True Smart and Green City?
8th Conference of the
International Forum on Urbanism

Conference Proceedings Paper

Refining the Complex Urban: The Study of Urban Residential Typologies for Reduced Future Energy and Climate Impacts

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Received: / Accepted: / Published:

Abstract: The complex urban environment has multiple levels of design and planning that are applied in the form of blocks, layouts and patterns of the city. The aim of this research paper is to develop an analytical study based on the study of urban blocks in dense residential environments of a large city in China. This explores issues of 'green infrastructure', 'urban environmental performance' and' urban patterns', as three main elements of the analysis. The city of Ningbo, located at the Eastern coast of China, is selected as the core case. The findings of the study will enable urban planners and designers to identify refining methods to improve design and planning of urban blocks, layouts and patterns of the cities. This study will emphasise the relationships between green infrastructure and urban environmental performance of the selected cases.

Keywords: Urban Design; Urban Block; Urban Layout; Urban Environmental Performance; Green Infrastructure; Ningbo.

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1. Introduction

In the rapidly growing cities of the developing world, urban development in the form of large scale blocks is a widespread typology. This model has advantages and disadvantages. With a basis in Chinese contexts we evaluate issues and options. Our focus is on residential developments, in particular their energy and environmental profiles, in the primary context of hot climates. Much work has been done on optimal urban typologies in relation to energy and climate; but what actually gets built depends very largely on city planning authorities and private investors. These operate within financial, cultural and local constraints that usually weigh far more heavily in decision making than environmental objectives, even where the latter are enshrined in national policies. We question what can be realistically applicable as of today, to provide considerable reductions in future energy use and climate emissions. Prerequisites to this approach are an understanding of why things get built as they do, and dialogue with both developers and planning authorities.

The future environmental impacts of developing country cities are a growing concern. Cities house most of the world's population and cause most of the energy use and climate emissions. Whilst transports typically account for around one third of this, most is due to resource and energy use in the buildings (1). This is in turn, in part attributable to overall urban structure and layouts. Within the buildings there is a huge trend towards air conditioning and other energy amenities. Good city planning and layouts are preventive medicine; they can significantly improve urban microclimate as well as health and energy efficiency. A few cities and communities have already managed to reduce their climate emissions by over 75% or phase out fossil fuels entirely (2).

Both in hot-dry and hot-humid climates, city conditions can become unbearable – especially for the poor. Due to the urban heat island (UHI) effect, cities are often several degrees hotter than the surrounding countryside. Global warming will aggravate this, with increasing heat related mortality, loss of productivity, and rising energy needs for cooling. One hears often that sustainable solutions are either too expensive, or else difficult for authorities to enforce. However, there are inexpensive and win-win options that do not needlessly hinder developers nor require heavily restrictive planning. Why are they seldom applied? There are many barriers, from local politics to land prices or lack of knowledge. In many countries there are few if any planning laws, few skilled planners, and few means of controlling what is built. Hence, it is important to investigate pragmatic approaches in urban development.

1.1 Specific Context of the Study

In this study we examine three typical urban block typologies in the city of Ningbo in southeastern China. Their characteristics and performance are considered in the comparative context of other developing cities and of European and American experience. We then explore opportunities for design improvements to their energetic and climatic performance in particular, however not forgetting the broader context of overall residential qualities.

Chinese urban apartment blocks are usually combined with commercial units at street level, mainly food outlets plus other small service businesses (banks, pharmacy, etc.). Within the blocks there is a greater or lesser extent of green space, parking either above or below ground, often a kindergarten, and sometimes facilities such as gyms or common rooms. Recent blocks are often impermeable, gated communities. In general they are increasingly high-rise.

The three types reviewed here are: 1) a 1990s development in linear 6 storey blocks; 2) a recent high rise block of up to 30 floors; and 3) a low dense residential quarter of a type fast disappearing in China but still common in many other developing countries. The high-rise block most closely represents current practice. Given the extreme pace of change in China, the first of these three is likely to be demolished and redeveloped within a few years. This site forms the basis for our study of alternative solutions; the initial one being described in Table 1.

Typical blocks in Ningbo cover 4-8 hectares and house 3,000-10,000 people. A requirement of recent years is that much of the site must be green space. Given high-rise typology this entails large and often attractive landscaped areas; however, their planning and functionality merit discussion. Each block is usually run by a management company and there is little by way of active resident participation. This criterion does not necessarily apply to superblocks in which a larger scale housing development is often predicted.

Table 1. Overall conditions of two main scenarios of the study

A. SIX STOREY BLOCK, EXISTING CASE	B. HIGH RISE SCENARIO FOR SAME BLOCK
Site area: 60,000 m2 Built area 10,500 res. + 3,400 commercial = total approx. 14,000 m^2 = SC 23%	Site area same: 60,000 m2 Built area 12x750 = 9,000 res + 5,000 commercial = total 14,000 m^2 = SC 23% - same as existing (Scenario: 12 blocks of 750 m2 = site footprint

	9,000 m2, 8 of 20 floors and 4 of 15 floors, plus commercial 5000 m2 x 3 floors)
Floor area 10,500 x 6 = 63,000 plus 3,400 x 2 = 6,800 = total approx.. 72,000 m2 = FAR 1.2	Floor area total 165,000 m2 res + 15,000 commercial = 80,000 m^2 = FAR 3.0
NOTES: A has about 800 apartments, B has around 2000; so 2.5 times. Parking for 2000 cars at 20 m2 each is 40,000 m2; i.e. 2/3 of total site area.	

