Possibility of Substitution of LOD1 Data for LOD2 Data on Photovoltaic Potential Estimation at City Districts Level Using a 3D City Model

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Abstract

We developed a system to estimate the photovoltaic (PV) potential of urban buildings using a 3D city model at level of detail 2 (LOD2), considering an arrangement of solar panels. Although the PV potential estimation of buildings at the level of city districts prefers LOD2 data, many urban city districts with buildings capable of installing solar panels on façades do not have LOD2 data owing to the high production cost of LOD2 data. Therefore, we investigated the possibility of utilising LOD1 data instead of LOD2 data in the PV potential estimation of buildings at the level of city districts. We conducted an experiment in the investigation using 3D city model data from 24 city districts, which are most of the large cities with LOD2 data in Japan. The experiment results suggest that LOD1 would not be a substitute for LOD2 data in the PV potential estimation of building roofs. The cause of the inadaptability is that most roofs in LOD2 buildings have more small polygons than LOD1 building roofs. Roofs of a LOD2 building with many small polygons have fewer solar panels than roofs of a LOD1 building with a large polygon. On the contrary, the experiment results indicate that LOD1 may be a substitute directly for LOD2 in the PV potential estimation of building façades that are expected to be used as a mounting platform for solar panels in urban buildings from now on. The average of the relative differences in the calculated PV potential of building façades between using LOD1 data and using LOD2 data is approximately 10% in the experiment.

1. Introduction

1.1 Background of the study

Recent global climate changes urge us to utilise renewable energy. Photovoltaic (PV) power generation is one of the most promising means to prevent global warming in present-day Japan. We have already been installing many solar panels in places suitable for panel mounting, such as ground surfaces and the rooftops of buildings. However, since Japan is a small and mountainous country, we would be required to plan to utilise the façades of urban buildings as a mounting platform for solar panels in the near future. Additionally, the recent development of light-weight perovskite solar cells encourages the utilisation of the façades of urban buildings. Therefore, we should estimate the PV potential of both the roofs and façades of buildings for urban energy management planning.

Estimating the PV potential of building roofs and façades would require a 3D city model. 3D city model data in some Japanese cities is currently provided by Project PLATEAU, which is a project started by the Ministry of Land, Infrastructure, Transport and Tourism of Japan (MLIT) in 2020. The project aims to construct 3D city models as a platform for urban activities, provide 3D city model data as open access data, and promote the utilisation of 3D city models (MLIT, 2024).

Since we had been unable to find any systems that have the capability to estimate PV potential at the level of city districts using 3D city model data at level of detail 2 (LOD2) in Japan, we started developing a system to estimate the PV potential of building roofs and façades using a 3D city model in the spring of 2022. Our prototype system was finished in the spring of 2023, and tests of the prototype system have been conducted using 3D city models of various cities. After improvements such as debugging, adopting efficient computation algorithms, and adding some functions, the system is now at an operational level (Matsuoka et al., 2024a; Matsuoka et al., 2024b).

1.2 Motivation of the study

The PV potential estimation of buildings at the level of city districts prefers using 3D city model data in LOD2. However, since the production cost of LOD2 data is much higher than that of LOD1 data, many urban city districts with buildings capable of installing solar panels on façades do not have LOD2 data. For instance, the Tokyo metropolitan area (23 special wards of Tokyo) has LOD1 data for the whole area of 627.57 km^2, but LOD2 data covers only 35.02 km^2 as of March 2024.

Therefore, we decided to investigate the possibility of utilising LOD1 data instead of LOD2 data in the PV potential estimation of buildings at the level of city districts. Since the developed system as presented in (Matsuoka et al., 2024a; Matsuoka et al., 2024b) is designed to utilise LOD2 data, we have modified it to be able to utilise LOD1 data. The paper reports on the investigation results using the modified system.

2. PV potential estimation system

The outline of the modified PV potential estimation system utilised in the study is shown in this chapter.

2.1 Major features of our system

The system to estimate PV potential at the level of city districts has two significant features: one is more rapid estimation of the hourly solar irradiance of points densely distributed on a building surface (Matsuoka et al., 2024a). The other is more flexible estimation of PV potential considering an arrangement of solar panels using dense solar irradiance distribution on a building surface (Matsuoka et al., 2024b).

The former enables the flexible PV potential estimation considering an arrangement of solar panels. The latter is expected to be useful in an investigation about differences between LOD1 data and LOD2 data in the PV potential estimation.

