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Comprehensive Evaluation of the Visual Environment of a Railroad Station's Platform, Focused on the User's Psychology

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Abstract: Through a comprehensive evaluation of the spaces of 25 railway stations, where power-saving operations are being conducted due to an earthquake, the effects of various components of the space on users' psychology were reviewed. For the platforms of railway stations, which are divided into 'island platforms' and 'side platforms' the 'physical quantity measurement' and 'impression evaluation' were assessed. When a simple power-saving method, such as partial lighting up is adopted, it has been shown that there is a negative effect on the users, both physically and psychologically. In particular, in the case of outdoor platforms, there is a concern that glare and anxiety due to contrast may increase; therefore, it is necessary to utilize the reflective surfaces effectively. Floor illuminance is fundamental to lighting design. However, some areas cannot be evaluated by floor illuminance alone. The difference in the results of the impression evaluation in five areas with floor illuminance around 50 lx was widely distributed, and it was found that the shape and material of the space affected the results. If platform screen doors are installed, a lighting method that can evenly illuminate the interior of the space is necessary. By reviewing each factor that determines the visual impression, it was revealed that the lighting location and lighting method were significantly affected.

Keywords: comprehensive evaluation; lighting environment; railway station; power-saving operation

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1. Introduction

For large public facilities used by many people, energy saving is an important element. Spaces with high ceilings and large areas, such as airports, focus on saving air conditioning energy by minimizing heat loss [1]. The efficient control of HVAC systems is essential, especially in cold or hot areas [2,3]. On the other hand, in facilities that require visibility and safety, the efficiency of lighting energy tends to be important, including office buildings and railway stations. In offices, lighting energy accounts for about 60% of the total energy consumption, and in the case of railway stations, where many users' movement lines overlap, lighting energy is in more demanded [4]. Among the energy consumed in railway station spaces, building energy represents the largest share, accounting for 81% of the total energy consumption [5,6]. In the breakdown of items included in building energy electricity accounts for 99.4% of the total [7]. Therefore, the management of power consumption is critical for the operation of railway stations [8]. Significant infrastructure damage was created by the Great East Japan Earthquake in 2011, and the damage to the nuclear power plant caused a major disruption in Japan's power supply [9,10]. Therefore, it was necessary to begin forced power saving nationwide, and the Japanese government issued a power use restriction decree to reduce power consumption in public facilities by 15% [11,12]. This significantly affected railway stations, which are representative public facilities used by numerous people, and users experienced many inconveniences. In the breakdown of items that make up the power consumption of railway stations, 44% is lighting energy, 16% is air conditioning equipment, 14% is mobile equipment, such as elevators and escalators and others comprise the remaining 17% [13,14]. It is almost impossible to reduce the operation of indoor air conditioning facilities and mobile facilities at railway stations and maintain the safety and comfort of the users [15,16]. For this reason, power savings through lighting energy which consumes the most power, was adopted as a reasonable way to reduce power consumption by 15%. However, because of the sudden power-saving operation due to the earthquake, a smooth transition could not be achieved, and a simple method, the 'using partial light' method was adopted. Therefore, it was argued that blind spots occurred in various places inside the railway station, the overall interior became dark, and accidents became a concern [17]. The darkening of the environment in the platform through which the train passes can lead to hazardous accidents [18,19]. In particular, if platform screen doors are not installed, there is a risk of falling [20,21]. Therefore, replacing lighting fixtures as a long-term and efficient power-saving method has been suggested as an alternative, and the introduction of next-generation lighting (LED, organic light-emitting diode, etc.) with low costs and high efficiency is gradually increasing [22]. Additionally, following the 2012 Japan Regeneration Strategy, next-generation lighting for all public facilities in Japan within 10 years was set as the goal [23].

The spatial structure of railway stations is more complex than that of other public facilities [24]. The structures are generally classified as 'platform', 'concourse', or 'staircase', and because the characteristics of the spaces are different, the required lighting performances are also different [25,26]. Therefore, the application of different standards is required for the lighting plan of the railway station and the power-saving method. If the using partial light method is adopted for all spaces, there is a concern that comfort and safety may deteriorate [27,28]. In this study, a large-scale survey was conducted to understand railway stations' environmental conditions after the power use restriction decree following the 2011 Great East Japan Earthquake, in Japan. In 25 railway stations, where power-saving operations currently exist, the actual conditions before the full-scale LED lighting was applied were examined in detail. In addition, the shape of the inverse space was classified into various patterns, and the influence of the shape on the physical characteristics of the spatial lighting environment was examined. The important purpose of this study was also to examine the change in users' psychology caused by the lighting change, to examine the relationship with each environmental element and to clarify the evaluation structure to create lighting design guidelines. Psychological evaluation of the users of public facilities is very important for environmental improvement. The subject that evaluates the comfort and safety of a space is the human being, that is, the user, and various physical factors affect it. In particular, vision contributes about 90% to human information acquisition, and visual impressions on space effectively evaluate the comfort of space. Therefore, research to evaluate the psychology of users in various spaces is actively conducted. Large spaces, such as outdoor spaces and libraries, are also targeted [29,30], and the visual quality of the spaces promotes the city's vitality [31]. Visual information also affects sociability between users [32], and 76% of overall environmental satisfaction is determined by visual information [33]. In the investigation, the station space was divided into the platform, concourse, and stairs, and a comprehensive evaluation of the spatial perspective was conducted. Subsequently, a physical quantity measurement, an impression evaluation for users, and a comprehensive evaluation of the evaluation method perspective were conducted.

2. Overview of the Investigation

2.1. Target of the Investigation

In this study, to review the lighting environment and operation status of railway stations from various perspectives, field surveys were conducted, targeting as many fields as possible. Figure 1 shows the front view of the platform for each of the 25 stations. Platform structures are generally classified into two types: 'island platform' with tracks located on both sides of the platform, and 'side platform' with a track located in the center and platforms on both sides. Additionally, various types of ceilings and roofs exist, depending on whether they are avobe-ground or underground stations. In particular, for outdoor platforms in above-ground stations without roofs over the tracks, the day and night light environment gap is significant, which causes discomfort.

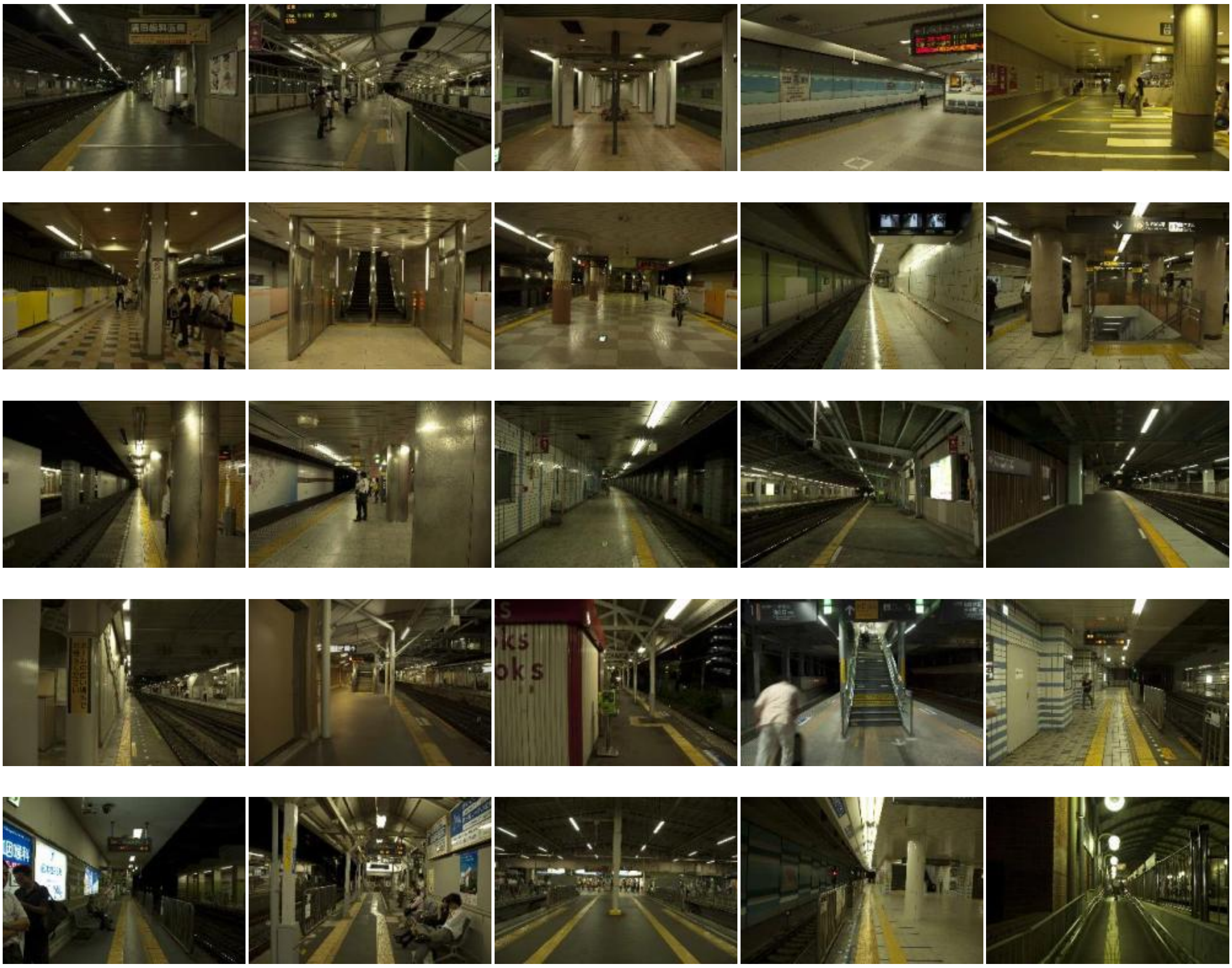

Figure 1. Front view of the platforms.

