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Exploring the space use mechanism of high-density campus in urban Beijing

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ABSTRACT

Despite the scarcity of city space and the transformation and disappearance of many work-units, campuses with enclosed and gated system remained its robust and sustainable development in urban Beijing. Hence, it is essential to trace back to their spatial strategy of maintaining its self-governance as well as benefiting from the new development of the city in a market economy.

This study firstly applies a regression model to reveal the key spatial traits that influence the daily balanced use of campus space. Furthermore, the spatial interaction with the adjacent urban areas has also been analyzed. Lastly, an in-depth institutional interpretation of its self-governance (vertically independent governance with the state) as well as its enclosure and gating system (horizontally independent governance with the city) is also combined.

Major conclusions are drawn. (1) Land use mix is determinant in the balanced use of campus space, while physical enclosure and gating further enhances this stability. (2) Campuses in Beijing relief their high-density burden through flexibly interacting with the adjacent urban areas, owing to its proximity to TOD nodes. We confirm that both the support from the state and local strategy of innovation industry and highly dense population inside the campus constitute the new driving forces to maintain the collective social and functional mix within the enclosed campuses in Beijing. This study contributes additional empirical evidences of spatial use strategy embedded in Chinese specific socio-cultural context to the stream of urban theories.

1. Introduction

Urban Beijing possess a largest number of renowned national universities, many of which belong to work-units built after 1949 in the socialist era (Huang, 2004). They are enclosed and gated compounds combining the residential and social spaces with a collectivist culture and function as the basic unit of political control (Huang, 2006). Together with work units belonging to enterprises and government agencies, they also constitute the basic unit for spatial organization (Bray, 2005; Zhang, 2004b) and economic system (Zhang & Chai, 2009). The self-sufficient life and land use mix developed inside the campus were “temporary measures” (Bray, 2005: P.98) to resolve the lack of public service which should be provided by the central government after 1949. Even though many other types of work units declined during the transformation of economy reform, those campus ones not only survived but also developed themselves in the market economy. Especially with the fast urbanization in China, the campuses realized a visible expansion on its space use as well as the absorption and output of young intellectual human capital (Shi, Ge, & Hokao, 2005). This is primarily driven by the sociopolitical governance and development strategy of the central and municipal government. On the other hand, the model of university cities (daxuecheng), designed in city periphery to address the challenge of limited space within urban areas, has largely failed to yield satisfactory educational outcomes and expected socio-economic integration. Moreover, students rejected the vision of isolated education enclaves as a style of living (Sum, 2018). **Hence, the space use issues of university campuses located in the crowded urban environments of megacity Beijing with 20 million people deserve our attention.** Nevertheless, while many studies focus on interpreting the rationality of enclosure and gating, very few studies investigate the inner space and identify which specific traits or mechanism are influencing the balanced performance of their space use.

The campuses nowadays have been criticized for their negative impacts since 1980s, which stems from that the segregation of campus spaces from the urban public, together with their large spatial scale, creates obstacles to the city's development of a dense urban road system and results in heavy urban congestion (Kwok, 1981, pp. 147–193; Zhao, 2006). In 2016, the government declared that new gated communities

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should not be built in principle and that existing gated communities would gradually be opened to the public (Xinhua News Agency, 2016). Some subsequently released news stated that several campuses would be opened to the public by removing the walls and gates. However, there is an immediate denial of this by the government (Xinhua Net, 2016). Those inconsistent attitudes reflect the controversial attribute of the gates system of the campus and may suggest that the spatial enclosure and gating has more underlying rationality and implication apart from providing the physical segregation. **Even though the permeable spatial pattern with mixed land use often gets praises by many western planning theorists for its good influence in vibrating the city environment and integrating urban experience (**Calthorpe & Katz, 1994; Lynch, 1984; Melia, 2012; Talen, 2002; Van Der Ryn & Calthorpe, 1986**), it might be too naive to simply deny and abandon the enclosure and gating system of Chinese work unit systems without considering the specific socio-cultural context (**P. Pow, 2019).

Unlike the western urban street life advocated in theory of Jacobs (1961), a huge number of residents in China still live and work in the legacy work-unit system (Sun, Webster, & Chiaradia, 2018b). In our study area, the campuses are supporting about 1/3 population's job and life only within 1/4 urban area. This is in accordance with intensive land use which is highly emphasized by Wang, Hui, Choguill, and Jia (2015). To fully understand how those campuses managed to accommodate its high-density population, we must trace back to their space use strategy of maintaining its self-governance as well as benefiting from the new development of the city in a market economy. Specifically, we will aim to answer the following two questions. **How is space utilized by the dense population within campus in the crowded megacity Beijing with 20 million people? And what is the spatial relationship of campus and the urban context (its outside public area) in resolving the space use issues?**

Individuals' interaction with the space of the work unit will be the departure point. Specifically, the question whether and how the dense inner population could occupy or stimulate their campus space use in a balanced manner across different times of a day will be a key research focus. This topic could only be unveiled through a combination of current big-data technology with an in-depth conceptual analysis of campus' self-governance of land use mix (in a vertical relationship with the central government). Furthermore, the enclosure and gating system of the campus, as well as the influence of outside public development on campus' inner space, will be another key study point to reveal the interactive mechanism between the campus and the city, in terms of their parallel independent governance and win-win relationship in current urban circumstance. Together with the attributes of land use mix, population density and residence floor-area, etc., new indicators are developed to portrait the land use mix and enclosure and gating mechanisms (towards inner individuals and outside public) for revealing the space use mechanisms in the campus.

The paper will be organized as follow: section two introduces our theoretical foundation as well as the current empirical research state on this topic. Section three presents our methodology including the data collection, framework of analysis, as well as the methods of analysis. Section four shows research findings. The last section discusses the critical issues and summarizes the major conclusions and implications of this study.

2. State of art

2.1. Existing studies mainly departure from the perspectives of culture, political, economic, and institution to interpret the mechanism and implication of an enclosed and gated work-unit system in China

In contrast with the understanding that gated and walled community is a result of social polarization and segregation (Caldeira, 2000; Leisch, 2002), Bray (2005, p145)deemed that "walls" of Chinese work-units should be seen as a productive rather than negative technique of social organization, and the things that happened within the walls should be paid more attention to. The western theories about private provision of services (Webster, 2001) and discourse of fear (Low, 2004; Wilson-Doenges, 2000) were utilized to explain the Chinese gating phenomenon (Miao, 2003; Wu, 2005), which led to further debate on the distinction of gated communities and work unit compounds (Deng, 2018; Huang, 2004, 2006). Residential segregation and social stratification appear in the gated communities under the background of social transformation (Tomba, 2010). In contrast, the social mix within work unit makes it hard to exclude any particular social stratum, which adds difficulties to the check of identities by the gating system (Wu, 2005).

A comparative study was applied to unveil the distinction of socio-spatial implications between the gated communities in the United States and those Chinese enclosed neighborhoods including work unit with collectivism-oriented culture and tight political control (Huang, 2006). By admitting the apparent shortage of dominant western-based theories in the analyzing of the mechanism of Chinese traditional enclosure and gating, the author deemed that "a multi-scalar perspective as well as the knowledge of the local culture and political system is needed" to better understand the dynamics of gating and its implications in specific sociopolitical context. Deng (2018) focused on the differentiation between work units in the planned economy and the private communities in the market economy from the angel of the "hold-up problem" in urban land use. Based on the institutional mechanism, the author wondered whether this type of compound, by integrating the land owner and the provider of local public goods in the work unit, would meet a revival process in China. In contrast, based on the new trend of housing development from late 1980's, Bray (2005, p.176) hold the opinion that the old work unit compounds will be "gone" in the market reform.

2.2. Few studies have investigated the daily lives within work units as well as their interaction with surrounding urban areas

Bray (2005, P.147) utilized the campus case to uncover that the daily lives of members inside the work units were "shaped not only by the routines and rhythms of the danwei (work unit) but also by the spatial forms within which they circulated." This corresponds to his declaration that the central aims of work unit's spatial design focused on executing the socialist state order and collectivized lifestyle. From a broader historical horizon, Huang (2006) emphasized that work-unit compound is strongly influenced by the collectivist culture, which also contributes to the intensive interaction among the work unit members. The study of Xu, De Bakker, Strijker, and Wu (2015) shed light on the promotion of place attachment with a campus by those students who need to adjust to the transition from living in remote areas to studying at universities in urban areas.

