Original Article

Chinese urban residential blocks: Towards improved environmental and living qualities

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Abstract The complex urban environment has multiple levels of design and planning that are applied in the form of blocks, layouts and city patterns. This paper develops an analytical study based on urban residential blocks in Ningbo city in China. It explores issues of density, green infrastructures, and urban quality with particular focus on environmental performance. At what point does exaggerated density reduce both living qualities and opportunities for good climatic design and a low carbon footprint? The study applies a simple methodology to evaluate and compare planning options for residential areas. The goal is pragmatic, seeking not ideal solutions but realistic and inexpensive alternatives to current practice which is particularly inefficient in terms of energy and climate emissions. Some potential advantages of low-dense as compared to high-rise solutions are noted. The study highlights questions as to optimal or appropriate typologies and densities for sustainable cities, in particular in the fast expanding cities of developing countries.
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Introduction

In the rapidly growing cities of the developing world, large urban scale block is a widespread typology of development. This model has advantages and disadvantages. With a basis in Chinese contexts, this paper evaluates issues and options. The focus is on residential developments, in particular their density and environmental profile, in the primary context of hot climates. Much research exists 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 in decision-making than environmental objectives, even where the latter are enshrined in national policies. This study questions what can be realistically applicable as of today, to provide improved urban environments as well as 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 environmental impacts of cities in developing countries are a growing burden. Cities house most of the world's population and stand for most of the energy use and climate emissions. Whilst transport typically accounts for around one third of this, most is due to resource and energy use in the buildings (Steemers, 2003). This, in turn, is partly attributable to overall urban structure and layouts. Within the buildings, there is a huge trend towards air conditioning and other energy amenities. For example in the City of Ningbo, China, access to air conditioning (AC) units in households has been increasing by 10 % per year (Ningbo

Annual Statistics Yearbook, 2013). A Hong Kong study noted *"the astonishing deterioration of the environment. The main environmental problems are associated with over-concentration due to high-rise and high-density development, and include poor air quality, water depletion, noise, and excessive waste production"* (Zhang, 1999). Good city planning is preventive medicine and can improve urban microclimate and energy efficiency as well as health. A few cities and communities have already managed to reduce their climate emissions by over 75 % or phase out fossil fuels entirely (Butters *et al*, 2010) and many more are proposing similar goals.

Both in hot-dry and hot-humid climates, city conditions can become unbearable – especially for the poor. Given 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: "*Increases of 0.5–3.0 °C and a corresponding increase in electricity demand of 2–4 % for each 1 °C increase in temperature have been found in several United States cities*" (Akbari *et al*, 2001). 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, but they are 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.

Context of the Study

This study examines the characteristics of three typical urban blocks in the city of Ningbo in southeastern China. After some Chinese and European comparisons, opportunities for design improvements are then discussed with a particular focus on density, energetic and climatic performance, however not forgetting the broader spectrum of residential qualities. Ningbo has commonalities with many of the other second-tier cities in China. In this level in China, most such cities are medium to large scale and have experienced major urban renewal and changes in the past two decades, and are continuing to do so. Ningbo is thus useful to highlight common issues of urban residential development in many Chinese cities. Whilst Ningbo does not represent the densest patterns seen in the four first-tier cities – Beijing, Shanghai, Guangzhou and Shenzhen – similar developments are already occurring in many smaller scale cities, which are likely to follow the same route.

The site selected for this study is an urban block, described below, presently occupied by six-storey apartment buildings dating from the 1990s which is almost certain to be redeveloped soon into a high-rise development. Since the late 1990s and the reform of housing policies in 1998, this pattern of change towards high-rise has been common. The trend of master planning in large blocks is relatively easy to implement and is favourable for developers, hence assisting rapid growth. This paper explores alternatives. It is indeed important to ensure profitability for developers and project owners, but equally to achieve a balance of benefits including for the users and residents, who will ultimately pay the costs of energy and maintenance, as well as for the broader long-term environment of the city as a whole.

Typical blocks in Ningbo cover 4–8 hectares and house 3000–10,000 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.

The urban residential blocks usually include a few commercial units at street level, mainly food outlets and other small service businesses. 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. There is thus only very limited mixed use. Recent blocks are often impermeable, gated communities. In general they are increasingly high-rise. Similar models are to be found in many developing country cities.

Construction in China recently has been at breakneck speed and is often of mediocre quality. The high-rise buildings are, for cost reasons, often compact and deep, resulting in restricted daylighting and poor if any cross-ventilation. Many apartments only face one direction, and those facing west or north attract lower prices, being colder in winter or exposed to troublesome west sun. There are no mandatory energy efficiency standards for the private sector; as in many countries, there is a reluctance to hinder economic growth by placing restrictions or requirements on builders.

Three Typologies

Before examining alternative scenarios for the redevelopment of the selected site, this study reviews three existing types of residential quarter in Ningbo: (1) an old quarter of a type fast disappearing in China but still common in many developing countries; (2) the above 1990s low-rise development and (3) a recent high-rise block of up to 30 floors, which most closely represents current practice. The three types are defined as traditional low-rise typology, typical low-rise blocks of six to eight storeys, known as affordable housing in China, and contemporary mid- to high-rise residential blocks (Galvez and Cheshmehzangi, 2015). These three serve to illustrate key issues of urban living, density and environmental quality.

The traditional low-rise typology

In China, the traditional typology known as 'hutong' is well known from Beijing; similar typologies are also found, often in disrepair, in other cities and in rural villages. In Ningbo only two such traditional areas remain today.