In addition to the lighting environment, various factors in the visual environment affect comfort in a space. Therefore, the investigation was conducted by subdividing the station factors, as shown in Table 1, to examine the influence of the various elements constituting the visual environment.

Table 2 shows the classification results for the platforms of the 25 stations surveyed according to the criteria in Table 2. For the station grade, 20 out of the 25 stations were B grade (10,000–150,000 passengers per day). There were four A grade stations and one C grade station. The form of station included 13 underground, 5 above ground, 4 elevated, and 3 combined. Regarding the shape of the roof, 23 stations had revealed structures and upholstered ceilings. A total of 10 stations had platform screen doors installed, but the majority did not. For the lighting method, as the most important feature is to illuminate the edge of the platform well, 13 locations used line light source methods centered on the edge of the platform, and additional lighting was installed in the center and on the wall around the edge of the platform. From this, it appears that the current platform lighting places importance on safety.

Table 1. Form classification criteria table of the platform.

Form	Classification	Classification Criteria
Station	25 Stations	25 station buildings
Grade of station	A grade	Stations with more than 150,000 passengers a day
	B grade	Stations with more than 10,000 passengers a day and less than 150,000
	C grade	Stations with less than 10,000 passengers a day
Form of Station	Above ground	Station located above ground
	Basement	Station located in the basement
	Elevated	Station with elevated tracks and platforms
	Above ground + elevated	Above-ground and elevated structure
	Basement + ground	Basement and above ground structure
Form of roof	Revealed structure	Partially open semi-outdoor form
	Upholstered ceiling	Flat + indoor
	Membrane	Membrane-covered structure
Platform screen doors	With installation	Platform screen doors are installed
	No installation	Platform screen doors are not installed
Lighting method	Line light source	Lighting method of line light source
	Line + point light source	Lighting method of line and point light source
Lighting installation position	Platform edge	Lighting is located in the row at the end of the platform
	Platform edge + center	Lighting is located in the row at the end of the platform and center
	Platform edge + Wall edge	Lighting is located in the row at the end of the platform and wall edge
	Center + wall	Lighting is located in the center and wall

Table 2. Platform morphology classification table.

Stations	Form Classification					
	Grade of Station	Form of Station	Form of Roof	Platform Screen Doors	Lighting Method	Lighting Installation Position
1	B	Elevated	Revealed structure	Not installed	Line	Platform edge
2	B	Elevated	Membrane	Not installed	Line + Point	Platform edge + center
3	B	Basement	Upholstered ceiling	Not installed	Line + Point	Platform edge + center
4	A	Basement	Upholstered ceiling	Not installed	Line + Point	Platform edge + center
5	A	Basement	Upholstered ceiling	Installed	Line	Platform edge + center
6	B	Basement	Upholstered ceiling	Installed	Line + Point	Platform edge + center
7	B	Basement	Upholstered ceiling	Installed	Line + Point	Platform edge + center
8	B	Basement	Upholstered ceiling	Installed	Line + Point	Platform edge + center
9	B	Basement	Upholstered ceiling	Installed	Line + Point	Platform edge + center
10	A	Basement	Upholstered ceiling	Not installed	Line	Platform edge + center
11	B	Basement	Upholstered ceiling	Not installed	Line	Platform edge
12	B	Basement	Upholstered ceiling	Not installed	Line	Platform edge
13	A	Basement	Upholstered ceiling	Not installed	Line	Platform edge
14	B	Elevated	Revealed structure	Not installed	Line	Platform edge + Wall edge
15	B	Basement + above ground	Revealed structure	Not installed	Line	Center + wall
16	B	Basement + above ground	Revealed structure	Not installed	Line	Platform edge
17	B	Above ground	Revealed structure	Not installed	Line + Point	Platform edge + Wall edge

Table 2. *Cont.*

Stations	Form Classification					
	Grade of Station	Form of Station	Form of Roof	Platform Screen Doors	Lighting Method	Lighting Installation Position
18	B	Above ground	Revealed structure	Not installed	Line	Platform edge
19	B	Above-ground + elevated	Upholstered ceiling	Not installed	Line	Platform edge
20	B	Above-ground	Upholstered ceiling	Installed	Line	Platform edge
21	B	Basement	Upholstered ceiling	Installed	Line	Platform edge + center
22	B	Above-ground	Revealed structure	Installed	Line	Platform edge + center
23	B	Elevated	Revealed structure	Installed	Line + Point	Platform edge + Wall edge
24	C	Basement	Upholstered ceiling	Installed	Line + Point	Platform edge + center
25	B	Above-ground	Upholstered ceiling	Not installed	Line + Point	Center + wall

2.2. Physical Quantity Measurement Method

As shown in Figure 2, the physical quantities were measured at 25 platforms and 16 concourses. First, the floor illuminance, which is the primary index of the Japanese Industrial Standards (JIS) standard for the design of railway station lighting, was measured. The horizontal illuminance, at a height of 1500 mm, assuming the user's eye level, and the vertical illuminance, in the four directions of east, west, north, and south were measured at the same height. For the stairs, more detailed measurements were performed. The stair space was divided into the upward entrance, downward entrance and stairwell to measure the floor illuminance, horizontal illuminance and vertical illuminance. The vertical illuminance of the stairwell was measured in the upward and downward directions. Additionally, an illuminance meter (IM-2D, TOPCON) was used to measure the illuminance, and the measurements were carried out by minimizing the effect of shadows.

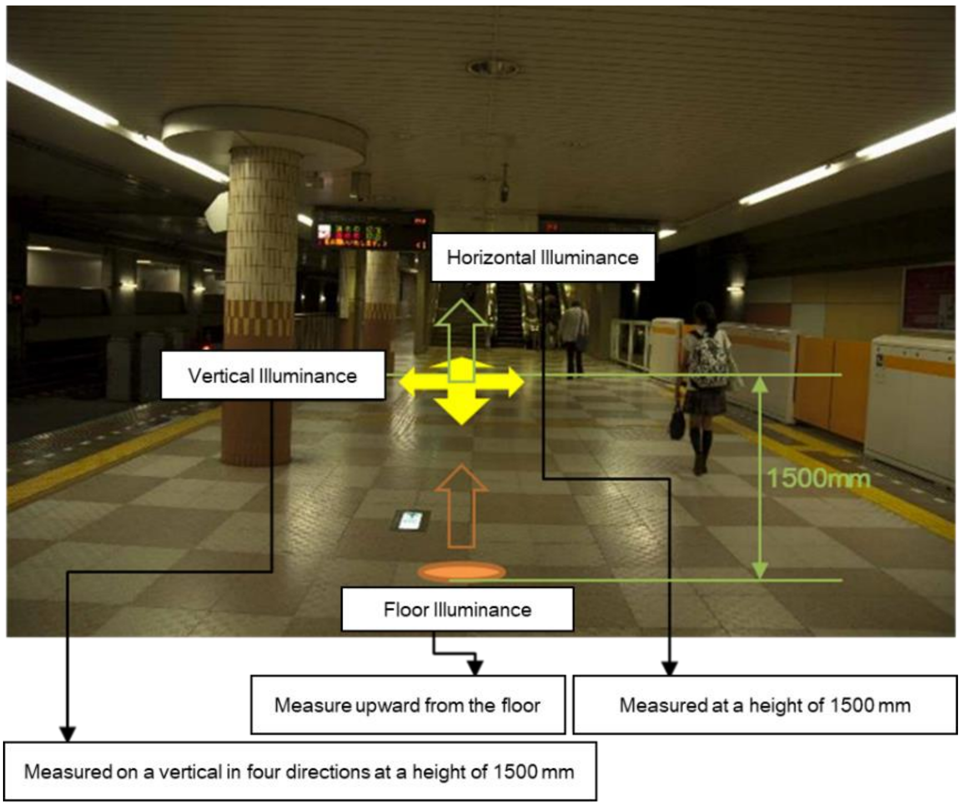

Figure 2. Examples of physical quantity measurement items.