1.2 Design and Technical Quality

Architectural design and apartment plans are generally of fair quality. The high-rise buildings are, for cost reasons, often compact and rather deep resulting in restricted day-lighting and poor if any cross ventilation. Many apartments only face one direction, for example west or north which attract lower prices, being colder in winter or exposed to troublesome west sun. Construction in China has been at breakneck speed and is often of mediocre quality. There are no mandatory energy efficiency standards for the private sector. As in many countries there is a reluctance to hinder rapid growth by placing too many restrictions or requirements on builders.

Whilst compactness is widely recognised as favourable for lower energy use and climate emissions, research has brought forth quite large divergences as to the relative importance, and effect, of the many factors involved such as density, building form, functional distribution, income, car ownership and so on. This large field of research is excellently discussed in (3, 4). The benefits – including economic – of green infrastructures are broadly reviewed in (5). There is however broad agreement in these and other studies that whilst the extremes of suburban sprawl and very dense high-rise cause higher impacts, between these lie a wide range of fairly dense urban typologies, all of which can offer excellent energetic and climatic results.

Urban density is measured in recognised ways including surface coverage (SC), floor area ratio (FAR), dwellings per hectare (dph), etc. Other useful measures include ‘green coverage’, ‘functional mix’ and (for energy needs) ‘surface to volume ratio’. Whilst all these are dependent on many contextual factors, such as household sizes, and whether adjacent transport areas are included, comparisons of SC and FAR suffice for the present discussion. Table 2 provides brief comparisons of various urban typologies.

Table 2. Some urban density comparisons

Urban Typology	SC	FAR	Avge. height
1. Ningbo low dense traditional	0.50	1.4	2.4
2. Ningbo 6 storey block	0.23	1.2	5.0
3.Ningbo high rise block	0.17	2.6	15.5
4.Jinan low dense traditional	0,54	1.2	2.2
5.Jinan grid 1920s	0.31	1.7	5.8
6.Jinan enclave 1980s	0.34	1.8	5.3
7.Jinan superblock 1990s	0.22	2.0	10.1
8.Europe, detached housing	0.10-0.30	0.2-0.7	1.5-2.5
9.Europe, row/terrace housing	0.15-0.35	0.5-1.0	2.0-3.0
10.Europe compact city block	0.35-0.55	1.5-2.5	4.0-6.0
11.Europe slab housing	0.15-0.40	0.6-2.0	3.5-6.5
12.Europe modernist high rise	0.10-0.25	1.0-2.5	8.0-14.0

Indicative figures, compiled from various sources. Own figures for Ningbo. Jinan cases from (6)
Notes:

1.The average height (in number of floors) in high rise areas is much less than the high rises themselves due to the inclusion of some low rise commercial and other buildings on most sites
2.Our Ningbo examples 1, 2, 3 correspond quite closely to 4, 6 and 7 in the Jinan study except that the more recent Ningbo high rise is significantly higher than the 1990s Jinan example.

2. Contextual Issues

In addition to the universal issue of density, every context has particular structural, economic and cultural features. In the Tiger economies, typical urban issues are:

- Limited-time land ownership, which encourages short-term thinking and a reluctance to maintain properties as leases draw near their end;
- The mixed blessing of extremely rapid growth, which alongside its benefits means that careful and environmentally optimal choices are often not made;
- Large blocks that are gated communities with little functional connection or social permeability.

In the case of China, green planning and technologies are not yet widespread and this is one reason why they may still be more expensive. As a recent Chinese study notes: "*there are very limited studies on the extent to which the property projects adopt green technologies, the impact upon green building costs and the barriers concerning the application of green technologies in property development projects*". The authors discuss and advocate the policy of a Green Strategy Plan as "*a vehicle for a more systematic use of green strategies to increase the sustainability quality of a property project…the incorporation of green elements can be integrated into the project life cycle and communicated in a structured way with regard to the developer's image and responsibilities*" (6).

2.1 Three Typologies

a) The Six Storey Block

This simple type is also found throughout Europe in mid-20th century social housing. In China up to six floors were permitted without a lift (initially up to 8 floors) as opposed to three or four in Europe. This block covers about 6 ha, with some 800 small to medium size apartments, plus commercial premises along two sides of the perimeter. Construction is mainly in brick masonry and other simple materials.

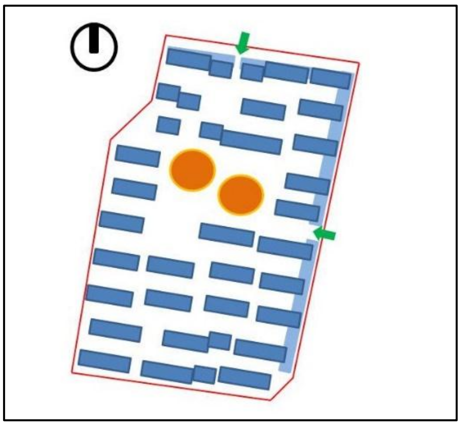

Figure 1. Plan of typical six storey block or slab housing with 23% SC. (Source: authors)

Figure 2. View of residential units. (Source: authors)

This typology, typical of working class districts in many countries, is unimaginative and provides little open space. Built before private car ownership was prevalent, there is no underground parking and much of the available surface space is now occupied by cars. A special feature is that the ground floor is mainly reserved for storage rooms. Another, often continued in present day high-rise, is balconies that can be closed in to extend available indoor space. This is visible in figure 2 above, where all balconies except two have been enclosed with glazing. Construction is simple and economical. A major quality is that these are slender buildings where all apartments are cross ventilated. In energy terms this typology is potentially as efficient as high-rise solutions. In terms of technical complexity and maintenance it is probably considerably more economical. Its major weakness is the lack of outdoor space. This typology has SC 23% and FAR of about 1.0 to 1.2.