This typology has moderate surface coverage (SC), around 60 % in the hutongs, and floor area ratio (FAR) between 1.0 and 2.0, occasionally slightly higher. It is not unlike traditional, low-dense settlements in many cultures. Qualities include human scale and sociability, as well as simplicity of construction and maintenance – perhaps especially relevant for low-income contexts. Green space within such low-density quarters is very limited, but can be small, intimate and attractive, a precondition being that therefore some larger urban parks nearby (it can be seen in Figure 1 that there is a park immediately adjacent to this area).

Narrow alleys with courtyard developments and small communal spaces attest to former family structures and an era before automobiles. The layout may be described as fairly chaotic, remembering however that this is a feature now much appreciated in Mediterranean and similar villages; this raises questions of changing values. If redeveloped in a modern context, former problems such as overcrowding, poor sanitation, fire hazard and accessibility could be remedied. However, such areas are generally "looked down on" in today's China. This area is in disrepair and likely to be either demolished or possibly refurbished and "gentrified" as a conservation area (Figures 2, 3 and 4).

Figure 1: Plan and location of low-dense typology; Xiushui community, Ningbo, China.

Figure 2: Low-dense streetscapes in Xiushui community, Ningbo, China.

Figure 3: The compact layout of residential units in Xiushui community, Ningbo, China.

The 1990s Six-Storey Block Type

This typology is typical of working-class districts in many countries, with simple low-rise apartment buildings arranged in a fairly linear pattern. Similar areas can be found throughout Europe in mid-20th century social housing. In China, up to six (initially eight) floors were permitted without a lift as opposed to three or four in Europe. The area, 'NanYu Community' in Yinzhou District, Ningbo, will be subject to redevelopment within the next few years. Measuring six hectares (200 m × 300 m), the block has 30 buildings containing about 800 mid-sized family apartments. The area has limited access for non-residents. It includes two communal buildings, two low podiums of commercial units along the perimeter, and two entrances. The SC is around 23 % and the FAR is 1.4. The buildings have five residential floors above storage and services on the ground floor. Construction is mainly in brick masonry and other simple materials.

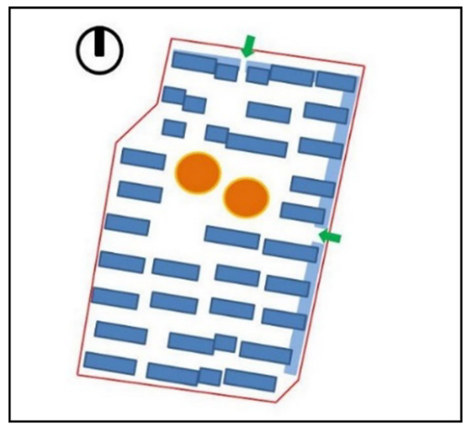

Figure 4: Plan of the six-storey block.

Built before private car ownership was prevalent, there is no underground parking and much surface space is now occupied by cars. A special feature is balconies that can be enclosed to extend available indoor space. This is visible in Figure 5, where all balconies except two have been enclosed with glazing. However, this feature, which is continued in new high-rises, reduces daylighting and ventilation. 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 simple and probably considerably more economical than the low-rise typology.

Figure 5: View of residential units; NanYu Community, Ningbo, China.

Figure 6: Open space in the six-storey housing area; kindergarten to the left.

Figure 7: Coverage and surface parking; high-rise in the background.

A major weakness can be a lack of outdoor space; but the outdoor spaces in this block, both the small green areas and the one larger open space, are used intensively for play and socialising. This block is, however, also in relative disrepair today. Unfortunately, the poor standard of construction means that refurbishment is probably not viable, even though this type of simple construction and building envelope is very amenable to upgrading to low energy standard, as witnessed by many projects in similar blocks in Europe.

The High-Rise type

A nearby high-rise block is typical of recent projects in urban China. Behind low commercial frontages of one to three floors along the street, blocks of up to 34 floors are spread around a central landscape.

There are 2000–2500 apartments, hence a population of perhaps 8000. Open space comprises some 70 % of the site. This typology has low SC, about 18 %, and FAR of about 2.6.

Construction is mainly concrete and steel, resulting in a very high carbon footprint. These are deep buildings, where most apartments have only single-sided ventilation. Some open galleries connected to the lift lobbies may assist stack ventilation; however, such internal shafts can present well-known problems of dirt or transmission of odours and noise. 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 additions harmonise with existing facades. But the added glazing will cause more overheating, in addition to reducing daylighting and ventilation (Figures 6, 7, 8 and 9).

The landscaping of many high-rise sites is extensive and attractive, but has few functional or ecological qualities. Traffic noise is partly abated by border buffer zones, which have no other function. There are few social spaces in the landscaping; it is largely aesthetic only, whereas it could be designed to actively enhance biodiversity, filtration of air pollutants and, not least, assist urban ventilation for better outdoor comfort and lower cooling needs. Similarly, building layout and orientation do not follow any climatic rationale with regard to sun and breezes but seem haphazard. Such environmental and microclimatic considerations should be key determinants of urban form, and provide at once ecological, economic and social benefits (Figures 10, 11, 12, 13 and 14).

Such blocks fulfil developer preferences for large, industrialised and to some extent uniform projects. European experience indicates that the application of even basic green planning, design and construction principles might reduce the energy needs of such blocks by half without significant added costs. This kind of development represents huge missed opportunities for developing country cities, where new urban millions are fast acquiring energy

Figure 8: The high-rise residential block in Ningbo.

Figure 9: Landscaping within the high-rise block.

amenities as well as cars, locking cities into huge future energy and climate burdens.

