅵ. Conclusions

In this study, based on the results of literature review and questionnaire survey, we determined the importance of installing the proposed device and obtained the consent of local residents and neighbouring rice farmers to make such an installation. In addition, by adopting a power supply system that uses renewable solar energy, we were able to develop a highly versatile device from the perspective of SDGs and disaster prevention.

In the future, to make the device more reliable,

we expect to add the necessary added value by conducting further demonstration experiments. We would also like to contribute to the realisation of a safe and secure society by implementing it widely in society.

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