IN-BETWEEN SPACES: DATA-DRIVEN ANALYSIS AND GENERATIVE DESIGN FOR PUBLIC HOUSING ESTATE LAYOUTS

KWAN KI CALVIN WONG[1] and JEROEN VAN AMEIJDE[2]
[1,2]*The Chinese University of Hong Kong*
[1]*kkwongcalvin123@gmail.com* [2]*jeroen.vanameijde@cuhk.edu.hk*

Abstract. As Hong Kong constructs increasingly high-density, high-rise public housing estates to increase land use efficiency, public in-between spaces are more constrained, which impacts the quality of social relations, movements and daily practices of residents (Shelton et al. 2011; Tang et al. 2019). Current planning practices are focused on the achievement of quantitative performance measures, rather than qualitative design considerations that support residents' experiences and community interaction. This paper presents a new methodology that combines urban analysis and generative design for the regeneration of social housing estates, based on the spatial and social qualities of their in-between spaces.

Keywords. Social Housing; Public Open Space; Generative Design; Urban Planning.

1. Introduction

Nearly half of Hong Kong's population is living in public housing estates, in public rental housing (31%) and subsidised home ownership schemes (17%). The government housing programme was started in the 1950's to resettle squatter home camps and expanded in the 1960's in response to a large population influx and social unrest (Yung, 2008). Similar to how in Europe large scale social housing projects were constructed as part of the post-war atmosphere of solidarity, the Hong Kong housing programme was systematised to ''help to build a sense of community and greater social integration among Hong Kong's people'' (Yu 1997, p. 543). To maximise the efficiency of the estates in relation to a limited amount of available land, Hong Kong's public housing is characterised by high-rise slab blocks or towers arranged in dense patterns with limited public spaces or greenery in between.

Over time, the planning strategies for public housing estates have gradually developed towards self-sufficient estates, through incorporation of comprehensive retail and public facilities such as for sports, recreation and socializing. In recent decades, the public space configurations have shifted from open spaces as the heart of community to retail malls to serve this function (Wang & Chen, 2018). With the increase of density, the under-supply of open spaces has become a problem in Hong Kong (Lai, 2017).

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Studies show that the quality of life of public housing tenants can be significantly improved through access to socialising spaces, recreational and green spaces, and community facilities (Saunders et al., 2014; Gou et al., 2018). Well-planned public spaces in housing estates can facilitate people's interaction with neighbours and the surrounding context, which contributes to public housing residents' well-being and integration within society (Zheng et al., 2015; Lau & Murie, 2017). However, studies have found that there is a mismatch in the type of public spaces that is provided, as spaces are found to be unequally distributed, overprogrammed or overregulated (Lai, 2018; Chow, 2018). There is a need for more precise studies into the actual use of public spaces in public housing, to understand how to improve their quality and effectiveness, to make more effective use of limited urban space.

2. Urban Theory: Neighbourhood Design and the Sense of Community

The design philosophy of Hong Kong's housing estates can be traced to the Town Planning movement, inspired by Clarence Perry's 'neighbourhood unit concept'. The idealistic vision was to create new urban communities which would be integrated and harmonious, containing residential buildings, community facilities and services for the residents. The physical layout of the housing estates was based on assumptions around the needs of local residents, aiming to give ''rational and idealised form to support their patterns of life and sense of community'' (Kan 1974, p. 160).

The 'failure' of several well-known international examples of public housing, such as the Pruitt-Igoe projects in St. Louis (demolished 1972-76) or the Heygate Estate in London (demolished in 2011-14), has demonstrated that the quality, management and sense of ownership of the public spaces plays a significant role in maintaining the reputation and social success of public housing (Glendinning & Muthesius, 1995). In Hong Kong, public housing estates are generally considered successful, but public spaces are designed to satisfy basic needs, rather than seen as an opportunity for the comprehensive design of community support infrastructure. The rigid planning of functions across estates results in a lack of adaptation to changing needs of the population.

