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https://hdl.handle.net/2324/5909041

出版情報：Bulletin of Geography. Socio-economic Series. 58, pp.75-96, 2022-11-18. Nicolaus Copernicus University
バージョン：

Bulletin of Geography. Socio-economic Series, No. 58 (2022): 75-96
http://doi.org/10.12775/bgss-2022-0035

BULLETIN OF GEOGRAPHY. SOCIO–ECONOMIC SERIES

journal homepages:
https://apcz.umk.pl/BGSS/index
https://www.bulletinofgeography.umk.pl/

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How to cite:
Mohammed A.M.S., Ukai, T. & Hall, M.W. (2022). University campuses' role in accelerating the natural urban transformation process. *Bulletin of Geography. Socio-economic Series*, 58(58): 75-96. DOI: http://doi.org/10.12775/bgss-2022-0035

Abstract. University campuses have proven to play a significant role in the productivity of cities due to their impact as knowledge and innovation hubs. Therefore, this paper examines the impact that building new campuses in suburban areas has, in order to see the extent to which a campus can affect the transformation process in its city. Kyushu University's Ito campus area was selected to be analysed using space syntax, spacematrix and the mixed-use index to see the impact caused by the campus from 1993 until 2017. The results show that, after Ito campus was established, urbanisation started to expand throughout the area, having previously been limited to accessible parts around major routes and stations. Therefore, the locating of a campus is considered to be a vital decision that needs to be taken with the engagement of the city, stakeholders and business owners to harness a successful campus–city relationship.

Article details:
Received: 11 March 2022
Revised: 14 July 2022
Accepted: 17 August 2022

Key words:
campus planning,
space syntax,
spacematrix,
mixed-use index,
urban morphology,
city urbanisation,
campus development

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1. Introduction

The relationship between university campuses and their respective cities is shaped by different factors, including the structure of academic activities, scientific projects, network platforms, social initiatives and educational programmes offered by the university. Innovative solutions produced by universities help the city to tackle different societal and economic challenges, which affect the city in direct and indirect ways (Den Heijer, 2011; Berg, 2021). In return, cities respond to the needs of students and staff by offering different types of services, convenient transportation, comfortable accommodation, affordable housing and ample amenities. Moreover, cities need to provide the required capacity of facilities to create an inspiring educational environment (Drucker & Goldstein, 2007; Fernndez-Maldonado & Romein, 2008). Therefore, the relationship between universities and cities is considered to be interrelated and connected, as cities need their universities to build their competitive profile and, in return, universities need their cities to satisfy their needs and requirements (Baltzopoulos & Broström, 2013). To get the most out of this dynamic relationship, universities tend to have a closer physical relationship with their respective cities due to the convenience that cities offer. However, due to high land prices and the expansion and globalisation of universities, new campuses are built on the outskirts of cities, which significantly affects the urban transformation process of cities' peripheries. Therefore, university campuses tend to have two main relationships with cities: a physical relationship and a functional one (Den Heijer & Magdaniel, 2018). The two relationships overlap, as campuses that exist near the core of the city benefit from the available variety of services and amenities. Conversely, campuses that are located away from the city tend to stimulate the urban transformation process of the city, resulting in the building of new facilities, railroad stations or housing complexes to respond to the emergent needs of students and staff.

1.1. The campus–city physical relationship

The campus–city physical relationship refers to the topological location of the campus relative to the city. Campuses can be gated within the city, integrated with the city, or located outside the city. Additionally, the spatial configuration of the campus according to the network of the city defines its topological relationship as well. Cities can be equal or disjointed, and can touch, contain or overlap the campus, depending on the urban network that connects the two (Magdaniel et al., 2018). Due to the expansion of universities, their physical relation with the city changes over time. Newly built campuses increase the number of students and staff, which results in newly built amenities that form new city centres. Therefore, universities are considered to be extensive landholders in the morphological structure of the city (Larkham, 2000). Although some universities try to be self-sufficient by offering needed facilities and services through their campuses, higher degrees of independence results in higher costs, meaning that the provision of services competes against educational and research objectives for resources. Therefore, the more dependent the campus is on the city, the more efficient their relationship becomes. However, the proximity to university campuses may come with downsides. Research has shown that areas around campuses are more vulnerable to crime than are campuses in isolation, as offenders seek victims in areas of high resident throughput such as student neighbourhoods (Cohen & Felson, 1979; Fox & Hellman, 1985; Weisburd et al., 2012; Cundiff, 2021).

Additionally, the physical connection between university campuses and the city plays a major role in the openness of the university and students' social life. Universities that exist on the outskirts of their respective cities need to generate their own social life to satisfy their students' needs (Hebbert, 2018). Moreover, the more open the campus is to the city, the higher its impact on its surroundings becomes. Research has shown that residents' perception of campus publicness is strongly connected to its physical relationship with the city centre. The campus–city-centre physical relationship generates a certain ecology based on emotions, actions and forms of publicness that affect residents' perceptions of surrounding urban settlements such as university campuses (Adhya, 2009). In addition, the campus–city physical relationship has proven to affect students in numerous ways. Research has shown that students' space needs are affected by the integration of the campus with the city, as the more connected the campus with the city is, the easier it is to find spaces for group activities (Kim et al., 2018). Furthermore, the location of the campus has been shown to affect students' academic performance, which has been reported from records of attendance and school climate (Hopson & Lee, 2011; Thapa et al., 2013; Berkowitz et al., 2016; Hamlin, 2020). Interestingly, research on the location of the campus and the amount of research funds granted has shown that universities located away from Beijing city gain fewer research grants than do closer universities, which is referred to as “capital advantages” (Li & Wang, 2020). Moreover, the location of the campus according to the surrounding urban density has been shown to affect the availability and quality of wireless network and data transmission on campus (Karpińska & Kunz, 2021). All this shows that the extent of the physical relation between the campus and the city can affect the university and its surrounding environment as well.

1.2. The campus–city functional relationship

The campus–city functional relationship refers to the available types and range of services and amenities that can benefit both. Campuses and their cities can offer a variety of services and functions, including retail and leisure, infrastructure, related businesses, residential facilities and academic services. These functions can describe how dependent a campus is. Therefore, the building of a new campus is usually accompanied by a rapid transformation of the surrounding environment (Mohammed & Ukai, 2022). Moreover, due to the high capacity of transporting students and staff from campuses, new stations are built, as public transport has shown to be students’ preferred mode of transportation (Daggett & Gutkowski, 2003; Etminani-Ghasrodashti et al., 2018). Furthermore, high concentrations of students result in high demand for accommodation that cannot be fulfilled by institutions alone. Therefore, real-estate agencies tend to cover students’ housing needs, which accelerates the urban change taking place (Moos et al., 2019; Rugg et al., 2000). Moreover, a high concentration of students results in noticeable social, cultural and economic changes that could be either positive or negative, depending on the city (Macintyre, 2003). Student areas may also result in conflicts between residents and students due to noise, vandalism or minor crimes, which may force many residents to move to other neighbourhoods with fewer students (Allinson, 2006; Selwyn, 2008). However, research has shown that students’ existence in a neighbourhood can also be beneficial for crime deterrence through citizen participation (Mohammed & Hirai, 2021; Sayed, 2021). Moreover, using the maslin multi-dimensional matrix, recent research has shown that the revitalisation of urban space should be socially inclusive (Starczewski et al., 2022). Therefore, students’ social engagement can prevent any form of segregation between original residents and students.

To accelerate universities’ economic impact, cities need also to harness the appropriate environment to attract universities’ spin-offs to invest in their local economies. This could be achieved by offering adequate incentives, accommodation, tax-waivers and land to adopt successful start-ups (Geenhuizen & Soetanto, 2012). By doing so, universities become one of the main drivers behind the revitalisation and development of cities, as described by Stoker et al. (2015). The development brought by universities to the city is considered to be a by-product and one of the three main missions of a university. The two first missions are the basic missions of any university: scientific research and education. However, the third mission is widening the diffusion brought by the university outside its borders (Moscati et al., 2010). This shows that the interaction between a university and its city can happen on many different levels, ranging from local community engagement to citywide engagement, which could be useful for both a university’s capacity and a city’s economy (Benneworth et al., 2010). Therefore, we can conclude that universities can contribute to the urban development and the urban landscape of innovation in the city as well (Borsi & Schulte, 2018). This also presents the depth and overlapped connection between campuses and cities that can benefit or harm both, depending on the nature of the urban transformation process taking place.

1.3. The theory of the natural urban transformation process

The theory of the natural urban transformation process interprets urban change as a process that transforms a deserted area into an attractive one (Van Nes & Ye, 2014). This transformation process occurs in a natural way as streets with high values of integration tend also to have higher degrees of commercial activities (Van Nes & Yamu, 2021). Therefore, highly integrated streets aggregate urban density, which in turn stimulates urban land-use mix. This results in a noticeable increase in land-use mixes and building density that occur naturally over long periods of time. Previous research has shown that assessing the correlation between the transformation that has occurred in urban street network, building density and mixed uses would help in assessing the degree of urbanity (Van Nes et al., 2012; Ye & Van Nes, 2013). However, the impact of new urban settlements on accelerating this natural urban transformation process has been only moderately discussed in previous research. Therefore, this paper is investigating the role of newly built large urban settlements (university campuses as a case study) in accelerating the transformation process. Previous literature has shown the depth and intercorrelation between campuses and cities. Moreover, universities have proven to play an auxiliary role in the urban growth of their respective cities (Molotch, 1976). Therefore, building new campuses would be expected to quicken the pace of the urban transformation process. This research aims to examine the validity of such a hypothesis. Therefore, a newly built campus of Kyushu University is selected to be examined using different urban analytics quantitative methods. Ito campus was selected due its unique location in a suburban area that is far from Fukuoka City and is considered to be an undeveloped area, which makes it easier to visualise the impact of the campus on the urban transformation process of this part of the city.