2.3. Impression Evaluation Method

In this study, the physical quantity measurements and impression evaluations were conducted simultaneously. The impression evaluation was conducted by dividing the seven items in Table 3 into perception and recognition amounts. The perceived amount was evaluated on a scale of seven levels (1 to 7) of unipolarity for three items: 'brightness' 'darkness' and 'glare' of the space [34]. The recognition amount was evaluated on a scale of seven levels of unipolarity for the three items of 'calmness', 'anxiety', and 'appropriateness of lighting', and on a bipolar scale for the item of 'want to change.' In the case of the subjects, young people in their 20s and 40s who use railway stations at least once a week were targeted, and 23 people participated in the evaluation of each railway station. The evaluation period was conducted from September to November 2011, right after the Japanese government issued the power use restriction decree. In addition, the evaluation was conducted only at night, when the role of lighting becomes important.

Table 3. Impression evaluation items.

Evaluation Items		Evaluation Scale	
Perceptual amount	Brightness Darkness Glare	Unipolar scale	The higher the number, the stronger the tendency ※Example (brightness) 1: Not bright at all 4: Neither 7: Very bright
Cognitive amount	Calmness Anxiety Appropriateness		
	Change the lighting	Bipolar scale	1: Want the lighting to be bright 4: Neither 7: Want the lighting to be dark

3. Results of Physical Quantity Measurements

Physical Quantity Measurement Results of the Platform

The measurements of the floor illuminance of the platforms are shown in Figure 3. For spaces with an illuminance of 200 lx or more (Nos. 4, 5, 10, and 12), the lighting efficiency is excellent, owing to the many reflective surfaces. In contrast, there are front view s in which the floor illuminance is less than 100 lx and the lowest, No. 14, is shown in Figure 4 and recorded as 46 lx. No. 14 is a semi-outdoor type with an open-top track, and it is dark because only part of the lighting equipment is operating.

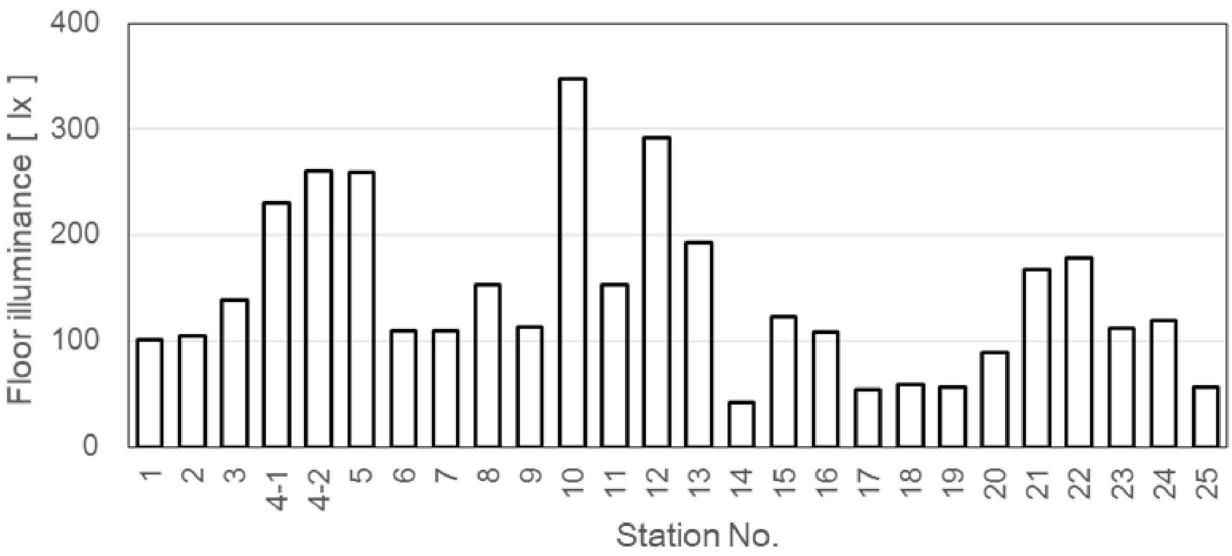

Figure 3. Measurement results of the floor illuminance of the platforms.

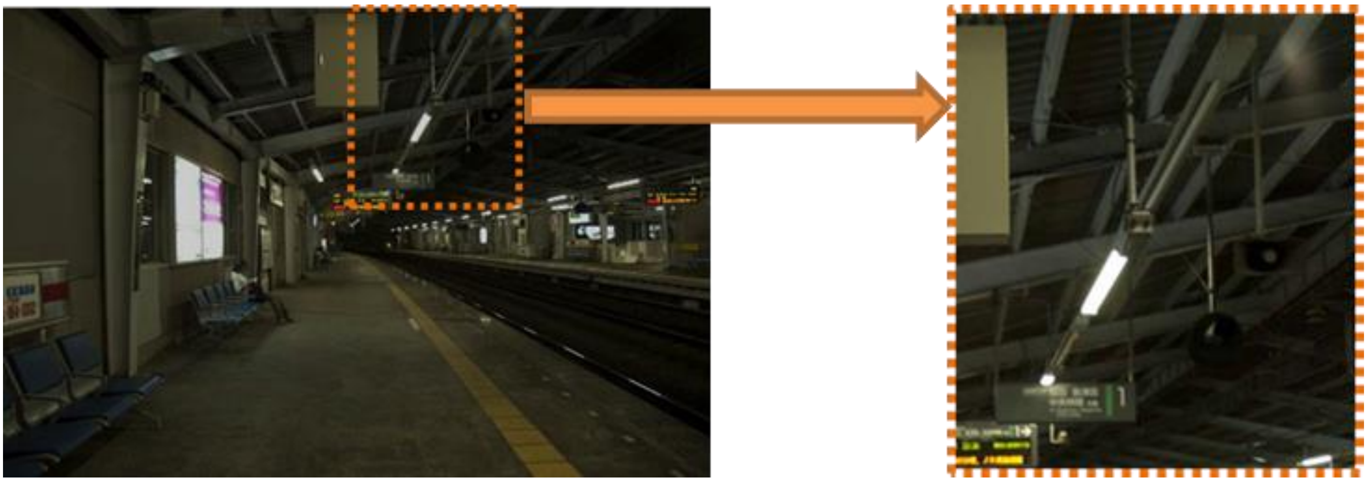

Figure 4. Lighting operation status of platform No. 14.

The vertical illuminance measurements of the platforms are shown in Figure 5. Overall, there was a proportional relationship with the results of the floor illumination, and the difference between the places was less than that of the floor illumination.

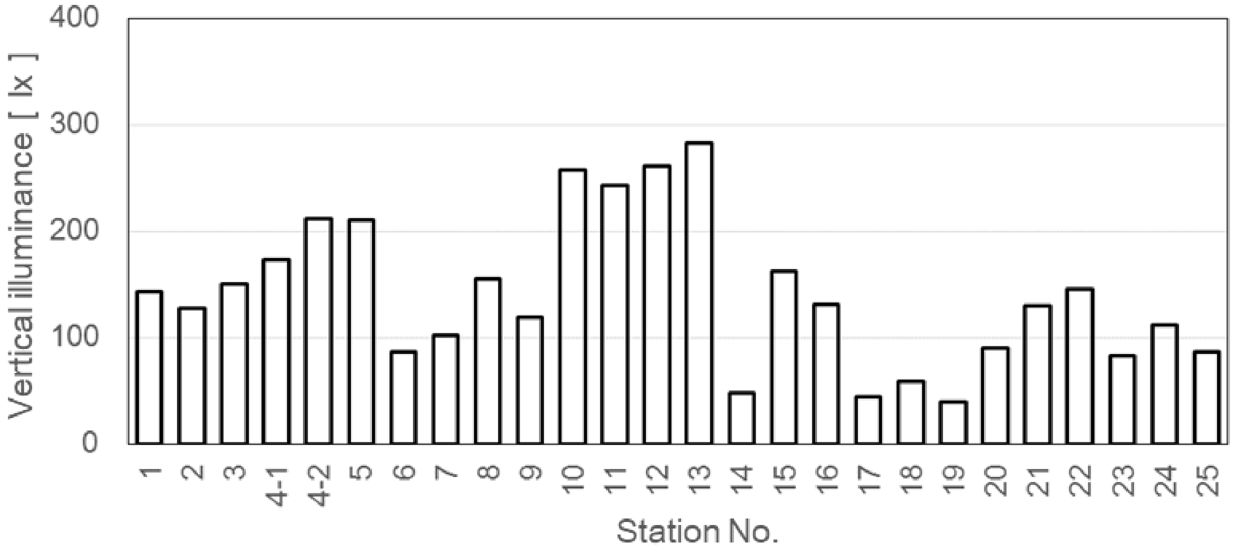

Figure 5. Measurement results of the vertical illuminance of the platforms.

