‘TEAR DOWN’ THE FENCES: DEVELOPING ABM INFORMED DESIGN STRATEGIES FOR UNGATING CLOSED RESIDENTIAL COMMUNITIES

Developing ABM informed design strategies for ungating closed residential communities

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Abstract. Embedded in China’s urbanization process, the growth of gated residential estates has gradually induced severance of urban spaces, resulting in an underutilization of public amenities, a lack of walkable permeability, and congestion of traffic. Responding to these negative effects on urban development, the CPC has released a guideline in February 2016 to prohibit the development of any new closed residential areas in principle and to advocate ungated communities. In this paper, we utilized ABM simulation analysis to test different degrees of openness, the position of new entrances/openness, and pedestrian network typologies, aiming to explore feasible strategies to accommodate the new urban design agenda. A series of typical gated compounds in Beijing were selected for comparative case studies, conducted under different degrees of openness of each case and under diverse ungating modes between cases. On the basis of these analyses, we summarized a sequence of pedestrian-centric design strategies, seeking to increase the communities’ permeability and walkability by suggesting alternative internal and external road network design options for Beijing urban renewal. By integrating quantified simulation into the empirical method of urban design, our research can positively assist and inform urban practitioners to propose a more sustainable urbanity in the future.

Keywords. Gated community; agent-based modeling; pedestrian simulation; computer-aided urban design; road network optimization.

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1. Introduction

The growth of gated communities and compounds is ubiquitous in China's urbanization process, with a history traced back to the introspective courtyard archetype of the feudal monarchy period of China (Miao et al., 2009). Earlier this century, Chinese urban planners and researchers noticed that multiple urban problems induced by gated compounds have gradually emerged. The closedness and segregation of gated communities tended to fragment urban spaces, exacerbating the disconnected traffic networks, underutilization of public amenities and social-geographical inequality. Responding to these negative effects on urban development, the CPC (Central Committee and State Council) has released a guideline in February 2016 to gradually prohibit the development of any new closed residential areas in principle, and to advocate ungated communities with denser and more public road networks. Preceding studies provide supporting evidence for the central government's wish to ungate China's superblocks: small blocks mostly produce a highly interconnected pedestrian network (Jacobs, 1961) and a more highly connected and walkable built environment is associated with better sustainability and physical health (Alfonzo et al., 2014). As prior gated community researches have commonly concentrated on empirical sociological studies (Low, 2001; Le Goix, 2005) and regional analysis of urban morphology, much less effort has been given to community-scale ungating strategy analysis. It is of great significance to develop an effective ungating strategy from a neighborhood's perspective, seeking to promote a better city form with permeable spatial patterns facilitating accessibility and maximising connectivity (Lynch, 1981; Talen, 2002).

Agent-based models (ABM) are widely used for the dynamic simulation of the simultaneous operations and interactions of multiple agents (Grimm et al., 2005). In the field of urban design, ABM is a useful tool for circulation simulation, as a person can be identified and traced as an individual entity (Ronald et al., 2007). The specificity and fine-grain analysis of ABM makes it suitable for neighborhood-scale investigation and studies of walkability and its essential dimensions. One such crucial dimension, permeability, is utilized in this research to investigate efficacious opening strategies to prosecute the objectives of the new urban design agenda of the CPC through improved walkability. We define permeability in this work as two complementary metrics of *through-movement* and *to-movement* (Hiller et al., 1993) to construct a two-tier system in the simulation process. Beijing, with widespread private secured residential compounds in its metropolitan area, is an apposite site of investigation. In our experiment, comparative ABM simulation analysis case studies of permeability with or without gating were undertaken for compounds around the Beijing CBD area. The research utilized PedSim, a free Grasshopper plug-in to model the movement and circulation of pedestrians (www.food4rhino.com/app/pedsim). Based on the existing population density and the location of public amenities, we proposed different strategies of opening with new entrances/openness, and simulated pedestrian patterns accordingly. We subsequently summarized diverse pedestrian-centric design strategies of each community type, suggesting an optimized alternative road network structure with shortened walking distances and

provision of more travel options. This digital design approach could extensively explore effective and diversified developments of open communities in the future instead of coercive removal of restricted gates.