2. Materials and methods

To assess the degree of urbanity caused by a university campus's existence, a mix of different methodologies has been used to evaluate the urban morphology and street network of the area under study. Table 1 shows in detail the different materials and methods used in this paper.

2.1. Study area

Ito campus is the newest campus of Kyushu University, which was built on the outskirts of Fukuoka City in the western part of Kyushu Island, Japan. The Engineering School was the first school to be built on Ito campus (in 2005) and, soon thereafter, other schools started to move out from Kyushu University's original Hakozaki campus to Ito campus. Once the move was complete (by the end of 2018), it was the largest and most advanced campus in Japan (Kyushu University Public Relations, 2021). It is also an urban open campus built on an area of 2,717,130 m^2 in the Nishi district, which contains nine different schools. In order to examine the transformation that occurred by the campus in the area, a buffer area of 5-km radius with Ito campus as the centre was selected for the morphological analysis to include surrounding major streets, main railroad stations and local centres. Moreover, data on building heights and uses for the area of the study in 1993, 2003 and 2017 were provided by Fukuoka City Urban Affairs Bureau. Since 1985, the Fukuoka City Urban Affairs Bureau has conducted surveys every five years to collect different types of socio-economic data that are available to researchers upon request. These data are released in the following year after the five-year interval period. Furthermore, urban street network

Table 1. Materials and methods

Method	Platform	Processed Data			
		Data Type	Data Collection Time	Data Source	Data Delivery
Space Syntax	Space Syntax Toolkit (QGIS)	Street network for 5-km radius buffer area around Ito campus	Late 1980s (1982–86)	Ima Mukashi Map Database	Drawn manually
			Early 2000s (1991–2000)	Ima Mukashi Map Database	
			Early 2020s (2020)	Open Street Map (OSM)	
Spacematrix	Spatial Analyst Tools (ArcGIS)	Footprint area and number of floors for buildings in 5-km radius buffer area around Ito campus	1993	Fukuoka City Urban Affairs Bureau	Provided on request
			2003		
			2017		
Mixed-Use Index (MXI)	Spatial Analyst Tools (ArcGIS)	Footprint area and uses of buildings in 5-km radius buffer area around Ito campus	1993	Fukuoka City Urban Affairs Bureau	Provided on request
			2003		
			2017		

Source: Authors' draft

data were retrieved from the Open Street Map and Ima Mukashi Map databases to get old maps of Fukuoka City in the late 1980s, early 2000s and early 2020s (OSM Foundation, 2020; Kenji Tani, 2021). The availability of a wide range of data over a 24-year period made it possible to assess and correlate the urban transformation process using a variety of urban analytical quantitative methodologies such as space syntax, spacematrix and mixed-use index.

2.2. Space syntax

Space syntax is a methodology for urban network analysis that has been established and developed over years of extensive research in the Bartlett School of Architecture at University College of London. Space syntax consists of analytical techniques that analyse street networks based on the theories established by Bill Hillier (Hillier & Hanson, 1989; Hillier, 2007). The spatial configuration of a space has proven to define the encounters and interaction of people in the space (Dawson, 2003). Therefore, space syntax analyses the social structure of spaces through its spatial configuration. This also means that spaces with higher degrees of integration will have more potentiality for interaction between people. In order to represent the spatial configuration of the spaces, streets need to be illustrated using axial lines, which are the fewest and longest lines that users can see or move through. Then, these lines are broken into smaller sets of segments or perceivable observations to be analysed using space syntax techniques, which is known as "angular segment analysis" (Penn, 2003). Different syntactic measures could be extracted from angular segment analysis, such as integration, which is defined as to-movement potential that could reflect the presence of people in a space based on the activity.

There are two different values of integration: global integration and local integration. Global integration is the integration measured overall by the system or area of study. On the other hand, local integration is the integration measured in a specific radius of the system. The correlation between global and local integration shows that the system is well integrated on macro and micro scales (Hillier, 2008). Axial lines for the area of study were manually drawn using Quantum Geographical Information System (QGIS) software for street networks in the late 1980s, early 2000s and early 2020s. Then, axial maps were converted to segment maps using space syntax toolkit (SST) in QGIS. Segment maps were verified to avoid any errors before the angular segment analysis. Moreover, the 5-km radius buffer area taken for the study helped to cover a large area surrounding Ito campus, which helps in avoiding the edge effect (Gil, 2015). Global integration (Rn) and local integration maps (R800) were calculated to compare between the to-movement potential on global and local scales. An 800-m radius was chosen for the local integration map to measure integration in a 10-minute walking distance. Both integration maps for each period were rasterised by a cell size of 100 m × 100 m, then merged by a matrix of 3×3 using spatial analyst tools in ArcGIS software to visualise areas with high values of integration in high and low metric radius (ESRI, 2001). By doing so, areas with high movement potentiality can be easily mapped to examine places where social encounters were highly expected in the street network in the late 1980s, early 2000s and early 2020s.

2.3. Spacematrix

Spacematrix is defined as a multi-variable index that is used to correlate urban density with urban forms in a quantitative way. Although some researchers have shown the independency of urban density and building types, density is still used as one of the pragmatic necessities in urban practice (Alexander, 1993; Forsyth, 2003). Therefore, Spacematrix is used to obtain a clear definition of urban density and to correlate it with urban forms so as to be able to visualise the morphology of the space. In spacematrix, the floor space index (FSI) is correlated with ground space index (GSI) to have nine different classifications of urban density and form. Building density is categorised into low-rise, medium-rise and high-rise buildings. On the other hand, building types are classified into point-type, strip-type and block-type buildings (Fig. 1). Other measurements such as open space ratio and number of layers (floors) can be retrieved from spacematrix as well. The use of Geographical Information System Software such as ArcGIS and the availability of building plot sizes and number of floors made it easy to calculate FSI and GSI values. In this research, values of spacematrix are calculated on the urban fabric level including streets and paths using the following equations (Berghauser & Haupt, 2010):

$$FSI_f = F/A_f$$

Where F is the sum of floors area in square metres and A_f is the area of urban fabric in square metres.

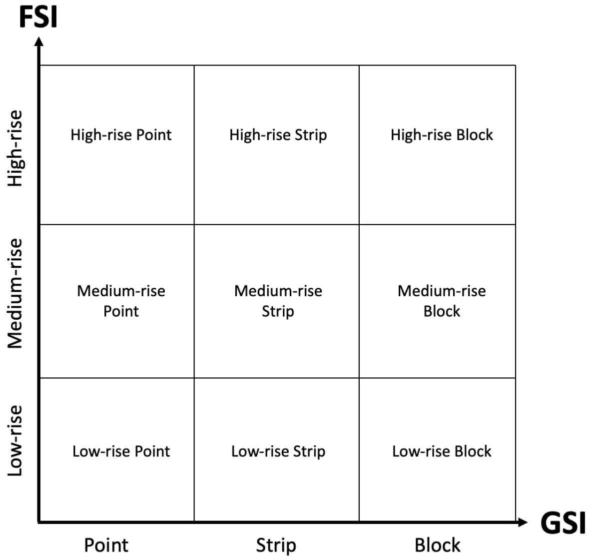

Fig. 1. Simplified illustration of spacematrix using floor space index (FSI) and ground space index (GSI)
Source: Authors' illustration based on Van Nes & Yamu, 2021; Berghauser & Haupt, 2010

$$GSI_f = B/A_f$$

Where B is the building footprint in square metres and A_f is the area of urban fabric in square metres.

Other measurements such as open space ratio (OSR) and the average number of layers (L) can also be calculated from the following equations:

$$L = FSI_f/GSI_f$$

$$OSR_f = (1- GSI_f) / FSI_f$$

Values of FSI and GSI were calculated for the area of study using the buildings' database of 1993, 2003 and 2017. Then, FSI and GSI maps for each period were rasterised by a cell size of 100 m × 100 m, then merged using raster calculator and spatial analyst tools in ArcGIS software to produce spacematrix maps. A comparison between spacematrix maps for 1993, 2003 and 2017 can show that the transformation happened in the area over a 24-year period to examine where urbanisation has been accelerating and its relation to the campus development. Based on the natural urban transformation process, high integration values of streets can aggregate building types and density over time. Therefore, spacematrix is used to examine the validity of this phenomena and to evaluate the morphological growth of the area after Ito campus had been constructed.