For vertical illuminance, the role of the reflective surface, that is, the wall, is significant. As in No. 13 (left picture in Figure 6), it is easy to obtain vertical illuminance using a wall in the case of the side platform. However, in island platforms, even if the floor illuminance is high (right picture in Figure 6), there is a significant loss in terms of the vertical illuminance.

Figure 7 shows the results of the direct comparison of the measured values of the two points. In No. 13, the floor illuminance was 193 lx, and the vertical illuminance was 283 lx. In contrast, in No. 10, the floor illuminance was the highest at 347 lx, but the vertical illuminance was 258 lx, which was lower than that of No. 13. A strong correlation can be found by examining the relationship between floor illuminance and vertical illuminance through regression analysis. Even though the floor illuminance was almost the same, this was a case in which there was a large difference in the vertical illuminance.

Figure 6. Structural comparison between side platform and island platform (**left**: No. 13, **right**: No. 10).

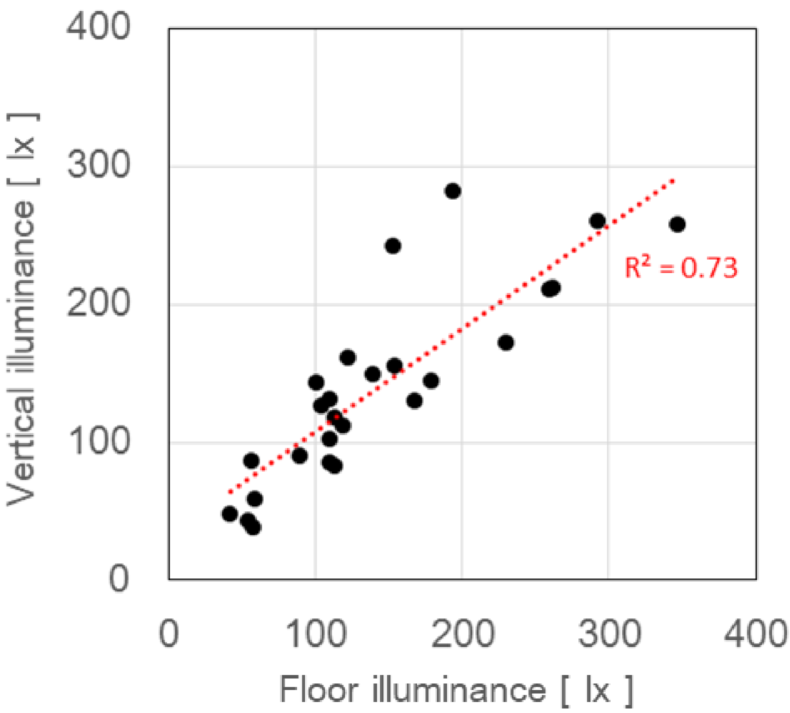

Figure 7. Regression line of the floor and vertical illuminances.

Although the floor illuminances were almost the same, the front views of Nos. 8 and 11 showed a large difference in the vertical illuminance, as shown in Figure 8. In the case of No. 8, the light from the line light source that illuminates the edge is brightly shining on the floor. However, because there is no wall from which the light is reflected, the loss of the vertical illuminance is significant. In contrast, in the case of No. 11, where a reflective surface exists, it was found that a sufficient vertical illuminance can be obtained with only the simple lighting method of a single row configuration.

Figure 8. Comparison of No. 8 (**left**) and No. 11 (**right**).

4. Results of the Impression Evaluation

This section describes the impression evaluation and the results of the physical quantity measurement in Section 3. Although there are 7 items in the impression evaluation, the discussion will focus on the results of four items: 'brightness', 'appropriateness of lighting', 'glare', and 'anxiety'. First, the results of the impression evaluation of the platform are as follows.

4.1. Result of 'Brightness'

The data results were divided into bar and line graphs. Both data visualizations are displayed simultaneously to compare the physical quantities measurement and impression evaluation results on the same graph. The bar graph (Figure 9) shows the results from the impression evaluation and it is based on a 7-point scale on the left axis. The line graph shows the results of the floor illuminance measurement and is on the right axis. The evaluation results of the brightness increasing on the platform shows a proportional relationship with the floor illuminance. The brightness evaluation value of No. 10 with high floor illuminance was also high, and the brightness evaluation values of Nos. 14 and 19 with low floor illuminance were low.

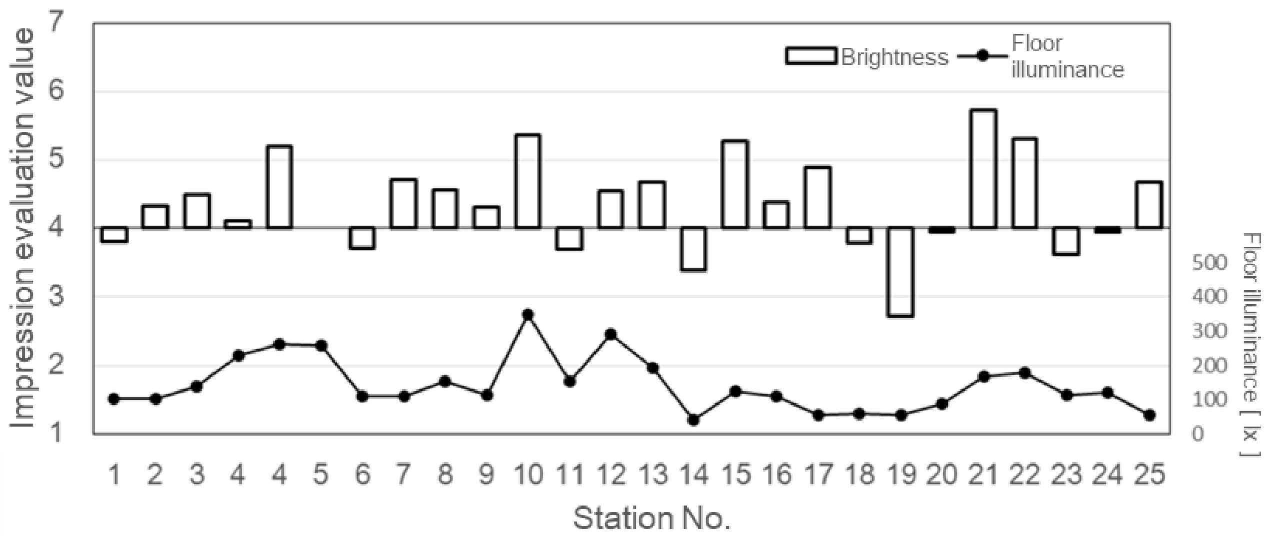

Figure 9. Results of impression evaluation of brightness and floor illuminance.

However, there is a difference in the psychological 'brightness' felt by the user, even when a similar level of floor illuminance is recorded. No. 19 is an island platform, as shown in Figure 10, and the floor is the only side that is illuminated, owing to the small number of reflective surfaces. Therefore, the spaces other than the floor felt dark, and the dark impression was strong when the entire space was evaluated. In contrast, No. 21, which is a side platform, was evaluated brightly even with a floor illuminance of approximately 200 lx, which indicates that the brightness of the vertical surface is also important in determining the impression of the space. For reference, the vertical illuminance at No. 19 is 39 lx, and the vertical illuminance at No. 21 is 129 lx, which is a significant difference.

Figure 10. Front views of No. 19 (**left**) and No. 21 (**right**).

4.2. Result of 'Appropriate Lighting'

The impression evaluation result of the 'appropriate lighting' category generally showed a similar trend to the result of 'brightness' and indicated a proportional relationship with the floor illuminance (Figure 11).

