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Siting Renewable Energy Facilities Using a Matching Algorithm: A Case Study in Japan

Noriko Irie [1,*], Ryusei Iwamura [1], Kaho Sugiura [1] and Naoko Kawahara [2]

1 Faculty of Collaborative Regional Innovation, Ehime University, Matsuyama 790-8577, Japan
2 Faculty of Business Administration, Kindai University, Higashiosaka 577-8502, Japan
* Correspondence: irie.noriko.jg@ehime-u.ac.jp

Abstract: Finding an optimal match between installation sites and renewable energy (RE) facilities while ensuring that private initiatives meet local socio-environmental needs is a significant albeit complicated task. Different sites may need diverse considerations, such as landscape conservation, while information on the true local preferences and costs of RE facilities is unknown to the planner, causing information asymmetry and inefficiency. This study explores how a matching model can be utilised for empirically planning RE siting using an illustrative case study. It employs the so-called 'college admission problem' of the matching model. The matching algorithm enables the matching of sites and RE specifications, reflecting the true preferences of local people regarding facility siting. The matching result would ensure the most desirable choice for local people, as adopting the 'student-optimal matching' algorithm generates desirable matching patterns for the locals among the stable matching patterns.

Keywords: matching algorithm; facility siting; land; renewable energy

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1. Introduction

Introducing renewable energy (RE) facilities is a global concern. However, finding the best fit for installation sites and RE facilities while ensuring that private initiatives meet local socio-environmental needs can be challenging. Different sites may require diverse considerations, such as disaster prevention, safety management, and landscape conservation. When planning RE specifications, information on the true local preferences and costs of RE facilities are unknown to the planner, and this information asymmetry causes inefficiency.

Mechanisms and allocation algorithms have been widely used in domains such as power and utility markets and supplier problems [1,2], facility location problems [3,4], and other problems [2,5], where stakeholder preferences are private information that has not been disclosed. Wang et al. [1] investigated mechanisms for an energy sharing scheme that incentivizes sharing distributed energy resources by minimizing the total costs of the aggregator and all users of the system. Zhang et al. [2] proposed a construction cost allocation mechanism for utility tunnels that optimizes the weights of the cost allocation indexes to obtain the highest overall satisfaction for the pipeline companies and is more acceptable and less costly than traditional cost allocation methods.

Mechanism theory typically assumes that individuals may dishonestly report their private information to the central planner or mediator to benefit themselves, impairing the system's overall efficiency. If the rational equilibrium is for everyone to be honest and obedient to the central mediator who is implementing a social coordination plan, then the plan is called incentive-compatible [6]. The truthfulness of the information reported by agents, that is, strategy-proofness and stability, is an important feature of mechanism design.

Problems with facility siting could be a significant application of mechanism design theory. In the facility siting problem, landowners and facility installers have different private information regarding their preferences, and as such, they have been studied in the schemes of mechanism design algorithms and closely related theories, such as game theory and principal-agent theory [4,7–9]. The literature on facility siting problems has, to the best of the authors' knowledge, only taken the view of optimizing facility location. Typically, such studies have set stakeholders' preferences based on physical properties, such as distance from the facilities. For example, Güneş et al. [3] examined the facility location problem by maximizing access to primary health care. Serafino and Ventre [4] analysed the problem of locating heterogeneous facilities, by minimizing the maximum connection cost of the agents. These models maximize social desirability or net benefits by minimization of cost based on pre-determined assumptions regarding the costs and benefits of the stakeholders involved and do not ask the stakeholders directly about their preferences. Models have been either deterministic if input is assumed to be certain or probabilistic if input is subject to uncertainty [10]. The strength of these methods is that stakeholders can be anonymous, which avoids the cumbersome procedure of questioning actual local stakeholders. However, the approximation of stakeholder preferences through proxy variables, such as distance to facilities, is limiting.

We propose a completely different approach to solving the facility siting problem using a matching algorithm. Our novel model features consulting companies as well as residents directly on their preferences. This optimizes siting heterogeneous facilities (in our case RE facilities) at heterogeneous sites easily, reducing bias in the cost and benefit estimations, when preferences are honestly declared to the central planner. The method considers all the relevant social costs and benefits including both financial (monetized) and non-monetized ones. As land siting problems involve evaluating many types of non-monetized costs and benefits, the magnitude of which are not correctly revealed in the market, questioning stakeholders about their preferences is a valid procedure. The weakness lies in directly questioning some (not all) local stakeholders about their preferences, because sampling bias arises when the preferences of stakeholders that participate in the discussion are not representative.

This study explores how a matching model can be used for empirically planning RE siting using an illustrative case study. To the best of our knowledge, no study has applied a matching model for facility citing problems thus far.

2. Materials and Methods

2.1. Methodology

The so-called 'college admissions problem' introduced by Gale and Shapley [11] is a simple model of a two-sided many-to-one matching [11,12]. According to Alvin and Sotomayor [12], the college admissions problem addresses the situation where colleges have preferences over students, and students have preferences over colleges; each college can accept at most some number of students, and each student can enrol in at most one college. 'The problem is to analyse what kinds of assignments might arise from such a market, with the primary theoretical tool being the set of stable outcomes (which is closely related to, and a subset of, the core) of the resulting game and, more recently, the dominant strategy and Nash equilibria of the corresponding strategic game' [12].

