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Vacancy Dwellings Spatial Distribution—The Determinants and Policy Implications in the City of Sapporo, Japan

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Abstract: As the population is shrinking in many municipalities in Japan, one of its effects is the vacant house crisis. The rise of empty houses profoundly affects the city's society and economy, e.g., property value reduction, increased crime rate, poor sanitation, and housing market stagnation. To better understand the mechanism of the vacant house crisis, the present study proposes to examine the determinants of housing vacancy spatial distribution with the case study of the city of Sapporo. The results highlight the severe vacant cluster in the central city, which would seem to link to the disequilibrium housing market rather than the urban decline. Regarding vacancy determinants, demographic features were the most influential factors, followed by housing and neighborhood characteristics. Specifically, the vacancy correlated strongly with a high density of single households, children, the elderly (in the center), and a high share of offices. The surplus in housing supply and the inelasticity in housing structures also affected the vacancy significantly. On the contrary, a high percentage of private property, household ownership, and the elderly (in suburban) would reduce the vacancy. For other facilities, clinics, parking, public transportation, and educational institutions had a medium effect on the vacancy. Finally, the influence factors varied, across city areas, in magnitude and direction. These outcomes would be helpful for decision-making to alleviate the rise of vacant houses and their effect on the urban area.

Keywords: vacant dwellings; urban housing policy; vacancy determinants; local spatial autocorrelation; shrinking city; Sapporo

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1. Introduction

In recent years, many reports show that vacant dwellings have not only increased rapidly but are also widespread in many countries and continents. In Europe, the number of unoccupied conventional houses reached about 38 million in 2011 [1]; some countries, such as Greece and Croatia, had a vacant house rate of above 30%. Meanwhile, the U.S. appears as a typical case of a vacant dwelling crisis in the Americas. According to Oversight and Reform (P. 14) [2], between 2000 and 2010, the country saw the number of vacant dwellings increased by 44%, equivalent to 4.5 million units, and the number of nonseasonal vacancies is 3 million units, up 51% and even over 70% in 10 states. The same situation also occurs in Asian nations, especially the developed economies. Countries that have a high vacancy rate are Japan (13.6% in 2018) and Taiwan (17.6% in 2000) [3,4]. Remarkably, the severity of the housing vacancy does not appear to be decreasing in such cases listed above. Therefore, understanding the mechanism of this problem remains a major challenge in the scholar community.

In characterizing the housing vacancy, the first factor that needs to be clarified is the identification of the problem and its effects. This means addressing the question of when the vacant crisis will occur and how it affects the socio-economic system. According to basic economic theory, to maintain the stability of the housing market, a certain number of exceeded dwellings is essential. This proportion is called the natural vacancy rate. As a rule of thumb, the threshold vacancy value is 5%, as introduced by Gentili and Hoekstra [5] and Glock and Häussermann [6]. Nevertheless, this rate may change when applying to a country or specific region, depending on the housing market characteristics. For instance, the ratio is 2.5% in the UK (2008), 5% in the U.S., 1–1.5% in Swiss, etc. [7–10]. When the actual vacancy rate is greater than the natural vacancy rate, it might not only reflect an imbalance between supply and demand, but also negatively affect urban sustainability. Many researchers state that vacant houses cause value reduction in the nearby properties, stimulate the increase of total abandoned dwellings [11–13] or, adversely, affect the neighborhood landscape [14]. Moreover, inefficient abandoned houses management can lead to social problems, such as rising crime rate and poor sanitation [15], high collapsed risk, and reducing tax revenue [12,16–18]. As a result, a large excess of vacant houses has become a challenge for not only urban areas but nationwide, particularly in developed countries.

As mentioned earlier, Japan represents the housing vacancy crisis countries. In 2018, the total number of vacant dwellings across the nation reached about 8.5 million units, equivalent to 13.6% of the housing stock [3]. This figure is significantly higher than some other developed countries, such as 2.6% in England, 12.3% in the U.S., or 4.3% in Hong Kong [19–21]. This figure is expected to continue increasing in the future as the country is facing the stage of a super-aged society and depopulation [22,23]. Further, the unoccupied dwelling problem appears not only in small- and medium-sized cities and suburbs of the metropolises but also spreads into the metropolitan centers [24,25]. As reported in a survey from Japan's Ministry of Internal Affairs and Communications [3], in 2018, the average vacant house ratio in the major metropolis of Japan was about 12.44%, with some cities hitting extremely high value, such as Osaka (17.07%), Kitakyushu (15.80%), or Sapporo (11.93%). Thus, the need to control the rise of vacant houses in urban areas becomes urgent.

In response to the stated problem, many studies have been carried out on the housing vacancy crisis in Japan to clarify its causes and effects. The summary from the previous works illustrates that most of the research focuses on three topics: the relation between demographic characteristics and housing markets, housing policies, and vacant dwellings distribution estimation. For instance, numerous researchers argued that population decline, out-migrating, and massive public housing supply are the major causes of vacant dwellings [26–28]. Meanwhile, policies related to the property tax and growth-oriented housing meant to stimulate economic growth are believed to account for the rise in the vacancy rate [28–30]. Regarding the last topic, researchers mainly concentrate on describing or identifying the spatial distribution and estimating the occurrence of vacant dwellings. For example, Nishiyama [31] and Yamashita and Morimoto [32] use the suspension water supply status to estimate the number of abandoned houses in Utsunomiya city. Likewise, Ishikawa et al. [33,34] and Miyazawa [35] apply the Geographic Information System (GIS)-based method to assess the occurrence of vacant dwellings in areas. These works are meaningful when they can help to detect the vacant house and its location. However, the mechanism of how it appears remains obscure.

Notably, the studies mentioned above limit in just describing the vacant house phenomenon and its negative effects, in which the vacancy determinants are investigated in small separate groups. We argue there are still a lot of concealed factors that need to be unveiled, e.g., geographical conditions, the public facilities quality, or the capacity of transportation infrastructures. In addition, though Japan has a high vacant housing ratio, its proportion of homeless people is the lowest compared with the OECD nations [36]. In 2020, the homeless population in Japan was 3992, which was even approximately equal to or less than that of some European cities, such as Brussels (5313) and Paris (3601) [37]. This raises the question that the vacancy problem in Japan may have distinct characteristics. Hence, clarifying these characteristics is necessary.

To fill this gap, we propose to conduct spatial autocorrelation and regression analyses to identify the determinants of vacant dwellings in the city of Sapporo, one of the largest metropolises in Japan. Specifically, the present study aims to address the following research questions: (1) Where—and how high—is the level of vacant houses in the city? (2) Among neighborhood, demographic, and housing features, which have a relationship with the vacant dwelling occurrence? (3) To what extent do these features influence the rise of unoccupied housing in both direction and magnitude? We suppose that the outcomes would not only contribute to the literature but also support the policy-making process in controlling the vacant housing problem. This paper is organized into six sections. In Section 2, we provide a background for vacant dwelling determinants. Following this, we introduce the data manipulating process and analysis method in Section 3. Section 4 presents the results of the analysis, including the factors that have a significant effect on the distribution of vacant dwellings, and assesses their impact level. Finally, Sections 5 and 6 give a conclusion and discussion of the study.

2. Literature Review

Since the second half of the 20th century, vacant dwellings have been mentioned as an aspect of globalization, suburbanization, depopulation, deindustrialization, and economic downturn in numerous studies [16,18,38–42]. Remarkably, there is no consistency of vacant house definition in the past studies [43,44], which causes difficulty in identifying the amount of the entity and executing the policies. To ease this issue, we used the Japanese definition and classification of vacant dwellings in this paper, which divides them into four categories: for rent, for sale, second housing, and other types of vacant dwellings, e.g., abandoned or seasonal use. Thus, the terms vacant, empty, unoccupied, and abandoned houses can be used interchangeably.

2.1. Housing Allocation and Housing Market Equilibrium

A fundamental theory in housing allocation was the bid–rent curve, first introduced by Von Thunen in 1826, which modeled agricultural land use with the market as the center. The model assumes that land is homogeneous and an increase in distance from the market would decrease the land rent and vice versa. In later decades, Alonso [45], Muth [46], and Mills [47] developed the bid–rent curve model for urban housing, commercial, industry, and other firms. Philip McCann [48] summarized the patterns of residential urban land allocation in five models, considering the different income groups. For the first model, the low-income tends to be highly allocated in the central city to reduce the commuting cost, while the high-income prefers the outskirts because it meets their demand for space. Likewise, the second model splits the high-income into two sub-groups: the young and the older. The young high-income would prefer to live in the center because they seem to have lower demand for space but higher demand for work location accessibility. The author suggested that this model is suitable for the financial and international metropolitan areas.

Contrary to the first model, the third model reverses the pattern when the high-income concentrate in the central city and the low-income move to the periphery. This pattern suggests that the opportunity cost of travel time is very high. Cities that illustrate this pattern are small, compact, and highly congested, such as Bangkok and Manila. The fourth and fifth models integrate environmental factors or amenities into the basic model. In these models, the high and medium-income would keep a distance from the central city and the high density of the low-income. This shift may reflect the concerns about pollution from industrial activities and social risks, such as crime. In these cases, the poor would occupy the entire city center. Though the housing allocation theory does not directly explain the housing vacancy problem, it is helpful to understand the urban structure and the housing market operation.

Later, a study by Wheaton provided a macro view of the housing market operation [49]. The study reveals the relationship between the housing price, the vacancy rate, and the change in household characteristics by applying the searching model. The author suggested that the prices determined by production costs, market activities, or turnover can explain the structural or natural vacancy in different places. A small vacancy would also cause a poor match possibility and, thus, cause housing prices to increase significantly by inducing it. When the vacancy increases, the matching process improves and, thus, shortens the sale time. Nevertheless, if the vacancy rate rises beyond a certain threshold, it will cause a longer time of sales and lower prices.

One worthy thing drawn from the study of Wheaton is that a healthy housing market needs equilibrium. That means all population groups can obtain a house that meets their preferences and ability to pay. Nonetheless, such housing markets do not exist because of their elastic and dynamic characteristics of both supply and demand. In the following subsections, we review these influence factors into three groups: demographic, neighborhood, and building, which are popular in previous studies.