2.4. Mixed-use index (MXI)

Mixed-use Index (MXI) is another quantitative approach of urban morphology. MXI is used to distinguish mono functionality from bi-functionality and multi-functionality of urban blocks (Van den Hoek, 2010). Buildings and urban blocks with one functionality only, such as housing (dwellings, apartments, housing complexes), amenities (shopping centres, recreational facilities) and working (warehouse, factories, industrial facilities, agricultural facilities) are defined as mono-functional. Meanwhile, a mix of two of those functionalities is defined as bi-functional, and a mix of the three functionalities is defined as multi-functional (Fig. 2). The MXI model presents the degree of functionalities for buildings and urban blocks based on the percentage of each type of functionality that exists in the urban fabric. In some cases, it is challenging to assign building usage to one of the three categories. For example, coffee shops and leisure places could be considered as a space for amenities or working depending on the user and the context. Although MXI has its shortcomings, it has been used by urban planners to present a holistic view of the degree of functionality for each block (Van Nes et al., 2012). MXI was calculated for the area under study in 1993, 2003, 2017, then presented as a raster map by a cell size of 100 m × 100 m using raster calculator and spatial analyst tools in ArcGIS (ESRI, 2001). A comparison between the maps of the three periods can help examine the validity of the natural urban transformation phenomena and the impact of Ito campus in aggregating the mixed-use functions of its surroundings.

2.5. The combination of space syntax, spacematrix and MXI

Using the framework introduced by Van Nes et al. (2012), Van Nes & Ye (2014) and Ye & Van Nes (2013), the resultant raster maps of space syntax, spacematrix and MXI were aggregated and combined using spatial analyst tools in ArcGIS software to provide an insight into how the urban transformation process occurred over a 24-year period. This technique was introduced to examine the degree of influence that the urban network can bring to the morphology of the space (Van Nes et al., 2012). This technique also allowed for measuring the degree of urbanity and maturation of cities to see how cities evolve and transform over time (Ye & Van Nes, 2013). Therefore, this combination of methods was used to measure the degree of urbanity

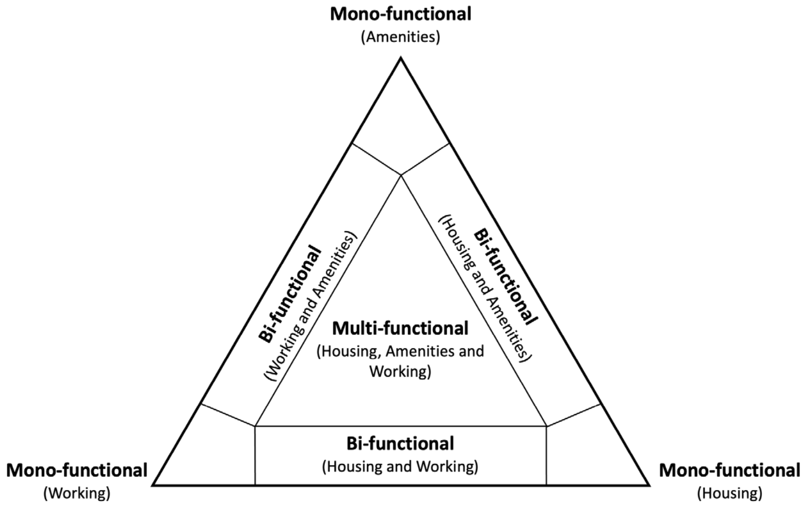

Fig. 2. Simplified illustration of MXI model
Source: Authors' illustration based on Van Nes & Yamu, 2021; Van den Hoek, 2010

in the Ito campus area and how it changed after the campus was built. This also allows the prediction of future transformation changes that could be used as a guide for decision-makers and stakeholders. Ye and Nes have shown seven different categories that can be used to classify the outcome of combining space syntax results with spacematrix and MXI (Ye & Van Nes, 2013). This classification depends on the values of each method varying between suburban, low-urban, in-between (low), in-between (middle), in-between (high), middle urban and highly urban areas.

Due to the nature and type of data of each method, raster maps are found to be suitable for aggregating the three methods. Space syntax results are represented using lines. On the other hand, spacematrix and MXI results are represented using polygons. Therefore, converting vector maps of the three methods to raster maps is found to be suitable for aggregating the outcome. A cell of 100 m × 100 m was selected for all maps to provide more precise results. Furthermore, the 100 m × 100 m cell was found to be suitable to cover most of the largest buildings and their neighbouring streets. Values of space syntax, spacematrix and MXI have been classified as shown in Table 2, and then aggregated to examine the degree of urbanity according to Table 3. Aggregation was done by calculating the maximum integration values of segments within a cell for space syntax maps. For spacematrix, aggregation was done by calculating the sum of floor areas and footprints divided by the area of the cell. For MXI, the percentage of three functions was calculated for each cell. Furthermore, space syntax values were calculated for available street network maps in the late 1980s, early 2000s and early 2020s. However, because socio-economic data are released in the following year after every five-year interval, space syntax maps of the late 1980s, early 2000s and early 2020s have been merged with spacematrix and MXI values of 1993, 2003 and 2017 respectively. Therefore, each socio-economic database is merged with the most relevant available street network map. Figure 3 shows the research methodology schema in a simplified way.

Furthermore, due to the nature of combining different types of methodologies and the classification method used for cell values, spacematrix and urbanity results shown in the next section are considered as relative values, not absolute ones. This means that the value of a cell cannot be compared with itself in previous years because it is relative to other cells in the one system. However, values can be compared within the same system of the same year only. Therefore, a cell could be classified as having a high value in a year and a low value in the following one depending on the relevance of the value of the cell to other cells in the same system. However, the classification criteria shown in Table 2 and Table 3 help to categorise cells values according to each other in the same system for the same year. It also helps to have an overview of high, medium and low values distribution all over the system to gain a holistic view of the area and how the situation changed over time. Therefore, the next section shows the results of the analysis in a descriptive way instead of a numerical one to explain where and why different values have appeared and changed over time.

Table 2. Classification of space syntax, spacematrix and MXI values

Method	Classification of values
Space Syntax	L = low GI and low LI, medium GI and low LI, low GI and medium LI M = high GI and low LI, medium GI and medium LI, low GI and high LI H = high GI and medium LI, high GI and high LI, medium GI and high LI
Spacematrix	L = low-rise point, low-rise strip, mid-rise point M = low-rise block, mid-rise strip, high-rise point H = mid-rise block, high-rise block, high-rise strip
MXI	L = mono functional M = bi-functional H = multi-functional

Source: Authors' draft based on the findings of Ye & Van Nes, 2013
L = low values, M = Middle Values, H = High Values
LI = Local Integration, GI = Global Integration

Table 3. Degree of urbanisation classified according to space syntax, spacematrix and MXI values

Degree of Urbanity	Values from space syntax, space matrix and MXI
Suburban areas	L/L/L, M/L/L, L/L/M, L/M/L
Low urban areas	L/M/M, M/L/M, M/M/L
In-between areas (low)	H/L/L, L/H/L, L/L/H
In-between areas (middle)	H/M/L, M/H/L, L/M/H, H/L/M, L/H/M, M/L/H
In-between areas (high)	H/H/L, H/L/H, L/H/H
Middle urban areas	M/M/H, M/H/M, H/M/M, M/M/M
Highly urban areas	H/H/H, H/M/H, M/H/H, H/H/M

Source: Authors' draft based on the findings of Ye & Van Nes, 2013
L = low values, M = middle values, H = high values

3. Results

3.1. Space syntax analysis results

Space syntax results have shown a significant change in the street network structure since the late 1980s. In the late 1980s, high values of global and local integration were concentrated around Route 202, Route 567 and Route 85. Route 202 is one of the main streets that connects different parts of Fukuoka city with each other and with Itoshima City. Therefore, many railroad stations are located nearby, such as Susenji station. Moreover, Route 567 is intersected with Route 202 and connects it with the far west part of the city. Route 85 is intersected by Route 567 in the middle of it and connects Fukuoka City with Itoshima City. Therefore, these three main routes are expected to be well integrated with the surrounding network due to their major role in connecting different parts of the city. However, in the early 2000s, the street network changed, and high integration values are located at the end of Route 202, near the coast and around Susenji station, in addition to some high values on Route 567 and Route 85. On the other hand, in 2020, high values of integration were scattered all around the area; starting from Route 202 to Route 567 where the campus is located. Moreover, new railroad stations such as Kyudai Gakkentoshi station

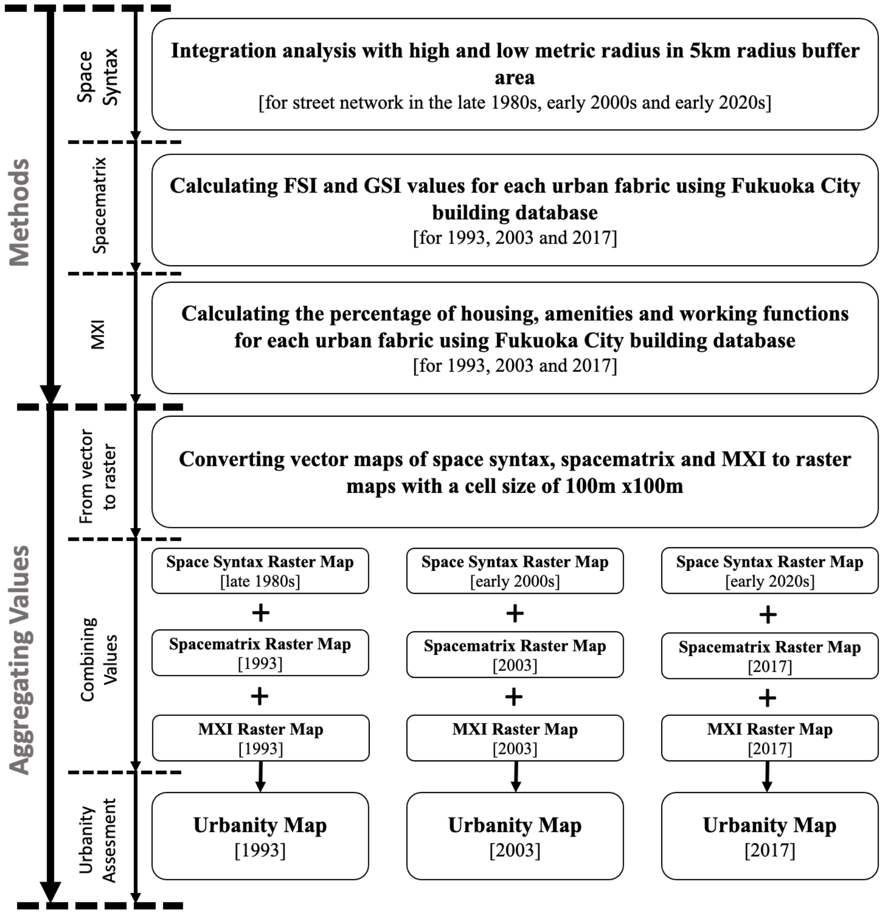

Fig. 3. Research Methodology Schema
Source: Authors' illustration

were built concurrently with the opening of the new campus in 2005 (Fig. 4).