Issues of Density

Many studies provide detailed insights into how various typologies perform in energy and climatic terms. They illustrate quite large divergences in the relative importance and effect of the many factors involved such as density, building form, functional distribution, income, car ownership and so on (Jabareen, 2006; Kockelman and Nichols, 2014). The benefits, including economic, of green infrastructures are broadly reviewed in Wang *et al* (2014) and Zhang *et al* (2011). Whilst the "compact city" paradigm offers advantages especially in terms of transport solutions, it equally implies a "compact" concentration of negatives: high land prices, congestion, air pollution and noise. A more subjective list might include insecurity, lack of local identity or lack of green and leisure spaces. Compactness is widely thought to be favourable for lower energy use and climate emissions; however, there is broad evidence in these and other studies that whilst the extremes of suburban sprawl and very dense high-rise cause higher impacts, between these lies a wide range of fairly dense urban typologies, all of which can offer excellent energetic and climatic results (Figures 15, 16, 17 and 18).

The reasoning behind dense, high-rise development is often said to be the need to house many people in a compact way. This argument is not valid; equally high population densities are achievable with quite low-rise. Traditional blocks in cities like Paris achieve FAR not just equal to but higher than the high-rise "superblocks" in Chinese and similar cities (LSE Cities/EIFER, 2014).

Urban density is measured in ways including FAR, SC and dwellings per hectare (dph). Other useful indicators include green coverage, functional mix and (for energy) surface-to-volume ratio. Whilst all these are dependent on contextual factors, such as household sizes and whether adjacent transport areas are included, comparisons of SC and FAR suffice for the present discussion. Table 1 provides brief density comparisons of various urban typologies.

With the sustainability triad of ecology, economy and society in mind, it must be recognised that, in reality, urban planning decisions are seldom made following ecological priorities. Principles for more sustainable design both of buildings and of cities are well known. They are, however, seldom applied in the rush for development, coupled with a rather unquestioning belief in high-rise models and the outdated zoning paradigm of the modernist era, as opposed to the mixed use principle that is recognised as

Table 1: Some urban density comparisons

Urban typology	*Surface coverage (SC)*	*Floor area ratio (FAR)*	*Average height of buildings (of total)*
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	0.18	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	1.5–4.0	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

Notes: Average height (in number of floors) in high-rise areas is less than the high-rises themselves due to the inclusion of some low-rise commercial and other buildings on most sites.
Ningbo examples 1, 2 and 3 correspond quite closely to 4, 5 and 7 in the Jinan study, except that the more recent Ningbo high-rises are significantly higher than the 1990s Jinan type.
Figures are indicative for comparison only.
Sources: Ningbo cases by the authors, Jinan cases from Yang (2010) and Europe cases from LSE Cities/EIFER (2014).
Average height of buildings is calculated based on the mean number of heights for residential buildings in a typical community. Since the buildings are of varying heights, including low podiums, the average height figure comes out as a fraction. The allowable building height (building regulations) might be 4, 8 or 20 floors, but that does not reflect the average of an area as a whole.
Surface coverage (SC) is based on a maximum of 1.0 as 100 % of the site; therefore, 0.1 is 10 % coverage/built of the whole site, 0.54 is 54 % coverage/built of the whole site and so on.

essential for eco-cities. In addition, high priority is still given to private car transport which has huge impacts on the ecological as well as social characteristics of cities.

As shown in the comprehensive LSE-EIFER study (2014), low-density blocks at FAR around 1.5–2.5 can be just as energy efficient as dense high-rise. In hot-dry climates, low density (with heavy materials) is a tradition not least for climatic reasons. In tropical regions, it is widespread too, usually employing lightweight materials and openness of structure to maximise air movement. Thus, it may be argued that low density is a viable option and deserves new attention.

Contextual Barriers

Every context has particular structural, economic and cultural features. In rapidly developing (or "emerging") economies, typical urban issues are as follows:

- limited-time interest-in-land, which encourages short-term thinking and a reluctance to maintain or invest 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-scale developments that tend towards gated communities with little mixed use, functional connection or social permeability; and
- a reluctance to impose strict planning requirements that might hamper growth.

In the case of China, green planning and technologies are not yet well recognised or widespread, nor are the required products available. This is also 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*" (Yang, 2010). The authors advocate 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*" (Yang, 2010).

Alternative Scenarios

Since it is due to be redeveloped, the site of the six-storey housing is taken as a basis for an investigation of alternatives – as noted with a focus on pragmatic rather than theoretical or ideal solutions. The FAR in the existing 1990s block 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. Typical European cities such as Paris, London and Istanbul with compact blocks of 5–8 floors have a FAR sometimes exceeding 4.0 (LSE-EIFER, 2014). In the study comparing low-dense, slab and medium-rise blocks in the City of Jinan, China, Jabareen (2006) observes that the overall population densities are

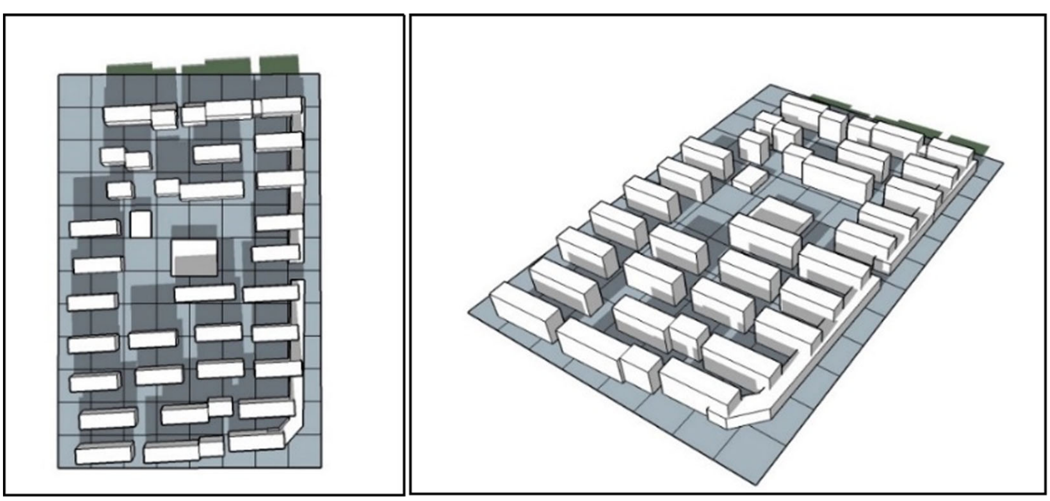

Figure 10: Plan and 3D representation of the existing six-storey block, SC 0.23.