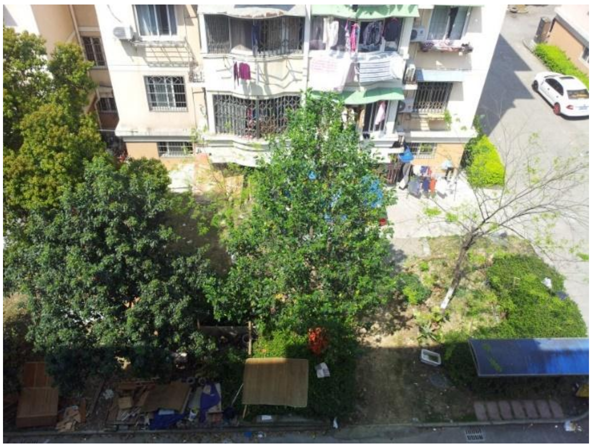

Figure 3. The spatial usage in a typical six storey block housing area.

Figure 4. Space coverage and surface parking of the six storey housing area, with high-rise in the background.

b) High Rise

This block is typical of recent housing projects in urban China (i.e. the past 10-20 years). Behind the low commercial frontage of one to three floors along the main street, blocks of up to 34 floors are spread within a landscape. There are 2,000-2,500 apartments, hence a population of perhaps 8,000. Open space comprises over 70% of the site. This typology has SC still as low as about 17% and a FAR of about 2.6.

Figure 5. The typical high-rise residential block in the City of Ningbo, China (Source: authors)

Figure 6. Landscaping between the blocks within the high-rise housing area in Ningbo (Source: authors)

Construction is mainly massive concrete and steel, resulting in a very high carbon footprint. Most apartments have only single sided ventilation. These are very deep buildings. Some of the towers have open galleries connected to the lift lobbies and/or vertical shafts that assist stack ventilation; however, such internal shafts can present well known problems of dirt or transmission of cooking smells and noise. The apartments are of medium quality. The individual air conditioning units are concealed behind slats in the facades. Adaptable balconies can again be noted, and most have already been glazed in. There are rules ensuring that such additions harmonise with the existing facades. This is often problematic since added glazing will cause more overheating.

Figure 7. Over-ground parking and landscaping of a typical high-rise site in Ningbo with residential blocks around the perimeter (Source: authors)

The landscaping is extensive and attractive; however, on closer analysis it has few functional or ecological qualities. Abatement of traffic noise is only partly ensured by border buffer zones, and there are few social spaces in the landscaping. Much as in other countries, the vegetation and landscape design is largely aesthetic only, whereas it could have been designed to actively enhance the block's environment, including biodiversity, filtration of air pollutants and, not least, urban ventilation to ensure both improved outdoor comfort and lower indoor cooling needs. Similarly, the building layout and orientation with regard to sun and breezes do not follow any bioclimatic rationale but seem rather haphazard. As discussed in this study, environmental and microclimatic considerations – energy needs, urban ventilation, solar access or protection, biodiversity, air quality and outdoor comfort - should be key elements determining urban form. This will have at once ecological, economic and social benefits.

c) Low Dense Typology

In China the low dense typology known as 'Hutong' is well known from Beijing whereas similar typologies are still widely found, often in disrepair, in rural villages. In Ningbo city only two such traditional low dense areas remain today. These often include courtyard type solutions, with communal spaces, often related to extended family or clan structures. It is relevant to include low dense since it is widespread in many developing countries; it is also a well-known, and appreciated, typology of European districts, including, notably some of the most successful examples of modern eco-neighbourhoods such as Vauban in Freiburg, Germany or Culemborg in the Netherlands.

Figure 8. a) Green housing neighbourhood in Vauban, Freiburg, Germany; **b)** Modern eco-neighbourhood in Culemborg, Netherlands; **c)** Eco-neighbourhood in Vauban.

This typology, typical of older settlements in many countries, has low to moderate SC (up to 0,6 in the case of the hutongs) and FAR between 1.0 to 2.0 (can be over 2.0). Qualities include human scale and sociability. Another is simplicity of construction and maintenance – perhaps especially relevant for low-income contexts. In a modern design context, problems such as overcrowding, fire hazard and accessibility are easily overcome. Green space within a low dense block is limited, but this can be small scale, sociable and attractive spaces, a precondition being some larger urban green spaces nearby. It is often argued that lower density implies more transport energy. However, it should be noted that compared to the Chinese high-rise blocks, the overall urban density achieved -and hence potential transport efficiency - may be quite similar.

Figure 9. Plan and location of a typical low dense typology in Ningbo; Xiushui community, one of the two remaining old residential districts of Ningbo

As shown in the LSE-Eifer study (3), low-dense at typical FAR of 1.0 to 1.5 can be just as efficient in energy terms as higher rise typologies. In hot-dry climates, low-dense, with heavy materials, is indeed an established tradition not least for climatic reasons. In tropical regions it is widespread too although openness of structure to maximise ventilation is a high priority. Thus, it may well be argued, at least in countries with less population and space pressures than China, that low-dense is a very viable option.