In the student-optimal matching algorithm [13], students sequentially submit proposals to their preferred colleges. A college can hold at most some proposals at a time. A college with an open slot accepts any application it receives. A college that already holds some applications will reject any application by a student who values less than the current applicants. If a college receives an application from a student that it values more than its current set of applicants, it will accept the application and drop its least preferred applicant. This process continues until all students are matched to colleges.

This two-sided many-to-one matching is suitable for our case, as each site is matched with one RE specification, whereas one RE specification can be installed at multiple sites. Although counterintuitive, we employ the algorithm by substituting the students' side with the sites' perspective and the college side with the RE specifications' perspective in the college admissions problem. The stakeholders on the site side are landowners and residents living near the sites, whereas possible stakeholders on the RE specification side are procuring RE companies. Both sides, the site and RE specification sides, may have competing interests; for example, local people living near a site may prefer higher RE specifications with lower costs, whereas RE procurement companies may prefer maximising profits.

We apply the 'student-optimal matching' algorithm in the college admissions problem, which is the most desirable option for the students' (sites) side among the stable matching patterns but could be undesirable for the colleges' (RE specification) side when the students' side truthfully declares their preferences [11]. This means that the adopted matching algorithm may be most desirable for the stakeholders of the site (landowners and local people), and they are expected to present their true preferences to the central planner. By contrast, the algorithm may not be desirable for stakeholders of RE specifications (procurement companies); however, as demonstrated in the later sections, this treatment could be valid if procurement companies propose all the possible RE specifications that are deemed desirable for them rather than not procuring at all for all sites (Figure 1).

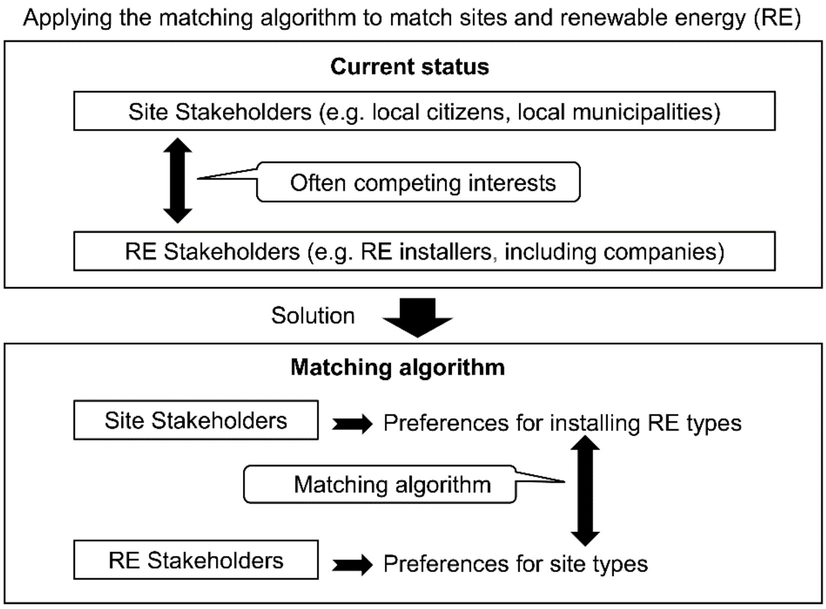

Figure 1. Applying the matching algorithm to match sites and renewable energy (RE).

The virtue of using the matching model is that finding indices and weights is an iterative commutation process between the project planner and relevant stakeholders and that local people's preferences are explicitly considered in RE installation planning, which may often be obscured in practice.

2.2. Model Formulation

2.2.1. Requirements of Laws and Regulations

The objective of the central planner is to match the locations of the REs under the requirements of current laws and regulations. In Japan, for example, the following laws must be considered. First, the Japanese Act on Promoting Quality Assurance in Public Works [14], which was executed in 2005, requires ensuring the quality of public works, defined as the level of satisfaction with performance and specification and includes environmental consideration, aesthetics, and reduced costs. Second, the Japanese Enforcement Regulations of the Natural Park Law [15] stipulates that when new photovoltaic (PV) power facilities are built, reconstructed, or extended on land, their colours and shapes should not be significantly discordant with the surrounding landscape; the land sizes where the facility changes the shape of land should be minimal; and the facility should not have a significant negative effect on wildlife habitats or conservation of landscape, among others. Third, some municipalities have additional landscape control standards based on the Landscape Act [16]. For example, in Tajimi in Gifu Prefecture, PV power facilities must be concealed by growing plants, when necessary, so as not to impair the roadside views in places where many people walk if the PV has certain sizes and installation techniques.

2.2.2. Procedures

First, potential installation sites, which have different characteristics in terms of location and size, are examined by the central planner, and indices and their weights for evaluating RE specifications are provided by local people, including landowners and residents living nearby, with the support of the central planner. Subsequently, procurement companies propose RE specifications, including information on the economy or payment per unit of energy produced in RE facilities and maximum availability numbers at a time for each installable RE specification. Information regarding RE specifications [1] should be relevant to the indices obtained by interviewing the local people. For example, if the indices chosen by local people include disaster prevention and landscape conservation measures, all RE specifications should contain information on how they are incorporated.