2.2 Process flow of our system

The developed system has the following process sequence shown in Figure 1, which is the same as most existing systems:
1) Creating tree-structured data for the succeeding process
2) Calculating solar irradiance distributions
3) Calculating PV potential

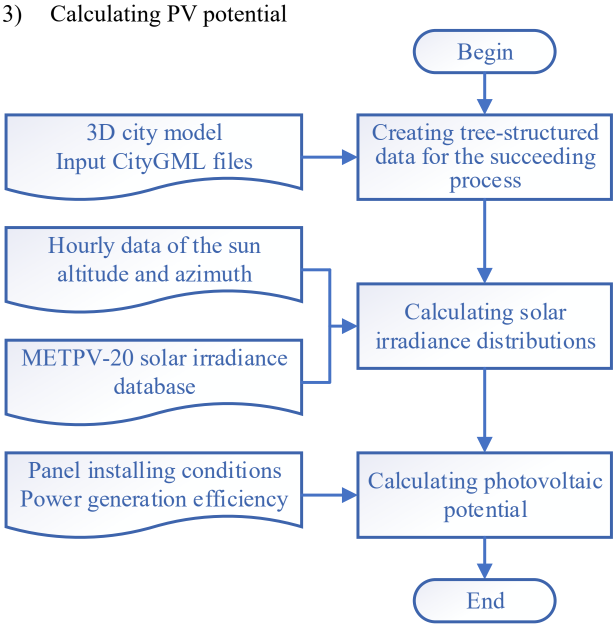


Figure 1. Process flow of our PV potential estimation system

2.3 Creating tree-structured data for the succeeding process

The first step of the processing sequence is the pre-processing step to prepare for the main processing. After loading CityGML files, the system extracts a normal vector, an azimuth, and a tilt angle of each roof and each façade of a building from its geometry. Additionally, the tree structure consisting of Building – Surface – Polygon – Vertex is constructed for the next main processing.

Buildings in CityGML files provided by Project PLATEAU are classified into two types, as Table 1 shows. LOD1 buildings have no LOD2 data, while LOD2 buildings have both LOD1 data and LOD2 data. Table 2 shows three processing types that the modified system enables to conduct.

	LOD1 data	LOD2 data
LOD1 building	No	Yes
LOD2 building	Yes	Yes

Table 1. LOD1 buildings and LOD2 buildings

	LOD1 building	LOD2 building
LOD1 processing	Target	Target / LOD1
LOD2 processing	To be utilised	Target / LOD2
LOD1+2 processing	Target	Target / LOD2

Table 2. Processing types of the modified PV potential estimation system

The LOD1 processing estimates PV potentials of all buildings using LOD1 data. The LOD2 processing estimates PV potentials of only LOD2 buildings using LOD2 data, where LOD1 buildings are utilised for consideration of the shadows of neighbourhood buildings. The LOD1+2 processing estimates PV potentials of all buildings utilising LOD1 data of LOD1 buildings and LOD2 data of LOD2 buildings. The modification of the system enables the LOD1 processing and the LOD1+2 processing.

The study compares estimation results of PV potentials of LOD2 buildings between the LOD1 processing and the LOD2 processing.

2.4 Calculating solar irradiance distributions

The determination of hourly sunshine regions on each roof and each façade is one of the key issues in our developed system. In a highly obstructed urban area, the determination of sunshine regions on each roof and each façade is important for ensuring the accuracy of the solar irradiance calculation. On the other hand, the determination of sunshine regions in an urban area with densely distributed buildings is a highly time-consuming task.

Existing systems (SimStadt, 2024; virtualcitysystems GmbH, 2024; Murshed et al., 2018) adopt the idea that “whether we can see the sun or not” indicates “whether we have sunshine or not.” On the other hand, our system adopts the idea that “whether the sun can see us or not” indicates “whether we have sunshine or not” from the point of view of computation time (Matsuoka et al., 2024a).

Our system utilises hourly projection images viewed from the sun, as Figure 2 shows. Figure 2 shows hourly projection images of Yokohama district from 07:00 through 16:00 on January 1 as clockwise from the top right. Each building surface in Figure 2 is coloured according to its ID.

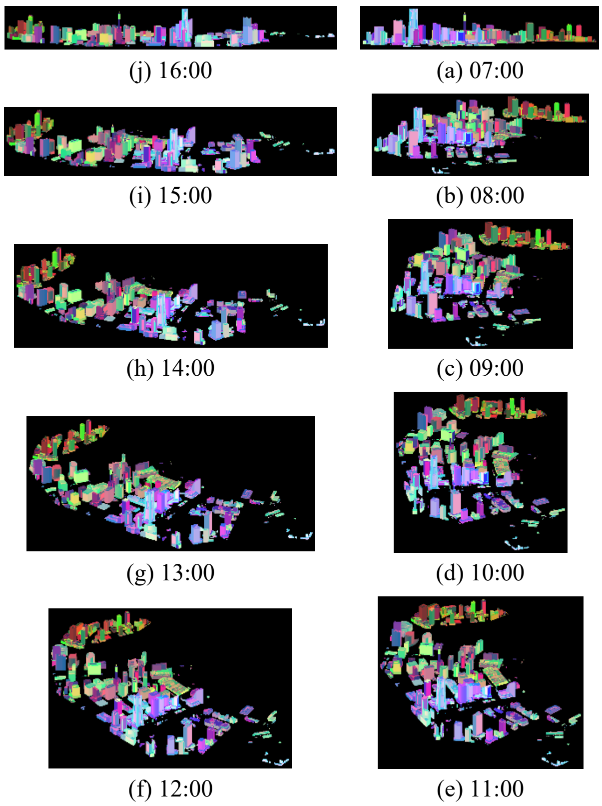


Figure 2. Hourly projection images of January 1 as clockwise from the top right

To know whether the sun can see us or not, our system utilises projection images viewed by the sun. Using computer graphics (CG) techniques such as the depth buffer (Z-buffer) algorithm that does not examine the intersection of the sun ray can provide projection images viewed by the sun much more rapidly. The utilisation of the images from the sun makes the system calculate solar irradiance distribution more densely in a permissible time, and we can investigate various arrangements of solar panels.