The interaction between work-units and the outside public has also attracted few scholar's attentions. The significance of full engagement of university campus with the surrounding communities is confirmed by the study of Zhong, Zhao, Zou, and Mason (2018). Lu (2006) studied the adjacent urban village around the universities to reveal the life of emigrants who lived outside and tried to earn their living inside the campus through working in temporary service sectors. Sun, Cheng, Lin, and Peng (2018a) studied the relationship between students' accessibility and local public transport to reveal the implications of campus in Wuhan for socio-spatial inequality. Hoyt (2010) pointed out the importance of reconfiguring the relationship between institutions of higher education and society and hopes that the academic and civic cultures communicate more continuously and creatively with each other. Li, Li, and Wu (2019)confirmed the university spillover effects on firm innovation.

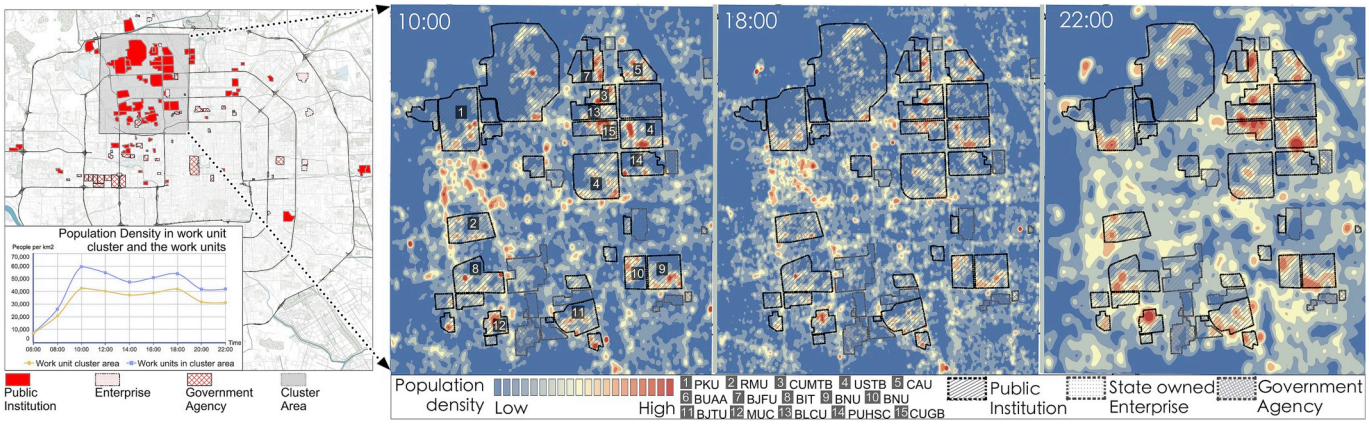

Fig. 1. Work-unit cluster areas in northwest Beijing (Left) and work-unit compounds including selected 15 campuses (Right) (Source: Based on field study and Baidu Map in 2017).

2.3. The permeable spatial pattern with mixed land use often gets praises for its good influence in vibrating the city environment and integrating urban experience, while enclosure and gating system is always criticized for an opposite effect (Pow, 2019)

Mixed use is the core premise of new urbanism and sustainable development (Grant, 2002, Hatuka & D'hooghe, 2007). After Jane Jacobs argued that fine-grain mixing of diverse uses is essential for creating vibrant and successful neighborhoods, support for mixed use have become common both in literature and in planning practice, especially in 1980s. TND and TOD compose two main streams of New Urbanism. The former refers to intensification and mixing compatible uses at a fine grain (Calthorpe & Katz, 1994), and the latter concentrates the development surrounding transit station nodes (Bernick & Cervero, 1997; Calthorpe, 1993; Kelbaugh & Brown, 1999; Nelessen, 1994). Long and Huang (2019) has verified the significant and positive relationship between the level of mixed use and the level of economic vitality for cities.

Other studies focus on the transport-related benefits of self-contained communities (Van Eck, Burghouwt, & Dijst, 2005; Cervero, 1996). Work units are regarded as an important means to achieve the compact city in Europe or new Urbanism in the US (Chai, 2012). On the other hand, spatial patterns that can facilitate accessibility and maximize connectivity is generally regarded as a good city form (Lynch, 1984; Talen, 2002). Permeability is considered as a positive attribute of an urban design scheme (Melia, 2012), while gated communities tend to segregate urban physical structure and fragment urban spaces (Sun et al., 2018b; Zhao, 2006).

2.4. Summary

While some empirical studies select enterprise work units to depict its decline, deconstruction and transformation in the economy reform (Yin, Liu, Dunford, & LIU, 2015; Zhang & Chai, 2014; Zhang, Chai, & Zhou, 2009), very few have investigated university campus ones which are not identical to those work units, in spite of a few commonality (Zhang, 2004a). Other studies on China's campuses focus mainly on the macro perspective on green development without considering the mechanism of space use within those campuses (Gao et al., 2017; Tan, Chen, Shi, & Wang, 2014). The survival and flexible adaption of those large-scale enclosed and gated campus ones in market economy lack solid empirical studies. In addition, the integration of planning and institutional mechanism for guaranteeing modern collectivized and mixed social life in China has been neglected in the past studies. Last but not the least, to our knowledge, very limited studies have taken the advantage of big-data analytics to investigate the dynamic real-time space use by dense population within the campuses in the megacity Beijing.

3. Methodology

3.1. Study cases and data source

3.1.1. Study cases

Fig. 1 shows that university campuses are located close to each other, forming a work unit cluster in urban Beijing. It is revealed that the density within many campuses is higher than the adjacent urban areas. This is in accordance with the national strategy of invigorating China through science and technology, thus there is an expansion of students enrollment and a trend of industrialization of education nowadays in China. Considering the high population density, the adequate area, and the data availability, 15 campuses (including PUHSC, BUAA and USTB etc.) are selected as study cases. The general statistics of the 15 campuses are listed in Appendix 1. The campus space is composed of inner space and boundary space. The campus inner space is the space enclosed by physical enclosures and gates, which is mainly occupied by faculty staff and university students. The campus boundary space is located between the campus inner space and the public urban areas, constituting an important part of the enclosure system (apart from the regular walls, fences and turn-outward buildings). They are composed of several independent buildings and landscapes, which are the functional expansion of the campus to the whole society. The key feature of boundary space is their fragmentation instead of continuity among the regular boundary space.

According to the fieldwork investigation, it is noticed that the larger fragmented boundary spaces of BUAA, USTB and PUHSC are accommodating extremely high-density population. To avoid the bias on the analysis of population density distribution within the campus, the boundary spaces of these three campuses are excluded in the correlation analysis in section 3.2.

3.1.2. WeChat and statistical data

Based on the progress of analysis methods with big data in temporal scale and granularity (Long & Huang, 2019; Long & Liu, 2016), the spatial-temporal patterns of individuals' spatial utilization are derived from the data collected from WeChat heat map. The advantage of using WeChat heat map (China Tech Insight, 2017; Quest Mobile, 2016) is that it has more than four times the users of Baidu heat map which has been used in former studies (Wu & Ye, 2016; Ye, Chen, & Zhang, 2017). Considering that the distribution of the population in the weekdays has a similar pattern (Kan & Ma, 2018), as observed in our data collected hourly from 6:00 to 22:00 between December 26th in 2017 (Tuesday) and January 3rd (Wednesday) in 2018, the data of 26th December is chosen for the analysis in this study. The corresponding descriptive data for 15 campuses is collected from their official websites.

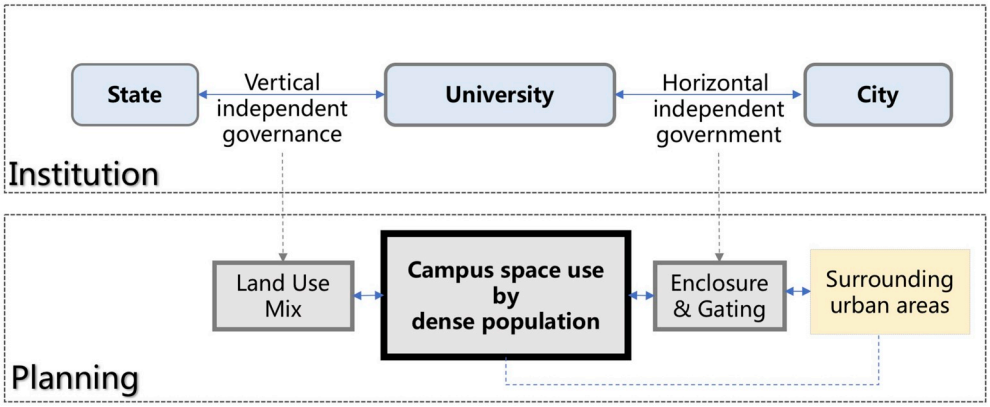

Fig. 2. Conceptual framework of the analysis in the study.