2.2. Demographic Features

Many scholars have agreed that the change in demographics is one of the major causes of housing vacancy. From the early 21st century, Cohen [44], Glaeser, and Gyourko [50] indicated that substantial population decline accounted for the vacant housing issue in U.S. cities. Meanwhile, Morckel [51] and Newman et al. [52] reported that the population change affected the increase in vacancies, but it was inconsistent or even insignificant. Similarly, Huuhka [53] claimed that the vacant house rate has a negative relationship with the population but a positive relationship with the elderly population in the Finnish cities. Likewise, the proportion of empty single-family houses was commonly high at about 10% and even ran up to 25–30% in some municipalities in Denmark and Sweden [54,55].

Depopulation reflects the direct consequences of the shrinking urban phenomenon, also known as suburbanization. In urban development theory, shrinkage refers to an inevitable stage that occurs following the urbanization process [56,57]. As a result, the issue led to the decline in housing demand and the imbalance in the housing market. In addition, the lack of effective measures (such as policies and restrictive local budgets) has resulted in a substantial accumulated number of vacant dwellings.

Another facet of urban shrinkage is the aging population and the change in household structure. As life longevity rises, the proportion of elderly increases, and when they pass away, there is no one to take over the entire house, and it will be vacant [58–60]. Further, it is stated that the increase in household quantity reflects the vacant house problem. The rise in the number of households comprises the rise in nuclear families, which detach from traditional households and elderly households. In the short term, it motivates the housing demand, but in the long term, the high possibility of vacant houses will appear [59–62]. Meanwhile, Appel et al. [63] report that the bigger the family size, the lower possibility of vacant houses in the area. Another factor that may reduce the vacancy ratio is the population of young people [64,65].

For Japan, since the end of World War II, the country experienced two baby booms in 1947–1949 and 1971–1974. Then, the fertility rate decreased and has not yet recovered. The change in socioeconomic aspects and the low birth rate have affected the demographic structure significantly. The country now has characteristics of an aging society with an increase in the elderly population and single households. We argue that these factors have a strong relationship with vacant dwellings in Japan. Thus, the present study will involve the demographic features in the analysis, especially the age and household structure.

2.3. Neighborhood Characteristics

Besides demographic factors, neighborhood characteristics (e.g., natural environmental conditions, the high rates of poverty, unemployment, racial and ethnic composition) are also believed to be associated with housing vacancy rates. For example, while Morckel [51] indicates that the high proportion of the African American population in the area would stimulate the rise of vacancy, Newman et al. [52] found the non-white population may have reduced the vacant houses in the U.S. cities recently. Likewise, though the severe unemployment was found to be a vacant houses determinant in U.S. cities, it did not affect the rise of vacancies in Columbus, Ohio [51,52,63]. Nevertheless, we did not include these factors in our analysis because the race and ethnic data were unavailable. Besides, compared to the OECD countries, Japan has a very low unemployment rate (less than 3%) [66].

In the literature, natural environmental conditions also appear as strong determinants of housing vacancy. Kubo and Mashita [60] claimed that houses located in disadvantaged topographical areas are more likely to be vacant due to barriers for residents when they age. Consistent with this statement, areas situated on high slopes, on lowlands, or on highlands appeared to associate with high probabilities of vacancy [25,67,68]. Nevertheless, these findings were in separate studies and, mainly, in Asian countries with a high rate of aging societies, such as Japan and South Korea.

Relating built-up environment attributes, Jeon and Kim [58] stated that the poor conditions of built-up infrastructure may cause abandoned dwellings, especially for the small houses in fragmented lots. In addition, areas with a high housing density and close to the industrial zone are more likely to have a high housing vacancy ratio [67]. In the study of Wuyts et al. [67], the authors did not find any association between the occurrence of a vacant house and the accessibility to public facilities, e.g., bus stops, hospitals, or schools. Meanwhile, another study by Baba and Asami [64] declared that the high number of grocery stores in areas might reduce the vacancy rate.

Remarkably, the relationship between public facility quality and the housing vacancy was not much concern in the previous studies. We hypothesize that, though a public facility may represent a service, it cannot satisfy the residents without the quality and capacity. This issue will be clarified in the present study.

2.4. Housing Characteristics

There is high agreement that there is a relationship between housing ownership status and housing vacancy. As Couch and Cocks [7] reported, privately owned housing made up a major proportion of the housing vacancy in England. Meanwhile, in Japan, though there were more unoccupied rental dwellings than vacant private dwellings, the relative increase in the number of vacant rental dwellings was less than that of vacant private dwellings [59]. Hence, we will verify whether this phenomenon is true in the chosen city.

Besides the ownership status, building type and constructions are also major variables in the vacancy problem. According to Couch and Cocks [7], the number of vacant apartments in England was almost two times that of abandoned houses. Likewise, the proportion of vacant departments and detached houses in Japan accounted for 67.8% and 32.2% of vacancies, respectively [28]. Interestingly, in Finland, Huuhka [53] found that, compared to blocks and flats, the vacant detached houses were higher in volume but were lower in total floor space. Meanwhile, in Japan and South Korea, Baba and Asami [64] and Park [25] claimed that houses with more floors and larger floor areas are less likely to be vacant. According to the authors, buildings with wood, block, or stone structure were more likely to be vacant.

Regarding the property value and condition, Morckel [51] and Park [25] reported that the high price of properties would increase vacancy. However, Baba and Asami [64] claimed that high-priced houses have an inverse relationship to the vacancy ratio. Another reason that causes the high-priced properties to become vacant is that the buy-to-leave super-rich buyers invest in these properties as a safe deposit box rather than for living or renting. This phenomenon happens in global cities such as London and New York [69]. By contrast, houses in poor condition are more likely to be abandoned [51].

Finally, building age is stated to have a positive relationship with the rise of the vacancy ratio. Different researchers declared that older properties are more likely to become vacant than newer ones because of outdated technology or structures, high maintenance and refurbishment cost, or residential preference change [31,67,70]. Furthermore, high-aged buildings are also the major factor that drives the rise of vacancy in declining cities. As Glaeser and Gyourko [50] stated, in the U.S. cities, the housing supply increased higher than housing demolition because of its durability. The depopulation caused by the out-migration, economic downturn, and employment loss also led to the decrease in demand. The joint effect would push the vacancy to rise significantly.

In the present study, besides verifying the above influence features, we propose investigate the other factors that may be associated with the likelihood of vacancy. They included the integrated facilities in the buildings and the mixed-use characteristics. We suppose this supplement would help to understand the housing vacancy problem further.

3. Data and Methodology

3.1. Research Area

The city of Sapporo is the capital of Hokkaido, the largest and coldest prefecture in Japan. Located on the Ishikari plain, Sapporo has typical characteristics of mixed topographical conditions. Most of the city area is flat, with a decreasing elevation from the South-East to the North-West. Besides, the city is one of the earliest aging demographics in Japan. In 2019, the city's elderly ratio was nearly 27% (approximately 533,000 people). This figure is expected to increase to 32% by 2030 [71].

Similar to other Japanese metropolises, Sapporo is facing the vacant house problem across the city. Table 1 exhibits the housing vacancy in some Japanese metropolises from 1973 to 2018 [3]. As the data illustrate, before a decrease in 2018, most cities saw a gradual increase in the vacancy rate from 1973 to 2013. Among nine metropolises, Sapporo had the vacancy rate (11.93%) and the number of vacant houses (125,400 units) of 4th and 6th rank, respectively. Besides representing a high vacancy problem, Sapporo also has inclusive characteristics of topography, weather, and demographics. Thus, the city can be the representative for investigating the vacant house determinants in Japan.

Table 1. Vacant houses ratio in Japan and some metropolises.

Year	Sapporo	Yokohama	Nagoya	Kyoto	Osaka	Kobe	Fukuoka	Kitakyushu	Kawasaki	Japan
1973	4.66	5.42	6.88	5.12	6.79	6.31	5.35	7.98	6.21	5.54
1978	6.82	6.46	10.68	8.36	10.55	9.37	8.96	8.45	7.63	7.56
1983	9.34	7.07	11.41	10.51	12.52	11.80	10.62	10.03	8.40	8.55
1988	11.21	6.78	11.65	11.40	13.91	11.26	11.57	12.38	7.33	9.38
1993	10.48	8.41	10.68	10.88	13.29	10.02	10.03	11.43	9.02	9.76
1998	11.98	9.96	12.64	13.59	15.91	14.40	9.96	12.07	10.85	11.47
2003	12.14	9.68	13.71	13.25	17.52	12.77	10.91	12.84	10.30	12.23
2008	13.76	9.66	13.18	14.12	16.67	13.50	14.65	15.30	10.13	13.14
2013	14.08	10.09	13.16	14.03	17.18	13.05	12.24	14.34	10.42	13.52
2018	11.93	9.71	12.71	12.91	17.07	13.32	10.54	15.80	9.49	13.60
VC *	125,400	178,300	156,900	106,000	286,100	109,200	94,200	79,300	73,800	8,488,600

(*) Total vacant dwellings in 2018.

3.2. Data

In this study, we acquired the data from four sources: (1) the Zenrin data package (a commercial data based on the field survey produced by ZENRIN Co. Ltd., Sapporo, Japan), (2) National land numerical information from the Ministry of Land, Infrastructure, and Transport (MLIT), (3) Sapporo city planning basic survey data, and (4) the Sapporo statistics data. From the Zenrin data set, we extracted the number of vacant houses as the dependent variable. Combining the first and the third data source, we derived the building's characteristics, such as the structure (the fireproof level) and the purpose of the rooms. The demographic status and public facilities and infrastructure indexes were extracted from the city's statistical data and planning survey data, respectively. Note that the particular data are mainly collected in the year 2019.

Based on the literature review and the collected data, we divided the variables into three groups: neighborhood characteristics, housing attributes, and demographic status. The first group contains categories including geographical conditions and public facilities indexes. Relating to the geographical features, we used three indicators, consisting of the average elevation, average slope, and inundated area. In terms of public facilities, we split this part into two sub-categories that represent the quantity and the accessibility to those facilities. The former category stands for the number of each facility in the 500 m radius area from the building, which is equal to about a 7–8-min walk based on the comfortable speed of 1.2–1.4 m/s. Likewise, the latter estimates the shortest distance from the building to those amenities. Public facilities represent education and health care institutions, public transport stations, or leisure places. Besides, for transportation indexes, we calculated the density of road, bus, and rail networks for the specific area that the building situates.