3. Refining the Urban: Alternatives

The site of the six storey housing is taken as the basis for our investigation of alternatives. This housing area is 'NanYu Community', located in Yinzhou District in Ningbo. It is subject to redevelopment within the next 5 to 15 years. This block of six hectares (200 x 300m) has 30 buildings containing about 800 mid-sized family apartments. The area is gated with limited access for non-residents. It includes two communal buildings, two podiums of 1-2 storey commercial units and two entrances (towards East and North). The overall Surface Coverage (SC) is around 23%, with less than 20% representing the residential blocks. All residential blocks are 6 storeys high, with 5 floors of residential units, and storage and services on the ground floor. We noted above its main features such as green spaces, mixed land-use and spatial pattern. The Floor Area Ratio (FAR) is 1.2, a fairly low density. A range between 1.5 and 2.5 is often suggested as optimal for energy efficiency and a good balance between built and open space. The very comprehensive LSE-Eifer study (3) illustrates typical European cities with compact blocks of 5-8 floors such as Paris, London and Istanbul which have a FAR sometimes even exceeding 3.5. In other words the traditional European city even though low rise, achieves high population densities as well as potential energy efficiency.

In another study comparing low dense, slab, and medium rise blocks in Jinan, China, Jabareen (8) observes that the total dwelling densities are very similar – from 120 to 145 dph. SC decreases with increasing height from around 50% to near our case (a) of 22%. Naturally, if one wishes for much higher population densities, then the SC can only be kept that low by building much higher rise buildings. This is illustrated in our scenarios for FAR 2.0 and 3.0 below.

Our methodology: The site of 200m x 300m is first divided into cells of 25m x 25m for investigation of alternative scenarios. Major parameters of lighting/shading, ventilation and air flow, and block pattern are briefly considered. These scenarios also serve to illustrate some of the environmental, energy efficiency and social urban qualities that are available or risk being diminished as one increases the density.

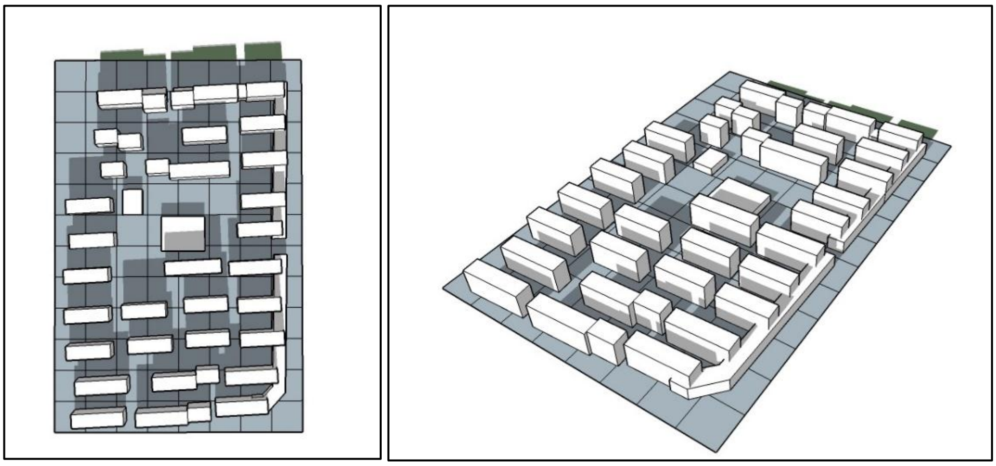

Figure 10. a) Plan of the six-storey block with SC 0.23 in its present form; **b)** Three dimensional representation (source: authors)

Scenario alternative 1: FAR 2.0

Keeping the SC of 23% (which is low in comparison to many contexts), the authors aim to first optimise the greenery and open spaces of the area and to double the FAR to 2.0. The green open spaces are kept inwards and the built areas are mainly along the edges of the block. A mix of 20, 15 and 10 storey heights are proposed, with low podiums of retail, commercial and communal space along two sides of the block. The basic paradigm of a high-rise block with one large, central green space is not questioned here but is commented below.

Building heights as well as positioning are to be optimised, primarily in function of solar protection and prevailing breezes. Buildings are shown here as simplified square forms but built forms too would be optimised, minimising East and West sun, maximising cross ventilation, etc.

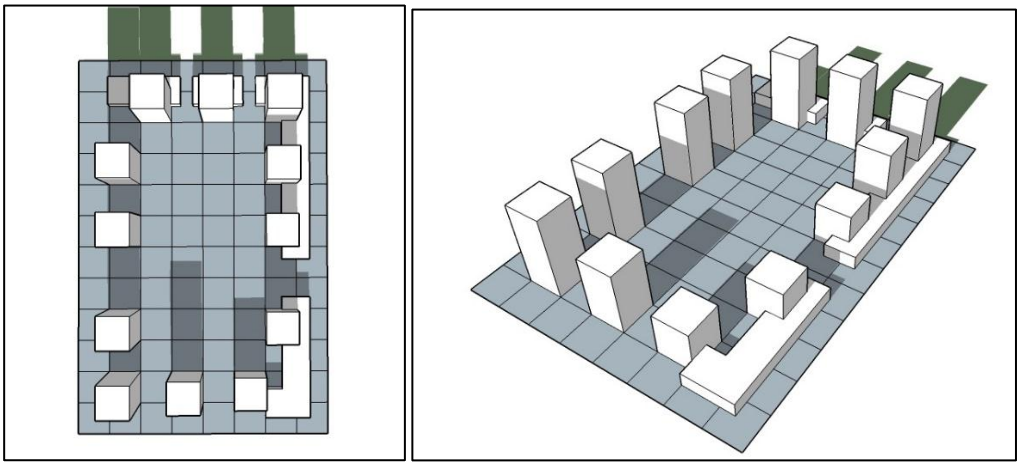

Figure 11. a) Plan of alternative 1 with FAR 2.0 and SC 0.23; **b)** Three dimensional representation (Source: authors)

Alternative 2: FAR 3.0

Based on analyses of environment, microclimate, economy and urban social qualities, the authors suggest FAR 2.0 to be reasonable, perhaps ideal, for future urban development (as noted, this density is achievable with low rise solutions too). However, developers may seek higher profitability. A model with FAR 3.0 is therefore made to evaluate the heights and complexities of the built environment at such density. To keep the SC at 23%, one must here build fully 34 storeys for some of the blocks, particularly towards the Northern and Western edges of the site. Although this reduces overshadowing during the summer and blockage or deviation of wind movement in winter, the overall height and density of residential blocks becomes much higher than in the two previous alternatives.