We clearly see that the number of cells of high global and local integration decreased from 380 cells in the late 1980s to 251 cells in the early 2000s. However, after the opening of the campus and the building of new railroad stations, the structure of street network changed dramatically, and the number of cells of high global and local integration increased to 404 cells by 2020 (Fig. 5). Moreover, the total number of cells reflects the scale of development that has happened in the area since the late 1980s, as the number of cells increased from 2,187 in the late 1980s to 2,365 in 2020 (Table 4). Nishi district, where the campus is located, used to be recognised as an agricultural area with an abundance of fields and hillside forests. Therefore, there was no need to invest in the street network and infrastructure of the area from the late 1980s to the early 2000s. However, the construction of the campus brought more attention to the area, which helped it to be more connected and well-integrated with the surroundings. This can be clearly seen through the expansion of red cells from Route 202 to the location of the campus (Fig. 6). This also reflects the impact and possibilities that the campus has brought to the area and the surroundings.

3.2. Spacematrix analysis results

The spacematrix results show that low-rise point cells have been dominant in the area since 1993. In 1993, Route 202 recorded some low-rise strip, mid-rise point and mid-rise strip cells. Moreover, mid-rise point and strip cells were concentrated mainly around Susenji station and some part at the end of Route 202. In 2003, there was a noticeable increase in the number of low-rise strip cells around Susenji station and along Route 202. However, there was a decrease in the number of mid-rise strip cells, as the number of cells decreased from 67 cells in 1993 to 32 cells in 2003 (Fig. 7). This shows that urban density started to decrease gradually along Route 202. In 2017, there

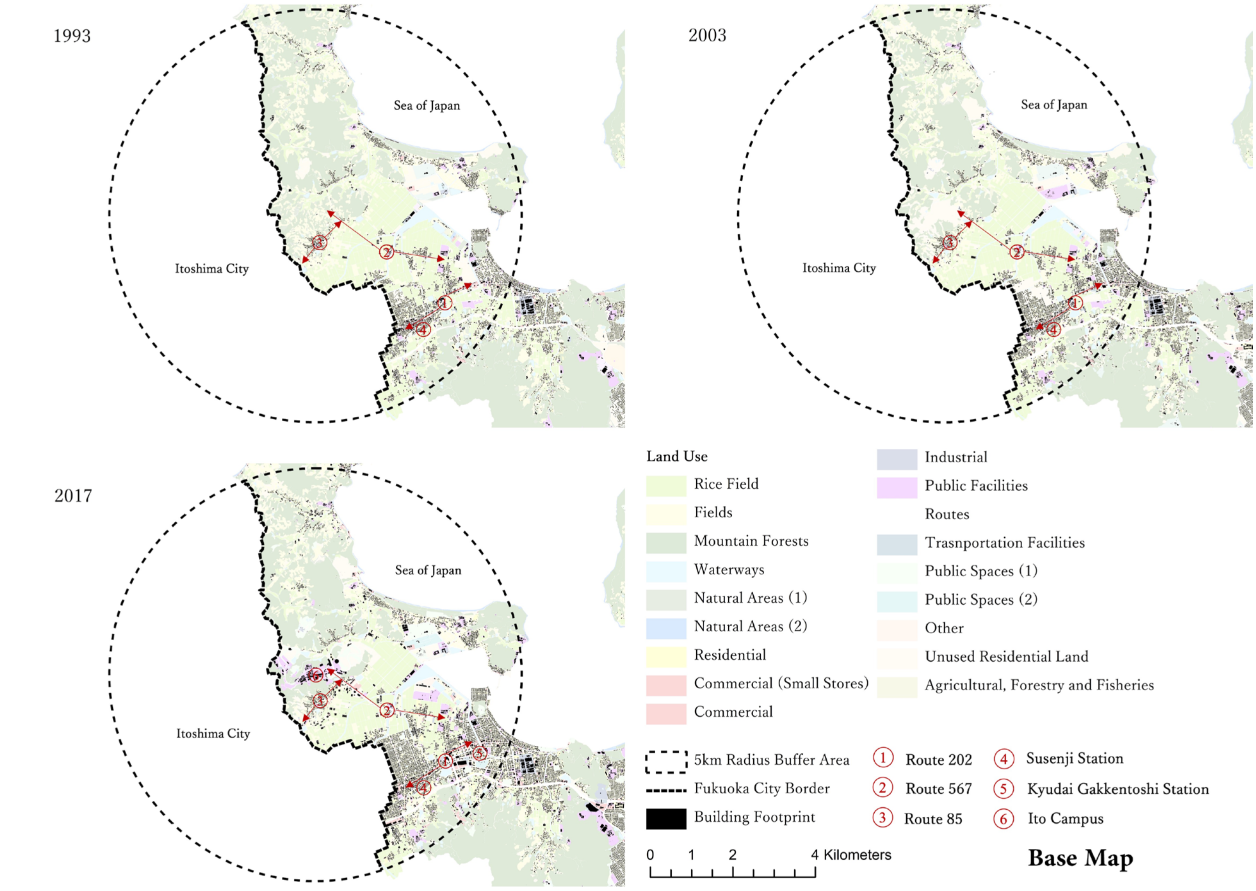

Fig. 4. Base Map for study area
Source: Authors' illustration

was a remarkable increase in the urban density of the area along Route 202 and around Susenji and Kyudai Gakkentoshi stations. Moreover, mid-rise block, high rise strip and high-rise block cells appeared for the first time in the area around the campus. Furthermore, low-rise strip cells started to sprawl from the area around Route 202 to the area where the campus is located (Fig. 8). This shows that railroad stations near to Route 202 and the campus work as a nodal that accelerates the increase in urban density between them. This also reflects the impact of Ito campus on the urban density in the area, especially after a noticeable decrease in 2003.

3.3. MXI analysis results

Mixed-use index analysis has shown that the area has had a mix of mono-, bi- and multi-functionalities since 1993. However, in 1993, the area was occupied mainly by mono housing uses. In 2003, the area started to include more bi- and multi-functionalities, but mono housing remained as the dominant type of building use in the area. In 2017, there was a noticeable balance of building uses, as shown in Fig. 9. From 1993 until 2017, mixed-use buildings existed near Susenji station and along Route 202. Moreover, bi-functional buildings existed along Route 567 – especially near to its intersection with Route 202. However, in 2017, a cluster of bi-functional buildings started to appear near to the location of the campus – especially along Route 85. This shows that the distribution of building uses started to spread in different parts of the area after being limited to the area near Route 202 or beside the railroad stations. Furthermore, the area near the seashore started in 1993 to host different types of mixed uses. Mixed uses near to Route 202, the location of the campus and the seashore could be visualised as three points of a triangle that have the potentiality to host more mixed uses in the future, as the area started to get more multi-functional in three different nodals instead of being concentrated in one location (Fig. 10). Despite the area near the seashore having started to include mixed-use buildings before the campus existed, the opening of the campus helped create a new cluster of mixed uses that more