Solar irradiance distributions are calculated in the following process sequence:

1) The system establishes an equally spaced grid of points on each roof and each façade where solar irradiance will be calculated.

2) The system creates a projection image viewed by the sun every hour using the sun’s hourly altitude and azimuth provided at the web site of the National Astronomical Observatory of Japan (NAOJ, 2024). Since the image indicates sunshine regions on each roof and each façade, the system easily determines whether a grid point on a surface has sunshine or not by using the image.

3) The system adopts a modified Perez sky model for the calculation of a diffuse component of inclined surface irradiance. Hourly parameters of the modified Perez sky model are determined by using a solar irradiance database provided by the meteorological test data for photovoltaic systems (METPV-20) of the New Energy and Industrial Technology Development Organization (NEDO) of Japan (NEDO, 2024).

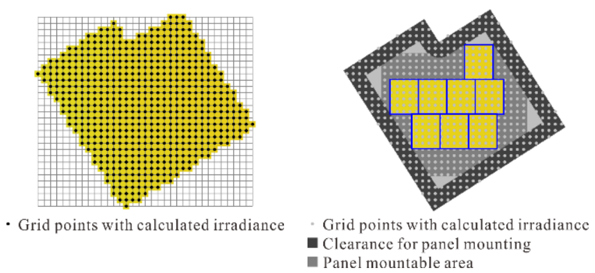
4) The hourly solar irradiance of a grid point on a roof or a façade is calculated based on whether the point has sunshine or not. If a grid point has sunshine, the point has direct irradiance, isotropic background irradiance, circumsolar irradiance, and horizon brightness irradiance. Meanwhile, a grid point without sunshine has isotropic background irradiance and horizon brightness irradiance.

5) The hourly solar irradiance of a grid point is summed up with respect to the given time slot. Usually, monthly or yearly solar irradiance is calculated.

2.5 Calculating PV potential:

The system can handle the arrangement of solar panels flexibly against the arrangement of grid points where solar irradiance is calculated.

Using mathematical morphological operations enables providing the width and height of a solar panel and the clearance around solar panels to determine an arrangement of solar panels. For instance, even if we calculate solar irradiance at intervals of 0.2m by 0.2m on a surface, we can determine an arrangement of solar panels at intervals of 0.02m by 0.02m on a surface. Figure 3 shows an example of determining the arrangement of solar panels according to a panel installation condition.



(a) Grid points with calculated solar irradiance (b) Solar panel arrangement with clearance

Figure 3. Arrangement of solar panels according to a panel installation condition

Our system determines an arrangement of solar panels on each surface according to a set of the following parameters:

i) type of arrangement of solar panels
ii) lower margin of a surface
iii) clearance around solar panels on a surface
iv) width and height of a solar panel
v) minimum solar irradiance of a solar panel
vi) minimum number of solar panels on a surface

The parameters from i) to iv) are panel installation conditions on the geometric aspects, while v) and vi) are those on the economic aspect. Sets of the above parameters can be given for building roofs and building façades, respectively.

Our previous experiment results indicate that the minimum solar irradiance of a solar panel has the largest impact on the PV potential calculation of building façades, and clearance around solar panels on a surface has a larger impact on the PV potential calculation of both building roofs and façades. The others do not have a large impact on the PV potential calculation. (Matsuoka et al., 2024b)

PV potentials are calculated in the following process sequence:

1) At first, the system establishes an equally spaced grid of pixels on each roof and each façade. The interval of pixels is a unit of determination for an arrangement of solar panels mounted on the surface, and that is usually given to be much smaller than that of grid points with calculated solar irradiance.

2) The system selects excluding pixels on each roof and each façade according to a given clearance by using mathematical morphological operations. Providing the width and height of a solar panel arranges solar panels on allowed pixels based on a dedicated algorithm.

3) Since each solar panel has several grid points with calculated solar irradiance, the system calculates the solar irradiance of each solar panel by averaging the solar irradiance of grid points belonging to the solar panel.

4) If the calculated solar irradiance of a solar panel is less than the given minimum solar irradiance, the solar panel will not be installed. Moreover, if the number of solar panels on a roof or façade is less than a given minimum number of solar panels on a surface, no solar panels are installed on the surface.

5) The solar irradiance of a solar panel is converted to electricity output by using the given power generation efficiency.

6) The electricity output of solar panels mounted on the roofs and façades of a building is summed up with respect to the building.