2. Background

2.1. GATED COMMUNITIES AND PERMEABLE WALKING SYSTEM

As discussed above, gated communities have been widespread in contemporary China's urbanization process as an effective residential unit for governance and management. Generally, enclosing walls and guarded gates are typical elements presented ubiquitously in gated compounds as barriers for through-traffic (Glasze et al., 2004; Xu and Yang, 2009), physically segregating the internal road systems of closed residential communities from the public road network of the city. Such isolation has induced impermeability of pedestrian travel between residential neighborhoods and greater car-driving behavior, which has sequentially given rise to the ineffective use of public facilities inside the community and traffic jams outside the compound (Normile, 2016; Wu, 2005).

The accessible level of to-movement and through-movement for pedestrians are two significant aspects of a compound's walking permeability. Previous studies have shown that the hypothetical removal of gated community barriers could strikingly increase accessibility and permeability for pedestrians (Sun et al., 2017). Guarded barriers may address safety and governing issues; strategies for ungating closed compounds therefore need to be prudent instead of advocating their complete removal. In this study, we simulated pedestrian networks under different degrees of openness, and compare effective ungating strategies for various types of closed residential communities.

2.2. ABM AND PEDESTRIAN SIMULATION IN ARCHITECTURAL AND URBAN DESIGN

In general, the agent-based model (ABM) is an approach to examining complex systems of the autonomous operations and interactions of multiple agents (Grimm et al., 2005; Macal and North, 2010). By modeling agents individually, the agent-based simulation focuses on modeling agents' heterogeneity across a population and the emergence of self-organization (Macal and North, 2010). Since the 1940s, ABM has become largely implemented for modeling complex adaptive systems (CAS), ranging from modeling agent behavior in the stock market (Arthur et al., 1997) to investigating the fall of ancient civilizations (Kohler et al., 2005).

In urban design, ABM has been increasingly developed and applied to simulating human movement over the past two decades. As a single person can be marked as an individual agent, diverse results can be observed from the collective behavioral patterns emerging from the interaction of micro-level agents (Ronald et al., 2007; Osaragi 2004; Kitazawa and Batty 2001;). In 1996, Turner first introduced ABM in micro-level studies of urban scenarios, realizing the application of ABM in the urban design domain. To date, most ABMs are integrated with other modeling strategies to develop more synthetic simulations. In 2D, a space syntax base ABM was developed by Turner and Penn (2001) in

the early time of this century. In 2008, procedural modeling and ABM were aggregated by Aschwanden (2014) as a synthetic tool. To realize ABM in the 3D digital dimension, Huang, White and Burry integrated Virtual Reality with ABM in 2018, simulating and visualizing pedestrian behaviors in urban environments with immersive design experience (Huang et al., 2018). Instead of conducting highly detailed ABM simulation in building scale analysis, this research utilized PedSim to investigate walkable permeability in the neighborhood scale and proposes future strategies for modifying neighborhood walkability.

3. Methodology

3.1. PERMEABILITY AND ASSESSMENT

Generally defined as the degree to which an urban form permeates the publicly accessible space, permeability has been identified as one of the essential aspects of walkability, together with safety, footpath quality, land use mix, density, and climate (Marshall 2005; Ewing and Handy 2009; Pafka and Dovey 2016). Its measurements relate to the ease of movement through a targeted urban area and the diversity of travel choices. Therefore, this research selected two types of movements to assess permeability in the neighborhood's scale. The first is named through-movement, representing the potential for pedestrians outside the neighborhood to travel through the community and to access the public facilities and landscape resources inside and surrounding the neighborhood. Second, the type of movement by which pedestrians living inside the neighborhood can access directly to public amenities around the community can be defined as to-movement. In this mixed measurement system, convenient and diversified through-movement and to-movement for pedestrians represent a neighborhood with good permeability.

3.2. ABM PEDESTRIAN SIMULATION

As described above, we have proposed a two-tier pedestrian simulation through PedSim. The location of public transit nodes, public facilities around the targeted closed compound, and the gates of surrounding communities were firstly set as the start-points and end-points for the simulation of through-movement. Public amenities and green space resources within the gated compound were marked as the targets that could be shared for pedestrians traveling through the community. Following a similar logic, we then set the location of each residential building's entrance as the start-point and set the surrounding public amenities as the end-point for the simulation of to-movement.

To evaluate the permeable pedestrian network under different degrees of gatedness, we use the cumulative density of agent path trajectories as an indication of travel choice. Summarizing travel choice tendencies, we correspondingly revised the position of new gates and the extent of boundary walls for further testing the next scenario. As additional indicators for optimizing pedestrian networks, the average travel time and distance of agents were calculated to measure the convenience and ease of movement. These two indications facilitated us to conduct comparative studies under various gatedness degrees within one

case, suggesting a series of optimized opening strategies accordingly. Based on the differentiation of optimized patterns among these cases, ungating strategies were summarized for a taxonomy of gated communities.