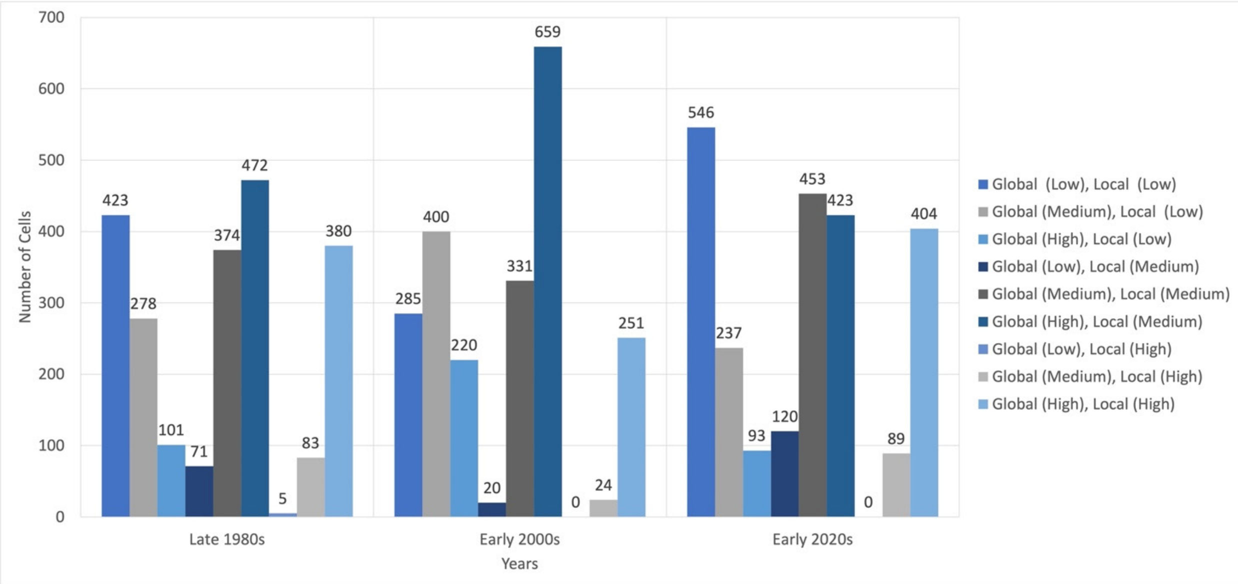

Fig. 5. Change in number of cells according to integration values classification
Source: Authors' illustration

Table 4. Number of cells in space syntax, spacematrix, MXI and urbanity maps

Method	Years	Classification	Number of Cells	Total Number of Cells
Space Syntax (Integration Values)	Late 1980s	Global (Low), Local (Low)	423	2,187
		Global (Medium), Local (Low)	278	
		Global (High), Local (Low)	101	
		Global (Low), Local (Medium)	71	
		Global (Medium), Local (Medium)	374	
		Global (High), Local (Medium)	472	
		Global (Low), Local (High)	5	
		Global (Medium), Local (High)	83	
		Global (High), Local (High)	380	
	Early 2000s	Global (Low), Local (Low)	285	2,190
		Global (Medium), Local (Low)	400	
		Global (High), Local (Low)	220	
		Global (Low), Local (Medium)	20	
		Global (Medium), Local (Medium)	331	
		Global (High), Local (Medium)	659	
		Global (Low), Local (High)	0	
		Global (Medium), Local (High)	24	
		Global (High), Local (High)	251	
	Early 2020s	Global (Low), Local (Low)	546	2,365
		Global (Medium), Local (Low)	237	
		Global (High), Local (Low)	93	
		Global (Low), Local (Medium)	120	
		Global (Medium), Local (Medium)	453	
		Global (High), Local (Medium)	423	
		Global (Low), Local (High)	0	
		Global (Medium), Local (High)	89	
		Global (High), Local (High)	404	

Spacematrix	1993	Low-rise Strip	1,036	1,209
		Low-rise Block	98	
		Mid-rise Point	0	
		Mid-rise Strip	6	
		Mid-rise Block	67	
		High-rise Point	2	
		High-rise Strip	0	
		High-rise Block	0	
		Low-rise Strip	0	
	2003	Low-rise Strip	1,170	1,394
		Low-rise Block	180	
		Mid-rise Point	0	
		Mid-rise Strip	6	
		Mid-rise Block	32	
		High-rise Point	6	
		High-rise Strip	0	
		High-rise Block	0	
		Low-rise Strip	0	
	2017	Low-rise Strip	1,296	1,613
		Low-rise Block	272	
		Mid-rise Point	4	
		Mid-rise Strip	3	
		Mid-rise Block	32	
		High-rise Point	3	
		High-rise Strip	0	
		High-rise Block	2	
		Low-rise Strip	1	
Mixed-Use Index (MXI)	1993	Mono Housing	464	1,209
		Mono Amenities	63	
		Mono Working	160	
		Bifunctional H+A	179	
		Bifunctional H+W	183	
		Bifunctional A+W	13	
		Mix 10% A+H+W	131	
		Mix 20% A+H+W	15	
		Mix 30% A+H+W	1	
	2003	Mono Housing	367	1,393
		Mono Amenities	85	
		Mono Working	256	
		Bifunctional H+A	168	
		Bifunctional H+W	288	
		Bifunctional A+W	24	
		Mix 10% A+H+W	183	
		Mix 20% A+H+W	19	
		Mix 30% A+H+W	3	
	2017	Mono Housing	324	1,612
		Mono Amenities	130	
		Mono Working	339	
		Bifunctional H+A	210	
		Bifunctional H+W	310	
		Bifunctional A+W	47	
		Mix 10% A+H+W	224	
		Mix 20% A+H+W	22	
		Mix 30% A+H+W	6	

		Suburban Areas	369	
		Low Urban Areas	102	
		In-between Areas (Low)	225	
	1993	In-between Areas (Middle)	184	987
		In-between Areas (High)	68	
		Middle Urban Areas	22	
		High Urban Areas	17	
		Suburban Areas	379	
		Low Urban Areas	135	
		In-between Areas (Low)	261	
Urbanity	2003	In-between Areas (Middle)	257	1,161
		In-between Areas (High)	111	
		Middle Urban Areas	6	
		High Urban Areas	12	
		Suburban Areas	508	
		Low Urban Areas	124	
		In-between Areas (Low)	267	
	2017	In-between Areas (Middle)	337	1,399
		In-between Areas (High)	144	
		Middle Urban Areas	12	
		High Urban Areas	7	