quite similar – from 120 to 145 dwellings per hectare (dph). Naturally, if one wishes for even higher population densities, then SC can only be kept that low by building much higher. The already studied case of Jinan (Jabareen, 2006) is useful as a comparative case for this paper's discussion on SC and FAR in the context of China.

Options are now investigated in five alternative scenarios for FAR 2.0–4.0. The study methodology is to divide the site into cells of 25 m × 25 m. Major parameters of block pattern, daylighting, shading, ventilation, and air flow were considered. Through simple illustrations, these scenarios indicate some of the environmental, energy efficiency and social qualities that are available, or risk being diminished, especially as one increases the density.

In all 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; a detail design stage should ensure that openings let prevailing breezes enter the green spaces at ground floor level.

The study comprises three alternative scenarios with the FAR values of 2.0, 3.0 and 4.0 respectively; one possibly more optimal scenario of moderated density; and for comparison, one scenario of a "Parisian" type block. These scenarios are then analysed and discussed.

Scenario 1: FAR 2.0

Keeping the SC low, at 23 % as in the existing site, the FAR is raised significantly to 2.0. This is still below typical high-rise cases of 2.5–3.0. A mix of 20, 15 and 10 storeys is now needed. In order to pursue the pragmatic route, the basic paradigm of a high-rise block with commercial perimeter, little mixed use and one large, central space is not questioned here, but is discussed below.

Building heights as well as positioning are optimised primarily in function of solar protection and prevailing breezes. Buildings are shown here as simplified square forms; in a detailed study, the built forms too would naturally be developed to minimise East and West sun and maximise cross-ventilation (Cheung and Liu, 2011).

Scenario 2: FAR 3.0

Developers may seek higher profitability. This scenario with a FAR of 3.0 illustrates higher density. To keep the SC at 23 %, hence the same amount of open space, one must then increase some of the blocks to around 30 floors. Although placing these towards the North and West reduces solar shadow in winter and summer blockage of air movement, the overall height and density become much more than those in the previous scenario. It will also impact on next block to the

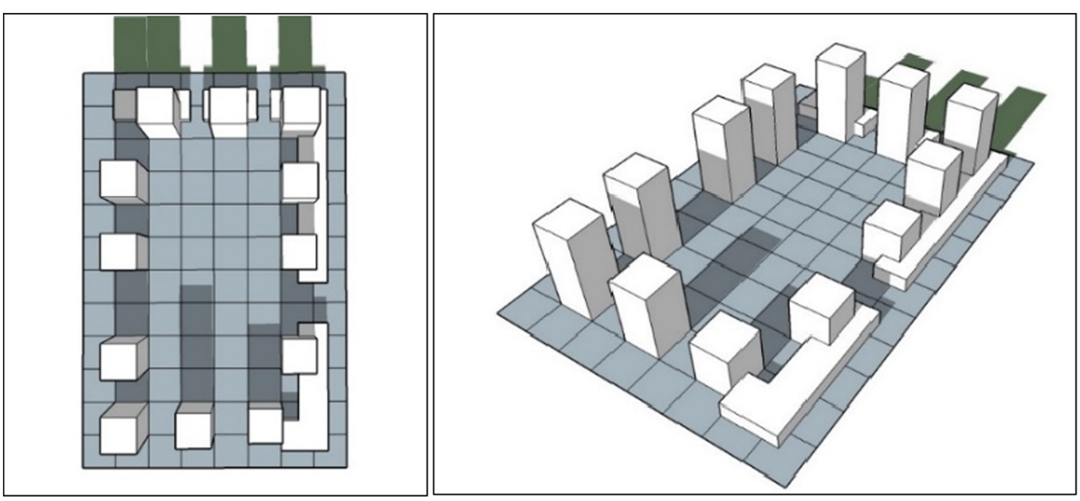

Figure 11: Plan and 3D representation of scenario 1 with FAR 2.0 and SC 0.23.

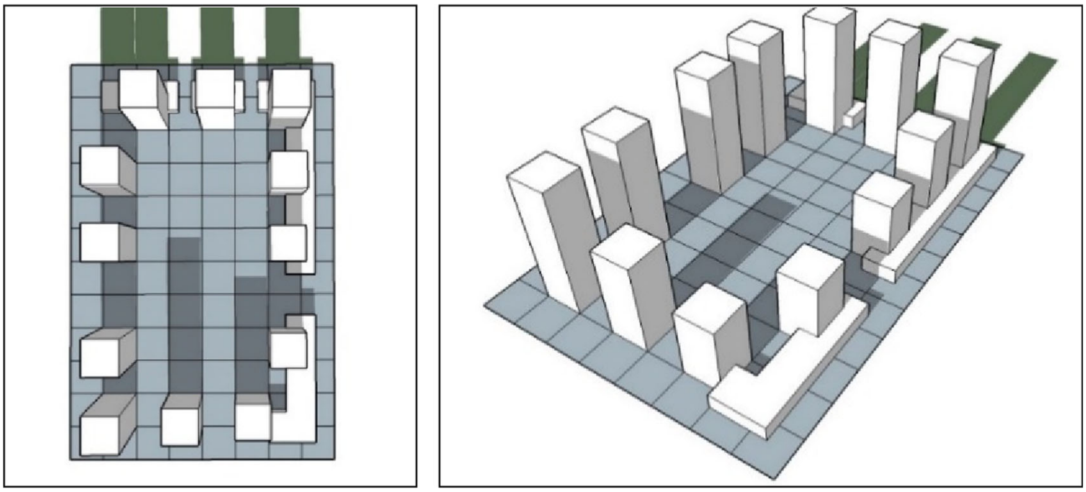

Figure 12: Plan and 3D representation of scenario 2 with FAR 3.0 and SC 0.23.