3. LOD2 building and LOD1 building

3.1 LOD2 building and LOD1 building in 3D city model

It is said that LOD1 is the well-known block model comprising prismatic buildings with flat roofs, while a building in LOD2 has differentiated roof structures and thematically differentiated surfaces.

Figure 4 shows a representation of the same real-world building in LOD0 – LOD3.

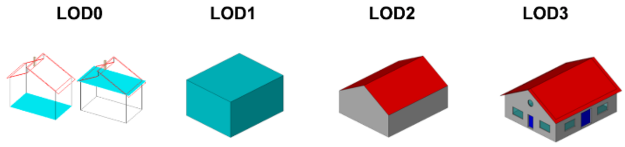


Figure 4. Representation of the same real-world building in the Levels of Detail 0 – 3 (OGC, 2021)

LOD1 data is suitable for analysis at the level of a city or region, while LOD2 data is suitable for analysis at the level of city districts or projects. Accordingly, it is to be desired that the PV potential estimation at city districts utilises LOD2 data if LOD2 data are available.

3.2 LOD2 building and LOD1 building in PV potential estimation

Figure 5 shows an example of panel arrangements corresponding to the minimum yearly solar irradiance of 0 kWh/m^2 and 800 kWh/m^2 calculated by using LOD2 data and LOD1 data. Each panel in Figure 5 is coloured according to its yearly solar irradiance. 800 kWh/m^2 is nearly yearly solar irradiance of vertical planes of the east-facing or the west-facing in Japan.

The panel arrangements shown in Figure 5 were obtained under the panel installation condition that clearance around solar panels on a surface is 0.5 m and a solar panel is 1.6 m wide and 0.9 m high.

Figure 5 indicates that LOD2 buildings have more polygons than LOD1 buildings especially on roofs. In the real world, some roofs consist of inclined planes, and some buildings have penthouses, chimneys, and cooling towers on flat rooftops. These facts make us expect that there are differences in the calculated PV potential of roofs between using LOD2 data and LOD1 data. In contrast, the differences in the calculated PV potential of façades between using LOD2 data and LOD1 data might be smaller.

4. Experiment

4.1 Outline of the experiment

We conducted an experiment to investigate the possibility of utilising LOD1 data instead of LOD2 data in the PV potential estimation of buildings at the level of city districts.

In the experiment, we calculated the PV potential of 24 city districts as shown in Figure 6. These experiment districts are most of the large cities with LOD2 data in Japan. Tokyo metropolitan area (23 special wards of Tokyo) has seven experiment districts, and Kawasaki city and Osaka city have two experiment districts.

Experiment results are evaluated in terms of the differences in the calculated PV potential of each experiment district between using

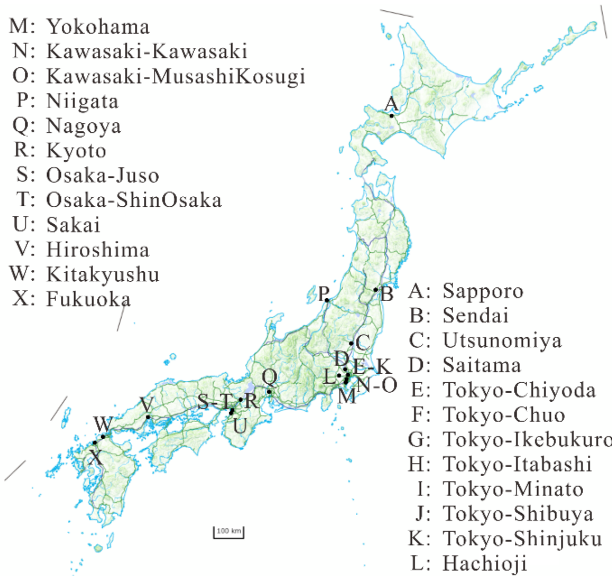


Figure 6. Experiment city districts

LOD2 data and using LOD1 data. Only LOD1 buildings that have LOD2 data are the subject of evaluation. In the evaluation, we set LOD2 up as a standard, and a relative difference is calculated by the following equation:

$$\text{Relative difference} = (\text{LOD1} - \text{LOD2})/\text{LOD2}$$

4.2 Results and Discussion

4.2.1 Direct substitution: Table 3 shows the number of buildings, area, yearly solar irradiance, and PV potential of the minimum yearly solar irradiance of 0 kWh/m^2 and 800 kWh/m^2 per building in each experiment district. From now on, the PV potential of the minimum yearly solar irradiance of 0 kWh/m^2 and 800 kWh/m^2 is abbreviated to PV000 and PV800, respectively.