3.2. Conceptual framework

As indicated in Fig. 2, our study focuses on the campus space use by dense population and analyzes its association with two distinctive spatial traits: namely land use mix and spatial enclosure and gating system. Regarding that these spatial traits are the outcomes of the institutional cooperation between the campus and state governance as well as between the campus and city governance, the role of institution is also applied here.

3.3. Regression model: which factors influence the balanced use of campus space?

$$DPMHA = F\ (\text{Entropy, Enclosure, Ranking, Fund, Gender\_ratio, Total\_area, Insti\_area, serv\_area, resi\_area}) \quad (1)$$

The dependent variable is the balanced use of the campus space, which is measured by the daily proportion of merged high-density areas (DPMHA). It is apparent that many factors would likely have an impact on the outcomes beyond spatial dimensions and therefore it was necessary to include these variables as control variables. Furthermore, entropy and enclosure, as two key spatial traits of the campus should be also included to investigate their independent influence. The full model contains the variable of entropy and enclosure degree, as well as the control variables (Formula 1 and Table 1). The final selected model is produced with a stepwise procedure to select the most relevant independent variables, while remaining the most efficient model.

Table 1
List of the key variables in the regression analysis with their definitions and sources.

Variables	Definitions	Sources
Dependent variable		
Y: DPMHA	Daily proportion of merged high-density areas	*By own calculation in* Formula (2)
Independent variables		
X_1: Entropy	Entropy-based land use mix	By own calculation in Formula (3)
X_2: Enclosure	Enclosure and gating degree	By own calculation in Formula (4)
X_3: Ranking	Ranking of University	www.gxeduw.com/daxuepaiming/beijing
X_4: Fund	Research Funding	http://www.moe.gov.cn
X_5: Gender_ratio	The ratio of female/male students	https://kknews.cc/news/ln6jnr9.html
X_6: Total_area	Total area of the campus	Baidu map + GIS analysis
X_7: Insti_area	Proportion of institution area	Baidu map + GIS analysis
X_8: Resi_area	Proportion of residence area	Baidu map + GIS analysis
X_9: Serv_area	Proportion of service area	Baidu map + GIS analysis

3.3.1. Y: balanced activation of space: proportion of real-time high-density areas (PRHA) and daily proportion of merged high-density areas (DPMHA)

Population density is classified into 7 categories (natural breaks) with the kernel density function in ArcGIS, and the three densest categories are indicated as "high-density areas". Rather than using a uniform classification, the classification of population density within campuses are calculated respectively for each campus. In this way, we could mitigate the huge variation of population density among those 15 campuses. The proportion of real-time high-density areas (between 6:00 and 22:00) (***PRHA***) are respectively calculated. In addition, we merge the high-density areas across the entire day to obtain the daily proportion of merged high-density areas (***DPMHA***) (Formula (2) and Fig. 3).

$$DPMHA = (a_6 \cup a_8 \cup \cdots \cup a_{22}) / A \quad (2)$$

Where A represents the campus area, and $\boldsymbol{a_n}$ represents the area of high-density at a specific time (e.g., 6:00, 8:00.). DPMHA could indicate whether each type of land use in the campus appears as the most vibrant area at least once across the entire day, reflecting how balanced the distribution of vibrant areas is across the space.

3.3.2. X_1: Entropy-based land use mix

Mixed use measure addresses the appropriate balance between different types of land use corresponding to different types of activities. The entropy of land uses is calculated according to the definition of Frank et al. (2005) and is indicated in Formula (3), where $\boldsymbol{b}$ represents the floor area of a certain type of land use in campuses, and $\boldsymbol{a}$ refers to the campus area. $\boldsymbol{n}$ is the respective total number of land uses. Considering the following formula mainly measure the relative proportion among different types of land use, regardless of the total number of land use types, we further apply a weight of n/8 to emphasize the importance of the number of land use types.

$$Entropy = \frac{-1}{a \ln(n)} \sum_{i=1}^{n} b_i \ln(b_i/a) \quad (3)$$

3.3.3. X_2: The spatial enclosure and gating degree

While other studies applied the ratio between the number of gates and the length of the wall to measure the enclosure degree of a work unit (Frank et al., 2005), our study calculates the enclosure degree by dividing the total area of the campus by the number of the gates, since the campus area is more directly related to the spatial utilization than the perimeter. Where A refers to the campus area, n refers to the number of gates.

$$\text{Enclosure degree} = A/n. \quad (4)$$

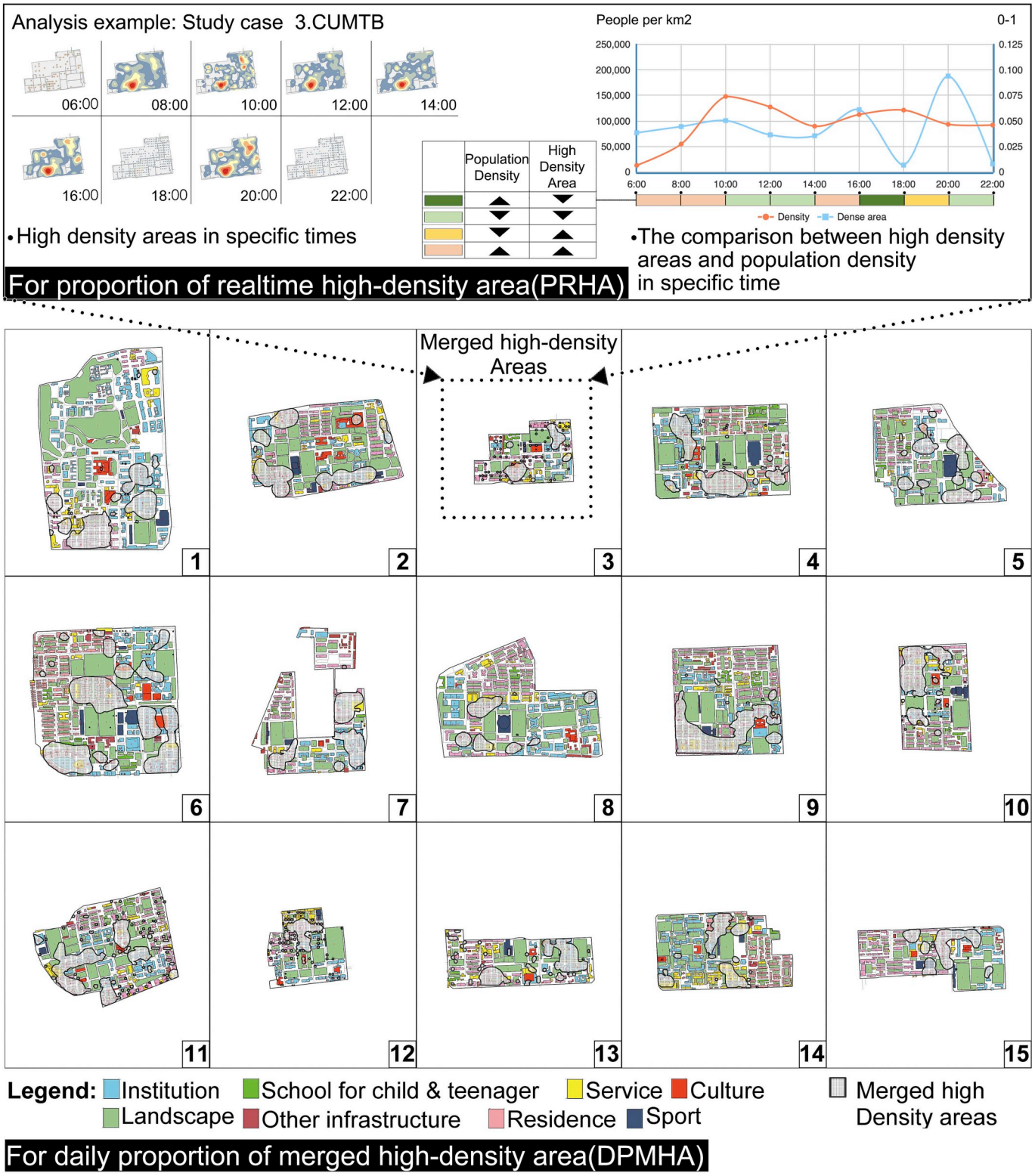

Fig. 3. Land use and DPMHA among 15 campuses with a demonstration of the detailed procedure to calculate DPMHA by taking campus 3 (CUMTB) as an example.