North. It is also well known that above a certain height, the space requirements for lifts and services become excessive per floor area; this has not been analysed here.

Scenario 3: FAR 4.0

Even further increases in the FAR will normally require higher SC. Whilst increasing developer profits, this would seem likely to have considerable negative impacts, greatly reducing available open spaces and urban quality. As can be seen, this scenario of FAR 4.0 requires very high blocks as well as SC being increased to at least 40 %. Block heights are now mostly 30 floors. This is common practice in many Chinese residential developments; in some cases with higher land values it is even increased to 40 floors and more.

Many will probably agree that this presents an extremely crowded picture, where both the quantity and quality of outdoor space are greatly compromised; negative trade-offs in terms of biodiversity, views, solar access and air movement are evident.

Scenario 4: FAR 3.0

One can attain a FAR approaching 3.0 whilst keeping SC low. However, low SC is not necessarily efficient or optimal. Two further options

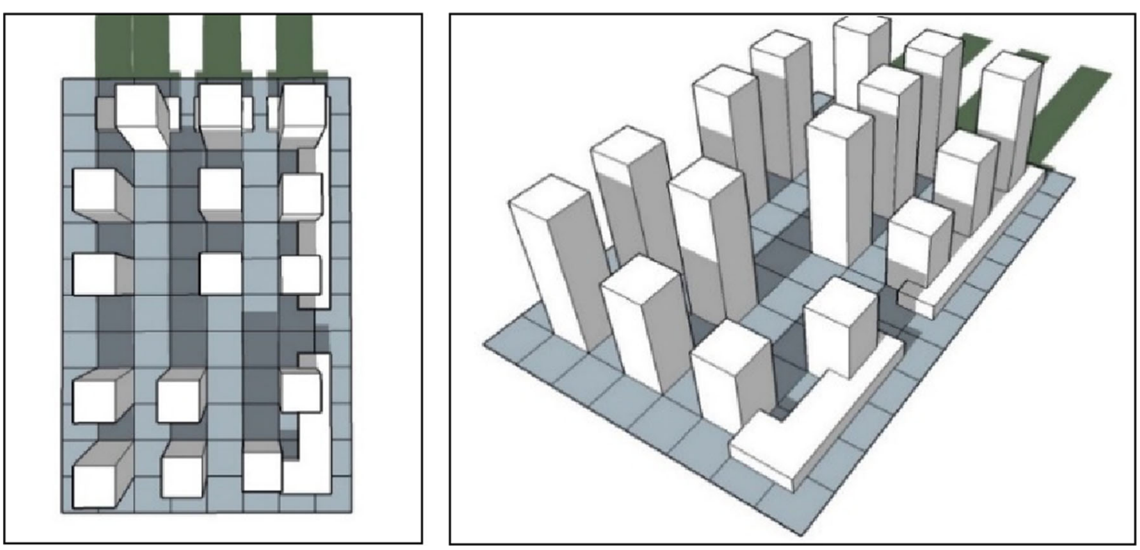

Figure 13: Plan and 3D representation of scenario 3 with FAR 4.0 and SC 0.40.

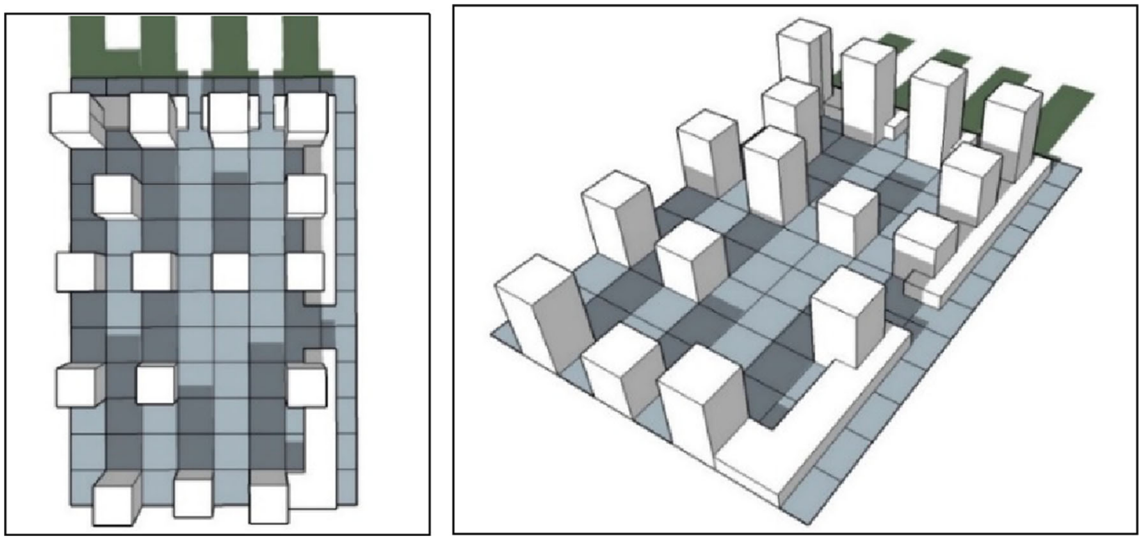

Figure 14: Plan and 3D representation of scenario 5 with FAR 3.0 and SC 0.30-0.35.

were therefore tested. In this scenario, one can achieve a variety of building heights, densities and zones, still fairly low SC, and green spaces designed to improve microclimate, outdoor comfort and reduced cooling needs. Some units are added on the Western side, whilst heights are modulated to optimise daylighting and shading. Green qualities are maintained with two fairly large inner spaces plus one linear axis across the middle.