Regarding the building's characteristics, the present study summarized the following information: parking area inside/belonging to the building, fireproof level, and the age of the building. Further, we extracted several indicators, including the number of private residence rooms and offices. Finally, we divided the demographics into five variables. With population features, we calculated the total number of children and elderly in the area. Meanwhile, the household indexes comprise the number of households that own a dwelling and the number of single homes.

As stated at the beginning of this article, the present study aims to investigate the spatial distribution of vacant dwellings. Thus, instead of using an individual building as an observation, we employ the spatial grid. Besides the advantage of covering the entire city's area, the spatial mesh approach also allows control of the data size via the grid scale. In this study, we set up the dimension of a grid equal to 250 m on each side. This figure is small enough to grasp the information about the location's characteristics and to avoid the mixing of an extensive number of buildings. After creating the mesh over the city's boundary, we assigned the information for each grid by following these steps.

For variables that contain numerous entities in a grid, the value is estimated using Equation (1)

$$X_{ij} = \frac{\sum f_{ijk} x_{ijk}}{\sum f_{ijk}} \quad (1)$$

where: X_{ij}—the target variable's value i of grid j. This includes average elevation, slope, flood area, average building age; f_{ijk}—the sub-area k for the variable i in grid j; x_{ijk}—the value of variable i for sub-area k in grid j.

For variables relate to density, the value is estimated using Equation (2).

$$X_{ij} = \sum f_{ijk} x_{ijk} \quad (2)$$

where: X_{ij}—the target variable's value i of grid j. This includes total population, number of children, and number of elderly people; f_{ijk}; x_{ijk} are similar in Equation (1).

The final data set is illustrated in Table 2 presents. Figures 1 and 2 visualize the distribution of dwelling and vacancy houses over the city area. Figure 1 shows that high-density housing is primarily found in the city core and along subway lines. Intuitively, we can recognize that there is a relation between the empty house's ratio and housing density. High-density housing areas are likely to have a high rate of vacant dwellings. A detailed explanation will be introduced in the upcoming part.

Table 2. Summary of data set.

No	Variable	Description	Unit	Type	Min	Median	Mean	Max
Dependent variable								
1	zenVCrooms	Number of vacant dwellings	-	Int	0	41.00	118.73	1457
Explanatory variable								
Neighborhood characteristics								
Geographic conditions								
1	ElevAv	Average elevation	m	Num	2.30	20.01	41.99	375.51
2	SlopeAv	Average slope	%	Num	0.00	0.61	1.93	27.54
3	FloodArea	Flood area	100 m^2	Num	0.00	0.00	38.75	625.06

Table 2. *Cont.*

No	Variable	Description	Unit	Type	Min	Median	Mean	Max
Public facilities in 500 m radius area								
4	R5ParkingA	Car parking area	1000 m^2	Num	0.00	15.55	17.40	73.00
5	R5Hosp	Number of hospitals	-	Int	0	0	0.55	6
6	R5Clinic	Number of clinics	-	Int	0	5	7.18	182
7	R5Welf	Number of welfares	-	Int	0	2	3.02	16
8	R5Cult	Number of cultural facilities	-	Int	0	1	1.43	13
9	R5RailS	Number of railway stations	-	Int	0	0	0.29	13
10	R5BusS	Number of bus stops	-	Int	0	4	4.47	37
11	R5Fuel	Number of fuel stations	-	Int	0	0	0.69	6
12	R5Univ	Number of universities	-	Int	0	0	0.08	11
13	R5HighS	Number of high schools	-	Int	0	0	0.13	3
14	R5Junior	Number of junior schools	-	Int	0	0	0.29	3
15	R5Ele	Number of elementary schools	-	Int	0	1	0.56	3
16	R5Kind	Number of kindergartens	-	Int	0	0	0.40	3
Nearest facilities distance								
17	HubPark	Distance to nearest park	100 m	Num	0.02	1.45	1.64	10.06
18	HubCultura	Distance to nearest cultural facility	100 m	Num	0.11	4.12	4.60	20.29
19	HubHospita	Distance to nearest hospital	100 m	Num	0.07	6.10	7.13	36.11
20	HubClinic	Distance to nearest clinic	100 m	Num	0.01	2.14	2.62	17.04
21	HubWelfare	Distance to nearest welfare facility	100 m	Num	0.00	2.83	3.25	16.69
22	HubRailS	Distance to nearest rail station	100 m	Num	0.25	10.39	16.82	167.32
23	HubBusS	Distance to nearest bus stop	100 m	Num	0.02	1.87	2.06	10.23
24	HubPking	Distance to nearest car parking area	100 m	Num	0.01	0.88	1.22	8.97
25	HubFuelS	Distance to nearest fuel station	100 m	Num	0.14	5.28	6.25	42.93
26	HubUniv	Distance to nearest university	100 m	Num	0.36	22.76	24.75	136.02
27	HubHighs	Distance to nearest high school	100 m	Num	0.24	11.38	12.61	103.82
28	HubJunior	Distance to nearest junior school	100 m	Num	0.10	7.03	7.38	23.53
29	HubEle	Distance to nearest elementary school	100 m	Num	0.14	4.96	5.29	20.72
30	HubKind	Distance to nearest kindergarten	100 m	Num	0.15	6.20	7.24	88.34
Infrastructure index								
31	RoadDen	Road density	km/km^2	Num	0.00	23.49	22.27	46.27
32	BusDen	Bus route density	km/km^2	Num	0.00	4.62	14.16	377.75
33	RailDen	Rail line density	km/km^2	Num	0.00	0.00	0.41	16.68
Building characteristics								
34	ParkingA	Total car parking area in the buildings	100 m^2	Num	0.00	6.62	12.68	1276.94
35	woodA	Total wood structure floor area	1000 m^2	Num	0.00	11.71	11.71	68.10
36	semifireA	Total semi-fire structure floor area	1000 m^2	Num	0.00	1.00	1.54	23.29
37	fireproofA	Total fireproof structure area	1000 m^2	Num	0.00	1.45	12.13	391.03
38	AgeFloorAv	Average floor age area	year	Num	1.06	26.58	25.98	90.00
39	zenPriRoom	Total private apartments	-	Int	0	128	128.17	758
40	zenOffRoom	Total office rooms	-	Int	0	5	10.65	544
Demographic characteristics								
41	Children	Total children	person	Int	0	48	51.75	267
42	Elderly	Total elderly	person	Int	0	123	123.09	680
43	HHowner	Total households that own dwelling	household	Int	0	103	105.10	528
44	HHsingle	Total single households	household	Int	0	41	88.54	1363

3.3. Local Spatial Autocorrelation

To examine the spatial distribution pattern of the vacant houses, we proposed conducting the local spatial autocorrelation analysis, Getis-Ord Gi*, introduced by Ord and Getis [72,73]. Getis-Ord Gi* statistics, or hot spot analysis, is an effective tool that maps similar (high or low) or dissimilar (random) features in an area. The application of Gi* is prevalent in many research fields, such as agriculture, epidemiology, urban studies, and social science [74–77].

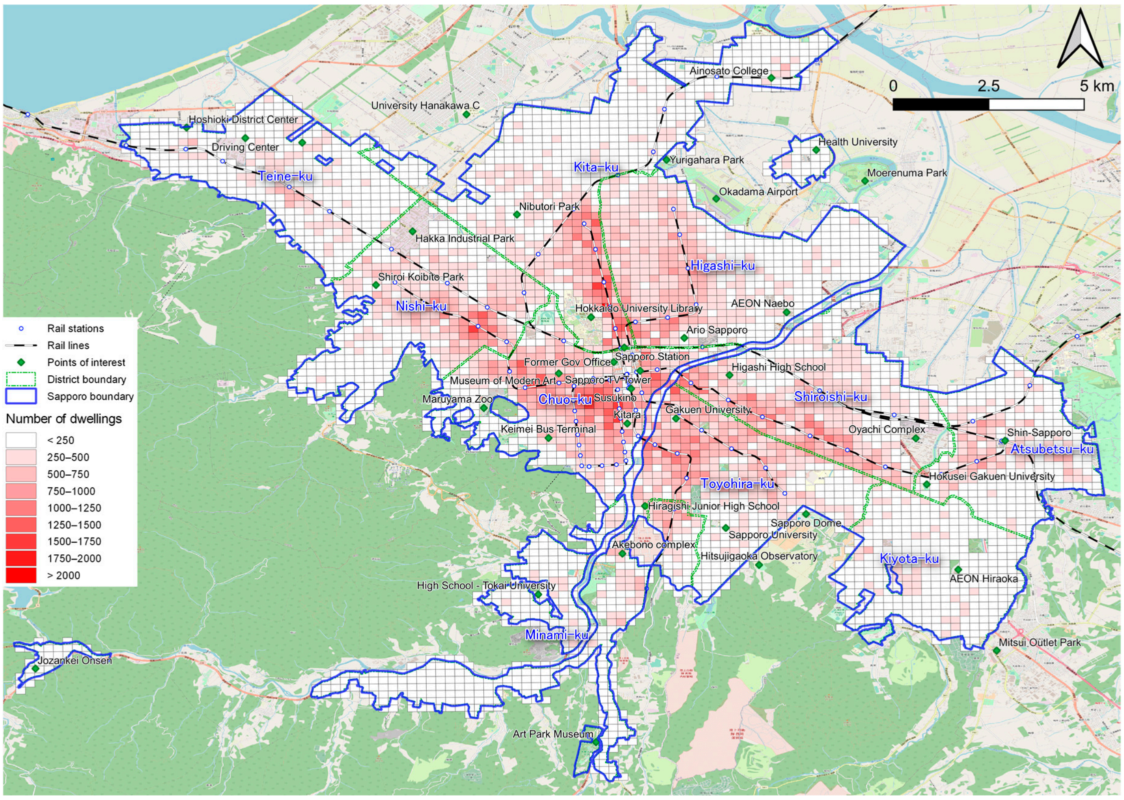

Figure 1. The spatial distribution of dwellings in the city of Sapporo.

