# Understanding students' residential dynamics around university campuses: A computational agent-based modelling approach

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# Understanding students' residential dynamics around university campuses: A computational agent-based modelling approach

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**Abstract:** *Highly populated student areas are known to be accompanied with spatial and social trends that result in disruption and segregation between students and original residents. Therefore, it is essential to understand different factors that affect students' accommodation preferences and the following residential dynamics. This paper uses agent-based modelling to visualize students' distribution and housing occupation around university campuses by applying four different scenarios. Results have also shown that highly populated student areas may become more evident around suburban campuses. Proposed model could be used by urban planners as an urban planning tool to come up with resilient student-oriented housing policies.*

**Keywords:** Agent-based simulation; housing policies; campus design; urban resilience; campus development.

## 1. INTRODUCTION

University campuses are known to be accompanied by a high influx of students in the surroundings, resulting in a phenomenon known as "studentification" [1]. Studentification caused around university campuses drives up the real estate market due to the rising demand to cover students' needs for housing and amenities. Furthermore, studentified areas are known to be followed by several economic variations that can be seen in the increase of land rent [2]. In addition to the social changes that can be seen in the displacement of original residents that takes place due to the segregation happening between students and other residents caused by the negative impacts of studentification [3]. Although studentification process is known to accelerate the urban land development where it occurs, research have shown that studentification is also followed by several downsides result from the increased number of issues caused by students such as: noisiness, littering, or walking home drunk [4]. Furthermore, the existence of high number of students living around university campuses results in seasonal immigration that occurs mainly during summer and winter vacations. In addition to empty houses that exist when the offered number of accommodations are more than needed [5]. All this shows that the real estate market variation occurring around university campuses is a complex and intercorrelated process that affects campuses' surroundings radically. Therefore, housing mechanisms around university campuses need to be investigated to offer evidence-based land management plans to cope with urban residential dynamics occurring.