Jane Jacobs (1961) argued that urban regeneration should considered the needs of city dwellers, in contrast to the Modernist practice of top-down urban planning. She suggested that housing should be connected and related to the city, so that they allow people and urban fabric to build on the city's diversity. William Whyte (1980) demonstrated correlations between human behaviours and urban form, which can be translated into design guidelines for the design and management of better-quality open spaces. Whyte's methodologies included the use of direct observation of users, and statistical analysis of their activities. Through watching how people use a space and by comparing users' reaction to different urban elements, we can form an understanding about which elements contribute to good quality public spaces.

3. Methodology

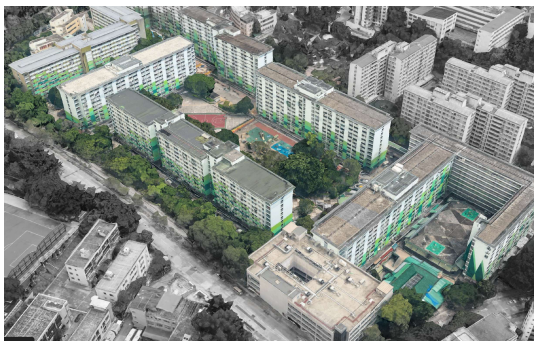

Figure 1. Nam Shan Estate in Sham Shui Po, Hong Kong.

Nam Shan Estate, one of the older public housing estates in Hong Kong that has lively public spaces (Fig. 1), was chosen to investigate the two key initial questions of this research:

- Which aspects contribute to the socialization of open space?
- How can we quantify the social performance of different open spaces?

3.1. FIELD OBSERVATIONS AND MAPPING OF SOCIAL ACTIVITIES

A series of site visits with a group of observers was organised to take snapshot observations of the amounts of people across the site, and the types and durations of social activities that they were engaged in. Several typical time periods were selected, such as weekday lunchtime, afternoon and evening, to capture typical short-term public space uses by various user groups which included residents as well as visitors from the surrounding district.

The activities in the open spaces of the estate were mapped into the estate plan, and categorized into various groups, to assists in the analysis of the different estate spaces. The type of activities was documented, as well as the duration of each activity (Fig. 2.1). Customised computational tools for the analysis and visualisation of closeness between people allowed to discern areas with higher potential for social interaction (Fig. 2.2).

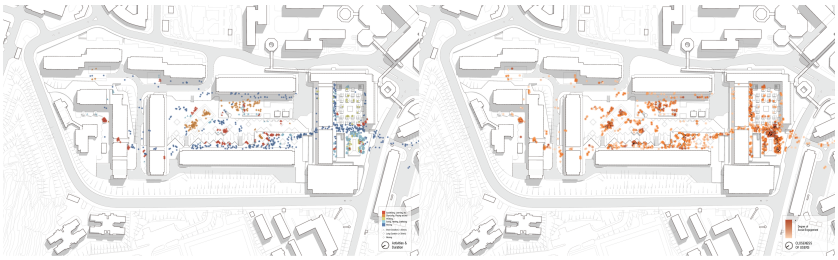

Figure 2. 1. Activities and Duration, 2. Closeness.

3.2. URBAN MORPHOLOGY ANALYSIS

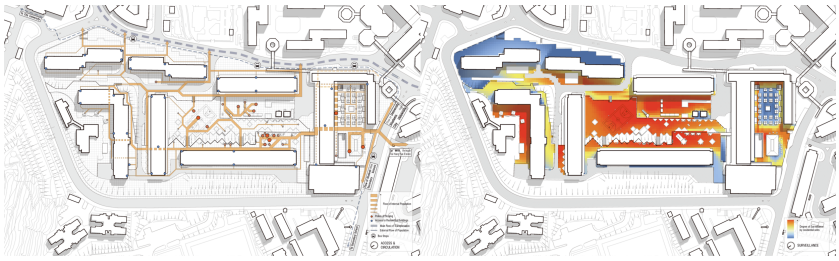

Figure 3. 1. Access and Circulation, 2. Surveillance by residential units.