Table 1. Simulation settings of the ABM system.

INDIVIDUAL AGENT SETTINGS	
AGENT NUMBER	The number of agents is assumed to be 200.
MAX SPEED	The agent moves towards targets and gates with this speed.
MAX FORCE	The magnitude of attracting force that makes a person move towards targets, which is set as 30 in this research.
LIFESPAN	Number of time steps an agent can survive
GOAL POINT SETTINGS	
GATE	Surrounding public facilities, the location of public transits, and the entrances for internal residential buildings
TARGET	Internal public facilities that can be shared, green spaces, schools and commercial buildings

4. Comparative Case Study

As one of the pilot cities for China's rapid urbanization, gated compounds have developed rapidly in the Beijing metropolitan area in the past few decades. In total, approximately 10300 privately secured gated communities were built up to February 2020 (The Beijing News, 2020.2.22). Borrowing theories from community openness evaluation, current gated communities in the Beijing metropolitan area can be classified into four categories on a continuum from closed to open: *enclosed community*, *semi-enclosed community*, *semi-open community*, and *open community* (Liu, 2016; Liu et al., 2020). Enclosed communities with guarding gates were widely constructed from the 1950s to the 1990s. The block length of these communities is relatively long, ranging from 60 to 400 meters; however, the number of gates on each side of the block is often limited to three. Compared to the enclosed community type, the other three types have smaller blocks with more gates and higher openness.

Although the development of open communities is only in an early stage, the *Jianwai SOHO* neighborhood is a successful attempt in Beijing. Designed by Riken Yamamoto and Field Shop, the site's existing superblock was subdivided into nine smaller groups while arterial roads and secondary streets were introduced into the site. The mixed road system and compound building type provide possibilities for the pedestrian that endow a high degree of liveliness of the community (Rowe and Kan). Despite the fact that a complete ungating strategy like Jianwai SOHO cannot be applied to every compound, this research proposes to maximise the openness degree while retaining the safety and privacy of each residential model.

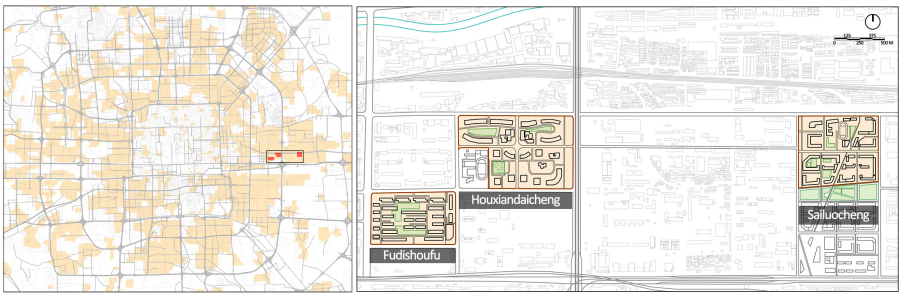
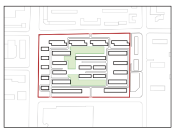


Figure 1. Distribution of gated communities in the Beijing metropolitan area and the position of selected cases.

Table 2. Existing site conditions of selected cases.

GATEDNESS/OPENNESS	FULLY ENCLOSED GATED COMMUNITY	SEMI-ENCLOSED GATED COMMUNITY	SEMI-OPEN GATED COMMUNITY	OPEN COMMUNITY
GATING/OPENING MODES	Gated residential community & Gated residential cluster	Open residential community & Gated residential cluster	Open residential community & Partially open residential cluster	Open residential community & Open residential cluster
BOUNDARY MANAGEMENT MODES	Continuous enclosing walls & Guarding Gates	Continuous enclosing walls & Guarding Gates	Partial enclosing walls & Guarding Gates	Guarding Gates
CASE	Fudishoufu Community	Houxiandaicheng Community	Sailuocheng Community-North Block	Jianwai SOHO
GATE NUMBER	3	7	14	
WALL MAPPING				

4.1. CASE 1 FUDISHOUFU COMMUNITY

As a typical fully enclosed residential community, *Fudishoufu Community* has relatively low existing permeability that inhibits through-travel and poses an inconvenience for movements to surrounding public facilities. It occupies a huge block covering a total area of 91937 square metres by 24 residential buildings. The largest block length measures up to 400 metres, with only four guarding gates in total. The existing permeability level is relatively low, inhibiting through-travel and posing inconvenience for movements to surrounding public facilities.