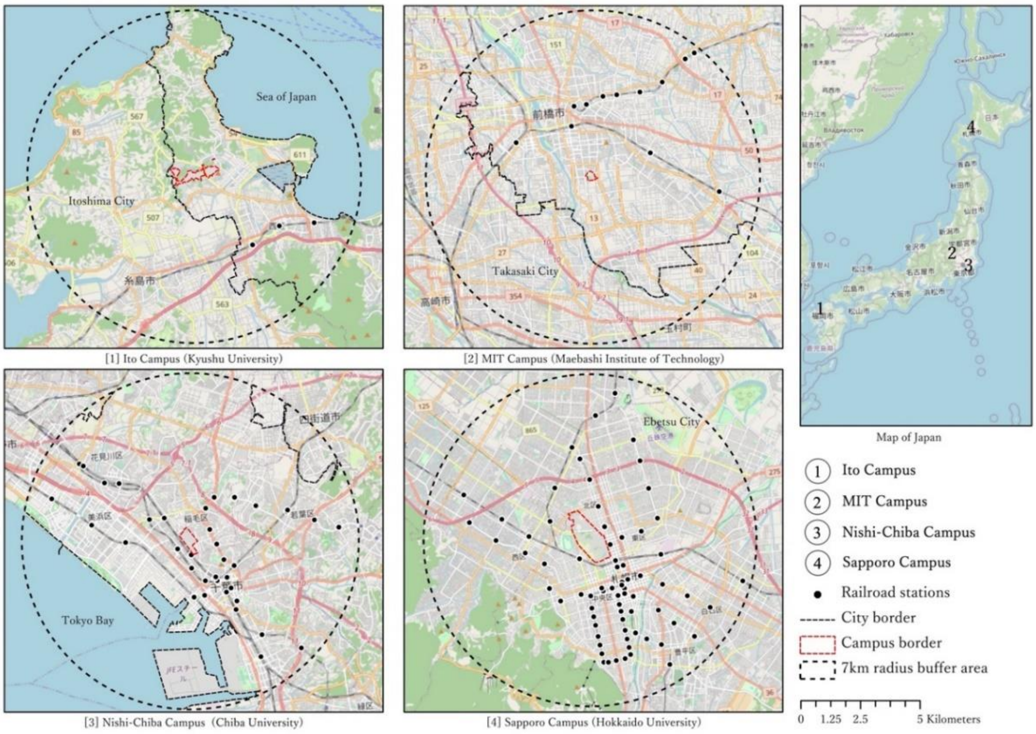



Figure 1. Study area

Table 1. Materials and methods

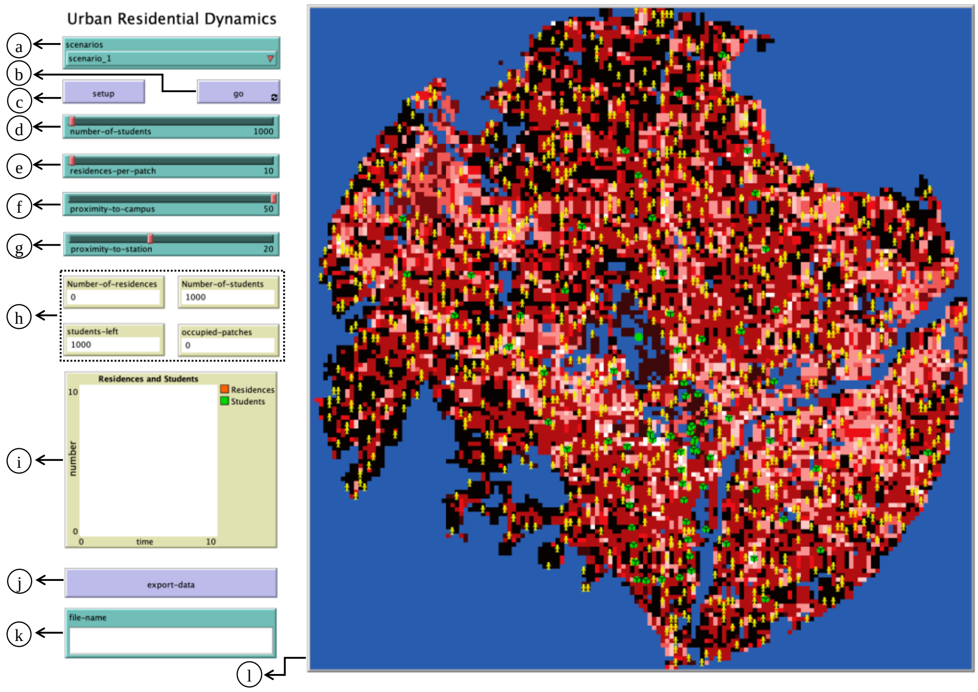
| Method | Platform | Processed Data | | | | |
|---|---|---|---|---|---|---|
| | | Data Type | City | Data Collection Time | Data Source | Data Delivery |
| Mixed-Use Index (MXI) | ArcGIS Desktop 10.4 software | Footprint area and uses of buildings in 7km radius buffer area around university campus | Fukuoka City | 2017 | Fukuoka City Urban Affairs Bureau | Provided on request |
| | | | Maebashi City | 2018 | Maebashi City Planning Department | |
| | | | Chiba City | 2018 | Chiba City Urban Planning Division | |
| | | | Sapporo City | 2020 | Sapporo City Planning Bureau | |
| Land value | ArcGIS Desktop 10.4 software | Land price (yen/m$^2$) | Fukuoka City | 2017 | Japanese national land survey data | Downloaded |
| | | | Maebashi City | 2018 | | |
| | | | Chiba City | 2018 | | |
| | | | Sapporo City | 2020 | | |