Accepting simplifications inherent in such comparisons, even with high FAR and SC, hence high profitability, one can still sketch options that include substantial areas of open and green spaces. This scenario, although denser still, offers considerable qualities; but some are arguably being compromised by the density. Here again, social acceptability aside, in energy/climate terms the built environment can achieve excellent energy efficiency; although the parking- and transport-related implications might become unacceptable. Might this scenario represent a realistic "maximum"?

Scenario 5: FAR 2.56

A classic feature of European cities is dense but quite low-rise city blocks. As noted, this can achieve equal and even superior population

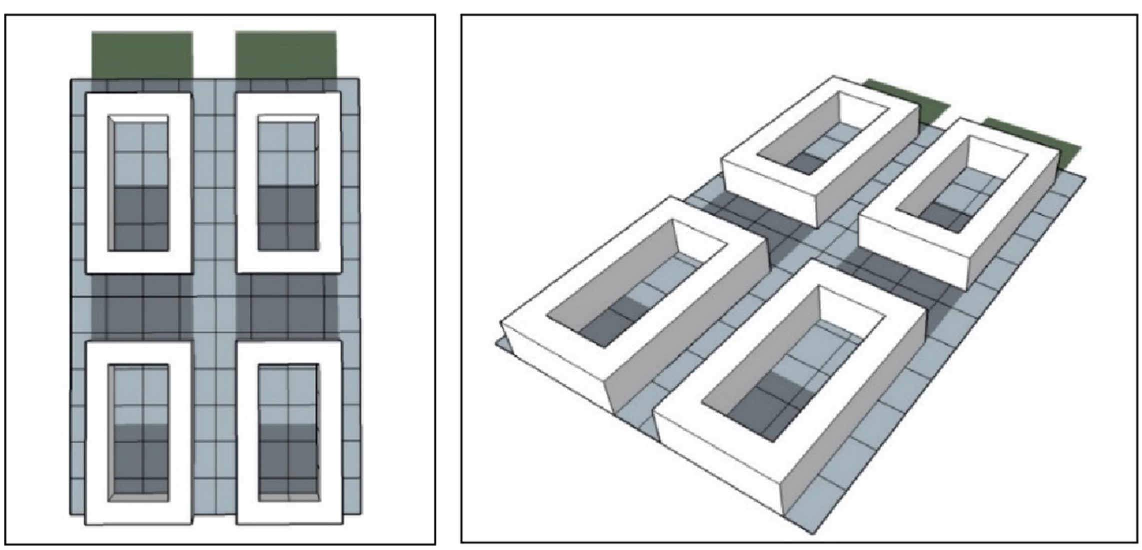

Figure 15: Plan and 3D representation of scenario 5 with FAR 2.56 and SC 0.25-0.35.

densities. For comparative purposes, a typical "Parisian" typology is therefore tested. The block is divided into four smaller ones, of only eight storeys, more slender buildings enabling cross-ventilation for all units. At the detail design stage, the simplified model illustrated would naturally also develop features such as varying heights for optimal solar protection and passages at ground level to increase through ventilation. This option can also be designed to provide substantial open space, such as the 45-metre-wide belt across the middle of the site. In this way, one attains a FAR of over 2.5 yet avoiding high-rise.

In a "Parisian" model, open space is limited to small if attractive areas. Large green spaces are located in urban parks nearby, with their potential for recreation, exercise and cultural events. These are open to all as opposed to the segregated and non-inclusive areas internal to the high-rise type blocks. The public urban parks can also be of a larger size that nurtures high biodiversity and nature experiences.

This highlights the question of the need for diversity in a spatial hierarchy, ranging from private balconies to semi-private outdoor areas, neighbourhood spaces and fully public spaces. In the high-rise blocks, the large central spaces are often less used and are available only to the gated community. It could be argued this is not only ecological but, more importantly, socially inefficient space planning.

Comparisons

The above scenarios invite discussion on desired city qualities, on urban paradigms and not least on the energetic and climatic targets that are now a central target for urban planning. Table 2 provides a brief comparative analysis of the scenarios, including SC, FAR and some overall advantages and disadvantages in each case.

Whilst keeping SC in a fairly low range of around 0.23–0.30 is feasible, keeping the FAR low is no longer realistic for the context of Chinese cities. Developments with low FAR are normally for high-end users only and similar to European or North American models.