The simulation of the Fudishoufu Community was conducted under various degrees of openness from completely open to partially open: the selected procedures are listed below. As mentioned above, the existing gates and the location of surrounding public transits and infrastructures were defined as the "gate" in simulations, while the internal green spaces and public amenities were set as the "target". According to the cumulative density of agent path trajectories under 100% open simulation, the tendency for travel choice was captured and analyzed, and correspondingly, the position of new community gates and the extent of new boundaries were designated for further simulation. Following the same procedure, the pedestrian simulation was iteratively conducted until the optimized pedestrian network was determined and integrated with the existing road

system.

Findings: The results illustrated denser and more connected pedestrian networks after the removal of the gates. However, as the enclosed community has few shared facilities and amenities, it's not meaningful to divide the block into small clusters. Furthermore, the building type in such communities is residential, which requires a high level of privacy and safety. Therefore, the optimized ungating strategy is to maximize the number of guarding gates at minimum private cost. (Figure 2)

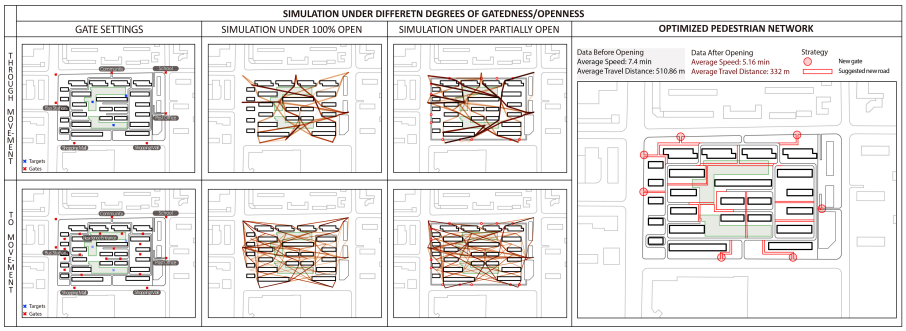


Figure 2. Simulation results of Fudishoufu Community and proposed new pedestrian network.

4.2. CASE 2 HOUXIANDAICHENG COMMUNITY

The *Houxiandaicheng Community* is located on Baiziwan Road in Chaoyang District, covering 206300 square metres. Different from Fudishoufu Community, it contains diverse building types, including residential, office, and commercial. The neighborhood is divided into four groups with separating roads that are open and connected to the city network. Compared with the traditional airtight enclosed residential areas around, the Houxiandaicheng Community is a progressive step towards openness in the design of Chinese urban communities.

Findings: The existing permeable level of Houxiandaicheng Community is better than case 1, which is consistent with the research results by Jane Jacobs that short blocks relate to a better interconnected pedestrian network (Jacobs 1961, pp.178-186). However, the simulation indicates the need to increase walkable connection between four residential groups. Specifically, a viable ungating approach for semi-enclosed communities is to improve permeability between groups by setting more gates and adding potential connecting pedestrian access above or below ground. (Figure 3)

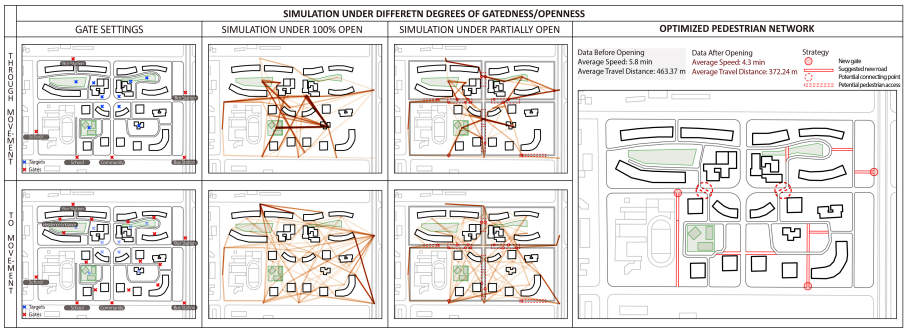


Figure 3. Simulation results of Houxiandaicheng and proposed new pedestrian network.