4. Research findings

4.1. Complex enclosure and gating system: enclosure system plus "thickened walls" constituted by fragmented boundary spaces

Based on the study with a classification on inner and fragmented boundary spaces of USTB, BUAA and PUHSC, the varied proportion of functions in boundary spaces among three campuses is evident in Fig. 4. The Major functions inside those campuses mainly serve the faculty staffs and students' daily job, study and life, so the proportions of different functions among different universities are more similar than that of fragmented boundary spaces. The definition of those fragmented

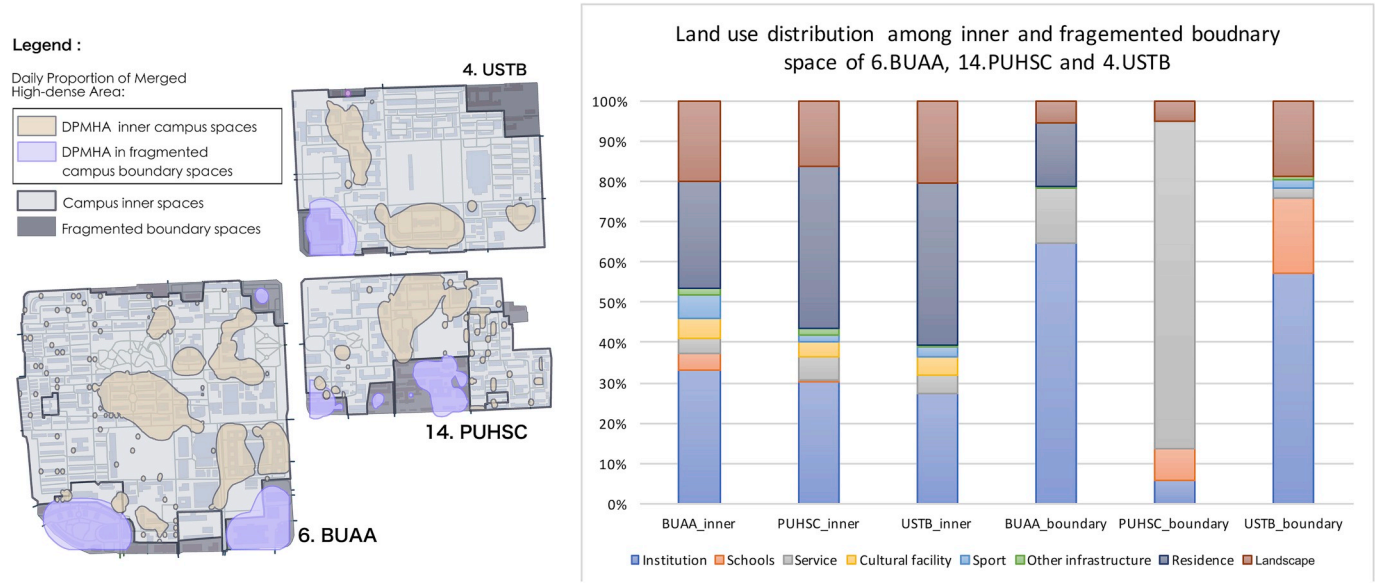

Fig. 4. DPMHA and land use distribution among inner and fragmented boundary space of BUAA, PUHSC and USTB.

boundary spaces is based on the respective attributes of these campuses and their duties or demands on the interaction with the city. For example, in the south fragmented boundary spaces of PUHSC, there are two large hospital and other public service functions. The fragmented boundary spaces of BUAA and USTB are filled with innovation companies, commercial-residence buildings, entertainment facilities and other service spaces.

The self-governance inside campus has some independence. On the other hand, though the "turn outward walls" and some "fragmented boundary spaces" have been integrated with the outside public by shared functions, they led to the complex interaction between the governance of the campus and the city. Compared to the former independent management of space use divided by the campus and the outside public, the new interaction between inside and outside on the boundary spaces increases not only complexity but also the risk for the governance. Due to this, some campuses would rather apply strict forbidden rules to guarantee the order within the campus (For example, the crowded patients of hospitals beside PUHSC are prohibited from entering into the adjacent campus).

4.2. DPMHA and its association with entropy and enclosure degree, while controlling other factors

As indicated in Table 2, it is noticed that when entropy and enclosure are added into the model, the explanation power increases immediately from 0.516 to 0.906. Nevertheless, the most efficient model only contains the four variables namely entropy, total area, the ratio between female and male students as well as the residential area. The overall proportion of merged high-density areas could be largely explained by the land use mix, total campus area, the ratio of female and male students, as well as the area of the residence buildings (R square = 0.875). The positively correlation with the entropy value is in accordance with our hypothesis that provided with a diversity of services with a relatively balanced distribution of various functions within the campus, both faculty staff and students could have more flexibility of choosing places to conduct their activities. In this way, each subspace of the campus would be sequentially activated as high-density areas, which will help to balance the large density burden born by the campus. Eventually, this would contribute to a continuous vital campus across different time periods (rather than only concentrated at certain areas and at a specific time). Secondly, we noticed that there is a negative correlation between the campus area and DPMHA. This indicates that if the campus with smaller area has a more compact combination of different functions, it will have more potential to stimulate the use of different spaces by the dense inner population. Thirdly, if a campus has a larger proportion of female students, the overall balance of land use is also more balanced. This might be related to the different rhythm of activities between female and male students. Lastly, the proportion of residence buildings is also positively correlated with the overall balance of land use. This implies that the students' flexibility of choosing the time to stay in the dormitories also contributes to the overall balance of the campus across different time periods.

Even though it seems that the enclosure and gating degree of the campus has no direct linear association with the balanced space use in campus, the physical segregation based on the enclosure of the campus contributes to reducing the complexity on the boundaries for campus management and enhancing the inner stable collective lifestyle. Indeed, we could get a conjecture that the existence of enclosure and gating guarantees a stable and close relationship between different spatial factors inside the campus. This implies that the development of boundary space is relatively independent from the inner space of the campus. The campus will be more motivated to develop a diverse and self-sufficient land use to balance the space use if they are stably protected by the boundary space, which is another way of enclosure and gating.

4.3. Real-time distribution and dynamics of high-density areas in relation to population density change

The real-time proportion of high-density areas from 6:00 to 22:00 indicates the spatial distribution of individuals within the campus. A small proportion indicates a scattered distribution of individuals, while a large proportion indicates the concentration of individuals in a certain area within the campus. Accordingly, the change of the proportion of high-density areas between two sequential times could inform us whether space utilization becomes more evenly distributed or not within a dense-populated environment. More specifically, the decreased proportion of high-density areas is under a balanced process. In

Table 2
Results of the regression analysis on factors that influence the DPMHA of campuses.

Model 1	Estimates	Std. Err	Model 2	Estimates	Std. Err	Model 3	Estimates	Std. Err
(Intercept)	0.131**	0.081	(Intercept)	(0.348)	0.114	(Intercept)	(0.349)	0.073
Fund	(0.030)	0.031	Fund	(0.019)	0.020	**Entropy**	**0.653****	0.087
Total_area	0.201	0.132	Total_area	(0.086)	0.096	**Total_area**	**(0.077)****	0.021
fm_ratio	0.025	0.107	fm_ratio	0.092	0.067	**fm_ratio**	**0.123***	0.039
Ranking	0.000	0.000	Ranking	0.000	0.000	**Resi_area**	**0.273****	0.064
Insti_area	(0.184)	0.324	Insti_area	0.194	0.218			
Serv_area	(0.606)	0.627	Serv_area	(0.525)	0.512			
Resi_area	0.121	0.147	**Resi_area**	**0.250***	0.085			
			Entropy	**0.656****	0.147			
			Enclosure	0.175	0.424			
R square: 0.516			*R square: 0.906*			*R square: 0.875*		

Remarks: Significance code: '***': 0.001 '**': 0.01 '*': 0.05.

contrast, an increased proportion of high-density areas would be defined as an unbalanced process. Furthermore, the overall increase of population density within the campus is associated with its interaction with the external public areas. Hence, the balanced and unbalanced process could be further differentiated into four categories (increased density with a balanced process; increased density with an unbalanced process; decreased density with a balanced process; decreased density with an unbalanced process).

Fig. 5 presents the (un)balanced processes of 15 campuses across eight periods. Among 120 cases, there are 57 balanced and 63 unbalanced processes. We noticed that more than half of the campuses are under a balanced process with an increased population between 16:00 and 18:00, which might relate to the mediation effect generated by the higher-level mix of service areas in the campus. Moreover, it is revealed that there is a similar pattern occurred between 10:00 and 12:00 as well as between 20:00 and 22:00. Specifically, most campuses tend to have a decreased density of population with a balanced process. This might relate to the outward flow of campus population towards the external environment, which benefits from their spatial proximity to transit stations. These two types of balanced process certify that the university campus was using two strategies to balance its high-density across the whole day: either inner land use mix or sharing the public service provided by the adjacent urban areas.

