DATA-DRIVEN URBAN POROSITY

Incorporating Parameters of Public Space into a Generative Urban Design Process

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Abstract. This paper presents an urban design project for a new city district, using generative design processes in architecture and urbanism developed over several years within academic research and practice work. The paper discusses the opportunities and challenges found when using a data-driven urban design methodology in relation to the complex logistical, social and economical networks of new urban centers.

Keywords. Design Methods and Information Processing; Generative System; Simulation & Optimization; Urban Planning and Design; Public Space Design.

1. Abstract

This paper presents an urban design project for a new city district, developed in the context of the authors’ architecture and urban design practice commissioned by the related local government body. The project employs the authors’ previous research into the use of generative design processes in architecture and urbanism, developed over several years within academic research and practice work. The paper discusses the opportunities and challenges found when using a data-driven urban design methodology in relation to the complex logistical, social and economical networks of new urban centers.

This paper gives a description of the tools and processes used for the project, and describes the parameters that were used to predict the qualities of urban spaces as developed in earlier research within the field. The paper then discusses the project’s application of rule-based and evolutionary design methodologies to create an open-ended design proposal for a 1x1 km new urban district. The final result demonstrates the allocation of programs and open spaces in a way that stimulates interaction between different user groups, conceiving urban massing as a complex multi-programmatic, three-dimensional framework for urban life.

2. Project Objectives

The brief for the new urban district included functions that would form a new hub for improved international collaboration and stimulate economic growth in
Central China. The district should house embassies, international companies and institutions, housing and services for expats and Chinese employees of internationally operating corporations. The brief also requested a “land-intensive development aiming to conserve natural resources, creating livable urban areas that promote quality of life, incorporating the most advanced types of commerce, science and technology, and ecology in a single modern city district”.

Following the requests for density and ‘quality of life’, we chose to focus our design methodology on the calibration of small open spaces within the urban fabric. In combination with the urban block sizes, the strategic placement of public spaces could catalyze the socio-economic synergy within the area. In between clusters of buildings of high density and efficiency, public spaces provide the means for people to meet and interact, either as part of their daily live-work processes or as part of the un-planned encounters or extra-curricular activities that make city life enriching and fulfilling.

3. Precedents

In order to be able to ‘parametrize’ the quality of public space, it is important to understand the relationship between the physical properties of urban spaces such as size, enclosure, surface materiality, sun access and the activities that humans are likely to engage in, if certain combinations of the right properties are all present. Extensive research in this field has been done in the 1950’s - 80’s by the sociologist William H. Whyte, who published several books on the subject, including The Social Life of Small Urban Spaces (Whyte 1980). Using measuring, mapping and direct observation techniques, he deducted many practical rule-sets for creating successful public spaces, including guidelines for visibility, accessibility, seating, greenery and environmental conditions such as sun and wind. Whyte consulted for several municipal governments on public space renovation and served as a mentor to Jane Jacobs, who published the highly influential book The Death and Life of Great American Cities (Jacobs 1961). Jacobs argued for the conservation of organically grown neighborhood qualities, against large scale urban renewal schemes that were at the center of political thought at the time. Jacobs in turn inspired Jan Gehl who wrote Life in Between Buildings (Gehl 1987), further developing the manifesto of the ‘New Urbanism’ movement which promotes environmentally friendly urban networks by creating walkable neighborhoods containing a mixture of housing types and work spaces.

Further research has attempted to deepen our understanding of the beneficial qualities of the mixed neighborhoods that Jacobs and Gehl promote. In their chapter of the book Heterotopia and the City, titled ”Public-Space Heterotopias”, Yael Allweil and Rachael Kallus argue how architecture can be used to establish ‘counter-hegemonic’ practices. They explain that ‘informal groups, having no demarcated space to enact their communal identity, carve out sites within urban public space by using them regularly’ (Allweil and Kallus, 2008). They discover that hegemonic tendencies towards spatial means of controlling cultural behavior can be reversed by fostering the diffusion of people, activities and ideas in open territory, or public space visible to all. This understanding has led us to incorporate specific parameters for urban spaces into our methodologies, related
to accessibility, visibility and flexibility, and creating deliberately un-programmed activity areas or covered urban spaces designated for non-commercial activities.

4. Methodology: Generative Urban Design

Following these precedents of thought, we set up a design methodology to create urban street networks and building massing strategies that would amend the currently prevalent urban planning models in China, moving from a car-dominated city to a pedestrian-oriented city. We applied a specific generative design process, using computational tools to help manage the complexity of the task and coordinate in between the different layers of information related to the site.

Our research methodology departed from the desire to explore and test new means by which we conceive of, and inhabit the city when it is understood as a highly complex set of interdependent ecologies. We are interested in how high-resolution mapping of urban spaces and the use of digital design software allow us to set up design processes that are calibrated against precise sets of social, environmental and programmatic information related to the urban environment.