Source: Authors' draft

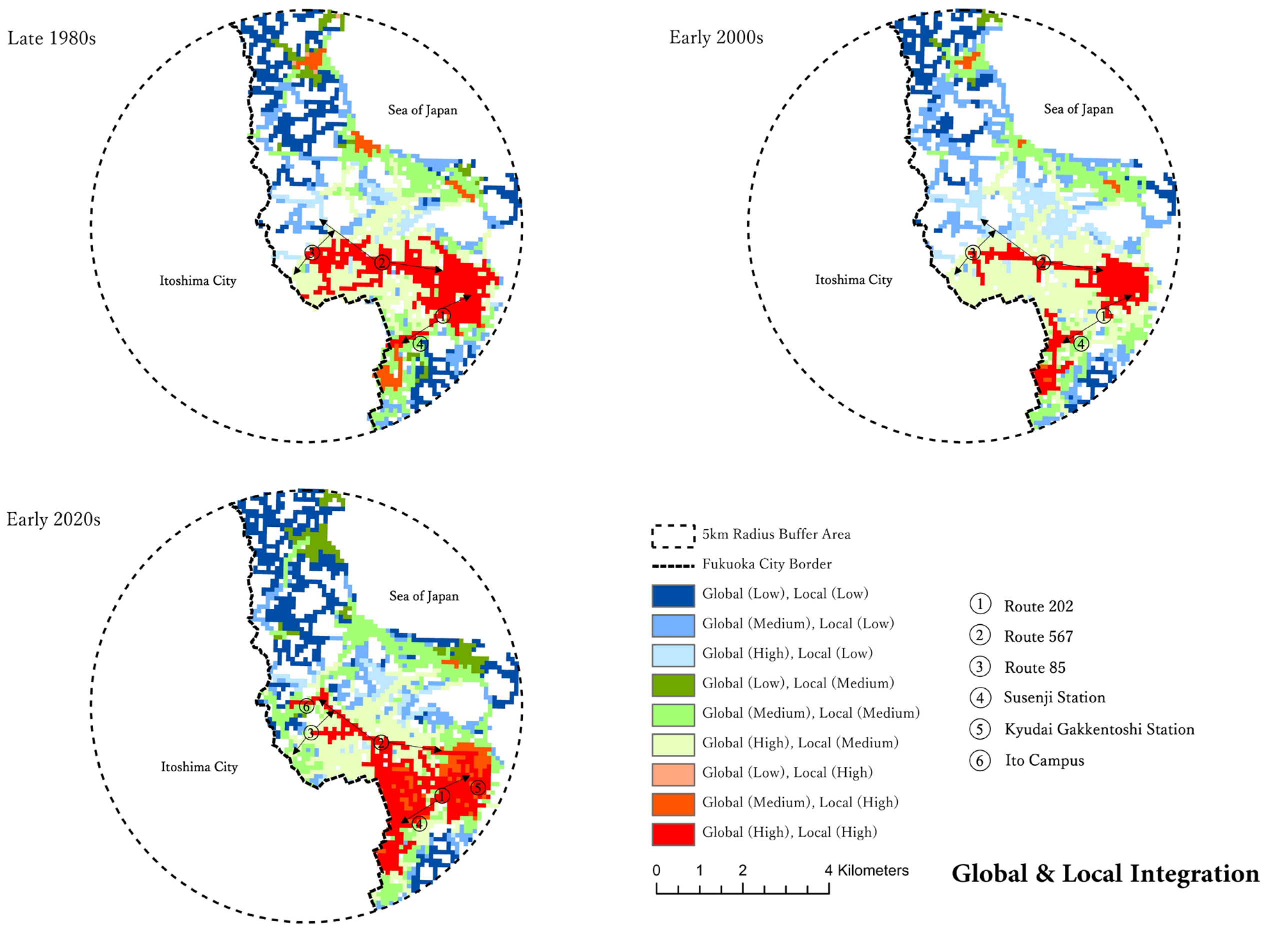

Fig. 6. Global and Local Integration Maps
Source: Authors' illustration

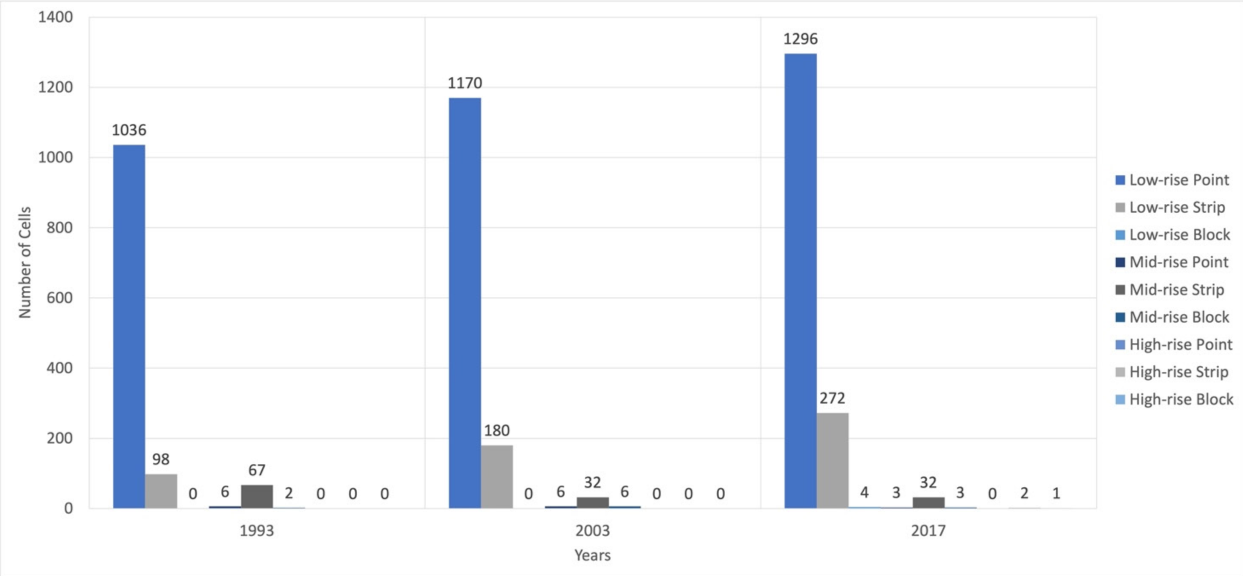

Fig. 7. Change in number of cells according to spacematrix classification
Source: Authors' illustration

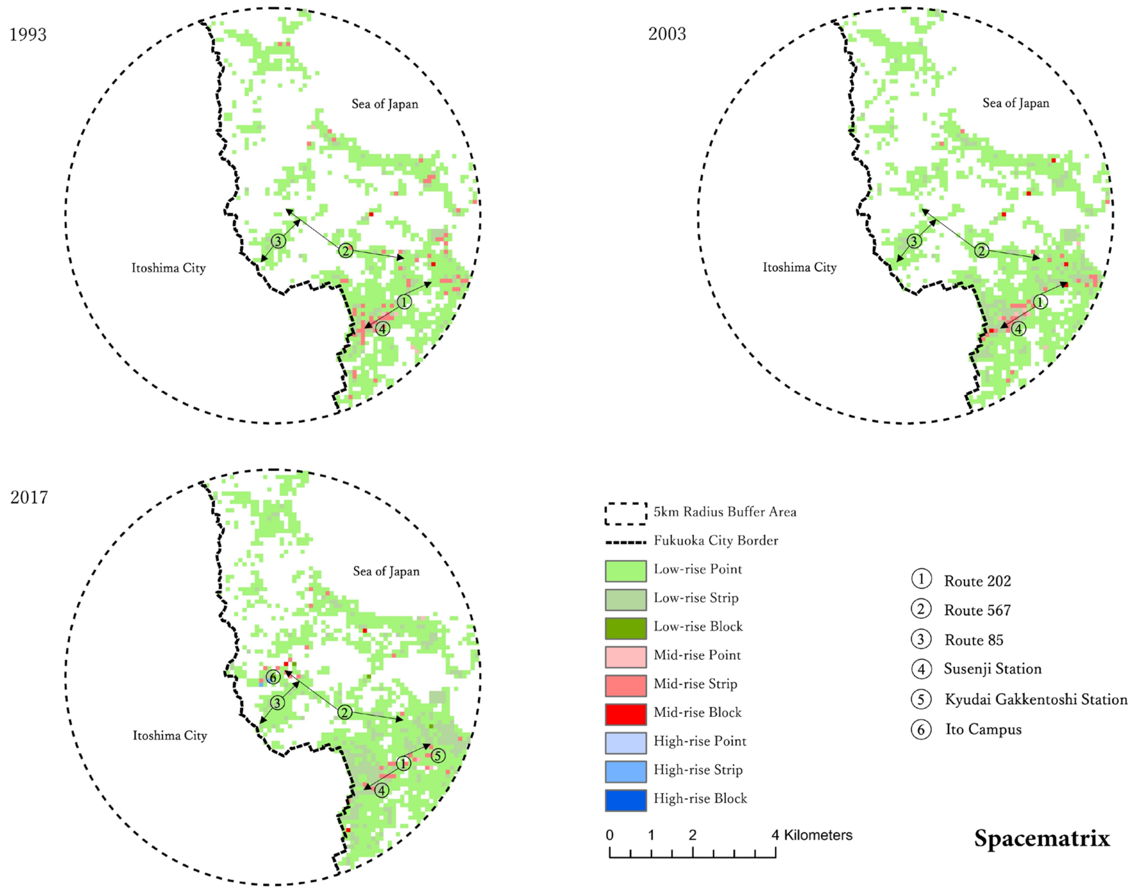

Fig. 8. Spacematrix maps
Source: Authors' illustration

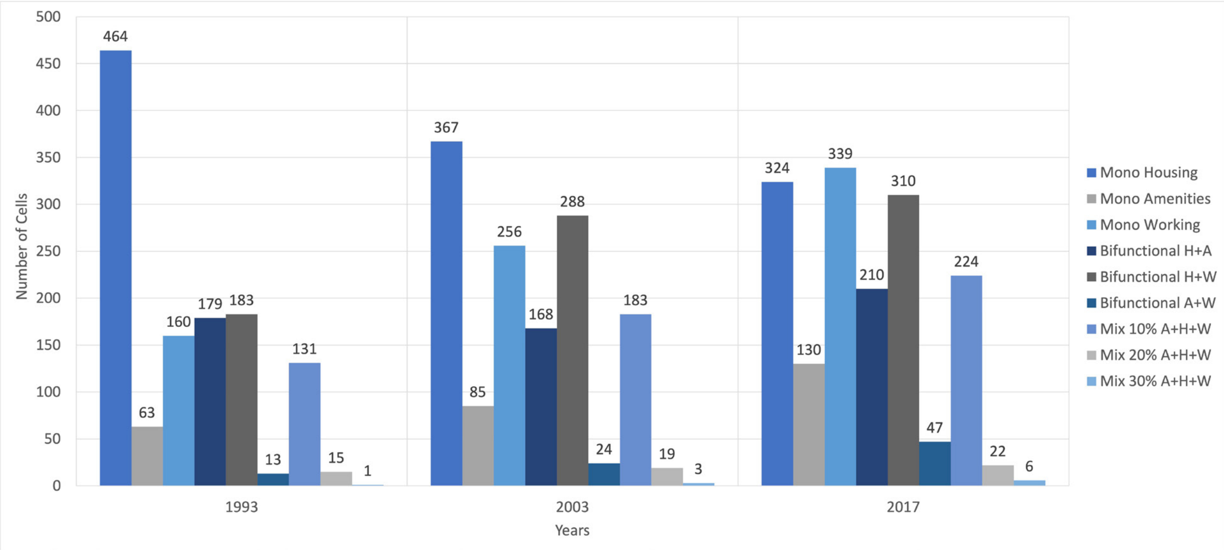

Fig. 9. Change in number of cells according to MXI classification
Source: Authors' illustration

consistently accelerates the expansion of the natural urban transformation process.

3.4. Combining space syntax, spacematrix and MXI results (urbanity)

By combining the results of space syntax, spacematrix and MXI analyses, a different degree of urbanisation could be assessed based on the natural urban transformation process, as explained earlier. The combining results show that most cells were considered to have low values of urbanity in 1993. The situation had changed little by 2003, except for a slight increase in in-between (middle) cells. However, in 1993 and 2003, most of the cells with high values of urbanity existed along Route 202 and Susenji railroad station. However, in 2017, there was a noticeable change in the degree of urbanity all over the area. In-between (high) and middle urban values were recorded around the location of the campus – especially near Route 85. Moreover, high values of urbanity were recorded around Kyudai Gakkentoshi station. There is also a noticeable sprawl of urbanisation developing from the area around railroad stations and Route 202 (Fig. 11). Furthermore, there is a significant increase in the number of cells with in-between (middle, high), middle and high values, as the number increased from 291 cells in 1993 and 386 cells in 2003 to 500 cells in 2017 (Fig. 12). Additionally, the total number of cells increased from 987 cells in 1993 and 1,161 cells in 2003 to 1,399 cells in 2017 (Table 4). This confirms the theory of natural urban transformation and shows the impact of Ito campus on accelerating the spread of this transformation.