Studentification and the following gentrification, is however, difficult to predict where and when will occur. Consequently, the way to which the private sector responds to student housing demands has been shown to be not so efficient [6]. Research have shown that the private rented sector is being poorly organized, as it is mainly dominated by amateur landlords or real estate agencies with small portfolios [7]. Additionally, studentification negative effects become more evident with increased student occupation. As students are usually young and have limited experience of managing a home which results in a widespread disruption that could lead to other issues related to noisiness and littering. Furthermore, based on the local context where studentification occurs, studentification can affect the urban development in the area due to its perceived negative impact. For example, unlike the United Kingdom, Japanese houses are known to be compacted and small, due to high land values, which results in compact dense student occupation that would escalate studentification negative effects [8], [9]. Therefore, resilient student housing policies need to be implemented to match the needs of students and counter the negative effects of studentification. This paper uses agent-based modelling as a method to simulate different scenarios of urban residential dynamics around four different campuses in Japan in order to anticipate the expected residential patterns of students. The aim of this paper is to uncover the main factors that impact students' residential patterns around university campuses. This paper also provides a simulation tool that would guide urban planners and decision makers to aid their policy making process. Furthermore, previous research focused mainly on a single case study, or a case study in a single region. However, this paper focuses on four different case studies with four different scenarios to have a holistic view of the expected residential patterns of students.

### 1.1. Residential patterns around university campuses

Students' preferable location for accommodation depends on many factors including: rent value, monthly allowance, proximity to campus, and available amenities and transportation services [10]. These factors are dependent on each other in a way or another. For example, the closer students to railroad stations are, the more probable to have a high rent, and the more amenities and services probably exist. On the other hand, the closer students to their campuses are, the more convenient it is, and the more engaged with their university they become. Another important factor that affects where students live is the communication happening between students about their favored location [11]. However, if all these factors are left unorganized or without careful consideration of their impact on students' residential patterns, students will end up living in highly populated student areas. This, in turn, would probably escalate the negative impacts of studentification[12]. Therefore, to come up with proper student-oriented resilient housing policies, their preferences and behavior need to be considered and positioned in a way that brings a positive impact to the area without causing any disruption [13].

Moreover, public transit is known to be the most common mode of transportation among university students [14], [15]. However, previous research has shown that biking and walking to school help students to build a deep relationship with communities off-campus [16]. Therefore, it is essential to adopt student-oriented resilient housing policies that encourage students to walk or bike to their schools with convenient public transportation in mind as well. Furthermore, adopting such policies not only serves the needs of students, but also reduce energy consumption in the city [17]. Moreover, students consider their universities not only as a place to learn, but as a community hub where they meet




| | |
|---|---|
| a | To choose the scenrio for the simulation |
| b | To start simulation |
| c | To setup the model before simulation |
| d | Number of students who enter the system |
| e | Number of residences limit per patch |
| f | Number of patches that defines the proximity to the campus |
| g | Number of patches that defines the proximity to the stations |
| h | Monitors that show the number of students and patches during the simulation to check its performance. |
| i | A graph that shows the relation between number of students and residences over time during the simulation to check its performance. |
| j | To write the simulation output into a shape file to be used in the GIS environment |
| k | To name the file |
| l | Window that shows simulation output before exporting data to the GIS environment. Yellow figures represent student agents. Red patches represent different uses based on mixed-use index (MXI) maps. Green circle represents the location of the campus. Green boxes represent the location of railroad stations. |

Figure 2. Model interface as programmed in Netlogo software (Sapporo campus case)

their friends and peers to engage in various physical and social activities. Therefore, deserted schools are known to affect students' social life negatively [18]. So, offering students accommodation close to their campuses and accessible public transportation should be considered in tandem. Additionally, previous research has shown that accessible university campuses are usually surrounded by mixed land uses [19]. However, campuses that are located in suburban areas may suffer from the lack of available amenities and services which, in turn, might impact students' residential patterns [20]. Therefore, student-oriented housing policies need to take into consideration the location where students' accommodations are built in relation to the surrounding land uses. Thus, this paper focuses mainly on three different factors that affect students' residential patterns: proximity to the campus, proximity to railroad stations, and available housing locations. The paper also simulates residential patterns for four different campuses with different sizes in urban and suburban locations in Japan to investigate the impact of campus size and location on students' residential patterns.