4.4. The overall active use of production space and consumption space among different types of campus

As shown in Fig. 6, the proportion of production space (teaching and research buildings) is smaller than the consumption space (including residence, service, cultural services as well as the sport activities) among most of the campuses (except PKU and BJFU). There is no apparent differentiation between universities with higher rank versus lower rank, as well as between those national-oriented and locally-oriented universities. This suggests that universities are not merely a place for research and study, it is also a place for cultural and leisure activities which enables informal exchange and creation of knowledge.

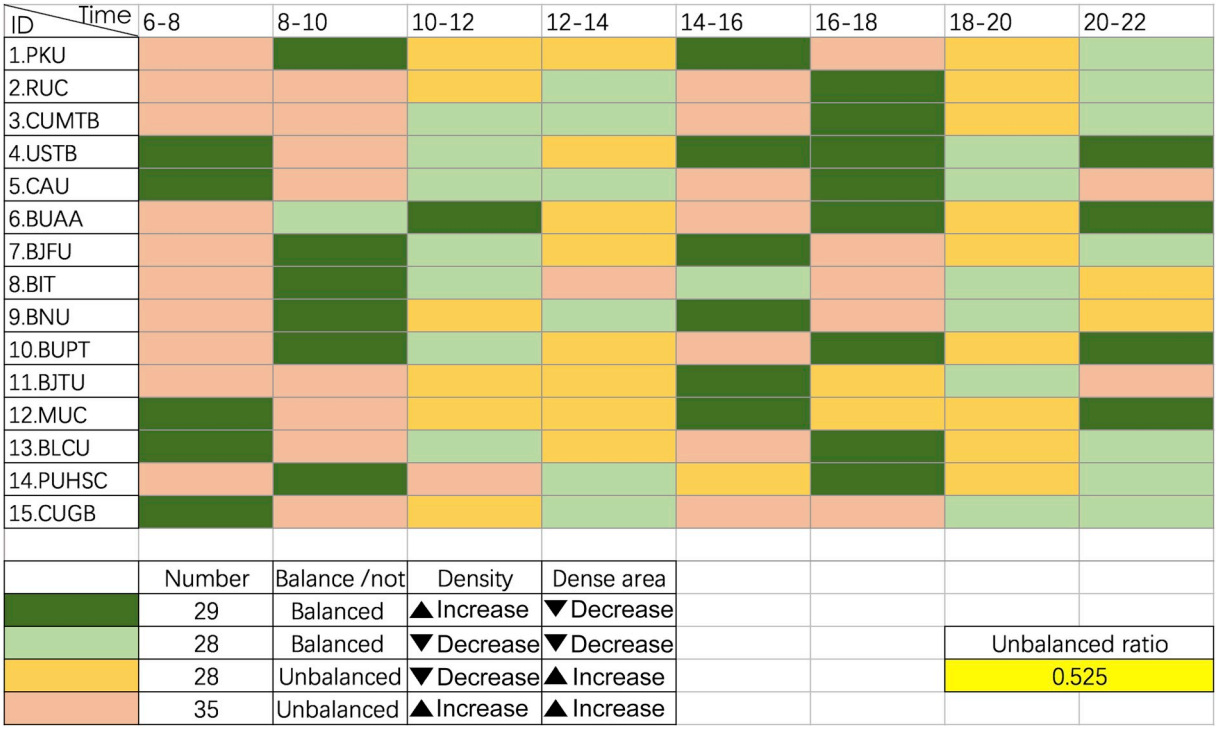

Fig. 5. Distribution of balanced and unbalanced state among eight periods within a day in 15 campuses.

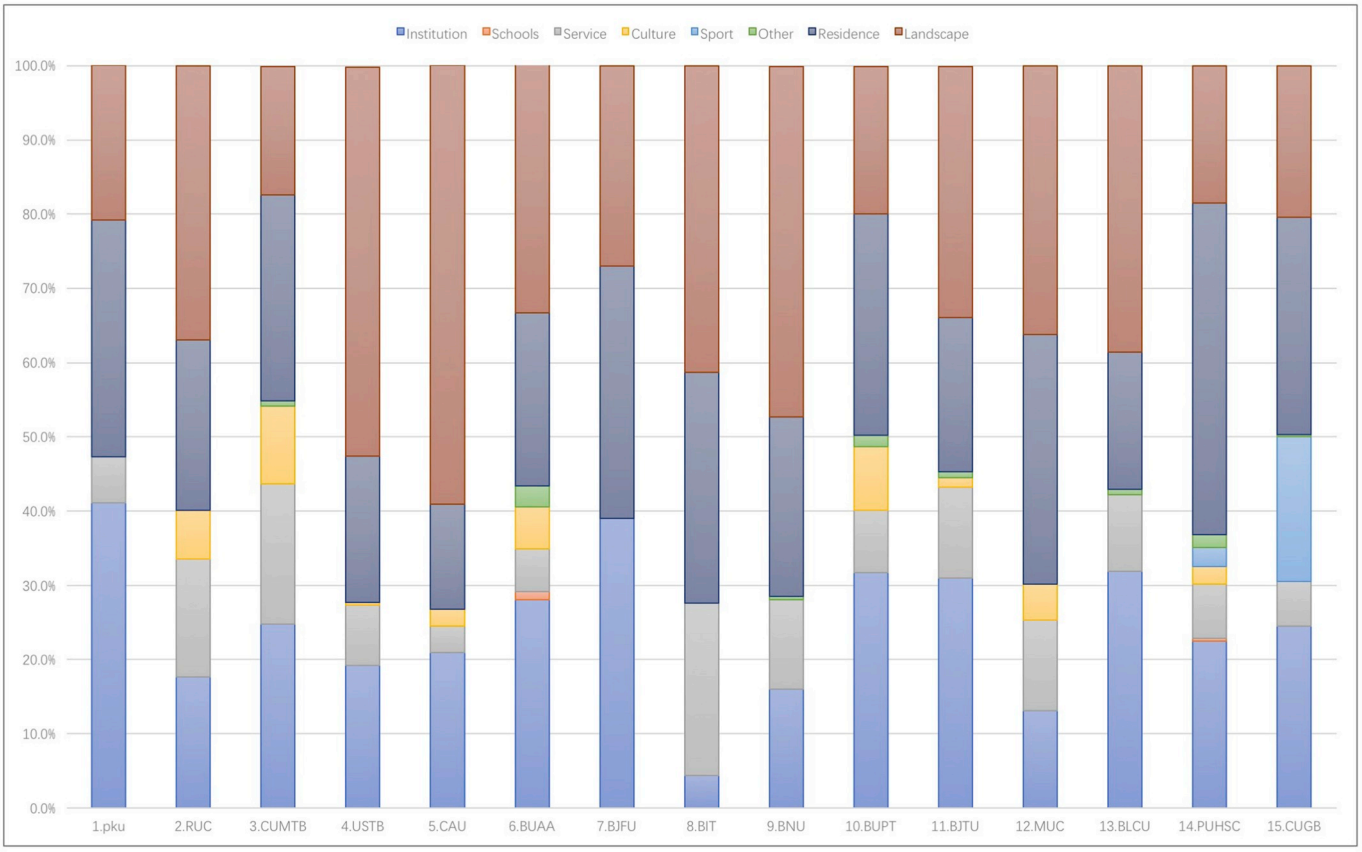

Fig. 6. Distribution of land uses within the DPMHA among 15 campuses.

In this sense, university campuses could be regarded as self-contained communities, starting to diverge from the conventional production-oriented work-units (product of socialist urbanization) occurred in the 1950s (Wu, 2005). PKU's highest proportion (41.1%) of institution indicates that it is strongly teaching and research oriented, its faculty members as well as students are more dedicated to their work or study.

Only CUGB has 20% of its high-density areas located at the sports function. This might relate to their original interests before entering universities. Students choose to study Geology or Geography-related disciplines very probably prefer field-work instead of in-door experiments, which might be reflected even in their preference of spending leisure time. It is as expected that individuals in RUC and MUC tend to have a relatively higher proportion of cultural activities, since the former's management discipline depends on intensive social interactions facilitated within these activities and the latter corresponds to diverse needs of cultural activities among the minorities. Similarly, the reason for BUPT with a high proportion of students patronaging cultural facilities might also relate to their interest in communication and interaction. However, the reason why CUMTB and BUAA has such high proportion of cultural activities still need further investigation and discussion.

4.5. The spatial co-location and interaction between campus and its urban context

1 km Euclidian distance, approximately equivalent to 15 min on foot, is chosen as the acceptable buffer radius of subway stations. Regarding that transit stations are often developed with high-density and mixed use under the TOD mode driven by the market economy, they function as the local centers of the neighboring catchment areas. Thus, the proximity to subway stations represents the potential opportunities of visiting all kinds of cultural and leisure facilities (e.g. shopping malls, museums).