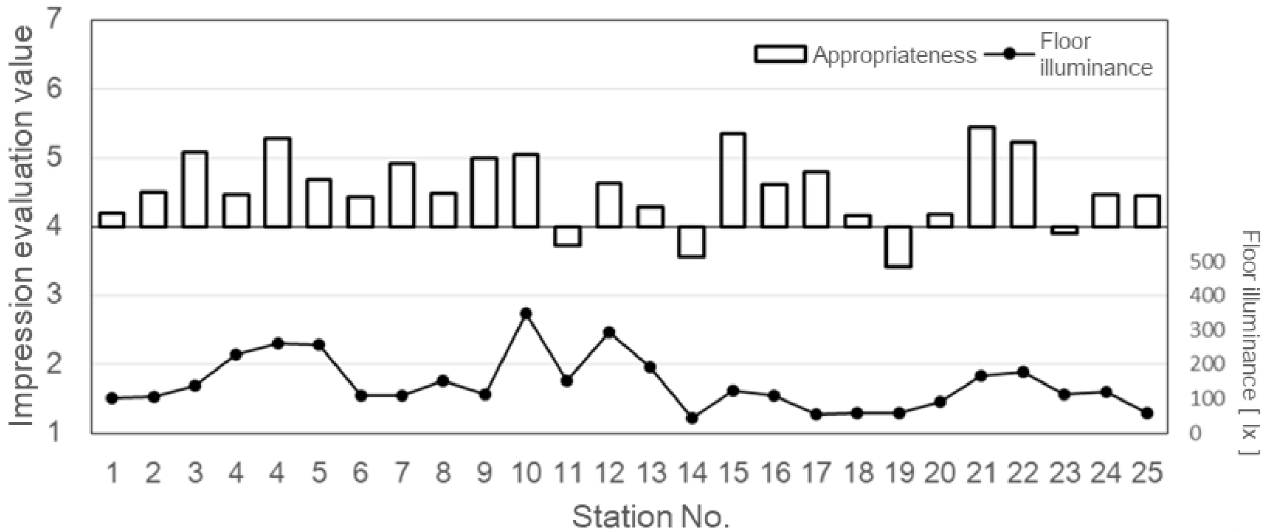

Figure 11. Results of the impression evaluation of appropriate lighting and floor illuminance.

However, it cannot be concluded that the evaluation criteria for brightness and appropriate lighting are the same. Therefore, the distribution of data was reviewed, as shown in Figure 12 (left), to understand the differences in the impression of space evaluation. As a result, a strong correlation was observed between brightness and appropriate lighting. It can be said that bright lighting is considered appropriate lighting; however, this was not the case at all stations, such as in Nos. 6 and 11. No. 6 is an island platform and does not have many reflective surfaces. However, there is a point light source that illuminates the center of the platform, and the platform screen is properly utilized as a reflective surface, so it was evaluated highly. In contrast, at No. 11, even though it is a side platform, which is advantageous for using reflective surfaces, the lighting operation rate is low, and the lighting is concentrated near the track, so the evaluation values were low.

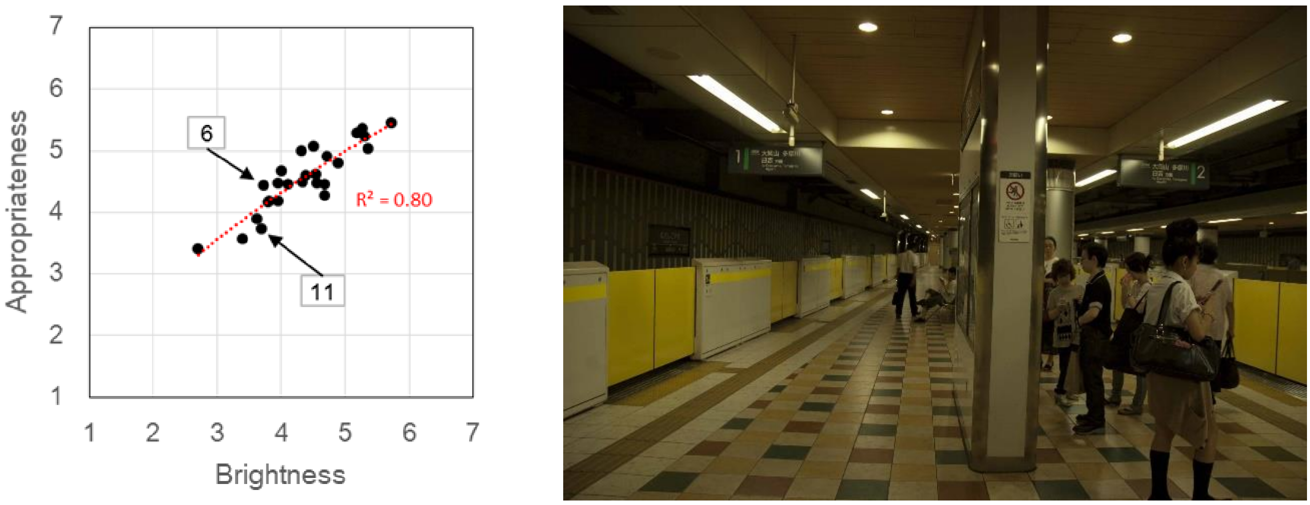

Figure 12. Correlation between brightness and appropriate lighting (**left**) and the front view of No. 6 (**right**).

4.3. Result of 'Glare'

The results of the impression evaluation of glare are shown in Figure 13. As the evaluation was completed during a period when power-saving operations for public facilities were being implemented, the platforms generally did not experience glare.

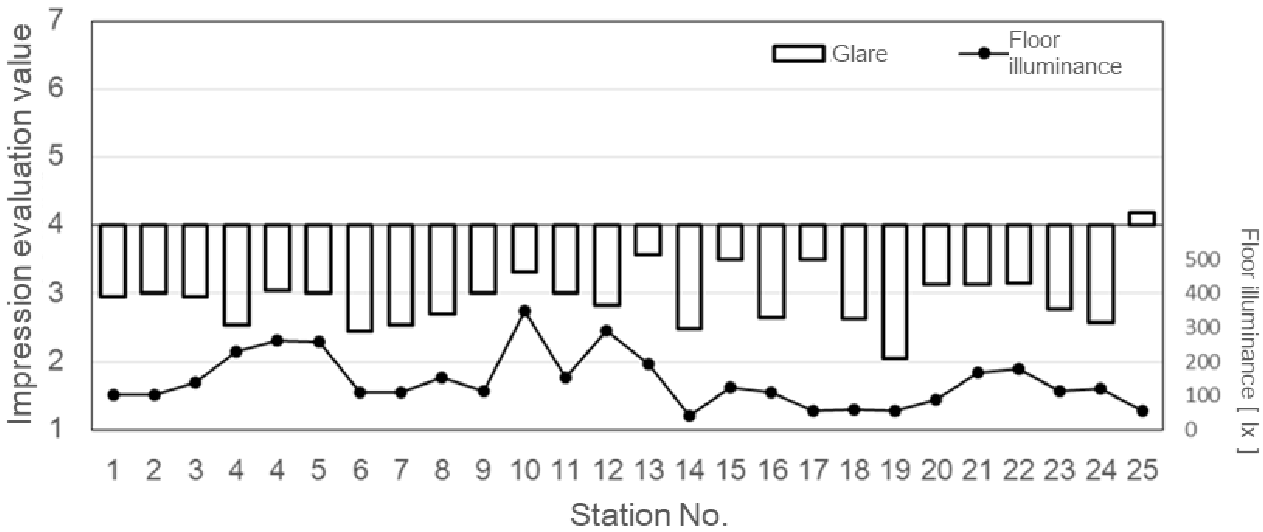

Figure 13. Results of impression evaluation of glare and floor illuminance.

Glare is also proportional to floor illuminance, and it is common to feel dazzled in a physically bright space. However, even in very dark environments, such as Nos. 15 and 25 (Figure 14), glare can occur. In the case of No. 15, the contrast between the light source and the surrounding environment is high, which is an example of glare. The floor, wall, and ceiling of the space are dark materials with low reflectivity, and only the light source is bright, so it was judged with 'I felt some glare'. In the case of No. 25, a special lighting method was adopted. It is a unique space that adopted globe lighting as its primary lighting method, which is not widely used in general public facilities. Because this lighting method has a wide light distribution characteristic, it easily illuminates the entire space, but glare is also likely to occur.