Second, with the municipalities' support, local people evaluate (score) each RE specification proposed for each site and notify the planner. Subsequently, procurement companies notify the planner of their site preferences for the different RE specifications they propose to install. For example, procurement companies may prefer larger or flatter sites with the same RE specifications and payments because of economies of scale or lower civil engineering costs. Some procurement companies may propose one RE specification, whereas others may propose more.

Third, the planner matches both sides using a two-sided, many-to-one matching algorithm (Figure 2).

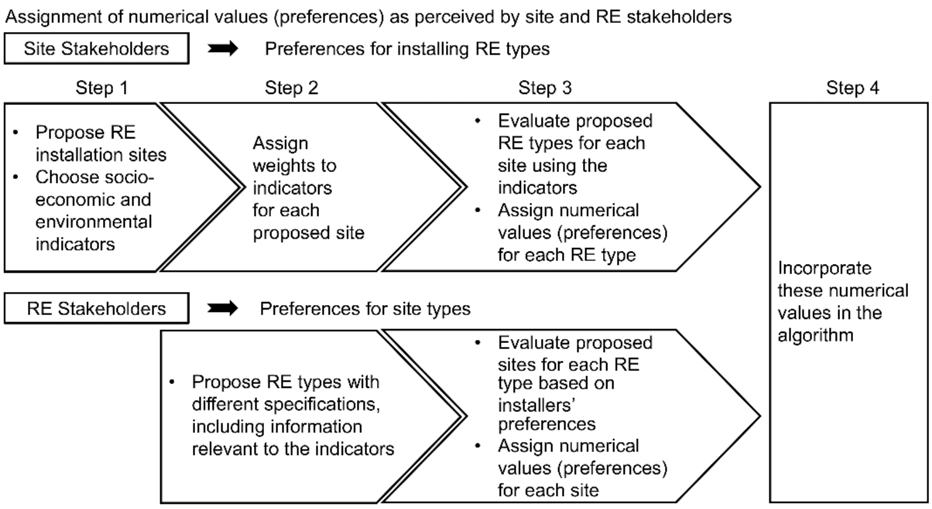

Figure 2. Assignment of numerical values (preferences) as perceived by site and RE stakeholders.

3. Results

3.1. Case of Nakajima Island, Ehime, Japan

The proposed methodology was applied to the case of a photovoltaic (PV) power facility located on Nakajima Island, a small island in Ehime Prefecture, Southwest Japan (Figures 3 and 4) [2]. Ehime is on Shikoku Island, which is among the four largest islands in Japan. Two authors played the role of central planners in supporting the locational municipality of Matsuyama City, the prefectural capital of Ehime. The city was selected as one of 23 'Eco-Model Cities' among 1700 municipalities [17] by the Japanese Cabinet Office in 2013. The city aims to become a society with virtually zero GHG emissions by 2050 [18]. As part of this effort, the city plans to achieve carbon neutrality on Nakajima Island, located in the northern part of the city, by introducing REs. The island, with 21,270,000 m^2 of land, is an agricultural and fisheries area where an ageing and decreasing population has been a serious problem. However, the island has favourable access from the central part of Matsuyama City and has a good landscape with an expectation of having tourist value. However, the island has one transmission line for electricity connected to Shikoku Island, and major disasters may cause blackouts. Therefore, it is expected that the introduction of REs on Nakajima Island would contribute to improving electricity security on the island.

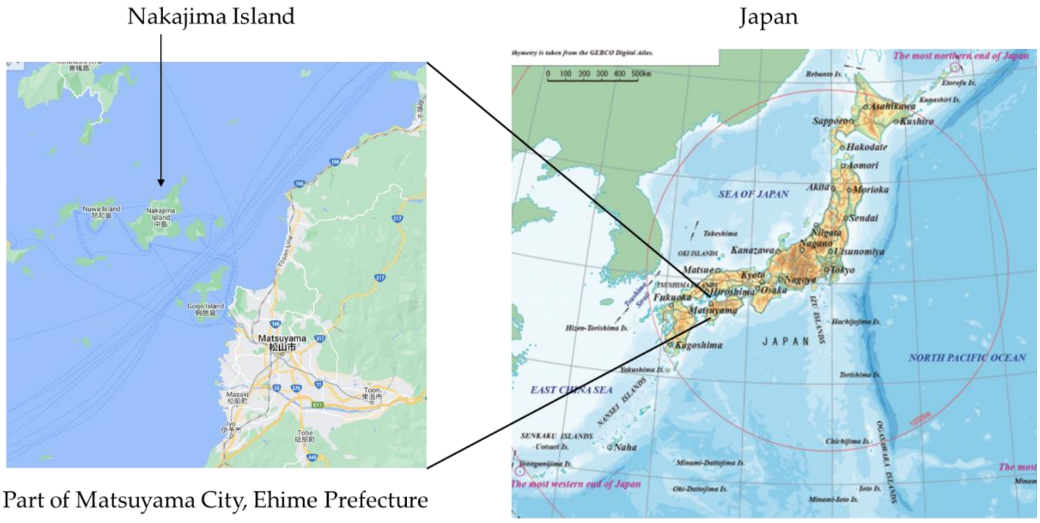

Figure 3. Nakajima Island in Ehime prefecture, Japan. Created using the author's partial processing [19,20].