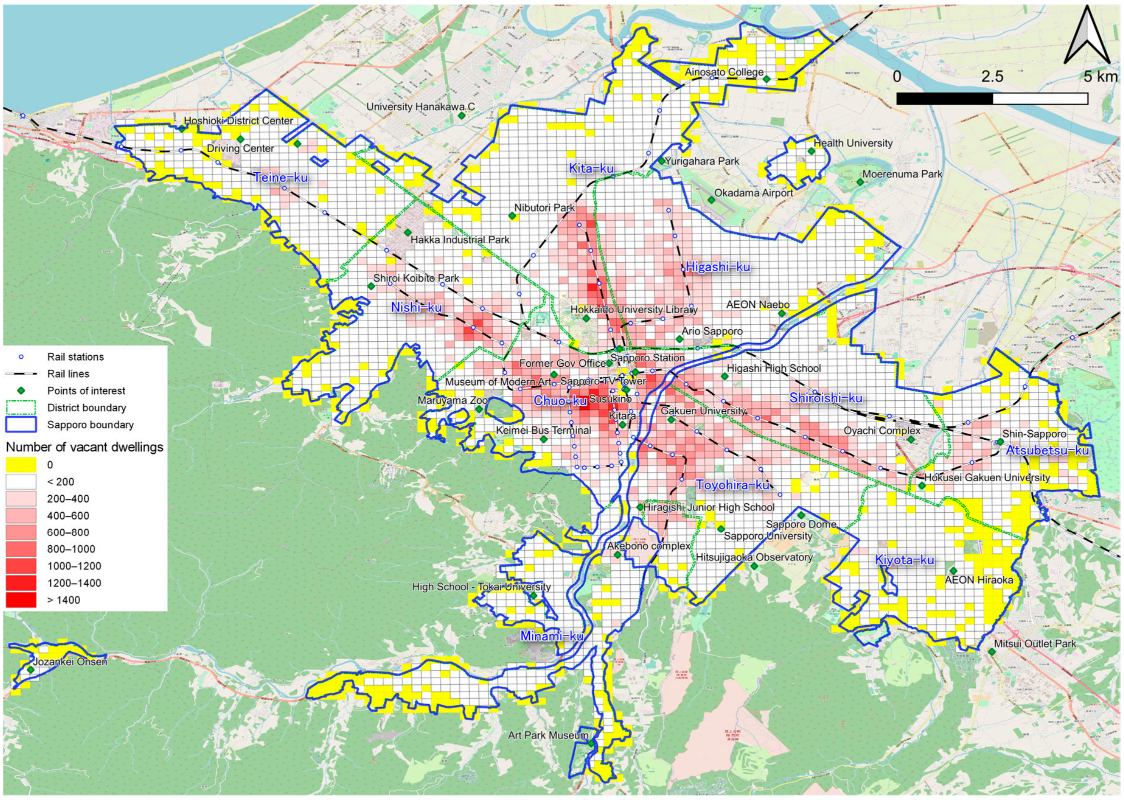

Figure 2. The distribution of vacant dwellings in the city of Sapporo.

In the present study, the G_i^* statistic of grid i is defined by Equation (3).

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij}x_j - \overline{x}\sum_{j=1}^{n} w_{ij}}{S\left\{\frac{n\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2}{n-1}\right\}^{\frac{1}{2}}} \quad (3)$$

where x_j is the number of vacant houses of grid j, w_{ij} is the spatial weight between grid i and j, n is the number of grids, $\overline{x}$ and S are calculated using Equations (4) and (5).

$$\overline{x} = \frac{\sum_{j=1}^{n} x_j}{n} \quad (4)$$

$$S = \left\{\frac{\sum_{j=1}^{n} x_j^2}{n} - (\overline{x})^2\right\}^{\frac{1}{2}} \quad (5)$$

Based on the value of Gi* and the statistical significance level ($p < 0.05$), we defined the three clusters of vacant houses, including Hot-spot (areas with a concentration of high vacancy grids), Cold-spot (areas with a concentration of low vacancy grids), and Random (areas with a mixture of high and low vacancy grids). We then examined these three clusters to identify the vacant house determinants and their variation across the city.

3.4. Partial Least Squares Regression

To address the second and third research questions, we used partial least squares regression (PLSR), one of the popular regression methods used in chemometrics, bioinformatics, ecology, or social sciences [78–80], to clarify the effect of the vacancy determinants. PLSR has characteristics of principal component analysis (PCA), multi-linear regression (MLR), and canonical correlation analysis [81]. Compared with PCA, PLSR uses the least components obtained from independent variables that best explain the dependent variable. Meanwhile, PCA identifies the number of components that best explains the independent variables. Thus, PLSR usually outperforms PCA in predicting the independent variable. A detailed description and interpretation of PLSR can be found in the studies of [78,79].

To find the optimal number of components for the final PLSR model and to control the over-fitting problem, we employed the cross-validation (CV) technique in the training process. First, we used 80% of the data to train the model with a five-fold CV and 100 repetitions. By scoring the root-mean-square error (RMSE), the optimal number of components was the components that had the lowest RMSE value. We then used the remaining 20% of the data set to test the model's performance.

Concerning the characteristics of the determinants, we extracted the variable's importance and coefficient from the final model. Since the model's coefficients alone do not reveal the role of the variable in mapping both independent and dependent variables [82], we used them to illustrate the direction of influence. A positive or negative coefficient implies the variable correlates to the dependent variable positively or negatively, respectively. Likewise, the variable importance index represents the influence level of the independent variable. This index is more stable and reliable than the model's coefficients [82,83].

Several methods produce the variable importance in PLSR, including Variable Importance in Projection (VIP) [82], Selective Ratio (SR) [84], or Significance Multivariate Correlation (sMC) [85]. Of these three methods, SR outperforms SMC in identifying the most significant variable in a PLSR model [86]. Likewise, VIP is more reliable than SR in scoring variables for the raw data [87]. Thus, we applied the VIP method in the current study. Equation (6) expresses the VIP value of the jth variable [83].

$$VIP_j = \sqrt{P\frac{\sum_{a=1}^{A} SS_a w_{aj}^2}{\sum_{a=1}^{A} SS_a}} \quad (6)$$

where P and A are the number of variables and components, respectively. w_{aj}^2 represents the contribution of variable j in component a, and SS_a stands for the sum of squares explained by component a.

Since the average squared of VIP is equal to 1, this value is usually used as a threshold to judge whether the variable is important [88–90]. Nevertheless, a lower value of VIP (0.80) is also considered to be the threshold in several studies [91–93]. In the present study, we used a VIP value of 0.9 to identify the significant variables.

4. Results

4.1. Vacant Dwellings Spatial Distribution

Figure 3 expresses the Gi* local spatial autocorrelation. As illustrated in the graph, the Hot-spot covered the central city. This area comprises Chuo-ku, the Central Business District (CBD), and parts of the districts, Nishi-ku, Kita-ku, Higashi-ku, Shiroishi-ku, and Toyohira-ku. Meanwhile, the Cold-spot was placed mainly in the outskirt districts, including Teine-ku, Kiyota-ku, and Minami-ku. The Random-spot allocated in the areas lying between the Hot and Cold-spot.

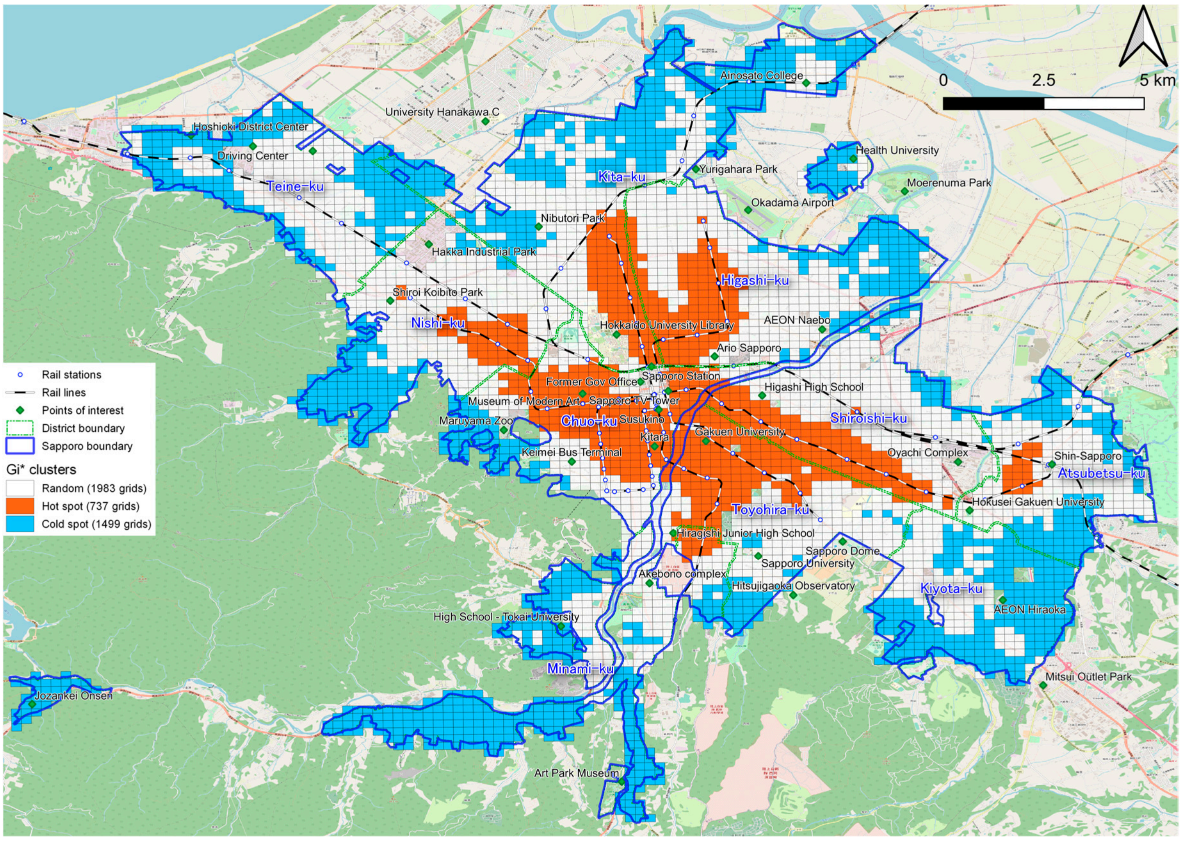

Figure 3. Local spatial autocorrelation Gi* clusters of vacancy in the city of Sapporo (significant level at 95%).

Table 3 summarizes the vacancy of the three clusters extracted from Appendix A. Among the three clusters, the Hot-spot had the lowest proportion of girds (17.5%) but the highest mean of vacant houses per grid (407.7 units). The random cluster took the highest part of the grids and had a medium value of vacancy, accounting for 47.0% and 89.41 units/grid. Meanwhile, the Cold-spot had about one-third of the grids, and its vacancy level was the lowest compared with the other clusters.