Scenarios 1 and 2 are typical high-rise models with a large central open space, often including artificial water bodies (ponds or small lakes) but not very usable green spaces. The underground parking largely determines the ecological qualities on the surface, being normally a 1–2 m deep layer of concrete plus green cover. Whilst the green infrastructures can be optimised, already at this density the compact layout of residential towers around the perimeter results in units with relatively poor daylight and ventilation. Scenario 3 is the extreme case of high FAR and lower SC, with various drawbacks, whilst scenario 4 seeks an optimised balance between profit, pragmatic pressures and ecological and social qualities. The Parisian model, whist culturally different, offers

Table 2: Comparative analysis of alternatives

Scenario	*SC and FAR*	*Advantages*	*Disadvantages*
Existing	Low SC, 0.23 Low FAR, 1.2	Low SC, low FAR; Cheap building type; Cross-ventilated units; Low-rise, low density	Lack of usable open space; Poor construction quality; Lack of greenery; Low FAR (uneconomic)
Scenario 1	Low SC, 0.23 Medium FAR, 2.0	Low SC, moderate FAR; Can have height variety; Medium size units	Large open space; Poor spatial arrangement; Moderate daylighting
Scenario 2	Low SC, 0.23 High FAR, 3.0	Profitable density; Some variety of building heights and spaces	Rather high FAR; Poor daylight and ventilation; Potential wind blockages
Scenario 3	Higher SC, 0.40 Very High FAR, 4.0	Maximised density for developers	Very high FAR; Poor daylight and ventilation; Poor wind environment; Lack of open spaces
Scenario 4	Medium SC, 0.35 High FAR, 3.0	Optimised wind environment; Optimised daylighting; Variety of open spaces; Well-defined edges	Rather high FAR; Challenging for wind, solar optimisation, daylight and ventilation; Reduced open space
Scenario 5	Medium SC, 0.32 Medium FAR, 2.56	Low-rise, medium density; Cross-ventilation to all units; Cheap, flexible construction; Sociable smaller blocks	Culturally relevant? Less open and green space, assumes larger parks nearby

quite high density and other advantages. It also allows for quite a large transversal green belt. It can offer green infrastructures, excellent energy efficiency, and improved permeability for an alternative residential typology.

These are considerations at the level of overall urban planning; complex simulations of local microclimate would follow in specific design studies. At the technical and detail level, all high-rises can be greatly improved through façade design, window shading, reflective colours and so on; this design level is not addressed here. Optimisation at the level of the whole residential block mainly concerns layout, green and social spaces, daylight and views, urban ventilation, ecological landscaping and resultant improved local microclimate. Lower outdoor temperature will in turn reduce cooling needs.

In this study, the authors have employed, but refrained from extensive use of, simulation tools in assessing the cases; focus is on comparisons of *the overall spatial, social and environmental potential* of various master planning and urban policy approaches. The considerations of energy, carbon and urban microclimate take on a central role in such design. Further detailed solutions, which in such contexts require necessarily very complex simulations, can naturally either exploit or fail to exploit the potentials. This study proposes some alternatives in layout and land-use patterns that are not existing practice. For residential functions, the fundamental practice of large-scale blocks, which only the "Parisian" model deviates from, could well also be questioned.

Discussion

Green Infrastructures

Green spaces need a certain minimum dimension (and configuration) both for biodiversity and in order to mitigate UHI effectively. Even quite small green areas of 30 m × 60 m can be 3.0 °C cooler than nearby hard built areas (Jabareen, 2006). These also cool adjacent city blocks. Other factors include appropriate shading, reflective surfaces and a minimum of impermeable surfaces (Zhang *et al*, 2014). As regards building layout, the two keys to reduce cooling needs in hot climates are maximising solar protection and air movement. Studies have also been undertaken as to spacing and staggering of high-rise buildings for optimum air movement (Saito *et al*, 1990–1991). The importance of green roofs is well known; one study showed that if just 5 % of the city area is green roofs, "*the impact of green roofs in the high density areas is even more pronounced… temperature across the city was reduced between 1 and* 2.8 °C". (Chen and Wong, 2006). Vegetation can be selected, which provides best shading and also filters pollutants. Urban gardening and water purification are other productive functions in green spaces. And access to nature is, according to the biodiversity hypothesis, necessary for improved health and wellbeing (Hahtela *et al*, 2013; Hanski *et al*, 2012). Beyond aesthetic improvements, the green and blue infrastructures should deliver specific microclimatic effects. Design principles for improved microclimate and passive cooling in cities have been long established, but sadly

Figure 16: A new "extreme case" development of 40+ storey residential blocks on a previously very low-rise housing area. *Source*: Authors.

neglected in practice (Olgyay and Olgyay, 1963; Givoni, 1998; Kwok and Grondzik, 2007). Again, these are large and low-cost missed opportunities for climatic and comfort amelioration and reduced energy needs.

State-of-the-art eco-neighbourhoods

It is relevant to include low-dense considerations here since this is widespread in many developing countries; it is also a much appreciated typology in Europe, including some of the most successful modern eco-neighbourhoods such as Vauban in Freiburg, Germany, Western Harbor in Malmo, Sweden, or Culemborg in the Netherlands. These neighbourhoods, exemplars in ecological, economic and social terms, exhibit a FAR of up to about 2.0.

It must be noted that land use, density and living quality are closely interlinked with transport policies and solutions for sustainable mobility. Much of the green space in dense high-rise blocks is in fact on top of underground garages. These "heavy" infrastructures, mostly in concrete and steel, are vastly more expensive and carbon intensive than ground-level parking which is possible in low-dense solutions. Although transport is not discussed here, high densities imply great transportation problems unless a very high proportion of mobility can be delivered by public transportation: "*In the absence of extra capacity in the form of effective integrated public transport, increasing the density will inevitably increase traffic*" (Steemers,

Figure 17: Green housing neighbourhood in Vauban, Freiburg, Germany.

Figure 18: The compact layout and green spaces of housing neighbourhood in Vauban, Freiburg, Germany.

2003). In order to achieve its aims, the "compact city" simply cannot be a "car city". The "walkable city" objective is a central feature of the eco-neighbourhoods.

The Ningbo six-storey low-density example is run down, with an unimaginative layout, and has few of the qualities of modern eco-districts. Nevertheless, low-density compared to dense high-rise housing typologies do offer a range of sustainability advantages including lower embodied energy/carbon in construction, infrastructures, site works, recurrent energy and post-use and excellent resilience over time. Those points are further explored in Butters and Cheshmehzangi (2016).