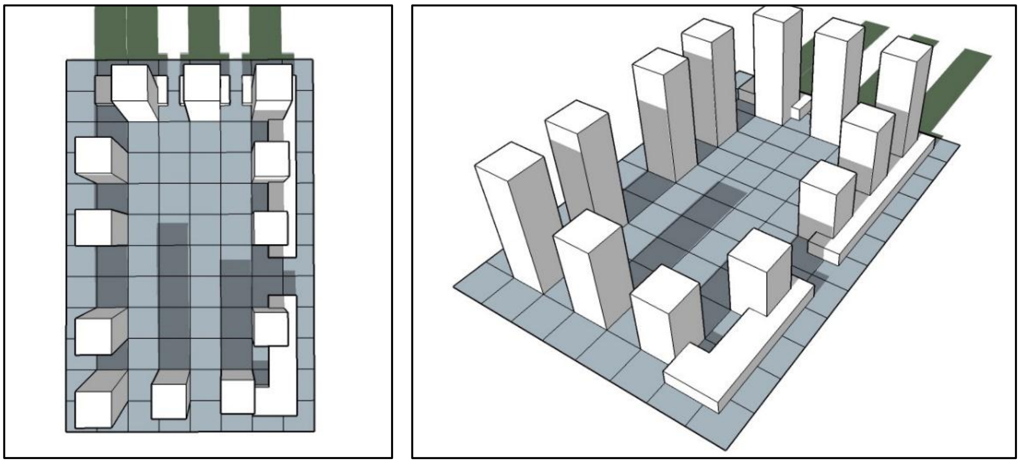

Figure 12. a) Plan of model 2 with FAR 3.0 and SC 0.23; **b)** Three dimensional representation (Source: authors)

Alternative 3: FAR 4.0

Allowing any further increase in FAR would require increased SC. This will increase developers' profits, but is unlikely to be beneficial for environment or the residents. Such a high density is likely to have considerable impacts on environmental performance, available green spaces and urban quality. Below, the scenario has FAR 4.0 and the SC is increased to about 35%.

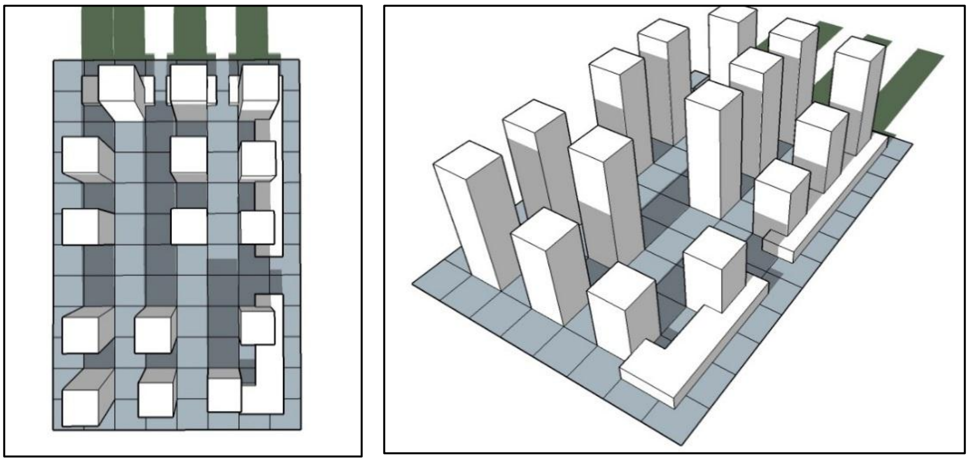

Figure 13. a) Plan of model 3 with FAR 4.0 and SC 0.35; **b)** Three dimensional representation (Source: authors)

It should be remembered that given today's typical requirements for at least one parking space per dwelling, most of the green space in dense high-rise blocks is in fact on top of an underground parking garage. Although we do not discuss transport in this paper, it seems clear that such high densities could also cause great transportation problems, unless a very high proportion of mobility can be ensured by public transportation. In much of the developing world on the contrary, private car ownership is sharply increasing. Transport policies, thus, have potentially at least as much impact as physical planning on the future of our cities, both as regards their living quality as well as their energy use and climate emissions.

3.1 Optimising the Block: Implementation of Green Infrastructure and Urban Environmental Performance

From the above three test models, it seems that attaining a FAR between 2.0 and 3.0 is reasonable and can be done whilst keeping a low SC. However, low SC is not necessarily efficient or optimal. Rather than one large space in the middle of each block, as in models 1 and 2, further models are tested to examine the potential for green infrastructure and improved urban environmental performance.

A key difference that may be noted from the classic European typology, is that in the dense but low rise European blocks there is little green space, deliberately limited to small if attractive areas. The large open spaces, with their potential for recreation, exercise, and cultural events are located in urban parks at a short distance away, and these are open to all city residents as opposed to segregated and non-inclusive areas internal to each residential block. In this way, the public urban parks can also be of a larger size that allows for high biodiversity and nature experience. This difference raises again the issue of which urban paradigms we choose. In terms of ecological sustainability there are several options; more substantial differences are probably to be found in the social qualities that can be achieved.