As documented by Lima and Kós (2014), the application of mathematical models as a mechanism for optimization of urban development has been studied and proposed by specialists since many years, including by Dantzig (1973) and Leite (2012). Leite understands the ‘smart city’ as one in which basic functions of the city - to establish economic and social freedom and offer freedom of movement - are optimized using new forms of information and communication technology (Lima and Kós 2014).

The potential role of generative design processes within this task has been identified early on by Mitchell and McCullough (1991), who contemplated the implications of computational processes being able to address a complexity of parameters and interactions, much greater than could be handled by human cognitive processes alone. They emphasized however the central role of the designer’s intellectual capacity instead of promoting ‘automated design procedures’, using critical human thought in the employment of algorithms, the input of data parameters and the definition of the evaluation criteria.

It is also important to define the way in which generative design in this context is employed, operating on the underlying relationships rather than formal characteristics of the built environment. As Lima and Kós write, ‘this form of algorithmic or parametric modeling transcends the understanding of the computational paradigm as a mere promoter of complex forms, and contributes to processes capable of forming models that contemplate several parameters involved in the functional, environmental and of the cities and the buildings they contain’ (Lima and Kós 2014).

An example of this currently expanding field of research is the 3D data visualization tool by Ferreira, Lage and others, developed to support decision making in urban development (Ferreira et al. 2015). Their system, named ‘Urbane’, integrates several layers of information from different sources into a 3D model of a city, allowing to quantify the impact of design decisions or compare various options. Besides analyzing the volumetric properties of a new building
or urban block such as sky exposure and views towards parks or landmarks, the system can incorporate data associated with quality of life in the city, such as the location of restaurants, noise complaints, crime reports, etc.

The limited accuracy of these data systems highlights that urban environments are highly dynamic, leading to the necessity to consider generative design proposals and scenarios that can adapt and evolve over time. Proposals need to be developed in dialogue with the potential occupancy of the buildings and the surroundings in which the solution is to intervene.

5. Design Development

The starting point for the design was the location of several center points and edge conditions based on the analysis of regional and local connectivity requirements. The points acted as program centers, locating new areas of specialized programs such as housing and offices, as well as a ‘mixing zone’ in between them (figure 1). The mixing zone contains smaller urban blocks and a higher plot density, intended to house hybrid programs and activities.

Figure 1. Diagrams showing how a ‘mixing zone’ was generated in relation to three program location points. The desired range of Floor Area Ratio (FAR) values was determined first, based on planning and development targets.

In the next stage, a range of urban massing typologies was mapped onto the site, using a detailed allocation of spatial requirements that was derived from an analysis of the qualities of the surrounding neighborhoods (figure 2). Zoning criteria for live and work buildings, commercial and cultural facilities were based on the proximity to urban or landscaped areas, or planned commercial and cultural centers in the masterplan for the surrounding urban areas. Zoning for ‘introvert’ and ‘extrovert’ urban block typologies was based on the ‘mixing zone’ location, placing spaces of higher social and commercial interaction towards the center of the site, drawing people in from the different program areas and stimulating the efficient and progressive sharing of activities and services.
Figure 2. Mapping of qualitative spatial and programmatic requirements for urban blocks on the site area in relation to the desired relationships of the area to the context.

The purpose of these mappings was to be able to populate each plot with an urban block typology generated by a digital process that produced hundreds of potential urban blocks, analyzed and categorized them according their spatial performance characteristics. Both the catalog of typologies as well as the site mapping were set up as fully parametric entities within the design software, which allowed them to be updated easily and generate different outcomes.

The plinth massing was generated by moving two cutting volumes (internal courtyards and street corner plazas). Urban block typologies were created by combining different types of volumes for the four different quadrants of each plot (figure 4). Using the genetic algorithm software ‘Octopus’ (a plug-in for Rhino/Grasshopper), a large population of urban block typologies was generated and evaluated for their characteristics.

Figure 3. Logic for the digital generation of urban block typologies.

The criteria used in this project included sunlight exposure in the open spaces,
the total FAR of the plot, the geometry of the blocks and their capacity to accommodate larger or smaller program areas, and the accessibility of the open spaces. If the corner plazas are open from the street, the plot is considered ‘public’ or ‘extrovert’, as opposed to ‘private’ or ‘introvert’ (figure 4).

![Image of evaluation criteria for spatial and programmatic opportunities for urban block typologies.]

The software automatically selected and refined the more successful typologies - depending on criteria that are defined as ‘successful’ (figure 5).

![Image of mapping of a field of block typology solutions against axes of success criteria.]