Table 3. Summary of vacant houses in the three clusters.

Cluster	Min	Median	Mean	Max	Total Grids	Percentage
Hot-spot	0	379	407.7	1457	737	17.5%
Cold-spot	0	5	15.41	231	1499	35.5%
Random	0	61	89.41	678	1983	47.0%

4.2. PLSR Models

Figure 4 presents the outputs of the training PLSR model process. As expressed in the graph, the RMSE decreased significantly while the number of components increased at a small value. In the Hots-pot and Random-spot, the value of RMSE became stable when the number of components reached about 8 to 9. By contrast, the Cold-spot model saw an increase in RMSE when the number of the component exceeeds 6.

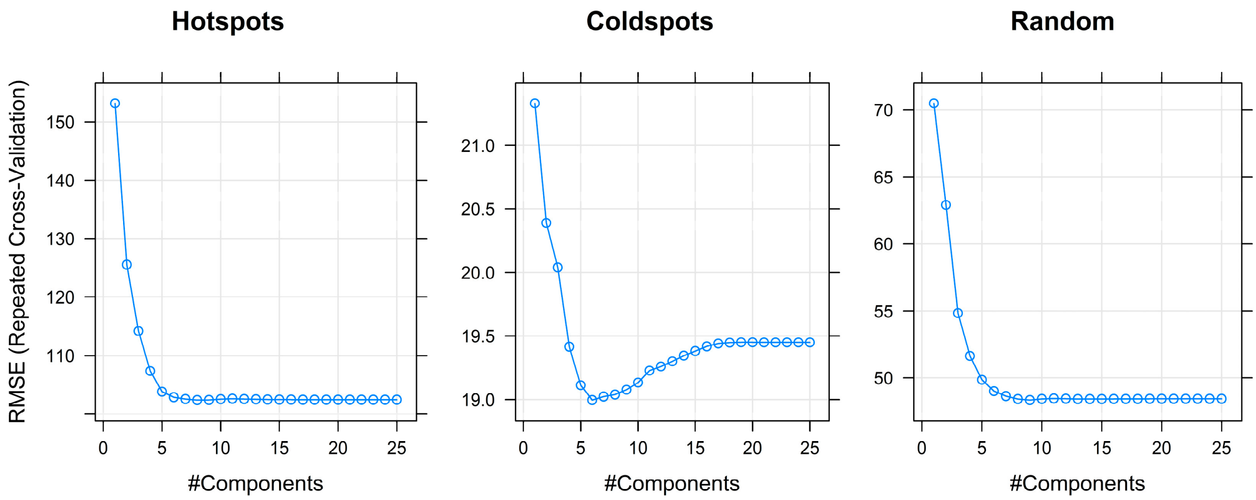

Figure 4. PLSR models training outputs.

Table 4 expresses the detailed outputs extracted from the training process. The optimal number of components of the Hot-spot, Cold-spot, and Random-spot are 8, 6, and 9, respectively. Of the three models, the Hot-spot had the highest performance with a cross-validated R2 value of 0.80, followed by the Random with a cross-validated R2 value of 0.74. The performance of the Cold-spot was lowest when the cross-validated R2 reached just 0.40. Notably, the R2 values on the testing data set of all models approximated their values on the training data. These values indicate that the over-fitting and under-fitting problems did not exist in the models.

4.3. The Determinants of Vacant Dwellings

Table 5 shows the significant variables and their affecting direction on the vacant houses in each model (extracted from Appendix B). As the results indicate, the number of important variables in the Hot-spot, Cold-spot, and Random were 14, 19, and 16, respectively. We found twelve variables that appeared in all models. These features are HHsingle, HHowner, Elderly, Children, zenPriRoom, fireproofA, woodA, ParkingA, HubRailS, HubPking, HubClinics, and R5Clinic. Four variables were significant in two models: semifireA in the Hot-spot and Random, zenOffRoom in the Hot-spot and Cold-spot, R5ParkingA and RoadDen in the Cold-spot and Random. Five variables appeared in only one model, including HubUniv, HubHighs, HubKind, ElevAv in the Cold-spot, and R5BusS in the Random.

Table 4. PLSR models training results.

# Components	1	2	3	4	5	6	7	8	9
Hot-spot									
VC. Exp	56.32	72.61	78.30	81.15	82.47	82.71	82.87	82.96	
RMSE (CV)	153.14	125.56	114.18	107.35	103.80	102.85	102.56	102.40	
R2 (CV)	0.54	0.69	0.74	0.78	0.79	0.79	0.80	0.80	
RMSE (Test)								89.15	
R2 (Test)								0.89	
Cold-spot									
VC. Exp	22.03	33.52	38.99	42.89	44.09	45.06			
RMSE (CV)	21.33	20.39	20.04	19.42	19.11	19.00			
R2 (CV)	0.22	0.31	0.35	0.38	0.39	0.40			
RMSE (Test)						16.42			
R2 (Test)						0.46			
Random									
VC. Exp	47.34	64.61	72.54	75.43	76.81	77.29	77.54	77.74	77.78
RMSE (CV)	70.48	62.90	54.84	51.64	49.85	49.00	48.63	48.42	48.35
R2 (CV)	0.45	0.59	0.68	0.71	0.73	0.74	0.74	0.74	0.74
RMSE (Test)									45.24
R2 (Test)									0.72

Table 5. Top influence variables.

No	Variable	Hot-Spot			Cold-Spot			Random		
		VIP	Sign	Rank	VIP	Sign	Rank	VIP	Sign	Rank
1	HHsingle	3.61	+	1	2.62	+	1	3.17	+	1
2	semifireA	1.87	+	2				1.01	+	13
3	Elderly	1.61	+	3	1.25	–	8	1.53	–	4
4	fireproofA	1.44	+	4	1.72	+	2	1.64	+	3
5	zenPriRoom	1.44	–	5	1.24	–	9	1.47	–	6
6	HHowner	1.29	–	6	1.61	–	3	1.49	–	5
7	Children	1.27	+	7	1.02	+	14	1.71	+	2
8	zenOffRoom	1.24	+	8	1.11	+	11			
9	HubRailS	1.18	–	9	1.01	–	15	1.02	–	12
10	woodA	1.16	+	10	1.31	+	7	1.07	+	9
11	R5Clinic	1.14	–	11	1.06	+	13	0.93	–	15
12	HubPking	1.11	–	12	1.24	–	10	1.03	–	11
13	HubClinics	1.06	+	13	1.09	–	12	1.05	+	10
14	ParkingA	1.00	–	14	1.40	+	5	1.00	–	14
15	R5ParkingA				1.44	+	4	1.17	+	8
16	RoadDen				1.38	–	6	1.22	–	7
17	HubHighs				0.98	–	16			
18	HubKind				0.97	–	17			
19	ElevAv				0.92	+	18			
20	HubUniv				0.90	–	19			
21	R5BusS							0.92	–	16

Among independent variables, demographical features were the most influential factors. Specifically, HHsingle stood at the first rank with a positive sign. Its VIP values ranged from 2.62 (in the Cold-spot) to 3.61 (in the Hot-spot). The Elderly had a positive effect in the Hot-spot but a negative effect in the Cold-spot and Random-spot. Additionally, the impact level of the Elderly was higher in the Hot-spot than in the Random and Cold-spot. The Children had a positive influence with a 2nd, 7th, and 14th rank in the Random, Hot, and Cold-spot, respectively. Meanwhile, HHowner's impact was negative. Its influence level decreased from the Cold-spot (3rd rank) to the Random and Hot-spot (5th and 6th grade, respectively).

Most housing characteristics significantly correlated with the vacancy except for AgeFloorAv. All housing structure types positively affected the vacancy. Of these three types, the influence of fireproofA was stronger than that of semifireA and woodA. The VIP rank of fireproofA was 2nd, 3rd, and 4th in the Cold-spot, Random, and Hot-spot, respectively. Likewise, the influence level of semifireA was higher in the Hot-spot (2nd rank) than in the Random (13th rank). Meanwhile, the woodA's effect decreased from 7th in the Cold-spot to 9th in the Random and 10th in the Hot-spot.

For the other housing characteristics, zenPriRoom and zenOffRoom were significant factors with an inverse effect. While the influence of zenPriRoom was negative, the effect of zenOffRoom was positive. The zenPriRoom's rank reduced from 5th in the Hot-spot to 6th and 9th in the Random and Cold-spot, respectively. Meanwhile, the influence level of zenOffRoom was highest in the Hot-spot and was lower in the Cold-spot. Finally, we found ParkingA had a negative effect in the Hot-spot and Random-spot but a positive effect in the Cold-spot.

As the results showed, only clinics significantly affect the vacancy. We found that R5Clinic's effect was positive in the Cold-spot but negative in the other models. Its rank decreased from the Hot-spot (at 11th grade) to the Cold-spot (at 13th grade) and Random-spot (at 15th grade). Meanwhile, HubClinic had a negative effect in the Cold-spot but a positive impact in the other two clusters. The influence level of HubClinic increased from the Hot-spot to Cold-spot and Random.

Regarding transportation features, R5ParkingA was positive in the Cold-spot and Random-spot with an influence level of 4th and 8th, respectively. In contrast, HubPking affected the vacancy negatively in all clusters. Its influence ranking varied from 10th grade in the Cold-spot to 12th grade in the Hot-spot.

For rail stations, the HubRailS was negative in all clusters. The effect level of HubRailS was highest in the Hot-spot (rank 9th and was lower in the Random and Cold-spot, with a ranking of 12th and 15th, respectively. For bus services, R5BusS had a significant effect in the Random cluster. Likewise, the effect of RoadDen was negative in the Cold-spot and Random with an influence level of 6th and 7th, respectively.

Regarding educational institutions, the results expressed the negative relationship between the vacant houses and HubHighs, HubKind, and HubUniv in the Cold-spot. The influence level of these variables was on the 16th, 17th, and 19th, respectively.

Finally, ElevAv had a significantly positive influence in the Cold-spot, with a VIP value of 0.92.