Figure 4. Nakajima Island in Ehime prefecture, Japan [21].

Matsuyama City aims to achieve carbon neutrality on the island mainly by installing PV facilities. Candidate locations for PV installations on the island include municipality-owned facilities, private abandoned farmland, and the rooftops of residential houses. Although city-owned facilities are the most reliable locations for these installations, their rooftops are not suitable for siting because of the low shock resistance of the buildings. Instead, free land spaces or car ports on city-owned facilities are suitable. Achieving zero emissions for electricity usage in city-owned facilities (approximately 700 MWh/year) would require approximately 8000 m^2 of land for PV installation. The land area is approximately one-fourth of the total floor area of the city-owned facilities (approximately 31,000 m^2), suggesting that zero emissions for city-owned facilities is technically achievable. However, electricity is also used in general households, estimated to be approximately 8700 MWh, and in other commercial facilities, including hospitals on the island. This means that installing PVs on private land is also necessary. The current proposition is to install agrivoltaic power stations on abandoned farmland (2,220,000 m^2 in total), where PV panels are set above farming land, which maybe a favourable option. Installing PVs on private farmland may be easier if the city has installed PVs on abandoned farmland rented from local farmers.

Careful consideration is necessary for PV installation, as some areas on the island are designated special areas according to the aforementioned Japanese Enforcement Regulations of the Natural Park Law [15] (Figure 5). Although there are no designated Class I special areas on the island where PV installation is prohibited, some treetop land is classified as Class II special areas where cutting plants, even on abandoned farmlands, is prohibited and where the colour of constructed objects should be amenable to the landscape. Agrivoltaic power stations [22] may be appropriate for this situation because they can continue fruit farming. To avoid greater construction costs for connecting electric lines from electricity generation sites to their demand sites, it is important to install PVs on treetop land only when private houses are nearby. The city also believes that the installation of land-unamenable PVs should be prevented, even in areas other than the Class II special areas.

3.2. Local People's Preferences Regarding Socio-Environmental Impacts

On 22 and 29 June 2022, five local students and the main author visited Nakajima Island and conducted short interviews on the street with 17 island residents. The purpose of these interviews was to learn about the significant socio-environmental effects that were expected because of PV siting on the island to find indices and weights to evaluate RE specifications. Subsequently, six local students also declared their own preferences, and the preferences of 23 local students were collected.

Next, with the help of Matsuyama City and the lead author, students, as site stakeholders, discussed the indices and their weights for ideal PV specifications for each site. The recommended indices include 'disaster prevention measures', 'salt damage countermeasures', 'economy', 'ease of operation and maintenance', 'environmental conservation measures', and 'gaining an understanding of the residents' (Table 1) [3]. Different relevancies were expected for each site depending on factors such as whether the site was abandoned farming land, rooftops of residences, or public facilities, as well as the height and distance from the coast, all of which led to different site indices and weights. The potential land for the city itself to locate PVs was divided into three main sites and facility types with different indices, including agrivoltaic power in the lowlands (500 m to 1 km from the coast), agrivoltaic power on elevated ground (above 1 km from the coast), and public grounds by the roadside (lowlands 500 m to 1 km from the coast), with possible minor classifications, depending on additional detailed site characteristics. For example, agrivoltaic power facilities located in the highlands placed less emphasis on salt damage countermeasures and more emphasis on environmental conservation measures than those in the lowlands near the shore (Table 2 and Figure 6) [4].