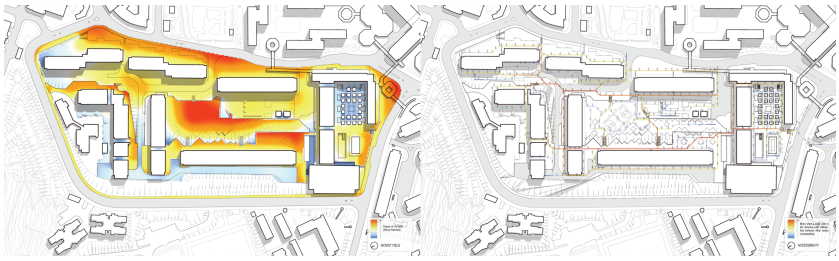

Figure 4. 1. Visibility, 2. Accessibility.

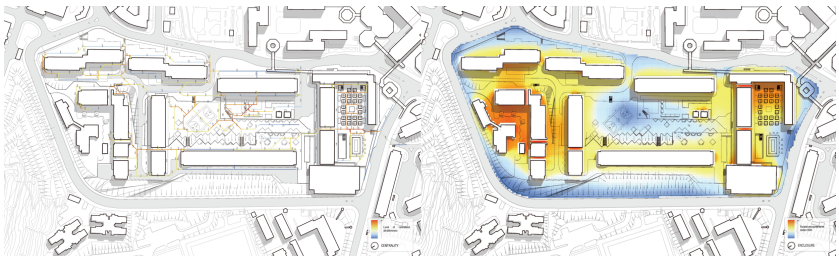

Figure 5. 1. Centrality, 2. Enclosure.

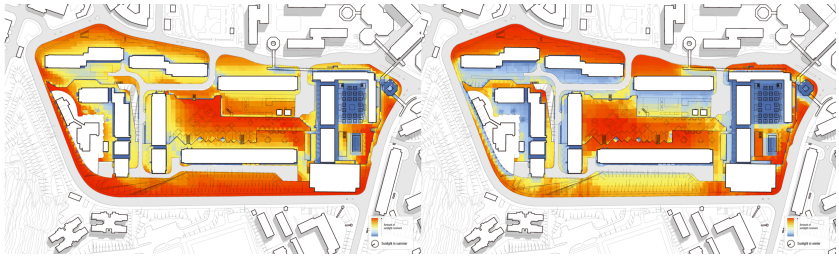

Figure 6. 1. Summer Sunlight, 2. Winter Sunlight.

In addition to the human-centric studies, a series of space-centric analyses was done to understand and visualise the housing estate's various in-between spaces.

Access and Circulation demonstrates how people travel between their individual housing blocks and the major destination points inside and around the estate's site boundary. Based on the observations of flow intensities along the different connecting pathways through the estate, different line thicknesses are visualised (Fig. 3.1).

Surveillance indicates the level of surveillance for each grid point of the public spaces, by analysing the lines of sight, viewing angles and distances to all visible surrounding windows (Fig. 3.2). Obstacles such as canopies or landscaping affect the value, creating different levels of privacy.

Visibility analyses how much of the surrounding area can be observed by subjects in the public space, viewing other areas of the estate (Fig. 4.1). This aspect is related to the sense of orientation, supervision and control, and may be linked to the public or private character of the spaces. Introvert people or behaviours may be found in areas with less visibility, while extrovert people may seek out more connected and visible sites.

Accessibility considers the attractiveness of origins and destinations around the estate, and evaluates the in-between spaces according to number of times a node is included in the shortest path calculation between these end nodes. The resulting value indicate whether a space is close to the main pathways through the estate, and whether it is convenient to be accessed (Fig. 4.2).

Centrality uses a similar analysis of shortest paths between possible origin and destinations, but considers all options of routes. Higher values indicate better connectivity to the other spaces in the estate (Fig. 5.1).