5. Discussion

5.1. Spatial Distribution of the Vacant Houses

The high concentric vacancy in the city center of Sapporo corresponds to the cases of Changshu, China [94] and Sao Paulo, Brazil [95]. In both these cases, the decline in the central cities and out-migration accounted for the rise in the number of vacancies. Specifically, the new towns and residential areas attracted people to move in by providing good facilities and services, as in the city of Changshu. Likewise, for Sao Paulo, the problem came from the fast population growth in the past, which left a large volume of low-quality housing, slums, flophouses, and homeless people in the center. As a result, the wealthy households moved to the new districts, and the lower income took over the historical center. This shifting would likely be consistent with the theories presented in previous studies [48,50]. Nonetheless, the situation for Sapporo is dissimilar. The central districts, such as Chuo-ku, Higashi-ku, and Kita-ku, have increased in population, while the suburban population has declined in recent years (refer to Appendix C). Thus, we suggest the high vacancy in the center would be more likely to be associated with the disequilibrium housing market rather than the population change.

Regarding housing allocation patterns, the city of Sapporo is likely to match the second model introduced by McCann. Specifically, the number of low-income households in Chuo-ku and Kita-ku ranged from 52.45 to 57.40 thousand. Meanwhile, these figures for the suburbs were about 15.79, 22.59, and 21.70 thousand for Kyota-ku, Atsubetsu-ku, and Teine-ku, respectively. In addition, the number of high-income single and couple households in the CBD was about two to four times higher compared to other districts.

However, compared to the suburbs, the rental and land prices in the CBD were about 10% to 30% and four times higher, respectively (see Appendix C). Besides, the travel cost, converted to primary earner commuting time, was comparable between districts. As expressed in Appendix C, people seem to spend more commuting time in Chuo-ku than in some areas, such as Atsubetus-ku and Minami-ku.

As expressed in Section 3, Sapporo has various sub-centers at the subway and rail stations, representing a transit-oriented development (TOD) approach. Hence, the city would likely be a mix of monocentric and polycentric patterns, which differs from the bid–rent curve theory. This development model substantially shortens the travel time from the suburbs to the downtown. Besides, each sub-center can provide reasonable amenities for its surroundings. Seemingly, the price discrepancy and equal travel costs would restrain the low-income from moving into the city center. This effect may influence the housing market when a segment of houses for these expected customers is stagnant.

5.2. Demographic Factors

As we expected, demographic features were the major vacant houses determinant, in which the number of single households was the strongest influence factor in all clusters.

Single households, in theory, represent the elasticity of housing demand. Specifically, single households are highly mobile because of their changes in housing preferences caused by marriage status, family members, or working locations. Hence, an area that has a high density of tenants would seem to have a high proportion of rental housing, which could be more likely to be vacant when the renters move. The study's results are consistent with earlier research [96–98]. Moreover, this reflects the progress of Japanese societal change.

As Kubo [99] and Kubo and Yui [100] reported that, since the significant rise in single-house demand for the young or marginalized people emerged, numerous condominium and mini-flats have been constructed in the late 1990s. These compact houses became less attractive and surplus for various reasons, e.g., overstock, lack of facilities, and estate market prices rising. Notably, at the beginning of this stage, about 70% of the owners were single women in their 30s and 40s. Three decades later, this group of people may have moved out after marriage, resulting in a high likelihood of vacancies.

Regarding the elderly population, the result is partly consistent with the findings of Nam et al. and Park et al. [65,101] when both studies found a positive relationship between the elderly population and the vacancy on the province and national scale in South Korea. Nevertheless, in the present study, the positive impact of the elderly appeared only in the Hot-spot, but the negative effect appeared in the Random and Cold-spot. This difference may present the mobility and housing preference of the elderly group.

Most studies state that, after the death of the elderly, their houses become unoccupied [58,60,102]. However, a proportion of mobile aging people would seem to affect the vacancy. For example, the independent and open-minded elderly would be more likely to move to a new residence since they still have sound physical health and financial status [103]. Regarding housing preference, the elderly and pre-seniors who are non-metropolitan residents prefer to live in rural or suburban areas [104,105]. Besides, they tend to reduce housing consumption, shifting from owning to renting, from detached houses to flats [106,107]. These characteristics are similar to the single households that induce the vacancy. Nonetheless, most aging people are reluctant to change their accommodations [106]. This aspect represents the immobility that would remain the housing occupied rate and, thus, reduce the vacancy.

For Sapporo city, the problems related to single households and the elderly appear to become more stressful. In 2018, the proportions of the single and elderly single households in Sapporo were 40.93% and 12.21%, respectively (refer to Appendix C). There were 167,900 single homes between the ages of 30 and 64 and 96,000 double-aged households.

This volume will add to the number of single-aged families in the upcoming years and make the problem even more problematic.

Compared to household status, the ratio of household home ownership is noteworthy when it can reduce the vacancy rate. This outcome is consistent with the findings of other studies [11,70]. From the view of the demand side, when families decide to purchase a home, it implies that they aim to secure their living place. Like the elderly, they become less mobile and, hence, reduce the vacancy.

In 2013, the ownership rate in Japan was 61.5%, which is lower than the average value of the OECD countries, at a rate of 69.7% [108]. This figure is even lower in Hokkaido (57.5%) and Sapporo (49.3%) [3,109]. The proportion of rental households seems to increase in the future when young people are less likely to purchase their own homes. This issue probably comes from the previous generation (the second baby boom in Japan). They prefer to be independent of their children and save for their retirement. The next generation, then, cannot buy housing due to the lack of finances, especially in and after the post-economic bubble collapse of the 1990s [110]. In addition, the mobility of working locations in Japanese culture may discourage the employees from purchasing outright accommodation [23,110]. Thus, we argue that policy should subsidize finances for the young and stabilize their workplace, as discussed in the studies of Druta and Ronald [110] and Hirayama [111].

One of the interesting findings is the children's variable. We suggest that this matter connects with the housing preference of child-rearing families. The concerns about the child-rearing amenities may make them mobile, and thus, this is supposed to influence the rise of vacancy. Essentially, families with children prefer to live near public facilities, such as educational institutions and commercial districts [112]. They are also willing to pay more to rent an apartment in a better neighborhood [113]. With time, the declining birth rate has resulted in a decline in housing demand for child-rearing households. However, they are still more likely to dwell in locations with high accessibility to public facilities. For Sapporo city, the proportion of infants dropped from 3.6% in 2015 to 3.4% in 2020 [114]. This fall suggests the problem will be more severe.

5.3. Neighborhood Characteristics

Consistent with previous studies, our findings showed an association between the elevation and vacant houses. This relationship appeared to reflect the effect of the highlands residing in the southwest city. Located on the Ishikari Plain, the northwest side area is low and suitable for agriculture. Hence, during the fast development of the economy, particularly in the late 1960s and before the 1972 Sapporo Winter Olympics, the city expanded mainly to the southwest side, which is a rugged area. Over time, houses in these places hinder the elderly from accessing the center and urban facilities, and thus, they became more likely to be vacant.

In terms of transportation facilities, as we expected, a good index of these facilities would increase the amenities of the areas and, thus, reduce the vacancy.

For the rail station, the shorter distance to the rail station that a building has, the higher amenity in commuting it achieves. Note that the accessibility distance to the station is between 2 and 3 km can still induce the growth of the nearby population [115]. Housing prices in this location may be affordable for low- and mid-income people since the walking time is acceptable. In Sapporo, the median distance to the subway station is about 1 km (refer to Table 2). Thus, it is a favorable factor for owning a house in this area.

For bus stops and road density, though the proximity to bus stations and main roads would improve the accessibility to the center and increase the nearby property's value [116], this effect seems to appear in the outskirt areas. As shown in Appendix A, the indexes of these two features decreased, gradually, from the center to the city boundary. Moreover, they were likely to be evenly dispersed in the center. Thus, their effect on the vacancy would be higher in the outskirt area than in the central city.

Regarding car parking facilities, as expected, the convenient access to the parking site would enhance the amenity of the houses and reduce the possibility of vacancy. By contrast, we suggest that, outside the central city, the large parking sites are placed, mainly, around commercial zones or near points of interest. These areas commonly provide massive apartments or mansions at a relatively high price. Thus, the disequilibrium in housing may occur in these places, which leads to an increase in vacancy.

Similar to transportation facilities, good educational services can significantly contribute to housing amenities. These services would likely be more important in the suburbs, which have limited resources and low accessibility. This distinction may account for the impact variation across areas. Besides, the difference in target customers of the housing market surrounding these institutions is also a reason. For instance, for universities, rental housing for students makes up a large proportion. In Sapporo, the number of students increased by 6%, within six years, from 2014 to 2019 [114]. Notably, the ratio of overseas students increased by 42% in the same period. Thus, the demand for student housing is expected to be stable and grow for at least some coming years.

Besides, we expected that the accessibility to clinics and their quantity would increase the nearby housing amenities and, thus, decrease the vacancy. Studies from the UK and Poland report that the elderly consider accessibility to healthcare services as one of the critical factors in their living area [104,117]. For Japan, clinic services play an integral role in the healthcare system when the number of clinics per 100,000 people was 131.1, while the figure for hospitals was 6.6 [118]. Nevertheless, the results did not fully support our hypothesis. Thus, this problem needs further investigation.

5.4. Housing Characteristics

The effects of the housing structures are partly consistent with the previous studies, which indicated that houses constructed of traditional materials have a higher vacancy rate [25,53,64]. For Sapporo city, all housing structures are positively associated with vacancies. We argue that the major causes of the problem are housing oversupply and housing inelasticity per se.

For the first issue, the statistics data show that the housing ratio size of the city of Sapporo has reduced significantly from 1.26 households per house (in 1963) to around 1.0 households per house (in 1978) [114]. After that, the figure continued to decrease and remained at a value of 0.9 households per house by 2018. In 1978, Sapporo saw a notable increase in empty dwellings, accounting for 9.34% of total housing stock (refer to Table 1). This evidence demonstrates the excess in the overall housing stock in the city.

For the second point, the structure's function and advantages represent the differences in housing elasticity levels. It is stated that concrete or steel structures outperform wood structures in load-bearing, sound, and heat insulation, and they are suitable for high-rise buildings. Nevertheless, these features cause the houses to be difficult to rebuild or reform. Thus, the solid structure is more likely to be vacant than the light structure.

The wooden houses, however, would seem to be a significant source of vacancies. Although a wood building is expected to be obsolete in 30 years and lasts for about 40 to 50 years [24,31], the proportion of this type of housing in Japan is substantial. As wooden houses can withstand earthquakes and provide a better atmosphere for the family, wooden houses remain popular [119]. Hence, before 2000, the number of wooden houses was greater than that of other structures [3].