As shown in Fig. 7, most universities are located close to transit stations. This corresponds to the decrease of population density within many campuses from 18:00 to 22:00, since individuals could have a wider option of service facilities outside the campus rather than the campus alone. Due to the denser population within the campus and the enclosure on the boundary, the interaction between the campus and its urban environment has a unidirectional feature from the former to the latter. Albeit suffering from the crowded spatial issues in campus, those students, teachers and other people working and living together nowadays absolutely have more choices to benefit not only from the self-sufficient collective life inside but also from the shareable and well-developed public service close to TOD nodes. Since BNU, BJFU and BJTU are relatively distant from the transit stations, it is noticed that the difference between the population density at 18:00 and 22:00 is much less compared to other universities. On the other hand, the co-location of university cluster and science-technology parks reflects the national strategy of encouraging the intensive cooperation between research-oriented and practice-oriented innovation. Owing to the spatial proximity, intense interactions between universities and science-technology firms could cultivate more start-ups, which would also enrich the education scope of universities.

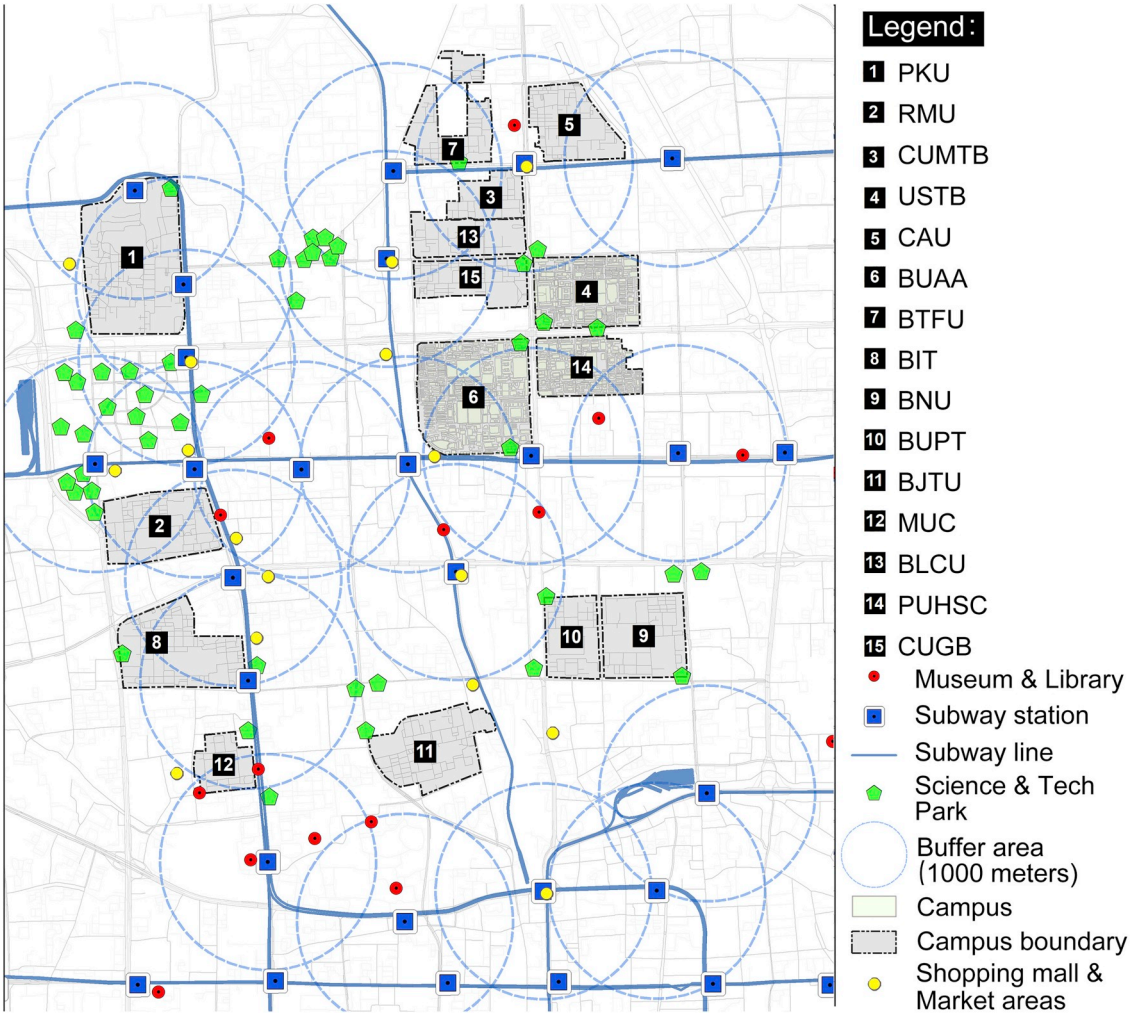

Fig. 7. Spatial co-location of campuses and other related spatial entities (shopping centers, museums, science-technology parks).

5. Discussions and conclusions

5.1. Discussions

It is not the area of service that matters for the balanced spatial use within the campus space. Instead, it is the land use mix measured by the entropy index that contributes the most to the balanced and vital space use. This study extends the significance of land use mix from the field of transportation to urban studies. The campuses in Beijing accommodate multi-functional spaces. The university staff and students living in the campus residence buildings share the accessible commercial services as well as the campus service facilities. Many low-rise buildings and lower-floors of the old residence buildings have been transformed into the commercial facilities. Moreover, the lower-floors of some newly built high-rise residence buildings are designed as service functions at the beginning of their construction. Those high-rise buildings are also satisfying the increasing population in the campus. Owing to the large and various demands of daily services and maintenance among the campus population, even small business streets or university center occurred in many campuses in Beijing. However, the consumption level reflected by the commercial services within these universities is obviously much lower, comparing with the CBD area and Sanlitun business circle in the east of Beijing. Even though the super mixed functions of the campus add to its self-sufficient life with self-governance, the construction level of commercial service facilities reflects the average affordability of the students who occupy a large proportion of the campus population (Fig. 8). That is also an important reason for those campuses to build more welfare facilities (such as stadium, natatorium, theater, canteen, hospital, hotel and restaurant) as a beneficial complement to meet the growing diversified demand. Furthermore, although our study focuses mainly on the major classification of land uses in campuses, we must emphasize that there are still largely diversified sub-functions within each major function. **To summarize, the diverse population accompanied with a large degree of land use mix constitute the overall vitality within Beijing's campuses.**

Fig. 8. University staff and student residence buildings and related commercial buildings of Beijing's campuses.

The enclosure and gating measurement of 15 campuses only focuses on physical accessibility, which is more relevant for the dense population working and living inside the campus. In reality, the enclosure and gating system includes the temporal-spatial restriction are more specifically designed for the public visit. In addition to this, many functions such as canteen, library, dormitory and hospital within the campus cannot be visited without a digital campus card. **From the spatial-temporal enclosure and gating system to the usage restriction of the inner functions, universities are deterring the outside public from sharing the campus resources.** When inner high density adds to the necessity of exclusion towards the public, the campus would be willing to simply turn to the solution of walls and gates. Despite the "compound wall economy" appears in market reform seems as a turning outward process for those enclosed campuses, these "turning outward walls" could not improve the accessibility between inside and outside the campus for the public. **In other words, though many of the fragmented boundary spaces are regarded as the functional extension of those universities to the public, they still function as the "thickened walls" between inner collective life and outside public life.** On the one hand, these "turning outward walls" and "thickened walls" contribute to the provision of more accessible public services to the society; On the other hand, they continue to execute the control function to lower the public accessibility and prevent them from sharing the campus resources.

To resolve the challenge of high density and scarce of space in urban Beijing, many strategies have been developed. Firstly, the campuses of PKU, RUC, BJTU, BJFU and MUC etc. expand their functional spaces including residence, institution, and schools to the other side of the surrounding urban public roads. Alternatively, some universities also develop new campuses far outside the fifth ring of Beijing. BUAA and BUPT build their new campuses, mainly for the freshmen and sophomores, in Shahe close to the north of the sixth ring. Other new campuses are located in Liangxiang university city, which is next to the southwest of the sixth ring. Another tactic is related to the housing exchange policy. Take THU for example, those teachers including retired professors who live inside the campus are asked to exchange their campus housing assets with housing in Bajia (1.5 km to the north of the campus). In this way, the full usage of housing will be activated by the young faculty members.