Enclosure is determined by the relative amount of building façades surrounding each space within a specified distance (Fig. 5.2). In addition to visibility, this analysis helps to understand the level of privacy of the activities that may take place. The amount of enclosure also indicates whether spaces are internalised in the estate, with less exposure to the surrounding urban context.

Summer Sunlight and *Winter Sunlight* analyse the amount of sunlight each area receives, using a computational tool to calculate solar radiation (Figs. 6.1 and 6.2). As Hong Kong's climate is relatively warm and humid during most periods of the year, shaded and well-ventilated outdoor spaces are much more suitable for social activities than spaces that receive direct sunlight.

4. Data Interpretation

By applying a scoring system with seven measurements as defined in section 3.3, the physical urban qualities of different open spaces were quantified and rated. This data was then translated into visual graphics to study possible correlations with the activity conditions found. Figure 7 shows each space described through circular diagrams. The upper one demonstrates the user behaviour interpreted from the data collected, while the lower circle shows the quantified results from the urban morphology analyses. The results highlighted in orange are the qualities that are found to have the most influence on the type of use of each specific space.

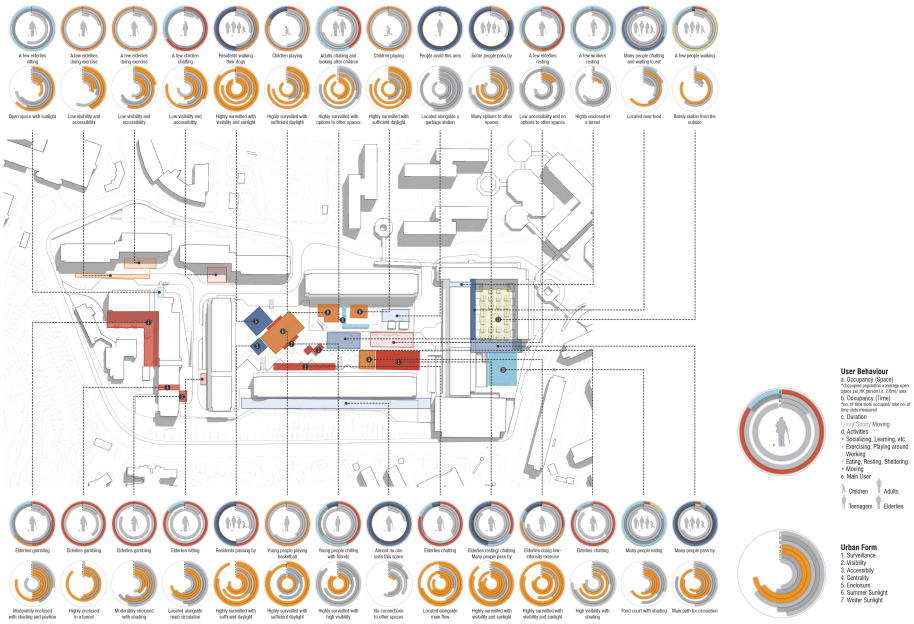

Figure 7. Interpretation of spatial analyses and observational data of activities.

Maslow's Hierarchy of Needs, also known as the Pyramid of Needs, offers a classification of different types of needs and desires ranging from basic needs to self-actualization. The categories translate into different aspects, including food, safety, love and self-esteem, which can be understood as the motivations for different types of everyday activities (James, 2019). We can differentiate shared facilities that address immediate physical needs such as to provide shelter or rest, from those that support mental health needs or personal development. This creates an evaluative framework to rate each of the different public spaces, and evaluate their importance regarding personal growth and community interaction.

A reflection on the use and spatial properties of Nam Shan Estate shows that the estate has several well-used spaces located in the large central area of the estate due to their connectivity, visibility and centrality, while there are several underused spaces around the perimeter. There is little variation in the spatial qualities of the central spaces, to cater for introvert or extrovert residents. Spaces for different age groups are separated from eachother through distance or through barriers. Older men gathering to play games and gamble seek out unattractive tunnel spaces as these are the only ones with limited surveillance. There seems to be a potential to improve the use of several perimeter spaces, although the quality of these remains limited due to the arrangements of the buildings on the site. These bad performing spaces have low visibility and accessibility, and low amounts of enclosure.