For the age of buildings, the joint effect of durable housing and urban decline causes a significant rise in the number of vacancies [50]. For the city of Sapporo, however, this relationship is likely weak for two reasons. First, the average age of buildings was about 26 years, which is still low (refer to Table 2). Second, the city's population is likely to be in the beginning stages of decline. The statistics show that, though the natural increase has been negative since 2009, the migratory increase has risen by about 10,000 people each year in the last decade [114].

Nonetheless, we argue that this situation seems to be changing soon due to housing preferences and tax policies. As one of the most vulnerable countries to natural disasters (i.e., floods, earth-quakes, and tsunamis), the Japanese people would prefer to own a modern house that could withstand such an extreme event. The expensive costs of demolition and renovation also cause the old houses to be less attractive. Besides, the current financial support program applies income tax reductions only to those who purchase a new or under-20-year-old house using a home loan [60]. According to statistics [114], the number of over-30-year-old housing units in Sapporo city will rise to nearly 58% by 2030, implying a worsening problem in the future.

Regarding housing ownership status, we found a similar statement in the study of Xu and Zhou [28]. The authors declared that the large proportion of public housing links to a high vacancy rate. This issue may present a difference in elasticity on the supply side between public and private housing.

Basically, public housing has the advantage of low prices. In the early stage of the housing development program in Japan, public houses were insufficient for the applicants. Since economic growth, people who have an income higher than the regulation threshold cannot access these types of housing, and those who are now living in these apartments have to leave [29]. Besides, as Kobayashi reported [29], these old public houses are low standard and undersized, failing to suit the needs of modern life. Meanwhile, the private sector provides diverse housing forms with better amenities, flexible time contracts, and straightforward procedures that satisfy the residents' budgets and personal preferences. Hence, the private home has an advantage over the public house.

Contrary to the private housing factor, the concentration of offices in the Hot and Cold-spot correlates with the increase in vacant houses. We suggest this state represents cost-effectiveness in the property market. Commonly, the high-density offices are located in the center of the business district, where the property price is excessively high. This price range mainly suits the high-income who may own these houses as second dwellings or for investment, as discussed in the study by Fernandez et al. [69].

For the attached parking lots, principally, this factor reflects the mobility habit of the Japanese. As reported by the Japan Automobile Manufacturers Association [120], the ratios of private passenger cars in Hokkaido and Sapporo are around 100 and 60 units per 100 households, respectively. This figure expresses the heavy dependence on the car when commuting. Notably, since parking lot certification is mandatory for owning a car in Japan, the availability of this facility is essential when finding new accommodation. Besides, even if the public parking area is nearby the house location, it is not as convenient as indoor or attached parking lots in the building. This element is even more fruitful in Hokkaido because of the extreme winter weather, with an annual snowfall of 484.8 cm and an average temperature of 5.7 degrees Celsius within the past 30 years [121]. However, attached parking lots are more likely in apartments in the central city and its surroundings. Meanwhile, in the suburbs, they denote detached houses. Thus, it may appear in a reversed impact direction.

5.5. Policy Implications

For years, besides the depopulation influences, the free housing market operation and the outdated housing policies have resulted in a mass of houses in the death stock. Responding to this problem, the Japanese government enacted the 'Vacant Property Management Limited Measure Act' in 2014 [27]. As a result, the vacancy rate declined nationwide and in most metropolises (refer to Table 1). However, we argue that this Act seems unsustainable when the burden of cost shifts from the private to the public sector. This issue, thus, will cause pressure on the local city budget. We propose that the decision-maker should consider the active approach with the following suggestions.

First, the city should implement a property tax on vacant houses simultaneously with conventional taxes. This tax could handle about a 13% decline in vacancy rates, particularly long-term vacancies [122]. The second option is to narrow the gap between the vacant land and empty house taxes. These two adjustments would influence the owner to demolish their deteriorated houses or transfer them to a new owner. In addition, it is to mandate registering the owner of the vacant house, which helps to solve the problem of an unknown owner or "ghost house." As a result, it will support the tax system for vacant properties. Further, it helps the management agency to decide on an alternative to the derelict houses—to either destroy or renovate.

Second, we argue that there is a need for quality inspection conduct to classify the old houses. For the re-useable accommodations, a refurbishment or renovation program can enable them to return to the housing market. From that, the in-charge agency will release a certification or guarantee that it fulfills the construction standard to give customers more confidence when purchasing a used property. Meanwhile, the no longer improper houses for a living can move to the conservation purpose, with vernacular historic buildings, or demolition.

Third, all new development projects should be thoroughly assessed, with an emphasis on enhancing the current environment. As Jeon and Kim [58] indicate, while the new town with better public facilities would attract the people to move in, the cancellation of the reconstruction projects would dissatisfy the local resident. Consequently, this problem creates the push-and-pull effect, so the people would leave the old to move to new areas.

Finally, policy implications should focus on easing the negative effect of depopulation. Specifically, the government should continue to improve the neighborhood conditions to increase the rate of child-rearing households, as stated in the study of Andrade et al. [112]. Besides, it is necessary to boost local economic programs which involve the young as the center subject. These programs can provide diverse and large-scale jobs that attract the young and the immigrations people and encourage them to stay.

6. Limitations and Conclusions

Though the present study has addressed various issues, there are limitations remaining that need to be further investigated. First, there is a lack of relevant explanatory variables, e.g., income level and state preference, to clarify the determinants of people's behavior in choosing or purchasing accommodation. This supplement could solidify the findings and support the decision-making more sufficiently. Second, the present study combined the vacant dwelling types (temporary and permanent vacancy) as one response variable. Though this can reveal the vacant houses in the market, from a more holistic perspective, we argue that splitting these two terms in the analysis would be meaningful for determining a solution for each vacant type. Finally, we used the stationary data for the model, which can only express the situation of the issue at a specific time. In the long term, all the factors and their influence may change. Thus, the analysis with time-series data would be worthy of discovering the variation of the vacancy determinants.

In conclusion, the present study has examined the determinants of vacant houses' spatial distribution in the city of Sapporo. The outcomes highlight the high vacancy cluster that occurred in the central city. In contrast to the other cities, the vacancy in Sapporo would seem to link to the disequilibrium housing market rather than the urban decline. The results indicate that the influence factors varied over city areas in magnitude and direction. Demographic features were the substantial factors, followed by housing and neighborhood characteristics. Specifically, areas with a high density of single households and children are more likely to experience a high vacancy. On the contrary, a high percentage of household ownership and the elderly (in suburban) would reduce the vacancy. Notably, a group of mobile elderly would increase the vacancy in the central city.

Regarding housing characteristics, the study argues that the surplus in housing supply stimulated the vacant houses intensively. Further, the elasticity in housing structures causes the different influence levels of the house to increase from flexibility to hardness. We also identify the high percentage of private shares as a primary factor that can keep the low rate of empty homes, especially in the central city and its surrounding. Meanwhile, the intensive concentration of offices would increase the vacancy in the center and outskirt areas.

For other amenities, we found the clinic, parking, public transportation, and educational facilities had a medium effect on the vacancy. Remarkably, some facilities had an inverse influence over areas, such as clinics and attached car parking, and some facilities had an effect only in specific areas, for example, educational institutions. This disparity would represent the variation in housing dynamics across the city. Thus, the policies should be flexible in implementation in a specific area.

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Appendix A. Summary of Cluster Data Sets

Variable	Hot-Spot				Cold-Spot				Random			
	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
Dependent variable												
zenVCrooms	0	379	407.70	1457	0	5	15.41	231	0	61	89.41	678
Explanatory variables												
Neighborhood characteristics												
Geographic conditions												
ElevAv	6.14	21.54	24.36	75.73	2.30	45.08	67.65	375.51	2.37	14.71	29.15	217.14
SlopeAv	0.01	0.50	0.66	10.39	0.00	1.90	3.28	27.54	0.00	0.55	1.37	19.74
FloodArea	0.00	0.00	11.98	559.04	0.00	0.00	49.92	625.06	0.00	0.00	40.25	625.06
Public facilities in 500 m radius area												
R5ParkingA	9.08	31.22	31.76	73.00	0.00	4.92	7.47	51.40	0.00	18.72	19.58	62.58
R5Hosp	0	1	1.14	6	0	0	0.20	4	0	0	0.61	4
R5Clinic	2	15	17.15	116	0	2	2.59	16	0	5	6.96	182
R5Welf	0	4	4.52	16	0	1	1.78	11	0	3	3.40	16
R5Cult	0	2	2.39	13	0	0	0.89	11	0	1	1.48	10
R5RailS	0	1	0.95	11	0	0	0.03	1	0	0	0.25	13
R5BusS	0	5	5.76	34	0	3	3.51	10	0	5	4.73	37
R5Fuel	0	1	1.27	6	0	0	0.35	3	0	1	0.74	6
R5Univ	0	0	0.20	11	0	0	0.02	2	0	0	0.07	3
R5HighS	0	0	0.25	3	0	0	0.12	2	0	0	0.10	2
R5Junior	0	0	0.39	3	0	0	0.26	3	0	0	0.27	2
R5Ele	0	1	0.71	3	0	0	0.44	2	0	1	0.60	3
R5Kind	0	1	0.62	3	0	0	0.26	2	0	0	0.42	3
Nearest facilities distance												
HubPark	0.07	1.61	1.90	7.69	0.06	1.38	1.60	10.06	0.02	1.43	1.57	6.58
HubCultura	0.16	3.33	3.41	8.77	0.15	5.07	5.65	20.29	0.11	3.96	4.26	16.18
HubHospita	0.10	3.94	4.17	12.64	0.17	9.07	9.70	35.96	0.07	5.57	6.28	36.11
HubClinic	0.01	1.25	1.35	3.81	0.06	3.28	3.75	17.04	0.03	2.02	2.24	14.05
HubWelfare	0.08	2.08	2.31	6.90	0.08	3.87	4.32	16.69	0.00	2.58	2.80	11.76
HubRailS	0.34	4.13	4.26	10.00	0.62	22.51	29.26	167.32	0.25	9.47	12.09	57.46
HubBusS	0.11	1.67	1.84	6.79	0.02	2.06	2.31	10.23	0.06	1.82	1.95	7.21
HubPking	0.02	0.50	0.56	2.54	0.05	1.49	1.83	8.97	0.01	0.80	1.00	6.64
HubFuelS	0.14	3.64	4.06	13.42	0.17	7.29	8.53	42.93	0.31	4.91	5.33	20.26
HubUniv	0.60	13.40	14.70	45.35	1.17	28.47	31.30	136.02	0.36	22.80	23.53	59.92
HubHighs	0.24	8.53	9.34	25.86	0.50	11.41	13.55	103.82	0.27	12.55	13.12	33.82
HubJunior	0.28	5.90	6.08	14.79	0.46	7.58	8.02	23.53	0.10	7.21	7.37	22.40
HubEle	0.14	4.33	4.33	9.46	0.19	5.60	6.14	20.72	0.14	4.81	5.01	16.19
HubKind	0.21	4.79	4.99	14.01	0.15	7.48	9.64	88.34	0.31	6.03	6.26	35.51
Infrastructure index												
RoadDen	0.86	24.76	24.71	46.27	0.00	22.48	21.16	43.47	0.00	23.54	22.20	44.51
BusDen	0.00	5.67	20.25	276.85	0.00	3.04	8.95	152.73	0.00	6.21	15.83	377.75
RailDen	0.00	0.00	1.03	9.75	0.00	0.00	0.08	5.11	0.00	0.00	0.43	16.68