## 2. MATERIALS AND METHODS

### 2.1. Study area

Four different university campuses located in Japan have been selected for this research. Kyushu University's Ito Campus, Maebashi Institute of Technology (MIT) Campus, Chiba University's Nishi-Chiba campus, and Hokkaido University's Sapporo Campus have been selected for the simulation (Figure 1). Selected campuses have been specifically chosen based on the availability of their geographical information system (GIS) data and to ensure a variety in campuses' sizes and locations in urban and suburban areas (Table 1).

### 2.2. Agent-based modelling

Agent-based modelling (ABM) is a computer-derived methodology that simulates a certain environment with a specific set of rules to allow for autonomous actions to achieve the objectives of the designed model. First, ABM starts with defining the type and behavior of agents in the system. By defining agents' behavior, agents start to have a DNA embedded decision-making framework that guides them through the process to achieve certain objectives or make specific decisions [21], [22]. In other words, ABM can be simply defined as a simulation process that consists of agents with different behaviors and decision-making frameworks in a controlled environment to examine how agents would interact. This, in turn, allows modelers to validate what have been observed in the real world or discover new emergent phenomena. ABM process starts with designing the model based on simple abstract rules retrieved from theoretical data or observed from empirical real-world data. The design of the model should be kept simple, and any level of complexity can be added when needed. By simplifying the model, it makes it easier to interpret the interaction happening between agents to explain why certain outcome occurs. After designing the model, it needs to be verified using sensitivity or statistical analyses to make sure that the model works as it is supposed to, and to verify that the model is designed with the same rules found in the targeted real-world system. Lastly, after verifying the model, it can be calibrated with real-world data or used with hypothetical experimental data to discover new phenomena or validate what have been observed.

This paper uses ABM to simulate residential patterns around university campuses using students as agents. Although students' residential dynamics have been investigated in previous research using ABM [11], the focus was on discovering the impact of land rent on students' residential dynamics. However, this paper investigates different factors that affect students' residential dynamics, so urban planners and decision makers could come up with student-oriented housing policies to limit the negative impact of studentification.

Table 2. Sensitivity analysis tests carried out to verify proposed model

| Test | Verification parameter | Result | Is this outcome expected? |
|---|---|---|---|
| A | Residences per patch | The higher the number of residences per patch is, the smaller number of students leave the system and vice versa | Yes |
| B | Proximity to campus | The farther the distance from the campus is, the more the number of occupied patches become and vice versa | Yes |
| C | Proximity to station | The farther the distance from the station is, the more the number of occupied patches become and vice versa | Yes |

2.2.1. Model design

Using students as agents, an agent-based simulation model has been designed to examine four different scenarios of where students might be living around university campuses. As illustrated in section 1.1, students might be willing to live near to the campus due to the convenience that campuses offer and the available number of services and facilities. Furthermore, students might also prefer to live near railroad stations, especially if their campuses are located in suburban areas [20]. Therefore, students' behavior in the proposed model is designed based on the proximity to the campus, the nearest station, or both. However, four different scenarios were taken into consideration to be able to compare between the possible economic and social impact of each one of the scenarios. The first scenario was designed to ask student agents to live in a 5km radius buffer area close to the campus. On the other hand, the second scenario was designed to ask student agents to live in a 2km radius buffer area close to railroad stations within 7km around the campus. University students, in Japan, usually own bicycles, as it is the cheapest commuting option they can afford. Furthermore, students can park their bicycles for free at their homes as well as at their universities. However, they need to pay a monthly parking fee to be able to park their bicycles at railroad stations. Therefore, students may prefer to cycle to their schools and walk to the nearest stations. In turn, proximity to the campus has been adjusted to be within 5km radius buffer zone which is equivalent to 20-minute cycling. However, proximity to the station has been adjusted to be within 2km radius buffer zone which is equivalent to 20-minute walking. By doing so, the proposed model makes sure that the farthest student residence will be located 20-minute away by bike from campus or 20-minute away on foot from the nearest railroad station.