5. Explorations around Data-driven Generative Design

The analysis described above indicated several key opportunities for improvement of Nam Shan Estate, if it can be speculated that the space distribution, circulation

network or even the building distribution on site could be redesigned. As this estate was inaugurated in 1977, it may be redeveloped in the medium-term future, as is being undertaken with other public housing estates that have an aging building stock and relatively low site density. As part of our study, we developed a methodology that allowed to explore several urban design solutions for the regeneration of the estate, based on the spatial and social qualities of their in-between spaces. To research the methodology, we explored how the generative design can be linked to the outcomes of the public space analysis, using this as a design driver for the generation of new estate layouts.

5.1. GENERATIVE DESIGN METHODOLOGY

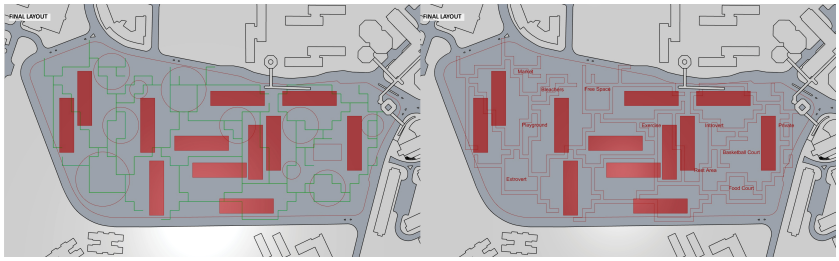

Figure 8. Generative process with the help of computational algorithms.

A computational workflow was set up with the help of Rhino/Grasshopper and Wallacei, a recent plugin developed by Makki, Showkatbakhsh & Song (2019) for analytical and evolutionary design development.

The control variables in this generative process were the Gross Floor Area (GFA) and area of open spaces. In the first stage of testing, twelve buildings were set up to have similar dimensions as the existing building blocks on site, resulting in a similar GFA as the existing estate. The areas of open spaces were also pre-defined, with dimensions based on their importance for socialization.

The independent variables were the locations of buildings, orientations of buildings and the locations of open spaces. The site was first split into grids, and sliders were created to move and snap the objects onto the grids, anywhere within the site boundary. The buildings were also provided with options to turn with a degree of 90 to allow more variations in urban layout (Fig. 8).

While running the Genetic Algorithm as part of the Wallacei platform, a number of combinations were generated and evaluated against several fitness criteria. A scoring system was used for evaluation, with objectives set up to minimise collisions of buildings and spaces, maximise desired connections of spaces, and maximise the physical qualities which were found conducive for the particular activity in the site analysis stage.

As the process cycles through numerous estate layout options, for each option the locations and qualities of public open space were analysed, using the same evaluation criteria as in our earlier research. The process searched for building arrangements which produce public spaces with the highest possible scores,

matching a pre-programmed list of public spaces and connections to support the estate residents. This list contained an improved offering of facilities similar to the existing, adjusted based on the research findings about which types of spaces were most in demand. An additional improvement introduced was to create connections that offer 'intergenerational collaboration', taking reference from the international precedents which bring users of different demographics together and enhance the degree of user diversity in a space.