Alternative 4: FAR 2.0

By breaking the block pattern towards a greater spatial diversity, we can create a variety of building heights, densities and spaces, still keeping SC low and creating a better basis for green and open spaces that are designed to improve microclimate, outdoor comfort and reduced indoor energy needs. In this way, summer air movement can be maximised and solar protection more easily optimised. As illustrated, one might also consider breaking a large block in two, providing two green spaces each being still of a considerable size, and perhaps with different qualities and functions.

In this alternative the overall SC is again kept down to 23% and the FAR is 2.0. The West (left hand) side of the block is designed to be more open in this scenario since it is along the river, hence attractive for views and walkways. In all the scenarios, the commercial podium is along the two main streets, North and East, only. These are also the two directions with most noise, which the podiums help to buffer. Whilst access to breezes is easier on upper floors, and can be optimised by building orientation and staggering, these podiums too should be permeable; the detail design stage should ensure openings to let prevailing breezes enter the green spaces near ground floor level.

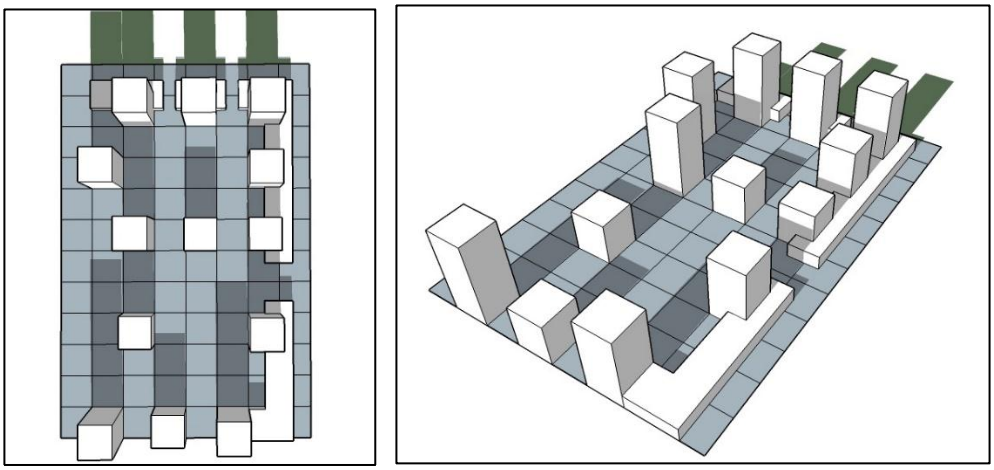

Figure 14. a) Plan of model 4 with FAR 2.0 and SC 0.25; **b)** Three dimensional representation of model 4 (Source: Authors' own)

Alternative 5: FAR 3.0

By reaching an even higher FAR and SC, one can still sketch options that include substantial areas of open and green spaces. In this alternative an additional row of residential units is added on the Western side of the block, whilst some building heights within the block are reduced to optimise day-lighting and shading. Here, adequate natural lighting is available to most residential units within the block, whilst the green qualities are kept with two large open spaces and one transversal linear, open axis across the middle. Compared to the existing block layout, this model although far denser still offers communal spaces. On the other hand, some urban qualities are, arguably, being compromised by this high density.

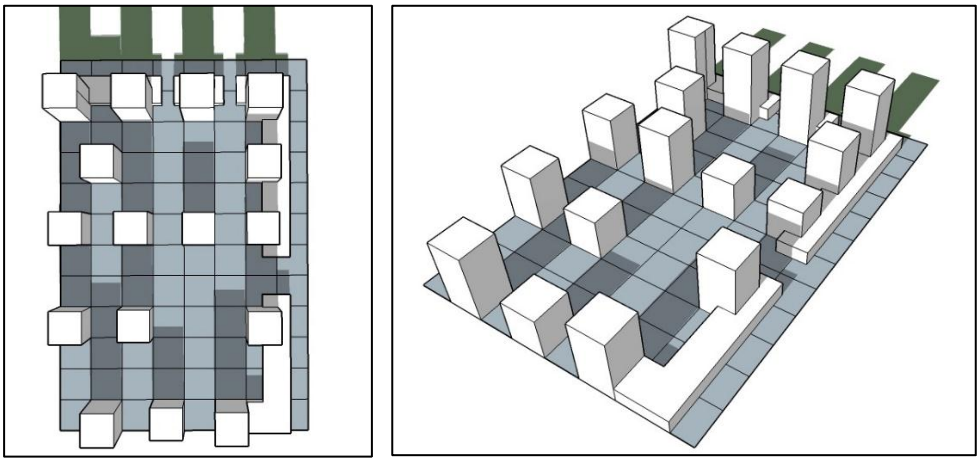

Figure 15. a) Plan of alternative 5 with FAR 3.0 and SC 0.30-0.35; **b)** Three dimensional representation (Source: authors)

Alternative 6: FAR 2.56

For comparative purposes a typical “Parisian typology” is tested. Using blocks of only 8 storeys, we break the large block into four smaller ones, comprising more slender buildings that offer cross-ventilation for all units. At the detail design stage this model would also ideally have varying heights for optimal solar protection as well as openings or passages at ground floor level to increase through ventilation. Whilst the other models do not offer such features, this model can also dedicate substantial areas to open and green spaces, such as the transversal 45 meter wide space across the middle of the site. In this way one can attain a FAR as high as over 2.5 yet avoid high-rise, which is not unproblematic.