The third scenario was designed to make students live within 5km away from school and 2km away from the nearest railroad stations at the same time. However, the fourth scenario was designed to ask students to choose to live within 5km away from school or 2km away from the nearest railroad station whichever applies. The third scenario limits where students may live. However, the fourth scenario maximizes the number of options where students can live. The proposed model has been programmed using Netlogo Software (version 6.2.2) and mixed-use index (MXI) maps of selected campuses as an input [23] (Figure 2). The simulation starts with adjusting the number of students to enter the system looking for a patch to accommodate based on the chosen scenario. When students find the right patch, they stay and convert to a residence agent. MXI maps are used to indicate where students should stay. If the patch is categorized as housing, housing and amenities, or housing and working, the agent can stay. Multi-functional patches are excluded because they are mostly located in an area with a high land value which means that students would probably not be able to afford. Furthermore, the model has been provided with three different parameters to control the environment and verify the model. First, 'residence per patch' parameter has been added to limit the number of students who can live on one patch which, in turn, can help the modeler to control student occupation in each patch. When the limit of residences per patch is reached, the remaining number of students are asked to leave the system and look for accommodation in another area. Moreover, 'proximity to campus' and 'proximity to station' were added to control the number of patches that represent the buffer area near to the campus or railroad stations. The model stops when all students find the suitable patch to accommodate. Then, a shapefile of students' location can be exported to a GIS environment.

2.2.2. Model verification

In order to verify that the design of the model is working as it is supposed to be, a sensitivity analysis has been conducted. Sensitivity tests were conducted using three different parameters: 'residences per patch', 'proximity to campus', and 'proximity to station'. Tests have shown that the model is working normally according to its design (Table 2). Test A shows that by decreasing the number of students who are allowed to live on one single patch, more students will leave the system looking for other areas or neighborhoods in the city. On the other hand, when the number of residences per patch is increased, the model will most probably cover the needs of a higher number of students who enter the system which may escalate the negative impacts of studentification. Moreover, tests B and C have shown that the model is working as intended.

2.2.3. Model implementation

Proposed model has been used to simulate students' residential patterns around selected campuses. Furthermore, values for model parameters for the four case studies have been matched to be the same for all cases except the number of students. Number of students that enter the system has been calibrated from the actual number of students in each university. However, only 50% of the actual number of students were allowed to enter the system for various reasons. First, most universities in Japan, especially large ones, have more than one campus in addition to few satellite campuses.