In parallel with campus' self-governance, the combination of the outside public developments in service and job forms a comprehensive strategy to address the high-density issues inside the campus. In nowadays Beijing, the public facilities outside the campuses has experienced 30 years of fast development in the economy reform (e.g. newly developed TOD system), which benefit the high-density population inside the campus. The subway stations and shopping malls built close to the gates of the campus absolutely contribute to the provision of alternative and advanced public service to the campus population. At the same time, those innovation sectors located surrounding these campuses formulate a win-win situation with the universities. In this way, the campuses could balance their inner space use issues under more flexible choices, while remaining a stable self-governance state.

With the analysis of social-spatial interaction within selected study cases in Beijing, we observed that those campuses are experiencing an era of vigorous development owing to its high functional mix. It seems that those campus, as the spatial legacy produced in a socialist economy, have adapted themselves to the market reform after 1978 in China, which is still a simple but effective urban spatial governance strategy. In this model, either benefiting from the top-down policy tilt or insisting on self-governance within enclosed boundaries, Beijing's campus ones are supporting a highly dense urban life by successfully integrating the socio-spatial resources inside and outside the campus.

Nevertheless, there are many aspects could be improved in the future study. Further analysis could extend the time horizon to understand the dynamic evolution of space use within campuses. Secondly, Land use mix applied in our study is a general categorization. A more detailed land use classification of certain services considering the opening time will be suggested in the future study. Thirdly, campuses are only one of the major types of work-units in China, work-units that belong to enterprises, or government agencies should also be investigated to provide a full picture of the space production under a collectivist culture and strict political control. Lastly, qualitative interviews would also be an important channel to dig more underlying factors that shape the pattern of spatial usage.

5.2. Conclusions

Our study reaches three major conclusions as below.

Firstly, land use mix is essential in the balanced use of campus space, while physical enclosure and gating further enhance this stability. With the background of dense population, even enclosure itself, the campus space is still activated via mixed land use in a balanced way across different time periods. This is a crucial finding *"since it promotes the assertions that high-density 'done well' could meet environmental and economic sustainability goals while not compromising social sustainability." (*Arundel & Ronald, 2017*)*. This partially diverges from the western postmodernism theories on advocating open blocks with mixed use. Instead, the robust and sustainable growth of Chinese campuses with a "work-unit" spatial configuration demonstrates that there is a "Chinese-style" of postmodernism cultivated in urban China.

In response to the long-persistent strategy of invigorating China through science and education, though the campuses in Beijing are suffering from a high dense population due to the enrollment expansion in the industrialization of education, a stable mechanism has been developed to optimize the space use issue. First, benefited from the realization of self-governance that is enabled by the central government (campus-state vertical independent coordination), the campus could rely on developing its land use mix to meet the diversified requirements of its dense population. Second, owing to the enclosure and gating system, together with the municipal administration, the campus could realize parallel independent governance of their respective spaces. The clear division of responsibility of land use management between the university and city government will reduce the transaction cost between different departments. **Self-contained land use mix, accompanied by the clear management body, will let the "gone" prediction of the collective work unit be premature.**

Secondly, campuses in Beijing relief their high-density burden through flexibly interacting with the adjacent areas, owing to its proximity to TOD nodes. The campuses in Beijing integrates the advantage of combining TND and TOD together. On the one hand, through its land use mix, it follows the guideline of TND. On the other hand, owing to the proximity to TOD, it makes full use of the services of the adjacent areas. The enclosed and gated campuses, with their collective life inside, remains a flexible interaction with the city in the past 70 years. This realized the aim of the formation of a healthy community through the equitable and rational allocation of community recreational facilities (Chen, Hui, Lang, & Tao, 2016). From the start of the planned economy after 1949, for reversing the plight of lacking public service that could not be supplied by the central government, land use mix was developed through the self-governance by those campuses. Nowadays, those campuses not only benefit from the public commercial service outside, but also provide human capital to the surrounding innovation companies. **Overall, Chinese campuses demonstrate that there are never fully enclosed and self-contained spatial entities. Instead, they effectively adapt themselves by integrating the inner**

and outer space in a flexible manner during the transformation from a planned economy to market economy.

Lastly, the distinctive utilization of spaces between different campuses reflects the socio-spatial differentiation occurred within university space, though the social mix of students inside every campus is guaranteed by the fair enrollment policy. Indeed, the university work units built their campus at the beginning with a similar standard and pattern after 1949 (Bray, 2005; P135), which brought not only the homogeneity but also equality between different universities. The social mixing state within the denselypopulated gated campuses makes them as the container of social equity in Beijing. However, in the reform from central economy to a market economy, different campuses formed their own spatial features which are closely embedded in developing their respectively preponderant disciplines. In addition, the national support policies for high education (such as project “211”, project “985” and current project “world-class universities and first-class disciplines”) provide differentiated levels of funding to those universities, which also adds to the heterogeneity of space use among Beijing's campuses. This explains why some campus could better balance their spatial use under continuous progress while others rely more on the surrounding public services to relief its burden.

From the American theories of fear and stratification to explain the reason of gated communities to the perspective of combining local collective culture and political governance to reveal the mechanism of the enclosure and gating of work unit in China (Huang, 2006), it is a constructive angle to help us understand the capability and limitation of western urban planning and city theories in different social backgrounds. The context of economy development and political institution should not be neglected in the study on urban spatial use patterns. When a state strategically pushes the development of industries and social lives, the special demand for human capital will be produced in this process. This will in turn affect the mechanism of urban spatial governance. **Apart from the diversified and integrated urban environments advocated by western theories, there are much more specific and distinctive motivations needed to be explored for revealing the mechanism of the enclosed spaces occupied by dense and mixed population in countries like China.**

Our study adds new empirical evidences on revealing the essential factors that influence the daily balanced use of work-unit space, taking Chinese campus as an example. Furthermore, the analysis of the robust existence of the Beijing work unit cases nowadays in our study uncovers new driving forces for regulating these well-developed campuses. **We might believe that the support from the state and local strategy of innovation industry and highly dense population inside the campus become the new driving forces to maintain the collective social and functional mix within the enclosed campus ones in Beijing.** Without the strong basis of development motivation and institutional support, the revival prediction of work units will also be premature.

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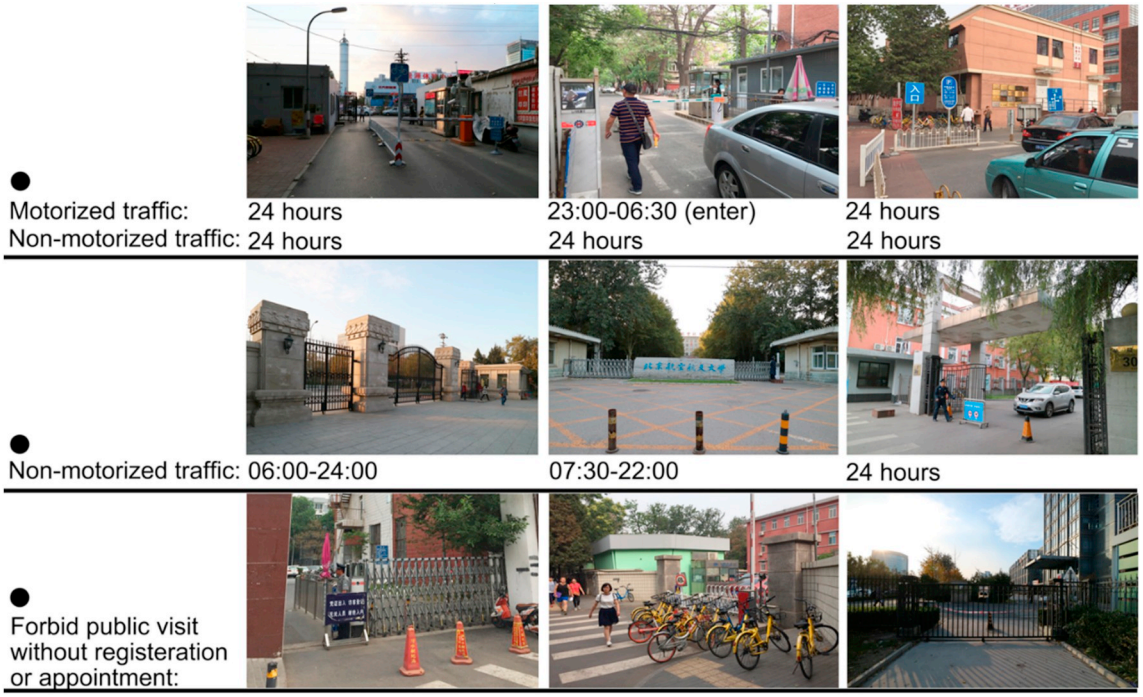
Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.habitatint.2019.102024.