4. Discussion

Previous analysis has shown that transformation happened in the area before and after the campus came into existence. The results also show where exactly this transformation started. In the final output of combining space syntax, spacematrix and MXI results, we clearly see the acceleration of urbanisation spreading all over the area from the strip near to Route 202 and railroad stations to the location of the campus. Before the construction of the campus, the area was considered rural, with many rice fields and hillside forests and few countryside residential houses. However, after the establishment of the campus, the area started in 2005 to urbanise more rapidly. If we compare the percentage of increase in high values of urbanity cell, we find that cells with in-between (middle, high), middle and high urbanity values had increased by 33% in 2003 and by a further 30% in 2017. Although the percentage increase is relatively similar, the distribution of those cell is totally different. In 2003, the distribution of cells took place around Susenji railroad station and along Route 202. However, in 2017, the highly urbanised cells started to extend consistently toward the campus. This urbanisation expansion would not have taken place without the existence of Ito campus in the area. The campus gave decision-makers and stakeholders a reason to be interested in investing in areas between railroad stations and the campus.

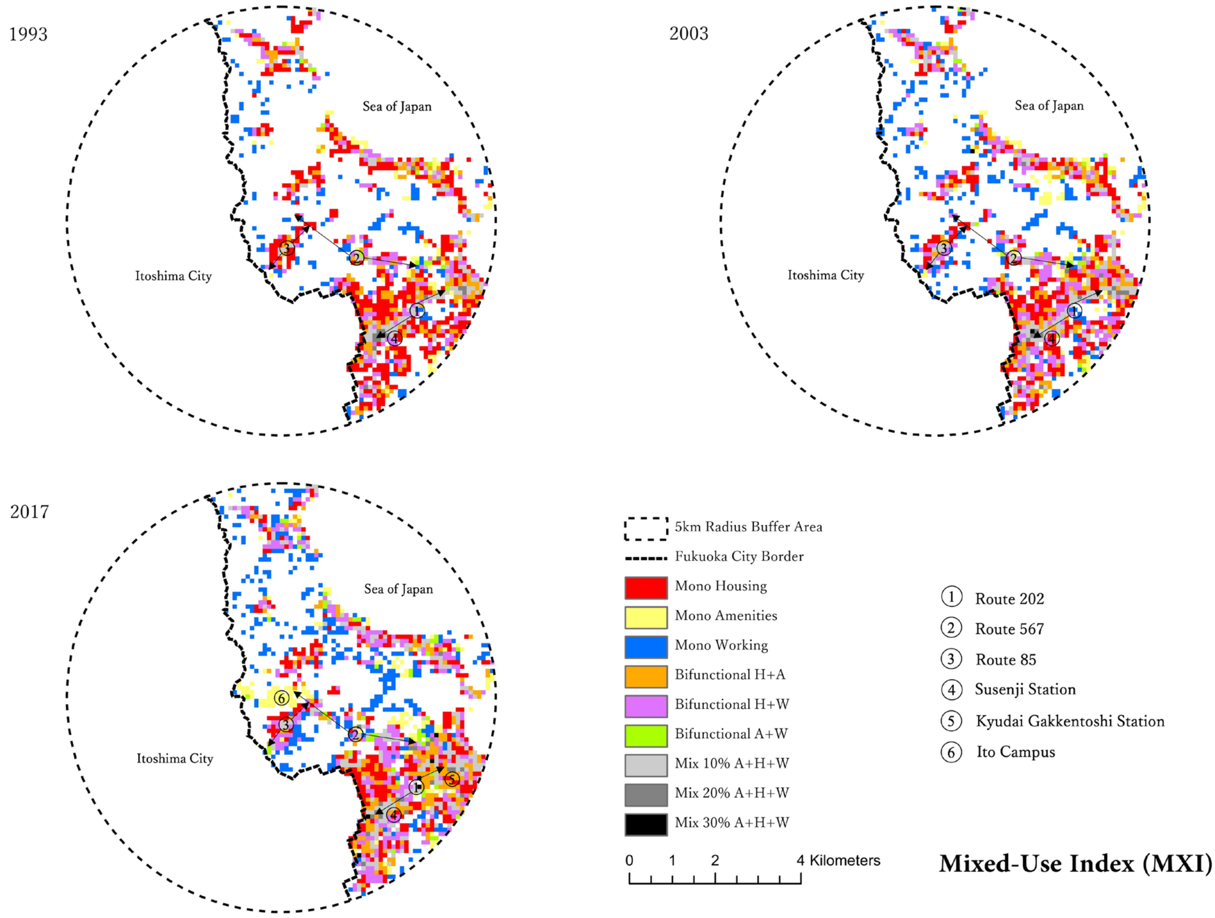

Fig. 10. MXI maps
Source: Authors' illustration

This also confirms the accuracy of the description of universities as extensive landholders that can change the morphological structure of the city (Larkham, 2000). Although previous research tends to focus mainly on the negative aspects brought by universities and studentification as a by-product, the impact that campuses can have on the urban transformation process has to be highlighted in order to more fully assess an institution's role in city urbanisation.

Another finding that has been revealed from previous analysis is that the transformation process starts from more accessible areas to extend to less accessible ones. Therefore, areas around Susenji and Kyudai Gakkentoshi stations and Route 202 recorded high values of integration, urban density and multi uses. Moreover, the more distance there is from Susenji and Kyudai Gakkentoshi stations and Route 202 to the campus, the lower the values become. Although the campus works as an attractive nodal for investment, stakeholders and decision-makers seem to be more interested in accessible areas first to serve students and non-students. However, as shown in the integration analysis, new roads and train stations are gradually built, which, in turn, make less accessible areas more accessible. This opens the door for more investment and development projects that contribute to city urbanisation. Beside the location of the campus and the accessibility attribute, the publicising of polices by decision-makers affects how and where the urban transformation process takes place. For example, Fukuoka City decided to open Kyudai Gakkentoshi station in 2005 concurrently with the campus opening in order to fulfil the capacity needed to transport students and staff. However, the name of the station was chosen to consist of two words: *Kyudai* which is the abbreviated Japanese name of Kyushu University and *Gakkentoshi*, which means "academic and research city". By doing so, the city officially announced the area as a "student area", which can hinder the urban transformation due to the perceived negative impact of studentification (Grabkowska & Frankowski, 2016; Toprak et al., 2017). Moreover, many stores in the area started to use the word *Kyudai Mae* (which means "in front of Kyushu University") in their signs and logos. This shows that store owners are declaring that the area is made to be a student area and it is