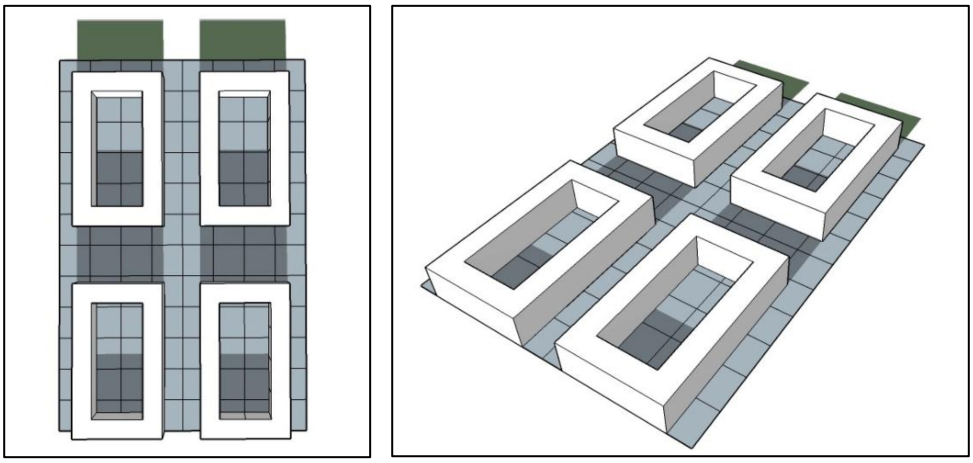

Figure 16. a) Plan of alternative 6 like a typical Parisian 8-storey model; **b)** Three dimensional representation (Source: authors)

Comparisons of such models invite a discussion on desired city qualities, on urban paradigms in general, as well as more specifically on the technical, energetic and climatic goals that are now a central goal for urban planning. Table 2 below provides a brief comparative analysis of all tested models:

Table 3. Comparative Analysis of all Tested Models

Housing Model	**Comparison SC and FAR**	**Advantages**	**Disadvantages**
Existing model	Low SC – 0.23 Low FAR – 1.2	Cheap construction; Low Surface Coverage; Cross-ventilated housing units; Low-rise and low density.	Lack of usable open spaces; Lack of greenery; Poor construction quality; Low FAR.
Alternative model 1	Low SC – 0.23 Medium FAR – 2.0	Suitable FAR; Low Surface Coverage; Variable height density; Medium-size residential units.	Large open space; Poor spatial arrangement; Poor lighting strategy.
Alternative model 2	Low SC – 0.23 High FAR – 3.0	Suitable density; Good variety of building heights and spaces;	Fairly high FAR; Inefficient lighting; Potential wind blockage.
Alternative model 3	Medium SC – 0.30 – 0.35 Very High FAR – 4.0	Maximised density for developers;	Very high FAR Inefficient lighting; Poor wind environment; Lack of open spaces.
Alternative model 4	Low SC – 0.23 Medium FAR – 2.0	More permeability; Good variety of open spaces; Good wind environment.	Undefined block edges; Some inefficient lighting.
Alternative model 5	Medium SC – 0.30 – 0.35 High FAR – 3.0	Optimised wind environment; Optimised lighting; Good variety of open spaces; Well defined block edges	Fairly high FAR.
Alternative model 6	Medium SC – 0.32 Medium FAR – 2.56	Low-rise and suitable density Optimised ventilation for residential units (i.e. cross ventilation) Cheaper construction; Breaking the block in to smaller cells.	Not contextually relevant; Less variety of open and green spaces; Inefficient lighting.

4.0 Discussions: Comparative Analysis of Typologies

Climatic optimisation requires detailed site specific studies not undertaken here; however, green spaces need to be of a certain minimum dimension (and configuration) in order to reduce UHI effectively. For example, Japanese research showed that small green areas of around 30m × 60m could be 3◦C cooler than the nearby hard built areas (8). These also help to cool the adjacent city blocks. Other factors are reflective colours and a minimum of hard surfaces. As regards the building layout, in hot climates the key design goals for reduced cooling needs are minimum solar exposure and maximum air movement. Studies have also been undertaken as to spacing and staggering of high-rise buildings for optimum air movement (9). As regards the buildings themselves, building orientation, form and façade solar protection are key factors in addition to the above two. Slender buildings enable cross ventilation, extremely important but impossible in many current high-rise buildings with deep plans.

Similarly, green roofs can have a large effect. One study showed that if just 5% of the city area is green roofs, then: "*the impact of green roofs in the high density areas is even more pronounced. [As a result], temperature across the city was reduced between 1 and 2.8◦C*". (11). Vegetation can be carefully selected which not only provides maximum shading but also filters pollutants. Urban gardening and water purification are other functions that can provide productive green spaces. Hence, instead of being largely aesthetic only, the green infrastructure, including vegetation and water features, can be designed to deliver specific microclimatic effects.

The design principles for improved microclimate and effective passive cooling in cities have been long established but sadly neglected in practice (12, 13, 14). Both in the layout, the landscape design and the building design, there are considerable missed opportunities for climatic and comfort amelioration and reduced energy needs, cost free.