Barriers and Processes of Change

Sustainable development and good planning are difficult anywhere; in many developing countries, planning and governance capacity are weak or absent. How then can reasonably sustainable urban development be promoted? Alongside gradual capacity building, only pragmatic approaches, attuned to local context, can succeed. Sustainable solutions are available, but success is a question of quite long processes. Where strong governance is unfeasible and public demand is low, authorities must gradually raise awareness and build dialogue with developers, backed with examples both locally and from elsewhere. European experience in pioneering eco-city developments has shown that there are win–win opportunities where environmental and social ambitions can be raised whilst maintaining the "bottom line" of profitability for the private sector. Green building is often not more expensive once established – though incentives are definitely needed to achieve initial market penetration. Low energy solutions are good for everyone's profitability, both individual and public finances. Many ecological solutions now have fairly short payback times. Developers can benefit from a greener image, even if this includes some superficial "greenwashing". There is also opportunity to become market leaders in view of future stricter environmental requirements.

Eco-city projects have often managed to achieve genuinely positive cooperation between planning authorities and business. This serves, equally, to promote more interdisciplinary and intersectoral dialogue and planning. Looking at the dynamics and processes of change, sustainable urban development almost everywhere has identified and pursued four difficult but essential processes which may be summed up as follows:

- from specialised spatial zoning towards mixed use,
- from specialisation to integrated design and planning – also a key to lower costs,
- from uncontrolled construction to voluntary energy efficiency guidelines and later to mandatory standards and codes for environmental quality and
- from private–public contradictions to a win–win models with better cooperation.

All of the above have been the subject of very major efforts and important shifts in policy, planning and practice in industrialised countries.

Pragmatic considerations

Issues of pragmatism have been noted. Compact urban environments are most unlikely to be available to those at the bottom of the pyramid. Many developing cities seem to follow 'western typologies', including high-rise that are not necessarily relevant to climatic conditions or to their societies. The modernist ideal of functional zoning is now largely discarded in favour of integration and mixed use. For low-income contexts, with limited access to skills, resources and finance, low-density options may offer considerable advantages. Dense "inner city" type environments require infrastructures, buildings and services of a high standard in order to be livable and avoid problems such as pollution, overcrowding, noise and urban heat island: "*High demographic growth, low levels of economic development, high income inequalities, small urban budgets and shortages of environmental infrastructure, shelter and basic services have a critical effect on densification policies and the effectiveness of policy instruments. The merits of densification at a high level of development may disappear at a lower level and are counterproductive without significant improvements to this level*" (Burgess, 2000). Whereas high-quality compact cities may provide satisfactory conditions, low-cost compaction and high rise may lead to little better than "vertical slums".

Pragmatism demands swift action to mitigate rising future burdens on cities, both social as well as energy use and climate emissions. Whilst high rise is likely to be unavoidable as a major trend, there are major – and fairly simple – opportunities for improvements. China's planners are extremely well placed in that they have the authority to determine densities, heights and other requirements. Densities above FAR 2.5 seem unadvisable; this still permits high profitability. Restrictive parking provisions should be considered. It is not unreasonable to require layouts of high-rise residential buildings to provide solar access and a minimum of one-sided units. Current construction is extremely heavy and carbon intensive; lower impact solutions, for example using at least some lightweight materials and less concrete, need not be less economical. In general, it is more difficult to reduce the embodied than the operational energy/carbon (Cole, 2012).

Whilst maximising sustainability aspects, solutions must be approached from and achieve a balance between four perspectives: authorities–designers–investors–users. Naturally, these four do not always have similar priorities.

The large urban block typology has significant advantages but, at the same time, disadvantages that demand questioning in terms of urban policy. One pragmatic advantage is easier planning and administration of fewer large-scale projects rather than many small ones. This enables developers to deliver at a faster pace and a larger scale. Large scale has substantial impacts on economies for construction profitability. Yet, this means that more expensive infrastructure is required for such projects.

Disadvantages and risks in the large block typology include high embodied carbon, complex maintenance and post-use, exclusive gated communities, mono-functional city zoning and poor social aspects such as for children and safety. Despite probable social as well as environmental advantages, there may also be structural, financial and even political reasons why low density is not considered favourable in some countries.

It is not easy to engage developers in dialogue; however, progress in Europe has depended on an increasing degree of involvement with the industry. This includes both green buildings, and microclimatically optimised layouts and green spaces. Guidelines and pilot studies, including both exemplar buildings and cost analyses, can help shift current construction practices in the private sector. At some point, however, there is undoubtedly a need to introduce energy and carbon requirements. This is not least in view of the well-known "split incentives" issue: private sector developers sell their products and are not responsible for climate emissions, nor for the energy bills or maintenance costs, which are passed on to the buyers.

Conclusions

There is a need for reflection on prevailing and future urban paradigms, not least of which is the large block typology discussed here. Dense high-rise is advantageous for large businesses, favouring a pro-developer approach to planning and design of cities. Even accepting this, there are many quite simple ameliorations of layout, design and construction which could greatly improve energy efficiency and carbon footprint as well as mitigating UHI and ensuring other living qualities.

Low-density alternatives offer potential advantages both in social terms and environmental performance. Given the energy and climate agenda, policies 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, they require revisiting in this "new" light of sustainability. Parallel to exploring "ideal" eco-city solutions, there is an equal, if not 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 here have relevance for many as yet less critical contexts, since the various options of low-dense, medium-rise or high-rise (and, naturally, mixes of these) are key policy decisions with long-lasting consequences.

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