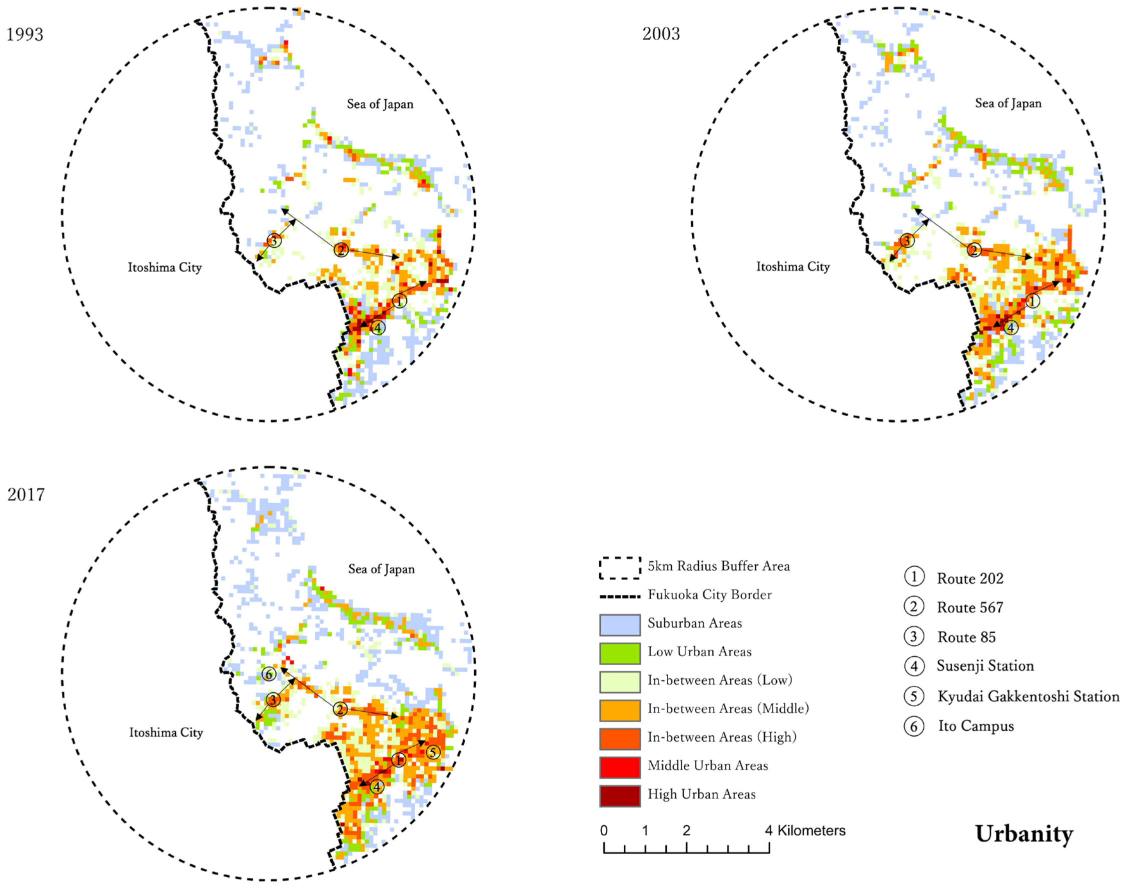

Fig. 11. Urbanity maps
Source: Authors' illustration

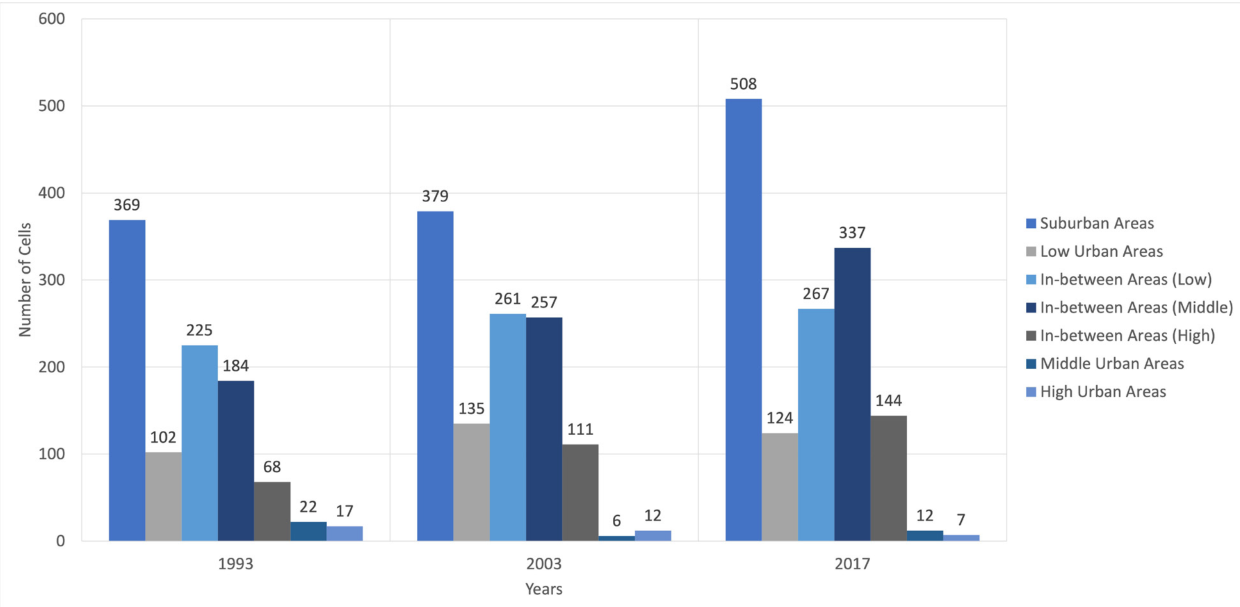

Fig. 12. Change in number of cells according to urbanity classification
Source: Authors' illustration

better for them to attract students to their business by orienting their prices, services and even signs to serve students' needs. However, further future analysis may validate the impact of such an aspect on the area.

In the Japanese geometrical design, design is categorised to three different levels: *Ten*, *Sen* and *Men* which translate as "point", "line" and "surface", respectively (Fig. 13). In the preceding analysis, we see that cells with high values of spacematrix, MXI and urbanity were located first as a point (especially around Susenji station) and then started to extend as a line around major streets such as Route 202. After the campus came into existence, cells started to extend towards the campus in the form of a surface extending from major surrounding streets to the location of the campus. Therefore, we can say that the existence of Ito campus helped the area to develop from the *Sen* (line) phase to the *Men* (surface) phase. Before the Ito campus's existence, the area transformed naturally from the *Ten* (point) phase to the *Sen* (line) phase, which is known as the natural urban transformation process. However, for the area to develop from the *Sen* phase to the *Men* phase, it needed a new nodal that would let it develop in different directions to form a surface-like expansion. Thus, the construction of the Ito campus accelerated the transformation from the *Sen* phase to the *Men* phase. Thus, we can deduce that the existence of a large new university campus accelerated the spread of the transformation. This also shows that large institutional urban settlements can accelerate the natural urban transformation of an area if they are situated in a way that forms a *Men* (surface) with surrounding streets and stations.

In conclusion, we can say that university campuses have the potentiality to more greatly accelerate the natural urban transformation process. New campuses work as magnets that attract more integrated streets, higher urban density and more multi-uses from the nearest accessible areas such as major roads or stations (Mohammed & Ukai, 2022). Therefore, locating new university campuses in less accessible areas may be a wise decision if the intention is to accelerate the large-scale urbanisation of an area. However, this may affect students' residential preferability, as students might prefer to stay near to their campus, which makes the area a "student area". On the other hand, if decision-makers locate new campuses in accessible areas, this might hinder the spread of urbanisation on a larger scale. However, this might be a wise decision in order to avoid the negative impact of studentification, because, if the campus is accessible, students can live anywhere in the city (Mohammed & Ukai, 2021). By doing so, the scale of studentified areas would be limited. In summary, the impact of university campuses on city urbanisation needs to be considered in the early stages of campus development to assess its consequences more holistically. Moreover, the participation between decision-makers, stakeholders, university administration and the city is considered essential in that case, so that it can come up with an effective urban strategy that benefits all (Hoyt, 2010; Russo et al., 2016; Mohammed et al., 2022).

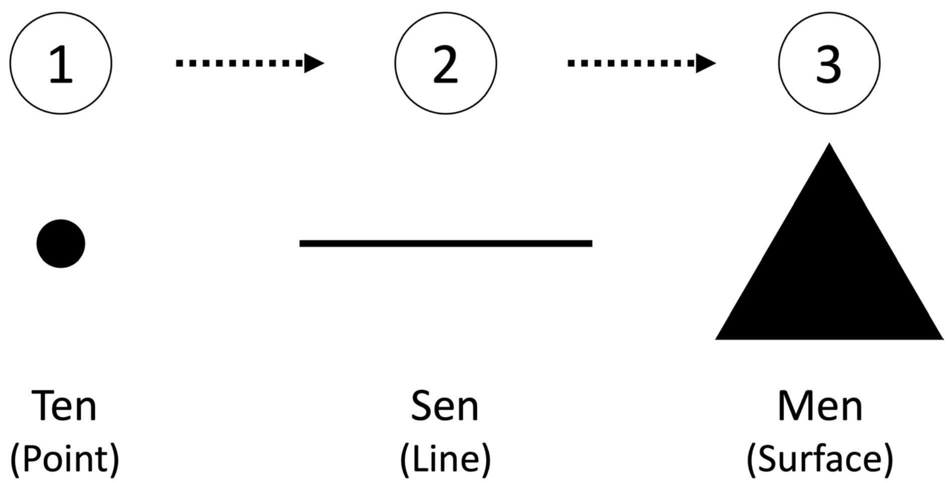

Fig. 13. Design levels in the Japanese geometrical design
Source: Authors' illustration

5. Conclusion

The role of universities in cities is mainly about empowering the knowledge required to overcome challenges that the society may face. However, the impact of a university on a city goes beyond that. Therefore, university campuses are considered to be an urban agent capable of upgrading suburban areas of the city. Even though suburban areas will become more urbanised through what is known as the natural urban transformation process, university campuses have the potentiality to accelerate such a process. This study examined the impact of Ito campus, which is Kyushu University's newest campus, on the urbanity change before and after the campus existed. In order to have a holistic approach, different urban analytics methodologies have been used, these being space syntax, spacematrix and the mixed-use index. By combining the results of these methodologies, urbanity maps that show different degrees of urbanity ranging from suburban to highly urban areas can be produced. The results show that the existence of the campus helped the area to urbanise more rapidly. After 1993, the urbanisation process took place near the major routes in the area and around railroad stations. However, after the construction of the campus in 2017 was completed, urbanisation started to sprawl in a more scattered way, and new urban settlements started to appear in new places. This shows that the existence of the campus and the capacity that was needed to serve students and staff gave stakeholders, business owners and decision-makers a reason to invest in the area.

Furthermore, the location of the new campus away from the nearest railroad stations made the urbanisation process gradual, starting from accessible areas near the station and progressing to less accessible parts of the area near the campus. Therefore, the accessibility attribute and the location of the campus were two of the main factors that affected how the natural urban transformation process took place. Moreover, other factors were related to the area's image and to its being publicised as a student area by using the name of the university in stations, stores and residential buildings names. This impacted the area by building the image that the area was made mainly for students, which could, in the long run, lead to the displacement of the original residents. These different aspects show how significant the impact of building a new campus can be. Therefore, decision-makers need to have a holistic view of the campuses' role in the city, especially in the early stages of the campus development. In the future, this research needs to extend to examine the impact of building new campuses from residents' point of view to determine the validity of new campuses' social impact. By comparing a campus's physical and social impact on the area, future research can provide a more comprehensive understanding of university campuses' role in city transformation.

Acknowledgment

Authors would like to thank Fukuoka City Urban Affairs Bureau for providing the data needed for this paper. This research wouldn't have been possible without their cooperation.

This paper is part of the PhD thesis of the first author, which is funded by the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT).

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