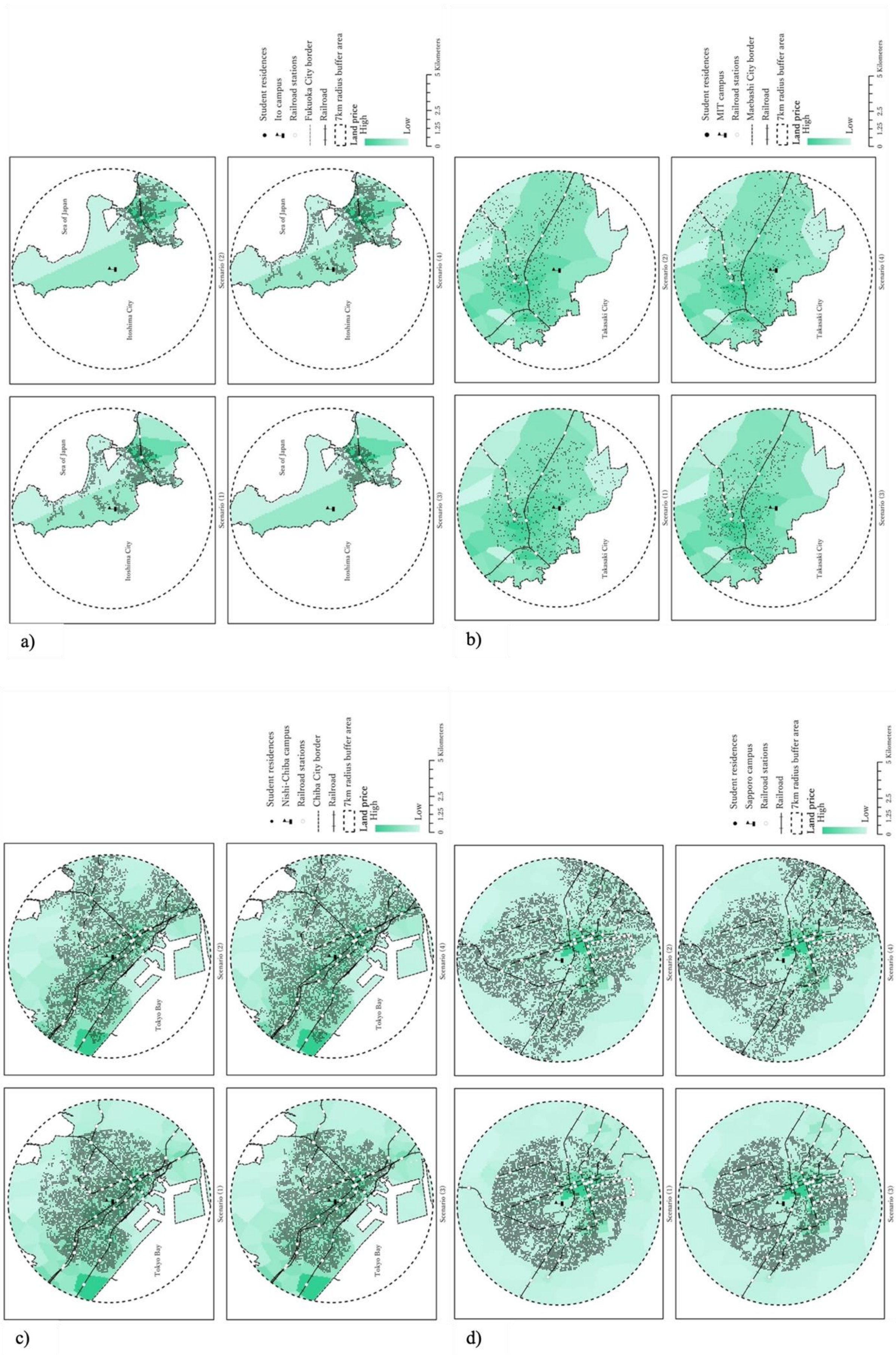



Figure 3. Simulation output: a) Ito Campus, b) MIT Campus, c) Nishi-Chiba Campus, d) Sapporo Campus

Therefore, students who attend those satellite campuses prefer to live near their campuses instead of living near to the main one. Furthermore, in Japan, there are three different types of students *jitakusei*, *geshukusei*, and *ryōsei*. *Jitakusei* are students who live with their parents in the same city, and *geshukusei* are boarding students