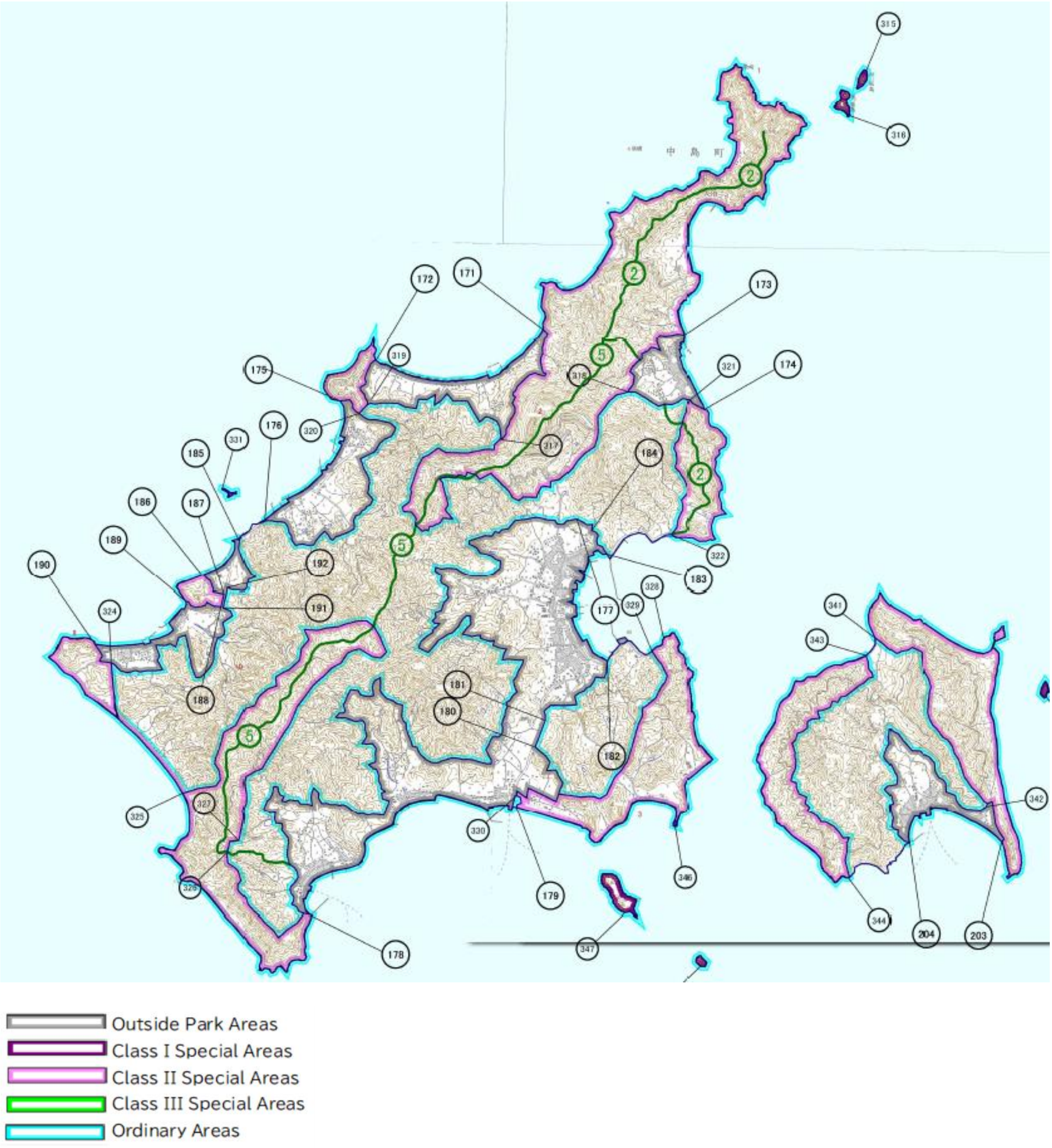

Figure 5. Special areas designated in natural parks [23].

Table 1. Indices.

Disaster prevention measures	• Panels with full consideration of wind pressure resistance and disaster prevention • Measures to avoid water damage during rainy weather
Salt damage countermeasures	• Use of equipment resistant to salt damage • Use of manufacturers that cover salt damage in the manufacturer's warranty
Economy	• Installation costs
Ease of operation and maintenance	• Whether the operation and maintenance are easy • Whether fire and salt damage prevention controls are in place
Environmental conservation measures	• Whether light pollution and noise control measures are in place • Whether the design is in harmony with the natural environment of Nakajima
Gaining an understanding of the residents	• Whether the community understands the installation of solar power by the city

Table 2. Weights of indices for some sites of agrivoltaic power areas.

Indices	Weighting (Five Levels)	
	Coastal and Lowland	**Elevated Ground**
Disaster prevention measures	5	3
Salt damage countermeasures	3	2
Economy	3	3
Ease of operation and maintenance	1	1
Environmental conservation measures	3	5
Gaining an understanding of the residents	1	1

Assumed installer: Matsuyama City.