The large urban block typology has significant advantages but at the same time, significant disadvantages that demand questioning in terms of overall urban development policy. One main advantage of such typology is the easier approach to planning and administration requirements for few large scale projects. This ultimately enables developers to speed up projects and develop at a faster pace and a larger scale. As a result, this scale would have substantial impact on economies for technical infrastructures and for construction profitability. Moreover, low surface coverage (SC) provides high potential for green spaces with social functions and qualities, which can be considered as high potential for biodiversity, water retention, low albedo and urban ventilation. There is also high potential for efficient centralised energy services, especially district cooling which can lead to energy efficiency strategies. On the other hand, there are major disadvantages or risks of large urban block typology, including poor social aspects of high-rise (e.g. negative for children playing areas and safety), poor permeability that leads to development of socially exclusive gated communities and mono-functional city zoning. The typological monotony disregards urban diversity. Furthermore, there are technical and cost-oriented complexities of high-rise structures. In terms of construction, high-rise is often more expensive and it is almost impossible to use low carbon materials. This paradigm is advantageous for large construction (and design) businesses, promoting a pro-developer approach to planning and design of cities.

There are other constraints and opportunities that we wish to note here. One can argue that sustainable development and good planning are difficult anywhere; in many developing country contexts both planning capacity and governance structures are largely absent. How then can reasonably sustainable urban development be promoted? We suggest that alongside gradual strengthening of those areas, only pragmatic approaches, closely attuned to local context, can succeed. Experience shows that where strong governance is unfeasible and public demand is low, authorities must gradually raise awareness and build dialogue with developers, backed with good examples from elsewhere. European experience in pioneering eco-city developments has shown that there are win-win opportunities where better environmental and social qualities can be achieved whilst maintaining the "bottom line" of profitability for the private sector. Eco-technology and green building is often not more expensive once established in the market – though incentives are definitely needed to achieve initial market penetration. Low energy solutions are good for everyone's profitability, both individual consumers and public finances. Many ecological solutions now have a fairly short payback time. Developers also benefit from a greener image, even if this does lead to some superficial "greening". They also see an opportunity to be market leaders in view of inevitable stricter environmental requirements. Hence, eco-city projects have often managed to achieve genuinely positive cooperation between planning authorities and business. This win-win attitude and dialogue with business has been hard to achieve – and some developing countries may see it as unthinkable – but it can be achieved, slowly, and is an essential ingredient of success.

Many developing cities seem to follow 'western city typologies', including high-rise, that are not necessarily relevant to climatic conditions, or to their societies. The modernist idea of functional zoning of cities is now largely discarded in favour of integration; and as a result, mixed-use planning is a key parameter for sustainable cities. Looking historically at the dynamics and processes of change, we argue that sustainable urban development (almost everywhere) has identified, and pursued, four difficult but essential processes:

- Moving from specialised spatial zoning towards *mixed use* city districts;
- Moving from professional specialisation to *integrated* design and planning; this is also a key to cheaper solutions;
- Moving as quickly as possible from *uncontrolled* construction to *voluntary* energy efficiency guidelines and later to *mandatory* standards and codes for environmental quality;
- Moving from private-public contradictions to *cooperation* and a win-win attitude, including public-private sector cooperation.

It should be noted that all of the above four have been the subject of very major efforts and very important shifts in policy, planning and practice in industrialised countries.

5. Conclusions

There is a clear need for reflection on prevailing and future paradigms, not least of the large block typology discussed here. There is an unexploited potential to find win-win solutions, better for the environment yet also acceptable to both authorities and developers. In countries like China there is a major need for authoritative guidelines and/or strong recommendations as soon as possible – as the necessary half way step on the (inevitable) road towards mandatory efficiency and emission codes. A key instrument to this end would be pilot projects to explore and develop modified urban processes as suggested in this study. This can, equally, serve to try out and promote more interdisciplinary and inter-sectoral dialogue and planning.

Given the energy and climate agenda, urban design must to a greater degree be informed, and urban design generated, by considerations of green infrastructures and favourable urban microclimate. Whereas the relative qualities of urban morphologies have long been studied, including all those examined above, this requires revisiting in the light of sustainability – including considerations of economic and social sustainability. Parallel to exploring "ideal" eco-city solutions there is an equal, if not even more pressing, need for pragmatic approaches that take into account the real drivers of change; and not least, the very pace of change in growing economies. Whilst focusing on the Chinese case of very rapid urban expansion, the questions addressed have relevance for many as yet less critical contexts, since the various options of low-dense, medium rise or high-rise (or, naturally, mixes of these) are key policy decisions, with long lasting consequences.

Environmental sustainability cannot be ideal. Whilst maximising sustainability aspects, solutions must be approached from, and achieve a balance between, four perspectives:

- Authorities and planning policies and regulations;
- Designers;
- Investors and developers;

- Users.

Naturally, these four do not always have similar priorities. The goal must, therefore, be a balance of partly objective criteria, such as planning limitations, functional requirements, energy performance and costs, and partly subjective criteria about desired qualities of living, city and the urban habitat.

Energy and microclimatic factors are not the only or even the largest parameters determining the overall environmental footprint of cities; but they are especially important since the other major factors – buildings and transports – can all change faster, given technological advances or modal shifts. Individual buildings can be improved, and will in any event be replaced within a couple of generations. Overall urban structure by contrast, addressed here, remains unchanged for a very long time. Inefficient city typologies and layout, once decided, will lock cities into very costly and undesirable future energy use and climate emissions. Hence the need for pragmatic avenues that offer refinements to current practice – improvements applicable at once, that are both advantageous for private sector developers, and realistic in terms of the planning and governance in developing country contexts.

Acknowledgments

This study is part of an ongoing EPSRC (UK) funded research program on energy and low income housing, including a broad scope of housing and community research in both rural and urban areas of China, Thailand, Tanzania and Uganda. The focus of this research paper is on China's urban housing.

Conflict of Interest

"The authors declare no conflict of interest".

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