Table 3. Simulation output

| Campus | Scenario | Number of residences | Number of students left | Number of occupied patches | Maximum number of students per patch |
|---|---|---|---|---|---|
| Ito Campus | Scenario (1) | 7,885 | 1,425 | 874 | 10 |
| | Scenario (2) | 7,238 | 2,072 | 768 | 10 |
| | Scenario (3) | 5,250 | 4,060 | 527 | 10 |
| | Scenario (4) | 8,764 | 546 | 1115 | 10 |
| MIT Campus | Scenario (1) | 653 | 0 | 602 | 4 |
| | Scenario (2) | 653 | 0 | 598 | 3 |
| | Scenario (3) | 653 | 0 | 575 | 3 |
| | Scenario (4) | 653 | 0 | 612 | 3 |
| Nishi-Chiba Campus | Scenario (1) | 7,121 | 0 | 3524 | 8 |
| | Scenario (2) | 7,121 | 0 | 4,041 | 7 |
| | Scenario (3) | 7,121 | 0 | 3,318 | 8 |
| | Scenario (4) | 7,121 | 0 | 4,205 | 7 |
| Sapporo Campus | Scenario (1) | 8,955 | 0 | 4,186 | 9 |
| | Scenario (2) | 8,955 | 0 | 5,448 | 9 |
| | Scenario (3) | 8,955 | 0 | 4,194 | 7 |
| | Scenario (4) | 8,955 | 0 | 5,510 | 6 |

who live on their own. On the other hand, *ryōsei* are students who live in universities' dormitories. So, only *geshukusei* who might live near to the campus causing studentification trends. Therefore, a constant value has been set for all scenarios, ensuring that a minimum of 50% of the total student population in the university are anticipated to be *geshukusei*, willing to reside around their main campus. Moreover, 'residences per patch' parameter has been adjusted to be 10 students per patch for all cases to be able to compare and reflect the distribution in each of the four scenarios and cases. Lastly, 'proximity to campus' and 'proximity to station' parameters have been adjusted to be 50 and 20 patches respectively. While each patch is 100 m × 100 m, so 50 and 20 patches will be equivalent to 5km and 2km radius respectively, which is calibrated as explained in section 2.2.1.

## 3. RESULTS AND DISCUSSION

Results have shown that Ito campus was the only campus to report students leaving the system in all four scenarios (Table 3). As all patches with housing, housing and amenities, and housing and working uses were fully occupied with the maximum number of residences adjusted. This could be understood according to the location of the campus. As Ito campus is the only campus among selected cases to be located in an underdeveloped suburban area of Fukuoka City (Figure 3). So, the number of eligible patches to be occupied with student housing is limited. Unlike other campuses which are located in more urbanized parts of their respective cities. Therefore, they were able to fulfil the needed capacity of student housing. This also offers evidence that the location of the campus plays a significant role in students' distribution across the city. Moreover, results have shown that the fourth scenario has achieved the lowest student occupation, which is predicted, as it maximizes housing locations within 5km from the campus or 2km from the nearest station. As illustrated earlier the private sector plays a major role in covering housing needs for students [24]. Therefore, if the aim is to reduce student occupation, especially in highly populated student areas, the private sector should be encouraged and incentivized to invest in building student residences across wider buffer zones around campuses and nearest railroad stations.

Moreover, unlike other cases, simulation output for MIT campus has shown a dispersed distribution of student residence in all scenarios. This could be explained according to MIT campus size. As shown in Figure 1, MIT campus is considered smaller than the rest of the cases with fewer number of students. In such case, the difference between scenarios will be minimal. The number of students in such case would not create any difference in student occupation, or even they can be accommodated in dormitories if the resources of the university allow so. Additionally, unlike what was expected, the third scenario has not shown a high occupancy of students in most cases except for Ito campus due to its unique location. Nishi-Chiba and Sapporo campuses' maximum number of students per patch in the third scenario were mostly lower than or similar to the first and second ones, which was not expected. As, the third scenario asked agents to live within 5km from the campus and 2km from the nearest stations, which might seem like narrow conditions, but the results show otherwise. This could be explained according to the location of the campus according to the nearest railroad stations. For example, Nishi-Chiba and Sapporo campuses are in areas privileged with many railroad stations making the output for the first and third scenarios look the same. As both campuses are surrounded by railroad stations from all directions. On the other hand, Ito campus's third scenario output has shown the highest number of students leaving the system. As explained earlier, the suburban location of Ito campus and the tighten conditions of the third scenario limited the number of available locations for housing forcing more students to leave the system. Additionally, the second and fourth scenarios' simulation output report similar student distribution in Nishi-Chiba and Sapporo campuses. This also could be explained according to the location of the campus in relation to the surrounding stations. As, railroad stations are distributed in a circle-like pattern around Nishi-Chiba and Sapporo campuses making the distribution of students look the same in both scenarios. Furthermore, land prices for areas surrounding selected campuses have been downloaded from The Japanese National Land Survey Database to be projected with simulation outputs [25]. Resulted maps have shown that the closer the area to stations is, the higher the land value become. In turn, rent values in areas close to railroad stations would become more expensive than what most students can afford. Therefore, despite the convenience that it provides, the second scenario might not be suitable for many students. Moreover, locating a campus in an area privileged with railroad stations might benefit the university. However, it may make it challenging for students to find affordable housing options, such as the case in Nishi-Chiba and Sapporo campuses. Therefore, the location of a university campus should be decided bearing in mind the interests of the university as well as its students.