APPENDIX

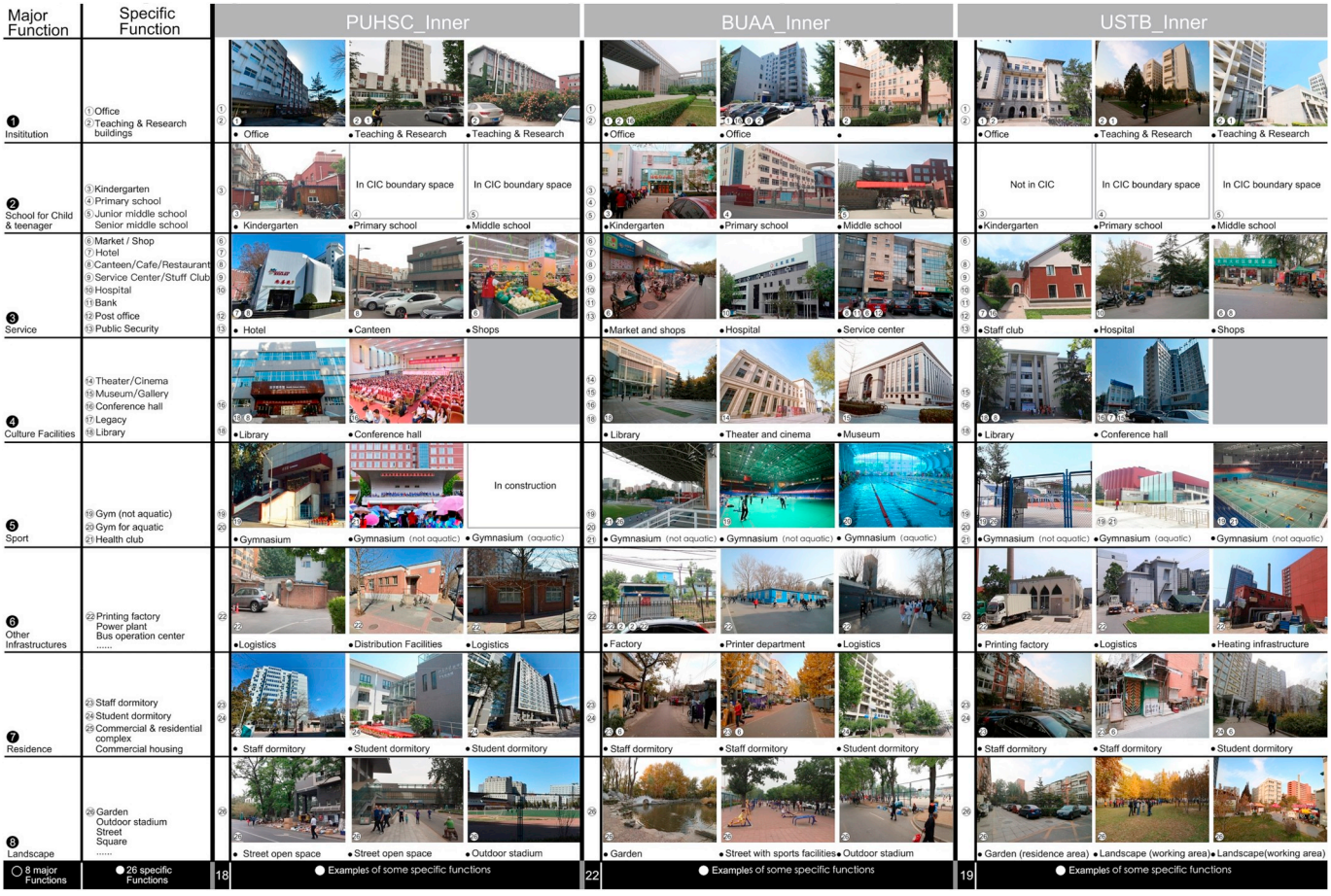
	DPMHA	Entropy	Enclosure	Gender_ratio	Fund	CIC_area	Ranking	Insti_area	Serv_area	Resi_area
1.PKU	0.125	0.693	0.15	52%	2.846	1.206	1	0.603	0.158	0.214
2.RUC	0.217	0.697	0.06	58%	0.085	0.622	7	0.304	0.076	0.357
3.CUMTB	0.166	0.723	0.04	33%	0.239	0.258	35	0.098	0.042	0.226
4.USTB	0.163	0.650	0.06	44%	0.239	0.633	10	0.225	0.043	0.33
5.CAU	0.189	0.643	0.05	54%	1.684	0.471	26	0.209	0.014	0.355
6.BUAA	0.228	0.806	0.06	26%	2.701	1.065	21	0.49	0.04	0.314
7.BJFU	0.223	0.620	0.04	64%	0.230	0.443	66	0.227	0.035	0.396
8.BIT	0.087	0.551	0.10	35%	2.626	0.723	32	0.49	0.074	0.357
9.BNU	0.240	0.737	0.05	56%	0.681	0.590	11	0.328	0.058	0.317
10.BUPT	0.252	0.750	0.04	36%	0.351	0.370	69	0.157	0.047	0.243
11.BJTU	0.227	0.658	0.12	47%	0.653	0.581	46	0.278	0.083	0.481
12.MUC	0.169	0.621	0.04	67%	0.016	0.253	80	0.174	0.028	0.114
13.BLCU	0.245	0.750	0.06	75%	0.002	0.360	202	0.112	0.044	0.197
14.PUHSC	0.226	0.710	0.11	70%	2.846	0.480	1	0.175	0.036	0.231
15.CUGB	0.181	0.638	0.05	42%	0.320	0.396	44	0.174	0.042	0.293

Appendix 1. The general statistics of 15 campuses.

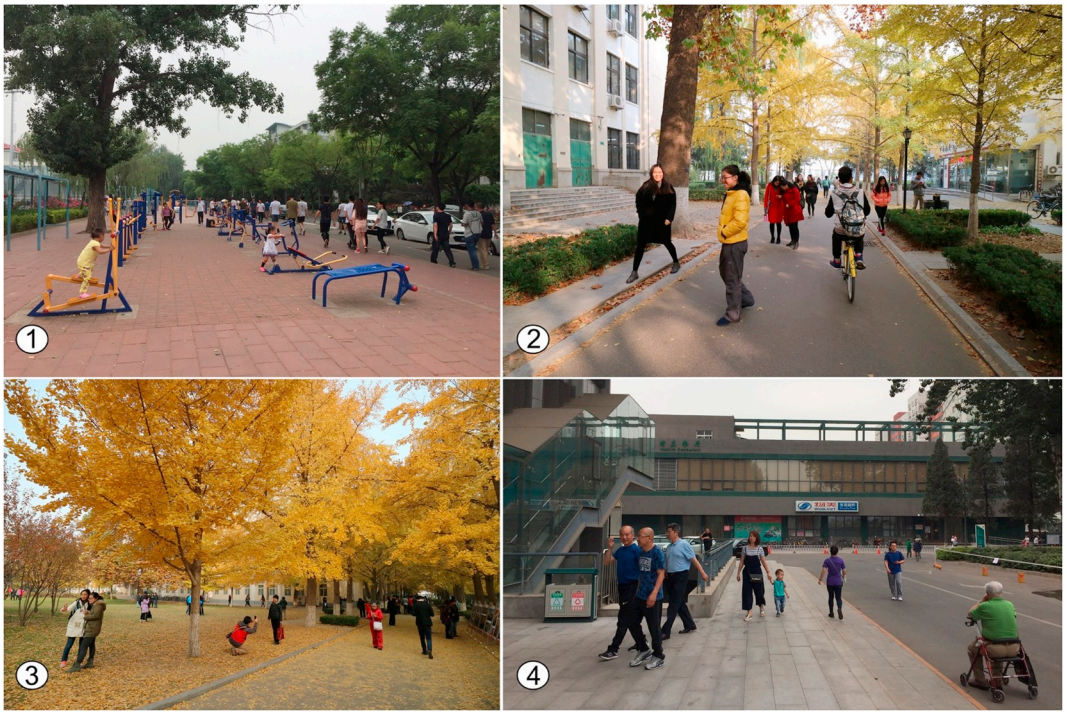


Appendix 2. Various types of public traffic management systems among CIC gates.
(Taken in 2017 and 2018)

Appendix 3. Main types and examples of the spatial segregation along CIC boundary
(Taken on 12th of June 2018)



Appendix 4. Land use mix within BUAA, USTB, and PUHSC
(The main part of the photos is taken by authors and the rest of photos are from Baidu map, Tencent map and websites of PUHSC, BUAA and USTB.)



Appendix 5. Scenes of university campus
(1. Taken on 12th of June 2018 in BUAA; 2 & 3. Taken on 10th of Nov 2016 in USTB; 4. Taken on 12th of June 2018 in PUHSC.)

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