4.3. CASE 3 SAILUOCHENG COMMUNITY-NORTH BLOCK

Located at a distance of 1.2km from the Houxiandaicheng Community, *Sailuocheng Community* has a higher degree of openness with block-oriented planning. The division of the internal clusters of the Sailuocheng Community can be regarded as a model of the "small blocks, dense road network" promoted by the CPC. The entire residential area consists of four rectangular areas arranged in a north-south direction, and each area is divided into three to five groups of mixed-use buildings with underlying commercial facilities. Under that condition, the simulation of this case focused on the optimization of existing pedestrian networks and the selective relocation of enclosing walls.

Findings: The planning modes of the Sailuocheng Community are close to a completely open community. Correspondingly, its existing permeability is the best among the three cases, which send a positive signal that a reasonable opening of gated communities can indeed have positive impacts on the urban pedestrian system. According to our simulation results, only a small number of guarding gates and enclosing walls need to be removed or relocated. (Figure 4)

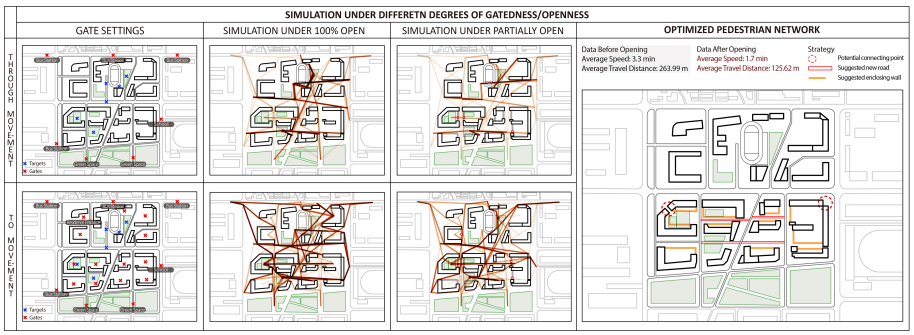


Figure 4. Simulation results of Sailuocheng Community and proposed new pedestrian network.

According to simulation results of three ungating scenarios, the ease of

movement has been improved to varying degrees with various opening strategies, indicating the potential and significance to develop specific opening approaches for different types of private secured neighborhoods.

5. Discussion and Conclusion

As discussed above, there is a striking difference in walking accessibility after compound gates have been completely opened and the enclosing walls have been removed. This is a positive indication that opening communities' internal road networks to the city can promote sharing public service facilities and green space resources, building a harmonious and unified neighborhood environment. However, wholescale and arbitrary removal of guarding gates and enclosures is unacceptable, which may give rise to a new urban conflict of property rights and safety issues. Thus, it is prudent to determine the ungating strategy for different types of gated communities at minimum political and legal cost.

Compared with conventional studies on the walkability of gated communities, this paper presents a novel research approach by establishing the two-tier pedestrian movement modeling through ABM, investigating changes in permeability among multiple opening scenarios, and informing corresponding patterns for Beijing's ungating urbanity. According to our research findings, different types of gated communities have obvious differentiations in the degree and mode of opening.

For the fully enclosed gated community type, building types inside the compounds are mostly residential buildings, which in and of themselves are inappropriate to be opened or shared with the outside of the community. Resources in these communities that may be of interest to the general public are limited and mostly green space resources. Specifically, our research has shown that the impactful ungating strategy for these gated compounds is to have more gates and more dynamic pedestrian networks, so as to facilitate walkability for pedestrians living in- and outside the compound.

Necessitating a different approach, the extant morphology of semi-enclosed and semi-open gated community types is division into smaller clusters than enclosed communities. Their internal road networks have correspondingly multiple layers and are partially connected with the urban road network system. Building types in these communities are more diverse and vertically compound, including community schools, local centers, surrounding community shops, and underlying commercial facilities. Ungating tactics for these compounds concentrated more on optimizing the pedestrian networks between sub-clusters to enhance the public utilization of shared amenities.

With the aid of computational simulation, this research demonstrates that road network typologies with varying degrees of openness have an influence on pedestrian travel choice. In investigating the potential pedestrian access of ungated compounds, we seek to increase the communities' permeability and walkability by suggesting alternative internal and external road network design options. However, this study has the potential for future extensions in both diversity and accuracy. For example, the neighborhood-level permeability study

concentrated more on investigating walking patterns and road networks without including spatial design at the building scale. Moreover, a more delicate road network could be developed, separating the cycling network from the pedestrian network. Considering that, we are now proposing a finer pedestrian network of micro permeability based on this research, offering a more pragmatic opening scenario for Beijing urban renewal.

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