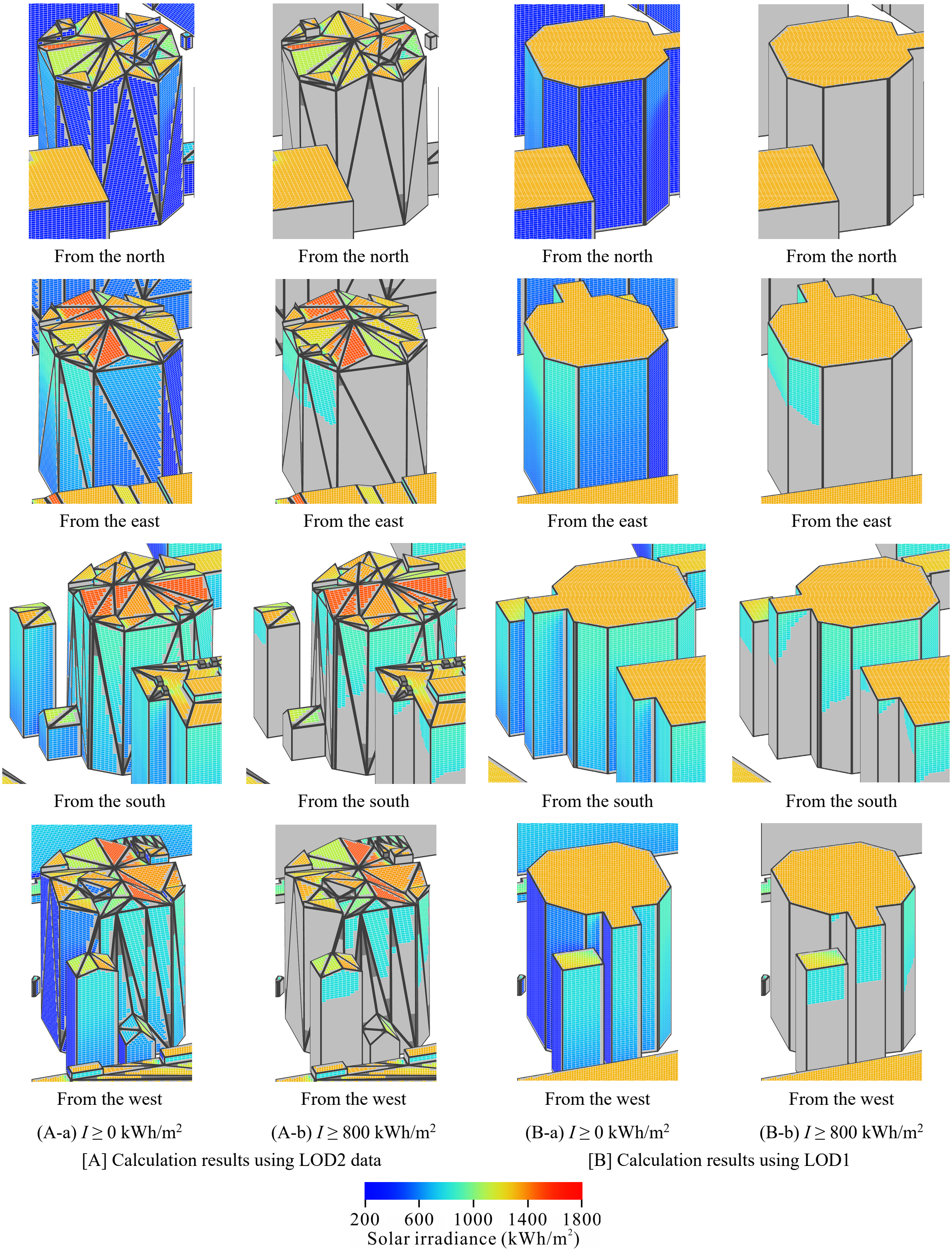
The PV potential shown in Table 3 was calculated on the panel installation condition that clearance around solar panels on a surface is 0.5 m and a solar panel is 1.6 m wide and 0.9 m high, the same as the example shown in Figure 5.

Figure 7 illustrates the area, yearly solar irradiance, and PV000 and PV800 per building in each experiment district. District E: Tokyo-Chiyoda is not plotted in Figure 7 and Figure 8, because all item values in the district are too large compared to the others.

Table 4 shows statistics of relative differences in area, yearly solar irradiance, and PV000 and PV800 between LOD2 buildings and LOD1 buildings in the 24 experiment districts. [N], [F], [O], and [P] in Table 4 mean District N: Kawasaki-Kawasaki, District F: Tokyo-Chuo, District O: Kawasaki-MusashiKosugi, and District P: Niigata, respectively. These four districts are plotted with their district IDs in Figure 7 and Figure 8.

Figure 7 and Table 4 indicate that differences in area and solar irradiance between LOD2 buildings and LOD1 buildings are not so large with respect to both roofs and façades.

As for building roofs, Figure 7 and Table 4 show that the PV potential calculated using LOD1 data is approximately 50% to 60% larger than using LOD2 data on average. Accordingly, we judged that LOD1 data is unable to be a substitute directly for LOD2 data in the PV potential estimation of building roofs.



Colour scale for representing calculated yearly solar irradiance I

Figure 5. Panel arrangements corresponding to the minimum yearly solar irradiance of 0 kWh/m^2 and 800 kWh/m^2
(Each panel in Figure 5 is coloured according to its yearly solar irradiance.)