To populate the most appropriate block typologies into the site, the site was analyzed by the genetic algorithm for the different requirements for each plot. These requirements were a combination of the several layers of information as described in figure 4, translated into fields of numeric values between 0 and 1. For each of the required plot characteristics, the closest matching individuals were selected automatically by the algorithm out of the solution space of the latest generation of optimized individuals. The urban block typologies were populated into the site, adapting the geometry to the particular topography and layout of
the area. The urban massing was calibrated against different setback lines (which could be adjusted for each of the different road type dimensions) and was split where plots are subdivided (figure 6).

Using a separate genetic algorithm, high-rise tower locations were varied and evaluated against the optimal configuration to maximize the sun exposure to all of the tower facades in the site. This minimized self shading and contributed to good quality living and working spaces, using passive heating in the winter season. Based on the ‘mixing zone’ mapping layer developed earlier, the FAR distribution map for the individual plots was generated. A range of building typologies was generated to populate the masterplan area following criteria for proximity to views, pedestrian areas, busy roads and some top-down zoning criteria set out by the local government. A residential zone in the north-east corner was populated with elongated tower slabs for high-end apartment buildings, while the high-rise around the mixing zone attracted a number of taller compact footprint towers suitable for corporate headquarters and tenanted floors including embassies and related international agencies.

6. Result: Urban Mixing to Promote Synergy

The final design proposal for the new International Communication District incorporates a range of public spaces suitable for a variety of social and commercial activities, materializing into a raised pedestrian network that is part of the public domain. The elevated pedestrian network is located within the ‘mixing zone’, emphasizing and intensifying the dynamic and diverse nature of this area. It
covers parts of the street surfaces in the center, creating an efficient and sustainable double use of limited urban space. The concept for the urban fabric on the raised plaza is that of ‘varying porosity’, using a transforming grid system to locate different conditions ranging from an open field with small free-standing retail unit to and dense cluster of larger commercial spaces.

The center of the International District becomes a dynamic and vibrant urban place, that has zones containing smaller urban spaces surrounding it, which allows for different atmospheres and activities to take place (figures 7 and 8). It creates opportunities for the collision between different types of commercial and cultural services as well as between different user groups, to promote social interaction and cultural exchange.

Figure 7. Central pedestrian zone with a porous urban fabric.
7. Conclusions and Future Developments

This project has demonstrated the application of rule-based and evolutionary design methodologies to generate urban design solutions centered around a strategic distribution of public space. Following research of urbanists from the past and present, we can quantify certain properties of urban spaces and use these in a generative design process that can create a highly differentiated urban fabric at a larger scale. The methodology allows to analyze and safeguard the properties of all of the building volumes and spaces within the urban proposal, despite the complexity of the overall design. The resulting solution, that could have never been modeled ‘by hand’, can easily be adjusted and different options can be evaluated in conversation with a client or other stakeholders, giving insight in the consequences of particular policy decisions.

The use of rule sets allowed us to generate site-specific outcomes within the limitations of the context, allowing the project to take full advantage of and contribute to the environmental, programmatic and connectivity characteristics of the surroundings. This approach to generative design resulted in a precisely calibrated design scheme, addressing several complex functionalities and accommodating its adaptation towards social, economical and environmental performance criteria and contexts.

We acknowledge that the socio-economic performance of these types of urban projects once realized is very complex and difficult to simulate, and will depend on many factors that are not covered in this design process and may not even be under control of the designers or the client. Our attitude towards this is that no urban design should aim to control the urban life within it to the last detail, but rather should incorporate flexibilities for changes in requirements and activities over time.
We aim to create ‘open-ended’ urban design proposals that stimulate economic and social development, based on general rule-sets derived from successful precedents and field research. As our current methodologies are limited to incorporating fixed data, it is our ambition to continue future research to develop methods that can incorporate dynamic information. If we can use detailed simulations of user patterns based on real-world data to evaluate our designs, we can use this feedback to incrementally improve our solutions in the context of the full complexity of our vibrant urban ecologies.

Our research will continue to explore multi-layered, multi-programmatic, networked architecture of hyper-density which accepts certain realities of development in the city, while at the same time fundamentally rethinking urban typologies. It is our ambition to design ever more informed projects that can function as attractors, reactors and mediators in the city. We will continue the development of generative design methodologies that incorporate more layers of information sourced from real-world and real-time data sources that are becoming increasingly available accessible.

Through further field studies with more developed mapping techniques and tools, we aim to incorporate and catalyze complex and dynamic existing cultural and socio-economic urban conditions and take advantage of open-endedness in design, construction and use. This could allow future projects to be conceived as ‘data-driven urban frameworks’, using innovative architectural systems to provoke the emergence of vibrant and unique new urban realities.

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References