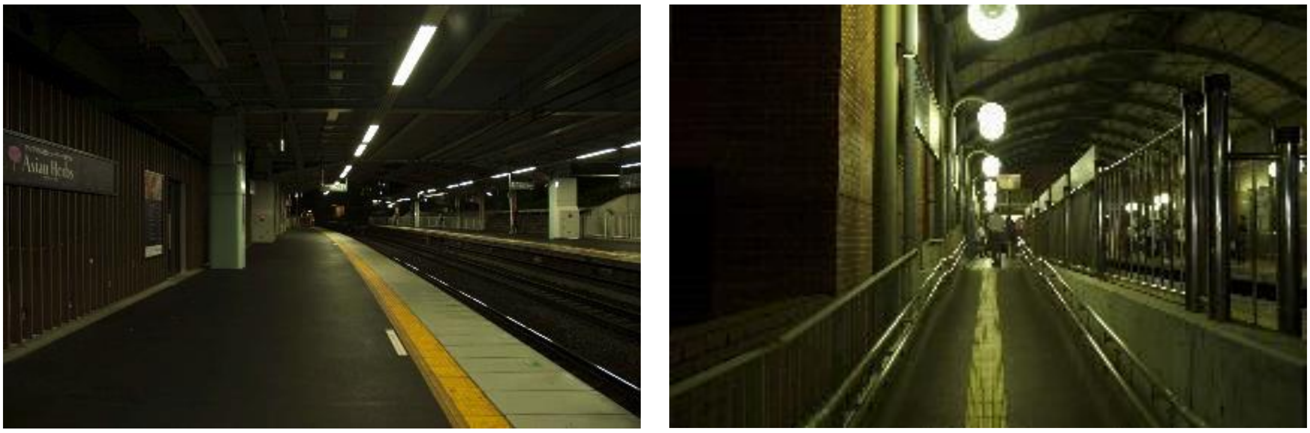

Figure 14. Font views of the No. 15 (**left**) and No. 25 (**right**) platforms.

4.4. Result of 'Anxiety'

The evaluation result of 'anxiety' is shown in Figure 15. At No. 1, an outdoor platform with few surrounding buildings, the darkness at night causes anxiety. In addition, No. 19, where the evaluation value of brightness was the lowest, was evaluated as the highest anxiety station. The lack of reflective surfaces and the dark side of the track are considered to have a negative effect on the impression of the space.

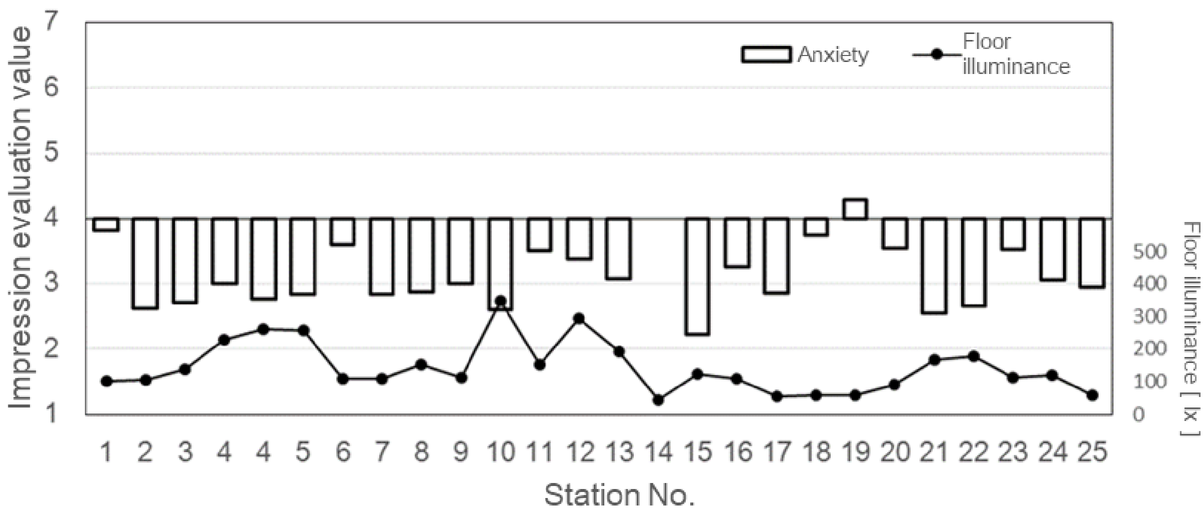

Figure 15. Results of the impression evaluation of anxiety and floor illuminance.

4.5. Result of 'Change the Lighting'

Figure 16 shows the evaluation results of 'want to change the lighting', which is an evaluation item that reflects the subjectivity of the desire to make the space brighter or darker. The results indicate that the points where the space was evaluated as the brightest (the closer it is to 1, the brighter it is) are Nos. 17 and 19, the points with the lowest floor illuminance (Figure 17). At Nos. 17 and 19, the floor illuminance is almost the same; however, there is a significant difference in the impression evaluation results. No. 17 is a side platform and was evaluated as not needing to be brightened because there is a point light source in the center of the platform, including the line light source that illuminates the side. In contrast, users at No. 19 reported wanting to brighten the space because of the lack of reflective surfaces and the bright side, as described above.

From these results, even in a low-illuminance space of 100 lx or less, the impression on the spot tends to be comfortable or unpleasant depending on the form and lighting method of the platform. It is considered that the lighting design should reflect not only the lighting fixture itself but also a comprehensive plan that considers the lighting method, layout, and spatial characteristics.

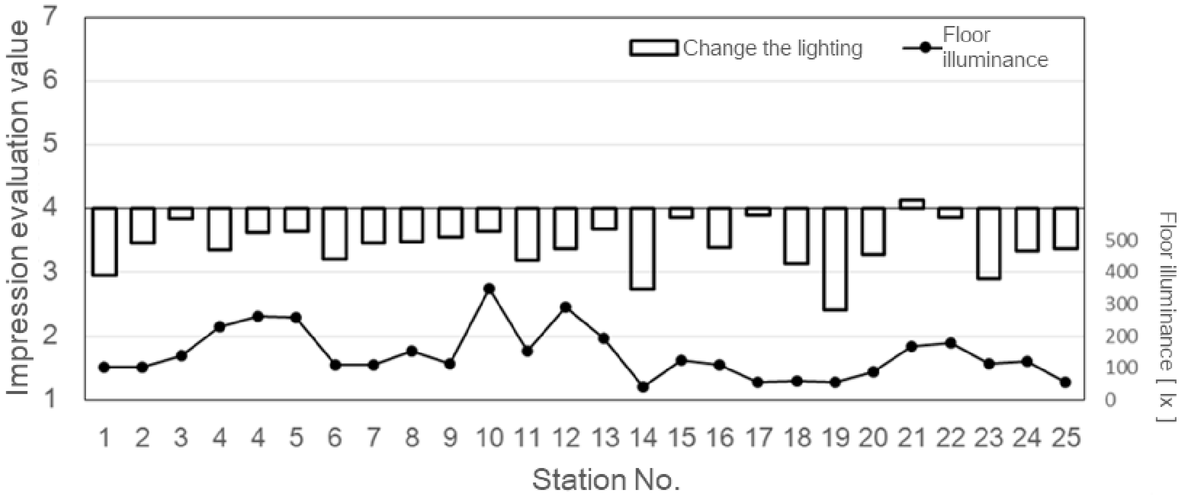

Figure 16. Results of the impression evaluation of 'want to change the lighting' and floor illuminance.

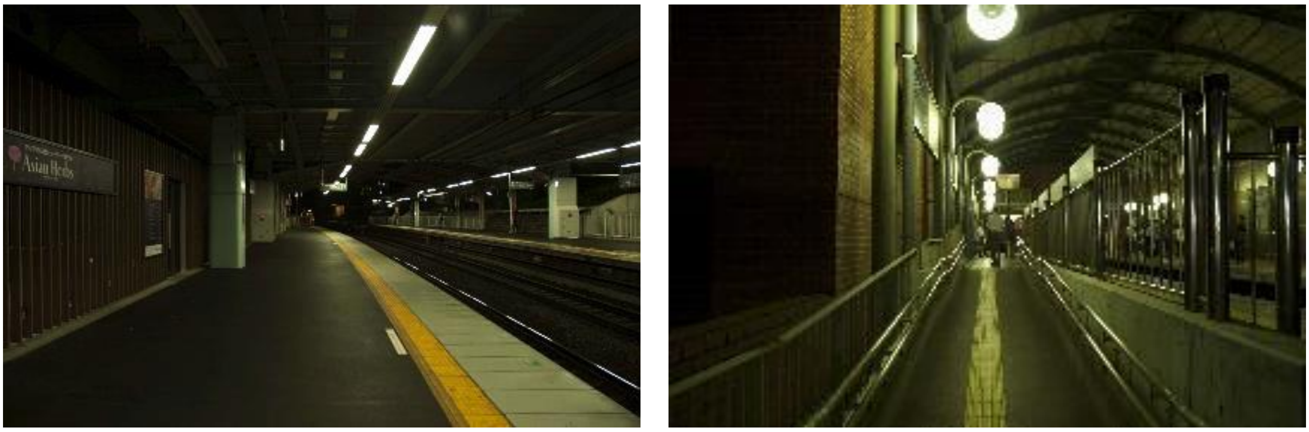

Figure 17. Font view s of the No. 17 (**left**) and No. 19 (**right**) platforms.