ID	District	Number of buildings	Roof				Façade			
			Area (m^2)	Irradiance (MWh)	PV000 (MWh)	PV800 (MWh)	Area (m^2)	Irradiance (MWh)	PV000 (MWh)	PV800 (MWh)
A	Sapporo	2,361	393	403.8	24.1	21.6	1,796	1,090.6	93.0	20.9
			381	426.8	45.0	43.6	1,609	947.7	87.2	18.7
B	Sendai	2,345	307	337.7	27.6	25.9	1,540	887.8	85.7	24.2
			302	353.5	35.6	34.6	1,498	848.9	80.7	22.4
C	Utsunomiya	6,721	142	181.9	10.0	9.7	496	326.1	22.7	9.0
			137	176.6	15.7	15.6	491	313.9	25.8	10.0
D	Saitama	3,220	145	181.8	11.5	11.2	596	351.4	28.2	9.3
			141	180.0	16.4	16.2	680	400.5	34.3	11.0
E	Tokyo-Chiyoda	397	1,691	1,747.1	132.8	115.9	10,247	5,941.9	604.3	164.1
			1,640	1,945.9	223.6	217.3	9,612	5,425.2	575.6	149.2
F	Tokyo-Chuo	7,088	230	240.3	11.3	9.7	1,602	869.6	72.8	16.5
			218	257.0	25.1	24.1	1,428	751.7	68.1	15.2
G	Tokyo-Ikebukuro	3,289	204	223.7	11.6	10.3	1,126	639.8	52.2	13.5
			191	232.2	22.3	21.8	1,013	558.9	48.8	12.6
H	Tokyo-Itabashi	4,293	217	275.9	21.6	21.3	579	373.7	31.0	12.8
			220	289.5	28.8	28.8	567	358.0	30.4	12.2
I	Tokyo-Minato	8,914	263	286.0	14.4	12.8	1,466	845.5	68.8	17.8
			244	292.7	28.7	28.0	1,385	772.0	67.7	17.0
J	Tokyo-Shibuya	2,342	291	306.2	16.1	14.1	1,752	978.3	80.8	19.9
			273	325.2	32.2	31.2	1,604	865.6	77.0	18.8
K	Tokyo-Shinjuku	3,489	319	331.4	19.3	16.5	1,850	1,052.4	92.2	21.6
			291	345.2	35.1	34.2	1,709	942.3	86.4	19.9
L	Hachioji	8,870	146	188.4	11.6	11.3	457	294.3	20.8	8.1
			140	187.1	16.6	16.5	436	273.5	20.4	7.8
M	Yokohama	2,123	500	589.0	47.3	44.6	2,244	1,346.1	127.2	44.5
			502	628.9	67.8	66.0	2,397	1,398.6	138.9	47.1
N	Kawasaki-Kawasaki	574	462	559.3	51.0	49.0	1,709	1,018.0	98.3	31.1
			458	583.8	62.8	61.8	1,535	906.1	89.9	28.2
O	Kawasaki-MusashiKosugi	1,401	276	316.9	26.4	25.2	1,129	684.9	63.3	19.6
			271	333.9	34.0	33.6	1,021	609.1	55.6	17.1
P	Niigata	3,045	229	257.0	16.6	15.7	777	439.9	35.8	6.7
			218	249.6	24.4	23.6	964	528.6	46.7	8.1
Q	Nagoya	5,140	281	337.2	26.7	25.3	1,516	910.8	85.3	29.2
			275	348.2	34.9	33.9	1,694	983.7	96.8	30.6
R	Kyoto	57,535	113	139.6	8.8	8.6	412	229.1	17.8	3.0
			107	135.1	11.3	11.2	388	213.9	17.0	3.0
S	Osaka-Juso	2,052	131	170.4	11.3	11.1	517	307.9	24.3	8.0
			127	165.7	14.6	14.4	594	342.7	28.7	8.7
T	Osaka-ShinOsaka	1,339	284	358.9	27.6	26.8	1,448	853.2	75.7	22.7
			276	359.8	35.8	35.2	1,622	930.6	85.6	24.0
U	Sakai	11,016	113	153.0	9.5	9.4	367	229.0	17.8	6.8
			107	147.4	12.0	12.0	380	232.9	18.0	6.7
V	Hiroshima	4,383	233	284.0	22.5	21.7	1,052	627.4	55.4	16.9
			231	299.2	29.3	28.9	1,030	598.0	54.6	16.1
W	Kitakyushu	1,432	274	325.4	25.0	24.2	1,005	567.4	49.6	11.1
			267	323.3	32.6	32.1	1,168	639.3	60.2	12.4
X	Fukuoka	1,913	392	466.5	36.3	35.1	1,985	1,076.2	101.2	17.3
			390	479.7	49.3	48.5	1,937	1,034.8	102.8	17.6