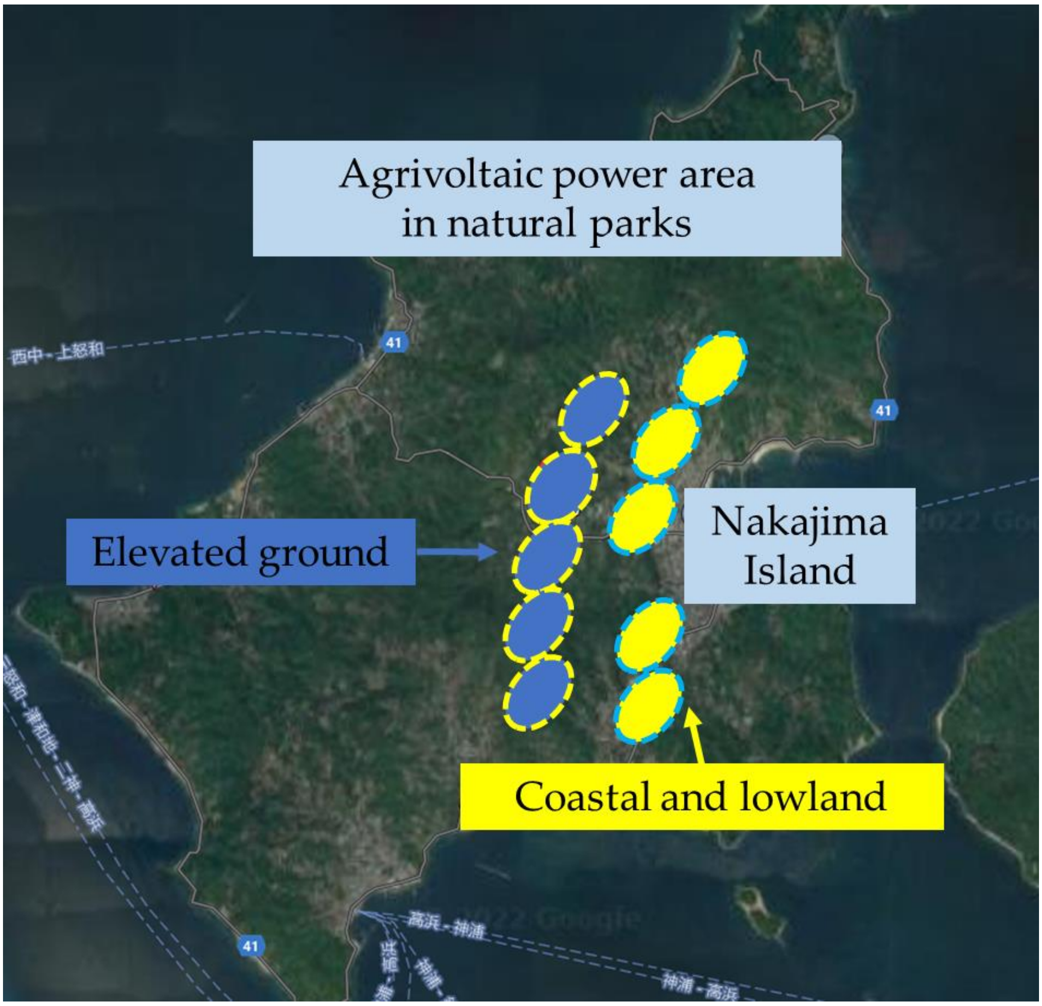

Figure 6. Agrivoltaic power area [coastal and lowland; elevated ground] in natural parks. Diagrams and comments added to the original photograph by the authors.

3.3. Preferences of Local People and Companies

It was proposed that locations closer to the coast would prefer PV specifications with better salt damage countermeasures, such as using equipment resistant to salt damage. To care for birds, landscaping near PV panels would have a higher preference for more environmentally sensitive areas, such as higher locations in the mountains. As companies had not yet provided concrete PV specifications at the time of this study, the actual preferences of the local people and procurement companies for concrete PV specifications were not available. Therefore, stakeholder preferences were roughly assumed and provisional figures were assigned to their preferences for illustrative purposes, as shown in Tables 3 and 4. The simulation assumed that 20 sites (Sites 1–20) were available for PV installation and there were 16 different PV specifications (PV 1–PV 16). PV procurement companies' preferences were assumed that sites that were similarly evaluated as good sites for installation of facilities were not very much different for different PV types (therefore, basic preferences were set the same for the same sites and different for different sites); however, different PV specifications had slightly different preferences for different sites because some PV specifications are more advantageously installed in some particular types of sites (therefore, random values were added to the preferences of different PVs).

Table 3. Assumptions of levels of preferences of stakeholders. Local people's levels of preferences for PV specifications for each site.

	Site1	**Site2**	**Site3**	**Site4**	**Site5**	**Site6**	**Site7**	**Site8**	**Site9**	**Site10**
PV1	74	74	84	84	84	61	61	67	67	67
PV2	72	72	83	83	83	62	62	68	68	68
PV3	73	73	83	83	83	60	60	66	66	66
PV4	73	73	83	83	83	60	60	66	66	66
PV5	70	70	84	84	84	59	59	65	65	65
PV6	71	71	85	85	85	60	60	66	66	66
PV7	73	73	82	82	82	61	61	67	67	67
PV8	68	68	73	73	73	58	58	64	64	64
PV9	61	61	75	75	75	50	50	56	56	56
PV10	53	53	70	70	70	47	47	53	53	53
PV11	59	59	75	75	75	50	50	56	56	56
PV12	59	59	75	75	75	50	50	56	56	56
PV13	63	63	79	79	79	52	52	58	58	58
PV14	64	64	80	80	80	53	53	59	59	59
PV15	65	65	78	78	78	55	55	61	61	61
PV16	61	61	68	68	68	51	51	57	57	57
Average preference	66.2	66.2	78.6	78.6	78.6	55.6	55.6	61.6	61.6	61.6
	Site11	**Site12**	**Site13**	**Site14**	**Site15**	**Site16**	**Site17**	**Site18**	**Site19**	**Site20**
PV1	67	67	67	79	79	93	93	93	93	93
PV2	68	68	68	78	78	90	90	90	90	90
PV3	66	66	66	78	78	90	90	90	90	90
PV4	66	66	66	78	78	90	90	90	90	90
PV5	65	65	65	79	79	91	91	91	91	91
PV6	66	66	66	80	80	94	94	94	94	94
PV7	67	67	67	77	77	89	89	89	89	89
PV8	64	64	64	68	68	80	80	80	80	80
PV9	56	56	56	70	70	84	84	84	84	84
PV10	53	53	53	65	65	77	77	77	77	77
PV11	56	56	56	70	70	82	82	82	82	82
PV12	56	56	56	70	70	82	82	82	82	82
PV13	58	58	58	74	74	86	86	86	86	86
PV14	59	59	59	75	75	89	89	89	89	89
PV15	61	61	61	73	73	85	85	85	85	85
PV16	57	57	57	63	63	75	75	75	75	75
Average preference	61.6	61.6	61.6	73.6	73.6	86.1	86.1	86.1	86.1	86.1

Table 4. Assumptions of levels of preferences of stakeholders. PV procurement companies' levels of preference for sites for each PV specification.