5. Statistical Analysis

5.1. Overview of the Statistical Analysis

The results of this investigation can be divided into physical quantity measurements in the field and impression evaluations. Here, the physical quantity measurement corresponds to an objective evaluation, and the impression evaluation corresponds to a subjective evaluation. Therefore, in this study, the relationship between the physical quantity measurement result at the site with objectivity and the impression evaluation was reviewed using statistical analysis. The causal relationship between various environmental factors in the field and user psychology is revealed. Additionally, objectivity can be provided to the impression evaluation results through the process.

The statistical analysis performed in this study was divided into a significance difference test (ANOVA) and correlation analysis. The purpose of this analysis was to test the significant difference in impression evaluations according to environmental factors through an analysis of variance and to determine whether the difference from the subjective impression evaluation results is significant. Additionally, we aimed to examine the degree of influence and correlation of the physical quantities constituting the environment of the space on the impression evaluation of the space through a correlation analysis.

5.2. Analysis of Variance

A significant difference test is important in research that conducts psychological evaluation on subjects. In particular, ANOVA can be a reference in detecting factors that effectively act psychologically from various environmental factors [35–37]. All statistical analyses in this study were conducted using JMP11 software. Table 4 shows the significant differences in impression evaluation results according to the classification of environmental factors constituting the visual environment of each station. No significant difference in the results was detected in the impression evaluation based on the grade of the station, the form of the roof, or the platform screen doors. From the results, factors related to lighting, such as lighting installation position, lighting method, and the form of the station of the platform can be said to be important factors that determine the impression of the space. In the case of the form of the station, it suggests an indirect lighting effect. The shape of the platform is an important factor in the visual environment, as the shape of the platform is related to whether or not the light is reflected, and the installation location can also vary depending on the shape.

Table 4. ANOVA results according to platform type classification (F value, * significant difference).

Form	Brightness	Calmness	Appropriateness	Darkness	Glare	Anxiety	Change the Lighting
Station	9.2 *	1.0	4.0 *	7.7 *	1.4	3.3 *	4.3 *
Grade of station	1.7	0.6	1.0	0.3	0.7	0.2	0.4
Form of Station	12.4 *	0.7	3.7	10.0 *	2.5	3.4	9.2 *
Form of roof	1.9	0.8	0.3	1.6	1.0	2.3	2.2
Platform screen doors	0.4	0.2	0.1	0.3	0.0	0.0	0.0
Lighting method	12.3 *	0.1	1.6	4.2 *	1.0	0.7	3.0 *
Lighting installation position	7.2 *	1.4	5.7 *	5.1 *	1.5	4.1 *	2.9 *

The detailed results of the ANOVA are shown in Figures 18 and 19. In the case of the significant difference graph (Figure 18) by the lighting method, a significant difference was detected in the impression evaluation items of brightness and darkness, and this was judged to have an effect on 'change the lighting'.

The significant differences according to the lighting installation position are shown in Figure 19. Significant differences were detected in many items such as brightness, appropriateness of lighting, darkness, and anxiety. Additionally, the glare item showed a tendency to have some differences.

When the lighting was installed in the center, the appropriateness of lighting was highly evaluated, and when the lighting equipment was installed on the wall, the glare tended to increase. Therefore, the installation location of the lighting is an important factor in evaluating the impression of the space. The significant difference, according to the lighting installation position, is thought to be due to the inability to secure uniformity in the lighting environment at the center of the edge, as the center of the space and the wall are relatively dark. Additionally, if the installation location of the lighting is close to the eyes (e.g., on a wall), the physical quantity measurement is good. However, because glare is prone to occur, it may interfere with the composition of a comfortable lighting environment.

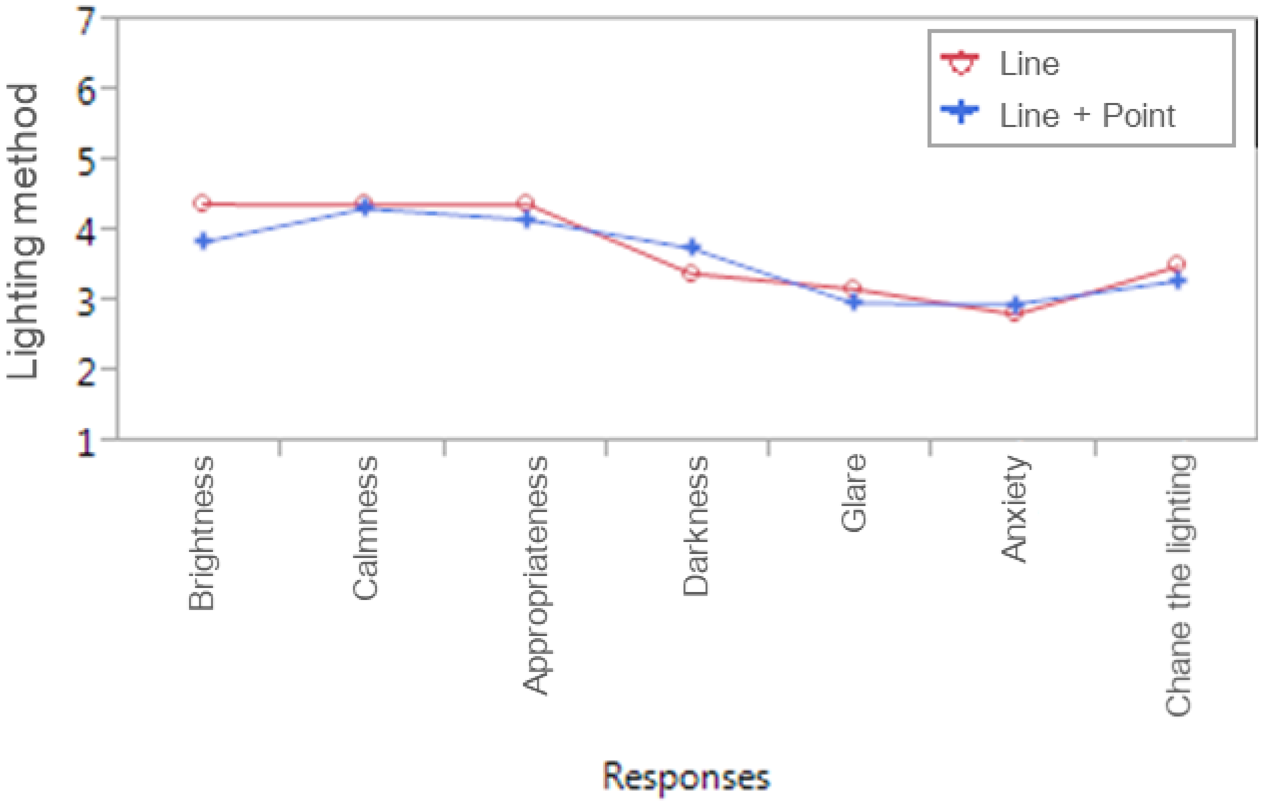

Figure 18. Significant difference depending on the lighting method.