5.2. GENERATIVE DESIGN OUTCOMES

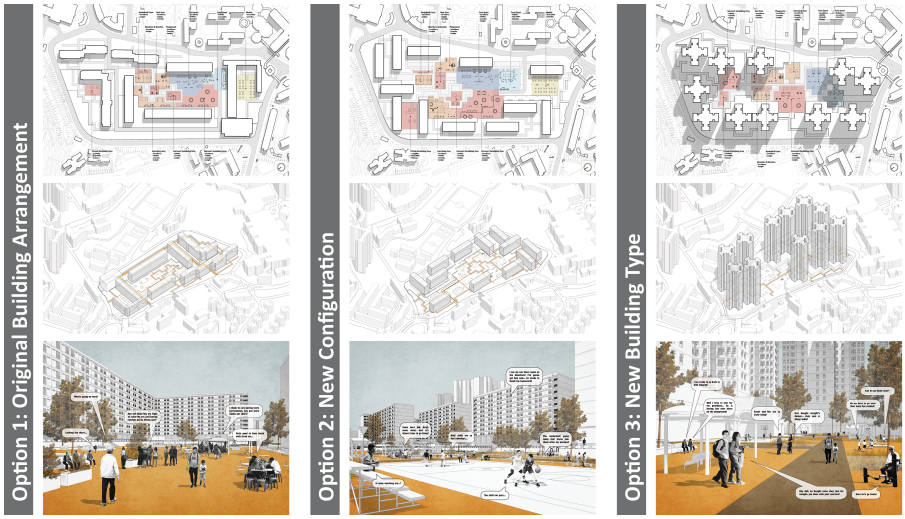

Figure 9. Three outcomes based on different requirements.

5.2.1. Option 1: Original Building Arrangement

For this option, the positions of the buildings were left unchanged. Public space and facilities were relocated at better positions in relation to the urban form and in relation to eachother. The outcomes were as following:

- The food court was moved near the central area to attract more people and to have the possibility to let users expand into a neighbouring open space,
- A flexible open space at the centre of the estate serves as attractor point and meeting space within the circulation network,
- More varied spaces emerge as separate introvert spaces are located at the eastern and southern perimeter.

5.2.2. Option 2: New Slab Building Configuration

In this scenario, the site coverage by buildings was left unchanged, yet buildings and public spaces were allowed to reorganise to achieve better spatial conditions and interrelationships for the public spaces. This resulted in an optimised solution

in which:

- The buildings moved towards the site boundary to create a larger central open space,
- More gaps between buildings were created to provide more connectivity to all spaces,
- A wider range of different (more public and more private) open spaces was created, yet with better visibility and connectivity between the different spaces and potential user groups.

5.2.3. Option 3: New Cruciform Tower Configuration

In the third scenario, the building typology was changed from 'slab' to the 'Harmony' type, keeping the site coverage similar but increasing the Floor Area Ratio (FAR). The buildings and public spaces were allowed to reorganise to achieve better quality public spaces and interrelationships. The result of this was:

- The towers were located around the site boundary to create a large central open space,
- The public spaces would receive more shading in summer,
- A higher degree of surveillance onto the public spaces, in particular in corner areas of the public spaces in between several buildings,
- A less wide range of different types of open spaces was created, due to the repetitive nature of the more compact footprint towers.

6. Conclusions

The ambition of this research was to explore new data-driven methodologies for the analysis and creating of public spaces in public housing estates, to address the insufficient qualities of current open spaces and the lack of planning methods aimed at user-experience, social interaction and community formation. Although there are many complex factors involved in predicting the success of public spaces, linking spatial analysis to environment-behavioural studies can offer new insights into the effectiveness of urban design. Analysing social aspects such as human activity patterns through spatial and quantified data offers new research opportunities in-between generative design and social science, enabling human-centric planning that creates environments that promote liveliness in public housing estates, enhancing social engagement, community support and public health and well-being.

This study has investigated how priorities and outcomes can be changed in planning processes for high-density housing, when the different physiological, psychological and self-fulfilment needs of residents are taken as a starting point for space planning rather than as an afterthought. This type of human-centric planning, when further developed with more accurate constraints around the technical, economic and environmental performance of public housing estates, could deliver urban living environments from all ages and backgrounds. As it has become clear that the doctrine of maximum efficiency is inadequate to deliver quality of life, it is time to rethink which other types of optimisation criteria can be used to create

housing environments that support people and communities in Hong Kong, and other cities with similar needs around the world.

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