	PV1	PV2	PV3	PV4	PV5	PV6	PV7	PV8
Site1	9	11	27	32	30	21	6	6
Site2	61	73	58	57	70	66	74	73
Site3	49	55	55	44	50	65	55	55
Site4	68	93	76	93	89	94	88	92
Site5	22	15	39	44	22	38	40	28
Site6	38	40	37	42	44	52	42	24
Site7	54	60	54	78	71	77	54	72
Site8	59	68	86	65	66	86	64	67
Site9	26	38	43	27	49	43	30	46
Site10	72	94	77	81	90	77	86	85
Site11	81	83	55	80	56	65	67	60
Site12	73	79	76	57	70	71	80	73
Site13	25	45	27	41	48	36	36	37
Site14	79	95	92	87	79	91	81	67
Site15	41	51	47	51	42	55	55	68
Site16	7	24	28	25	28	3	11	26
Site17	40	29	25	12	28	39	19	20
Site18	29	16	16	16	35	18	34	34
Site19	78	72	72	91	94	84	96	96
Site20	19	19	35	8	28	9	14	9
Average preference	46.5	53.0	51.3	51.6	54.5	54.5	51.6	51.9
	PV9	**PV10**	**PV11**	**PV12**	**PV13**	**PV14**	**PV15**	**PV16**
Site1	2	30	4	2	30	32	12	13
Site2	68	55	67	85	67	71	68	69
Site3	58	61	66	64	63	39	52	53
Site4	75	66	73	73	85	82	71	91
Site5	34	23	23	34	25	20	22	43
Site6	44	41	34	25	25	50	42	31
Site7	67	68	62	72	82	72	62	68
Site8	81	86	56	77	64	62	68	84
Site9	38	33	37	26	33	54	31	27
Site10	89	85	83	85	73	98	91	80
Site11	83	66	69	59	63	70	58	77
Site12	81	80	60	71	75	71	81	80
Site13	39	36	37	37	52	43	51	36
Site14	96	86	71	70	83	87	95	85
Site15	59	46	61	42	50	42	58	56
Site16	30	11	13	31	9	20	30	8
Site17	23	22	14	10	35	22	15	15
Site18	12	28	38	13	26	31	23	13
Site19	80	76	69	91	82	90	79	85
Site20	38	10	9	8	26	14	21	14
Average preference	54.9	50.5	47.3	48.8	52.4	53.5	51.5	51.4

In this simulated case, local people preferred PV 1 most and PV 10 least for Site 1 because the maximum and minimum preference scores for Site 1 were 74 and 53 for PV 1 and PV 10, respectively (Table 3). By contrast, the PV procurement companies preferred Site 11 for PV 1 because the maximum preference score for PV 1 at Site 11 was 81 (Table 4). The average preferences of the local people for PV 1–16 were calculated and are displayed in the last row of Table 3. For example, local people would be most satisfied with the PV installed at Site 16–20 on average. The average preferences of PV procurement companies for Sites 1–20 are shown in the last row of Table 4. This assumption also includes the procurement number for each PV specification at a time, which was assumed to be one to ten availabilities (slots) (Table 5). For example, only one PV1 was procurable, whereas ten PV8s were procurable at a time.

Table 5. Assumption of available procurement numbers for each PV specification.

PV specification	**PV1**	**PV2**	**PV3**	**PV4**	**PV5**	**PV6**	**PV7**	**PV8**
Available number	1	3	2	2	3	4	5	10
PV specification	**PV9**	**PV10**	**PV11**	**PV12**	**PV13**	**PV14**	**PV15**	**PV16**
Available number	5	3	1	1	2	3	1	6

3.4. Matching

The 'galeShapley.collegeAdmissions' function in the 'matchingR' package of the free software R was used, and 20 sites (student side of the algorithm) were matched to 16 PV specifications (college side of the algorithm).

4. Discussion

All 20 sites were matched with certain PV specifications (Table 6). For example, site 1 was matched with PV 3 and Site 2 was matched with PV 1. Some PV specifications, such as PV 2 and 3, were matched with more than one site (Table 7); such PV specifications were installed at multiple sites. By contrast, nine PV specifications have no matched sites, even though some unmatched PV specifications, such as PV 8, have large availability for procurement.

Table 6. Matching results for sites.