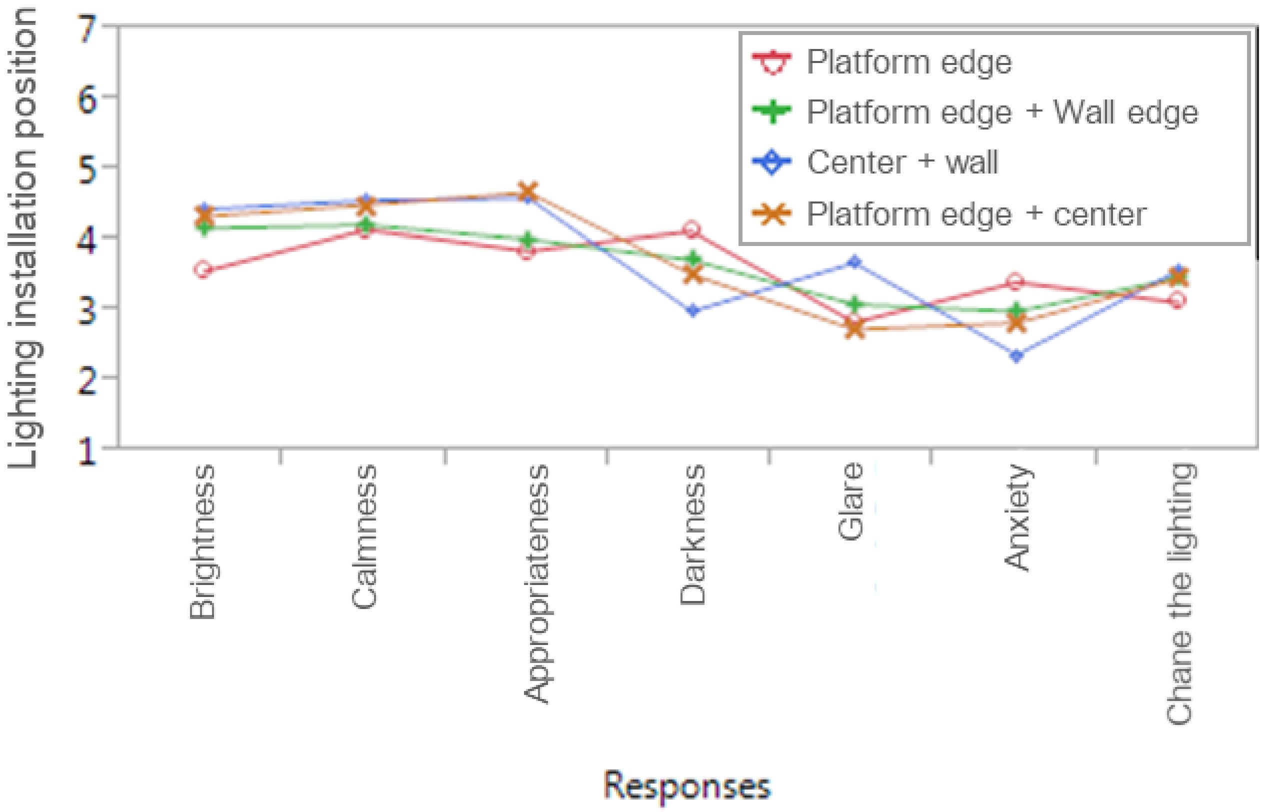

Figure 19. Significant differences depending on the lighting installation position.

5.3. Correlation Analysis

Table 5 shows the results of the correlation analysis to examine the relationship between the physical quantity of the space and the impression and to identify the factors that have a significant influence on the impression of the space. In items other than calmness, there was a tendency to be somewhat correlated with the physical quantity. It can be said that impressions such as brightness and appropriate lighting are usually determined by changes in the physical environment of the space. However, the correlation coefficient was not high, and other factors, such as the type and installation of platform screen doors, were considered to be reflected in the impression evaluation. In particular, even if the environment has a sufficient illuminance level, this is different from the evaluation of brightness in the impression that users feel; a qualitative review is needed to establish an environment that feels bright in low illuminance.

Table 5. Correlation between physical quantities and impression evaluation items (*$p < 0.05$).

	Brightness	**Calmness**	**Appropriateness**	**Darkness**	**Glare**	**Anxiety**	**Change the Lighting**
Floor illuminance	0.49 *	−0.07	0.44 *	−0.46 *	0.32	−0.45 *	0.41 *
Horizontal illuminance	0.50 *	0.04	0.44 *	−0.43 *	0.21	−0.38	0.39
Vertical illuminance	0.42 *	−0.18	0.29	−0.40 *	0.47 *	−0.40 *	0.39

6. Conclusions

In this study, a comprehensive evaluation was conducted on 25 railway stations in Tokyo, where compulsory power-saving operations were implemented due to the earthquake. A comfortable environment cannot be achieved with the existing power saving method, using partial light, which negatively affects the psychological effect. In particular, on outdoor platforms, discomfort increases due to the contrast effect, which may affect safety. You can change the impression of a space comfortably by using the reflective surface effectively and changing the lighting method. In addition, this study can be a guideline for lighting planning that is suitable for the environment of railway stations, where the installation of platform screen doors is increasing.

The results of this study were verified through statistical analysis by measuring physical quantities and evaluating user impressions of 25 stations in Tokyo. The primary results of the comprehensive review are as follows.

It was found that the differences in the measured physical quantities were largely dependent on the station. A lighting method that primarily illuminates the front end rather than the center was common. Regarding the power saving method, it was common to maintain the existing lighting system but operate only a part of the system. Therefore, there were many places where the brightness of the space was uneven, and in some cases, blind spots occurred. Additionally, in the case of platforms exposed to the outdoors, a night sky was visible in the upper part of the field of view, and a bright platform was visible in the lower part of the field of view, resulting in glare due to the brightness contrast. For the side platform, where the track is located in the center, it is easy to secure vertical illuminance because the wall surfaces are located on both sides. In contrast, in the case of the island platform, it is difficult to secure vertical illuminance because there is no wall surface to reflect light, and the lighting system has a disadvantage in that it must depend on the ceiling and the floor for surface reflection.

Based on a summary of the impression evaluation, there was a tendency for the evaluation to be of the physical characteristics of the space. However, depending on the structure and shape of the station, the lighting method, or installation location, there were cases in which there was a difference in impressions even in environments with the same physical quantities. In particular, the results of the relationships between the brightness, corresponding to the perceptual amount, and the appropriateness of lighting, corresponding to the cognitive amount and the physical quantity of the space are shown in

Figure 20. In the case of brightness, as the average values at five points distributed around 50 lx varied widely, ranging from 2.7 to 4.9, it is thought that floor illuminance only is insufficient to explain the brightness felt by humans. Among the five points, the points with the highest brightness evaluations corresponded to Nos. 17 and 25. Both places are side platforms and possess good vertical illuminance because there is a wide surface where light is reflected. In particular, at No. 25, a globe-shaped device, a lighting device prone to glare, was installed, but the overall impression evaluation results were excellent. This suggests that a lighting environment providing a sense of safety can be established, even if the line light source is not concentrated at the edge of the platform. In particular, with the spread of platform screen doors, it is no longer necessary to limit the location of the lighting to the edge of the platform. It is time for a plan to secure both a diverse platform lighting environment and the brightness of a space simultaneously. Furthermore, among the five points, the point with the lowest brightness evaluation is No. 19, and as described above, it is difficult to secure vertical illuminance because the reflective surface is insufficient due to the nature of the island platform. As such, there are factors to be considered in addition to the physical brightness. In particular, consideration of the reflective surface is essential in lighting design, and a plan tailored to these conditions is required.

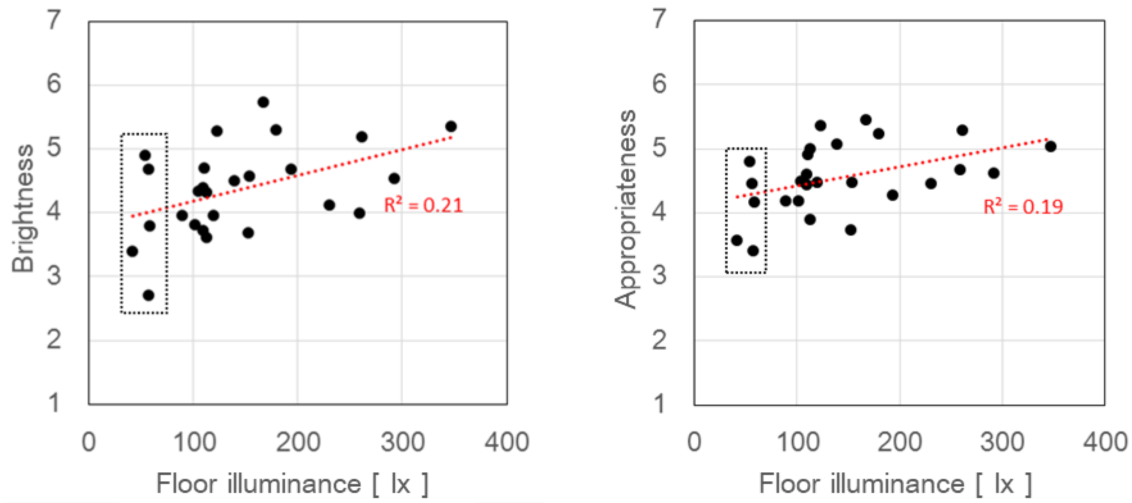

Figure 20. Relationship between floor illuminance and impressions.

A statistical analysis (ANOVA, correlation analysis) revealed that the shape of the platform had a significant effect on the impression evaluation. In particular, the installation location of the lighting and the lighting method appeared to be important factors along with physical brightness. The location of the lighting installation is important for making a space appear brighter than it actually is. If the lighting equipment is placed in the center of the platform, it feels brighter, and lighting equipment installed directly on the wall causes glare. This suggests that qualitative design is as important as quantitative design. This study found that it is important to actively utilize the surfaces inside the platform.

As described in the introduction, there are many studies targeting energy conservation in large-scale public facilities. However, most of them aim to conserve thermal energy through HVAC and other air-conditioning facilities, and few studies deal with actual field data. After the advent of LED lighting, energy-saving through lighting has been solved to some extent. However, clear results on the effects of the environment on users' psychology remain a challenge, and more on-site evaluations are needed. Through this study, the possibility of improving the physical environment by using a qualitative method was suggested. In the future, it is necessary to expand the scope and verify it in various spaces. An evaluation targeting the elderly will also be required to consider the aging population, which is a global problem.

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