Variable	Hot-Spot				Cold-Spot				Random			
	Min	Median	Mean	Max	Min	Median	Mean	Max	Min	Median	Mean	Max
Building characteristics												
ParkingA	0.00	23.38	31.87	557.59	0.00	3.96	5.06	269.61	0.00	7.19	11.31	1276.94
woodA	0.00	12.41	13.00	68.10	0.00	10.86	10.69	27.91	0.00	11.98	12.00	44.47
semifireA	0.00	2.27	2.80	21.72	0.00	0.56	0.95	21.35	0.00	1.04	1.52	23.29
fireproofA	0.00	28.36	37.11	339.60	0.00	0.00	1.89	276.62	0.00	3.07	10.59	391.03
AgeFloorAv	1.82	24.33	24.18	57.27	1.96	27.13	26.04	62.07	1.06	27.00	26.61	90.00
zenPriRoom	0	169	175.60	758	0	101	101.70	460	0	133	130.60	652
zenOffRoom	0	18	29.07	404	0	3	4.17	47	0	6	8.71	544
Demographic characteristics												
Children	1	74	76.40	267	0	35	37.52	216	0	51	53.35	209
Elderly	3	189	191.67	680	0	79	83.98	411	0	130	127.17	390
HHowner	0	142	151.45	528	0	88	85.28	331	0	103	102.85	523
HHsingle	5	257	290.96	1363	0	18	20.71	97	0	53	64.58	530

Appendix B. Variable Influence on Projection (VIP) and Coefficients Values of the Four Models

No	Variable	Hot-Spot		Cold-Spot		Random	
		VIP	Coef	VIP	Coef	VIP	Coef
1	ElevAv	0.40	3.02	0.92	0.42	0.47	0.77
2	SlopeAv	0.60	4.39	0.87	−0.43	0.61	−0.10
3	FloodArea	0.23	−3.94	0.30	0.56	0.38	1.19
4	R5ParkingA	0.74	4.26	1.44	1.50	1.17	1.18
5	R5Hosp	0.82	8.51	0.54	−0.44	0.79	0.76
6	R5Clinic	1.14	−9.74	1.06	0.54	0.93	−1.61
7	R5Welf	0.33	4.92	0.71	0.76	0.51	−1.28
8	R5Cult	0.52	3.39	0.40	−1.42	0.51	−0.83
9	R5RailS	0.79	10.42	0.49	0.47	0.86	1.04
10	R5BusS	0.82	5.16	0.85	0.41	0.92	−0.10
11	R5Fuel	0.42	−0.65	0.83	−0.86	0.55	1.82
12	R5Univ	0.39	−2.55	0.25	0.22	0.47	−1.44
13	R5HighS	0.27	1.29	0.54	−0.37	0.30	−0.45
14	R5Junior	0.21	−2.68	0.34	0.54	0.50	−0.85
15	R5Ele	0.31	6.83	0.65	0.76	0.70	−1.29
16	R5Kind	0.39	3.61	0.67	1.21	0.55	−2.89
17	HubPark	0.63	−3.22	0.84	−0.08	0.75	−1.98
18	HubCultura	0.60	0.45	0.53	0.95	0.64	−3.30
19	HubHospita	0.66	7.91	0.53	−0.76	0.87	−1.73
20	HubClinic	1.06	0.49	1.09	−0.54	1.05	0.02
21	HubWelfare	0.58	11.38	0.82	−0.41	0.61	−1.50
22	HubRailS	1.18	−11.18	1.01	−1.57	1.02	−2.47
23	HubBusS	0.62	−1.60	0.78	−1.30	0.48	−0.71
24	HubPking	1.11	−3.73	1.24	−0.95	1.03	−2.42
25	HubFuelS	0.52	−0.58	0.81	−0.72	0.73	3.03
26	HubUniv	0.40	3.41	0.90	−0.51	0.56	0.22
27	HubHighs	0.27	0.15	0.98	−1.62	0.42	0.06
28	HubJunior	0.29	−2.79	0.52	−0.61	0.72	3.03
29	HubEle	0.33	1.95	0.79	0.70	0.81	0.56
30	HubKind	0.32	1.24	0.97	−0.18	0.82	−3.19
31	ParkingA	1.00	−12.68	1.40	0.13	1.00	−9.29
32	woodA	1.16	45.50	1.31	1.03	1.07	12.51
33	semifireA	1.87	19.38	0.83	2.26	1.01	8.54
34	fireproofA	1.44	46.08	1.72	4.11	1.64	27.88
35	AgeFloorAv	0.55	−1.79	0.58	−1.82	0.58	3.43
36	zenPriRoom	1.44	−58.99	1.24	−0.41	1.47	−26.87
37	zenOffRoom	1.24	13.05	1.11	2.16	0.71	3.44
38	RoadDen	0.80	−5.21	1.38	−4.01	1.22	−9.24
39	BusDen	0.60	−4.64	0.40	1.06	0.42	0.08
40	RailDen	0.56	−7.05	0.19	−0.34	0.48	−1.91
41	Children	1.27	26.15	1.02	3.71	1.71	23.44
42	Elderly	1.61	14.42	1.25	−0.18	1.53	−4.00
43	HHowner	1.29	−0.28	1.61	−8.92	1.49	−2.19
44	HHsingle	3.61	171.87	2.62	15.24	3.17	69.57

Appendix C. Dwelling, Population, and Commuting Indexes of Sapporo's Districts

Index	Atsubetsu	Chuo	Higashi	Kita	Kiyota	Minami	Nishi	Shiroishi	Teine	Toyohira
Real estate market										
Average rental price 2018 (1000 JPY/house)	42.37	55.51	46.50	47.51	50.63	45.37	52.03	47.39	47.15	48.20
Average land price 2018 (10,000 JPY/m^2)	63.70	141.00	65.80	56.50	48.00	38.00	77.10	67.40	42.00	89.80
Dwelling indexes										
# dwellings 2018 (1000 units)	59.81	157.26	140.42	150.04	48.19	68.29	108.9	120.13	63.65	129.46
# occupied dwellings 2018 (1000 units)	55.63	128.35	125.12	134.54	45.58	58.95	97.34	105.98	58.62	110.79
# vacant dwellings 2018 (1000 units)	4.18	28.91	15.3	15.5	2.61	9.34	11.56	14.15	5.03	18.67
Dwelling vacancy rate 2018 (%)	6.99	18.38	10.9	10.33	5.42	13.68	10.62	11.78	7.90	14.42
Owned dwellings rate 2018 (%)	53.1	40.77	42.32	52.79	72.59	67.72	58.04	37.09	69.29	42.03
Rental vacant dwelling rate 2018 (%)	80.62	50.78	75.95	67.48	52.49	43.90	71.97	82.47	37.38	46.01
Change in dwelling 2008−2013 (dwellings)	−720	13,260	3900	−60	1130	−1530	4,60	1090	−2040	4220
Change in dwelling 2013−2018 (dwellings)	1120	8340	6590	11,470	3150	−1270	3300	−1680	5950	4840
Change in vacant dwelling 2008−2013 (dwellings)	60	7410	−460	−510	−990	1150	3060	−4490	−70	−710
Change in vacant dwelling 2013−2018 (dwellings)	−1720	−,520	−2590	−1470	−220	−320	−2400	−5410	−340	−90
Demographic										
# Households with elderly (1000 households)	25.60	35.28	40.72	47.79	20.30	28.72	37.50	31.70	24.26	34.42
Proportion of households with elderly (%)	45.85	27.41	32.47	35.43	44.27	48.47	38.34	29.83	41.16	31.01
# Low−income households (1000 households)	22.59	52.45	48.72	57.40	15.79	23.86	36.90	42.34	21.70	47.31
Proportion of low−income households (%)	40.61	40.86	38.94	42.66	34.64	40.47	37.91	39.95	37.02	42.70
# High−income households (1000 households)	8.80	22.95	12.98	15.87	7.92	7.32	13.25	9.07	8.31	12.29
Proportion of high−income households (%)	15.82	17.88	10.37	11.80	17.38	12.42	13.61	8.56	14.18	11.09
# High−income single/couple household (1000 households)	3.02	12.53	4.64	6.24	2.43	2.92	4.55	3.95	2.71	5.16
Proportion of high−income single/couple household (%)	5.43	9.76	3.71	4.64	5.33	4.95	4.67	3.73	4.62	4.66
Population 2020 (1000 persons)	124.39	250.01	265.1	289.4	111.63	135.05	217.09	211.37	142.71	225.85
Change in population 2010−2020 (1000 persons)	−4.17	29.52	9.13	10.39	−5.05	−11.19	5.90	7.05	2.88	13.57
Change in population 2015−2020 (1000 persons)	−3.30	12.00	2.97	3.71	−4.05	−6.09	3.68	1.90	1.64	6.99
Elderly proportion 2020 (%)	32.90	23.02	25.76	26.7	30.52	35.54	27.62	25.15	31.52	25.26
Change in elderly population 2015−2020 (%)	14.59	13.87	11.12	12.06	16.42	7.00	9.29	11.03	16.66	10.88
Commuting time										
Proportion of household's earner commuting time less than 30 min (%)	69.11	58.65	63.8	63.75	56.71	59.6	59.79	51.03	52.62	54.69
Proportion of household's earner commuting time less than 45 min (%)	89.92	83.76	85.85	88.28	78.00	85.18	77.87	74.80	83.10	73.88

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