Table 3. Number of buildings, area, yearly solar irradiance, PV000 and PV800 per building of the experiment city districts (upper row: LOD2 building, lower row: LOD1 building)

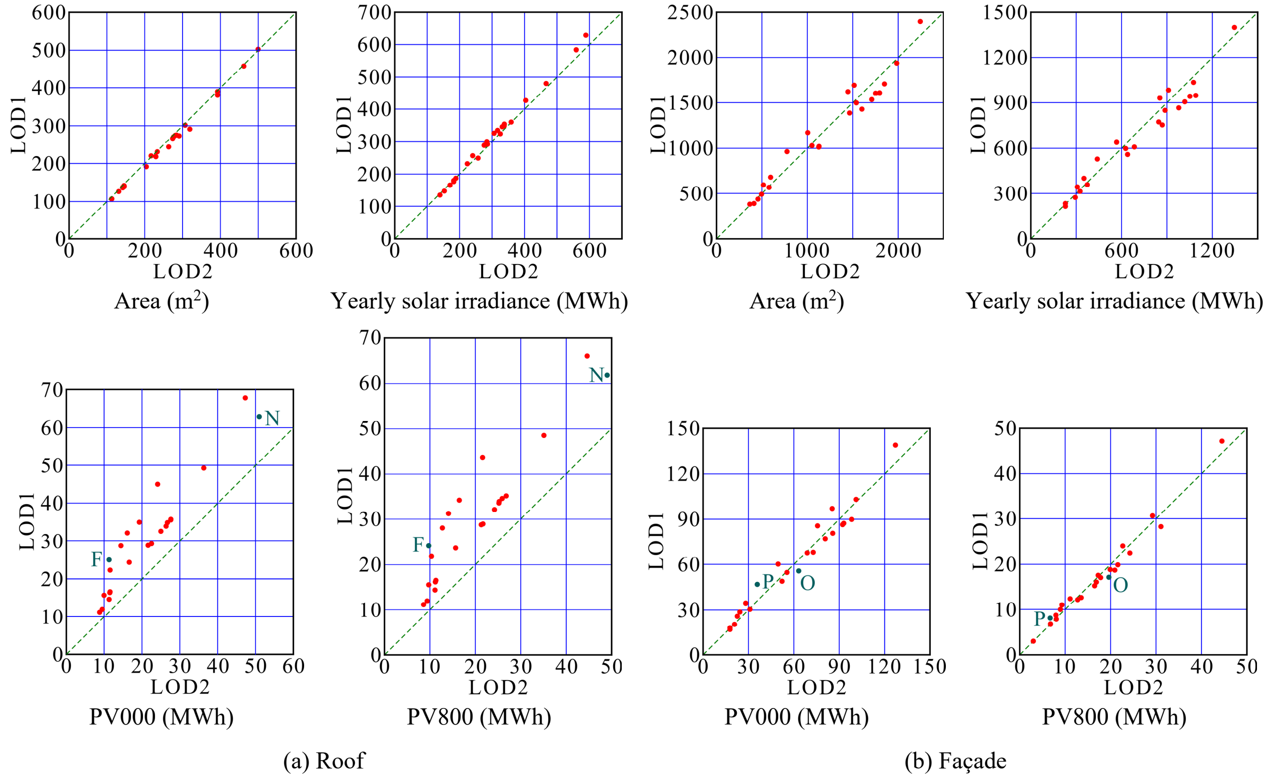


Figure 7. Area, yearly solar irradiance, PV000, and PV800 per building of the experiment city districts

	Roof				Façade			
	Area	Irradiance	PV000	PV800	Area	Irradiance	PV000	PV800
Average	-3.4%	2.5%	51.5%	59.5%	0.2%	-2.3%	2.9%	-0.2%
RMS	4.2%	4.7%	59.0%	70.1%	10.0%	10.0%	11.7%	9.0%
Range	-8.7%	-3.7%	[N] 23.2%	[N] 26.1%	-10.8%	-13.6%	[O] -12.1%	[O] -12.8%
	1.4%	11.4%	[F] 121.6%	[F] 148.0%	24.1%	20.1%	[P] 30.4%	[P] 20.4%

Table 4. Statistics of relative differences in area, yearly solar irradiance, PV000, and PV800 between LOD2 buildings and LOD1 buildings

We guess that the large differences in the calculated PV potential of building roofs shown in Figure 7 and Table 4 are caused by the fact that most LOD2 building roofs have more small polygons than LOD1 building roofs. Due to the clearance around solar panels in each polygon, a roof with many small polygons of a LOD2 building has fewer solar panels than a roof with a large polygon of a LOD1 building as Figure 5 shows.

Although the PV potential estimation of an individual building is not the aim of our study, Table 5 shows the calculated PV potential of the building shown in Figure 5 for reference. Table 5 shows differences in the PV potential of the roofs of the building are larger than differences in the PV potential of the façades of the building as well.