	Site1	**Site2**	**Site3**	**Site4**	**Site5**	**Site6**	**Site7**	**Site8**	**Site9**	**Site10**
Matched PV	3	1	6	6	4	7	7	7	7	2
Preference of matched PV	73	74	85	85	83	61	61	67	67	68
	Site11	**Site12**	**Site13**	**Site14**	**Site15**	**Site16**	**Site17**	**Site18**	**Site19**	**Site20**
Matched PV	2	2	7	6	5	5	4	5	6	3
Preference of matched PV	68	68	67	80	79	91	90	91	94	90

The average preferences of the matched PVs for local people (Table 6) were larger than the average preferences for all potential PV specifications (Table 3). However, for some PV specifications, the average preferences of the matched sites for procurement companies (see Table 7) were lower than the average preferences for all potential site types (Table 4).

Previous facility location problems using mechanism design models would find site locations from a few pre-determined factors, such as distance from the site. However, our model obtains a desirable PV type for each site based on consideration of multiple complicated stakeholder preferences, including 'Disaster prevention measures', 'Salt damage countermeasures', 'Economy', 'Ease of operation and maintenance', 'Environmental conservation measures', and 'Gaining an understanding of the residents', which include previously unknown factors. In addition, the proposed methodology is advantageous because the preferences of local people are more clearly reflected with a more transparent procedure in the site-PV specification choice than usual cases where local people's preferences could be obscured in complicated and time-consuming decision-making. Moreover, the matching result would ensure the most desirable choice for local people as adopting the student-optimal matching algorithm in the college admissions problem generates desirable matching patterns for the students' (sites') side among the stable matching patterns. The asymmetry of the level of satisfaction between the site side and the RE facility procurement side is caused by the student-optimal matching algorithm; however, the presence of companies is still not negative because companies only propose installing worthwhile PV specifications in any case.

Table 7. Matching results for PV specification.

	PV1	PV2	PV3	PV4	PV5	PV6	PV7	PV8
Available number	1	3	2	2	3	4	5	10
Matched sites	2	10 11 12	1 20	17 5	16 18 15	3 19 14 4	9 13 6 7 8	N/A
Preferences of matched sites	61	94 83 79	27 35	12 44	28 35 42	65 84 91 94	30 36 42 54 64	N/A
Average preference of matched sites	61.0	85.3	31.0	28.0	35.0	83.5	45.2	N/A
	PV9	**PV10**	**PV11**	**PV12**	**PV13**	**PV14**	**PV15**	**PV16**
Available number	5	3	1	1	2	3	1	6
Matched sites	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Preferences of matched sites	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Average preference of matched sites	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Note: 'N/A' represents no matched sites.

This explicit consideration of local people's needs in iterative communication between stakeholders would improve social acceptance of RE facility siting, as local people discussed desirable designs of the facilities and tended to agree with them. This improvement in social acceptance of RE facilities would, in turn, promote the installation of better REs for society.

5. Conclusions

This study proposes a novel application of the matching model for RE facility siting problems. The proposed method includes finding indices of favourable designs and their weights for local stakeholders so that the scores of multi-objective weighted indices evaluated by local stakeholders are as large as possible, ensuring economy for procurement companies in siting decisions. The matching algorithm instantly enables the matching of sites and RE specifications, and all sites are matched with one RE specification for each, reflecting the true preferences of local people regarding facility siting.

Although the previous facility location problem using the mechanism design models would find site locations from a few pre-determined factors, such as distance from the site, our model obtains a desirable facility choice based on consideration of multiple complicated stakeholder preferences. In addition, the proposed methodology is advantageous because the preferences of local people are more clearly reflected with a more transparent procedure in the facility specification choice than in usual cases where local people's preferences could be obscured in complicated and time-consuming decision-making. Therefore, the matching result ensures the most desirable choice for local people.

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Notes

1 Capacity is certainly a necessary consideration for RE site matching. However, here RE specifications only concern RE designs, such as how they are compatible with the surrounding landscape or gentle to birds and other living animals in the surrounding areas, and do not consider capacity. Different sites may have different RE capacities (because of different strength and duration of sunlight, among others), which can be managed by adjusting the electricity generation capacities for different sites, depending on the electricity demand at those sites. This can be taken into account by changing the area (size) of facilities installed at the site. Some sites may have vacant spaces not used for the RE facilities, whereas other sites may be completely occupied by the RE facilities installed but still not supply enough electricity to meet the demands of the site (in such cases, either another near-by site can also be employed for PV power generation or electricity can be bought from an electricity company). This adjustment is easier in the case of PVs, biomass boilers, small wind-power, and small hydro power, but is difficult in the case of typical biomass power generation (for example) when sites are too small.

2 Although the methodology proposed in this study would be applicable to siting a variety of RE facilities, this study focuses on a PV siting case, as limiting the type of RE, in this case PVs, renders the methodology more understandable and accessible.

3 How the availability of materials required for operating an RE facility affects stakeholders' preferences was not considered. The implication is that when the materials for operating an RE facility are unavailable, the site side preferences are not met.

4 Indices and weights were determined by a focus-group of local students who consulted with the island residents about their ideas through short interviews. The indices were extracted considering what local people perceived as important when installing PV facilities at each site, and the weights were assigned using Likert scales from 1 to 5 for the importance of each index at a particular site, which were all discussed and decided by the students.

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