Although results proposed by the model are merely suggestions, the model still could be used by urban planners and investors as an urban planning tool to indicate the suitable location to build or invest in student-oriented housing market. The model could also be used by university administration to explore where university dormitories could be built to bring the convenience for students. The model also offers evidence that the location of the campus, according to the city as well as the surrounding railroad stations, and its size are two of the main factors that affect students' distribution significantly. Although the location of the campus and its size might be controlled by other factors including land availability, university resources, or city masterplan, housing policies adopted by the city where the campus is located can be adjusted to match the needs of students and the interest of the private sector. One of the most common student-oriented housing policies, especially in Europe, is building purpose-built student accommodation (PBSA) around university campuses. However, research have shown that PBSAs are not a sustainable solution, as they cause disruption in the space and increase studentification's negative impacts [26]. Although PBSAs are not common in Japan, as students depend heavily on the private sector, PBSAs have proven to only benefit students and landlords not the city. Therefore, student-oriented housing policies should be implemented in a subtle way. For example, instead of building entire accommodation built and promoted mainly for students which may cause segregation between them and original residents, it is advised to offer students suitable options to live with residents to achieve low student occupation and prevent studentification from escalating. For example, student-oriented housing policies should be encouraged to offer one room apartments, which is the most common type of apartments rented by students, in widespread buffer zones around campuses or railroad stations as proposed in the fourth scenario. Furthermore, most universities, especially in Japan, conduct apartment search orientation for students to help them find suitable accommodations. So, universities could partner with the private sector and city planning departments to encourage students to live in widespread buffer zones around campuses or railroad stations. Lastly, we can conclude that adopting such housing policies is only feasible through partnership between universities, stakeholders, and the private sector which has been extensively discussed through the literature [10].

## 4. CONCLUSION

Previous research has shown that the influx of students living around university campuses cause various spatial and social trends that may cause disruption in the space if left unplanned. Furthermore, students' decision on where to live around the campus is affected by many factors including proximity to campus and nearby stations, rent value, monthly allowance, and available amenities and services. So, it may seem difficult to ask students where to live because their needs and abilities may vary, but it is possible to predict where they might be living which is useful in establishing proper housing polices. Therefore, this paper used ABM as a simulation methodology to anticipate the distribution of students' accommodations based on three main factors: proximity to campus, proximity to nearby stations, and available housing locations. Simulation output has shown that:

1) Suburban campuses increase students' residential occupation due to the limited housing options which might intensify studentification impact unlike urban campuses.
2) Students' residential occupation is a factor in campus size, accessibility, as well as land value.
3) The location of the campus according to the city and the surrounding railroad stations in addition to its size are two of the main factors that significantly affect student housing occupation.

In conclusion, this paper has shown that there are two main factors that affect students' residential patterns around university campuses: campus size and its location according to the city as well as the surrounding railroad stations.

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