	Roof		Façade	
	PV000	PV800	PV000	PV800
LOD2	194.0	187.7	618.2	137.1
LOD1	350.7	350.7	811.1	162.1

Table 5. PV potential (MWh) of the building shown in Figure 5

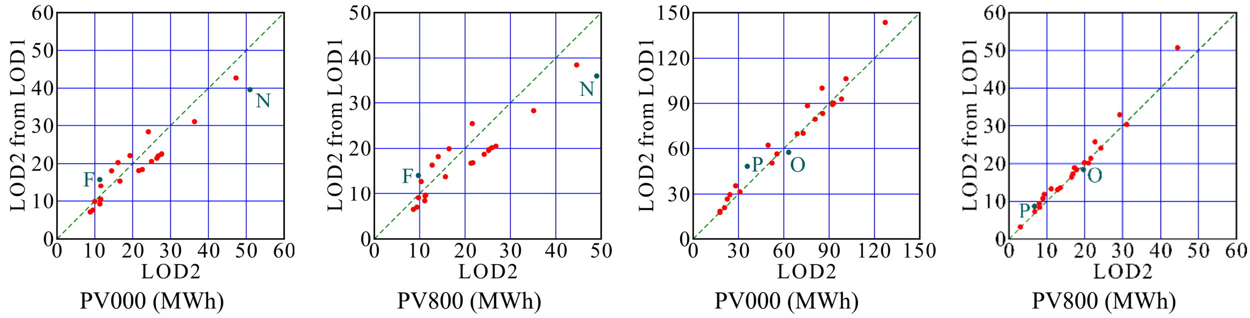
On the contrary, the experiment results shown in Figure 7 and Table 4 indicate that the RMS and the maximum relative differences in the calculated PV potential of building façades between using LOD1 data and using LOD2 data are approximately 10% and 20%, respectively. From the experiment results, we judged that LOD1 data would be a direct substitute for LOD2 data in the PV potential estimation of building façades.

4.2.2 Scaling correction for substitution: Scaling correction LOD2 ← k × LOD1 was examined to substitute LOD1 data for LOD2 data in the PV potential estimation of buildings. Scaling factors k that were obtained by using the PV potential of the 24 experiment districts are shown in Table 6.

	Roof (corrected)		Façade (corrected)	
	PV000	PV800	PV000	PV800
Scaling factor *k*	0.6370	0.5949	0.9598	0.9941
Average	-3.5%	-5.1%	-1.2%	-0.8%
RMS	18.6%	22.5%	10.9%	9.0%
Range	[N] -21.5%	[N] -25.0%	[O] -15.6%	[O] -13.3%
	[F] 41.2%	[F] 47.5%	[P] 25.1%	[P] 19.7%

Table 6. Statistics of relative differences between the PV potential calculated by LOD2 data and those estimated by scaling correction using calculated LOD1 data

Figure 8 illustrates the PV potential per building calculated by LOD2 data versus those estimated by scaling correction using calculated LOD1 data in each experiment district. Table 6 shows statistics of relative differences between the PV potential



(a) Roof (b) Façade

Figure 8. PV potential per building calculated by LOD2 data versus estimated by scaling correction using calculated LOD1 data

calculated by LOD2 data and those estimated by scaling correction using calculated LOD1 data.

Figure 8 and Table 6 indicate that scaling correction may be effective in substituting LOD1 data for LOD2 data in the PV potential estimation of building roofs to some extent. The scaling correction made the RMS of relative differences in the calculated PV potential of building roofs between using LOD1 data and using LOD2 data approximately 20% in the experiment. The relative differences of RMS 20% in PV potential estimation might be permissible for some purposes. We consider that more investigation into substituting LOD1 data for LOD2 data in the PV potential estimation of building roofs is required.

As for building façades, scaling correction would have no effect on the improvement of the substitution of LOD1 data in PV potential estimation.

5. Conclusion

We investigated the possibility of utilising LOD1 data instead of LOD2 data in the PV potential estimation of buildings at the level of city districts. In the investigation, we conducted an experiment using 3D city models of 24 city districts, which are most of the large cities with LOD2 data in Japan.

The experiment results show that the PV potential of building roofs calculated using LOD1 data was approximately 60% to 70% larger than using LOD2 data on average. We judged that LOD1 data are unable to substitute directly for LOD2 data in the PV potential estimation of building roofs.

The experiment results suggest that scaling correction may be effective at substituting LOD1 data for LOD2 data in the PV potential estimation of building roofs to some extent. However, we consider that the correction results would not be fully satisfactory. We will investigate some algorithms for correcting the PV potential calculated by using LOD1 data in order to substitute LOD1 data for LOD2 data in the estimation of the PV potential of building roofs.

On the contrary, differences in the PV potential of façades between LOD2 buildings and LOD1 buildings are not so large that LOD1 data may be a substitute directly for LOD2 data in the estimation of the PV potential of building façades.

The utilisation of façades of urban buildings as a mounting platform for solar panels is expected to come into wide use from now on. Accordingly, we consider that our investigation conclusion that LOD1 data would be a substitute directly for LOD2 data in the PV potential estimation of building façades would be significant until the completion of LOD2 data.

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