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SUSTAINABLE LIVING AND URBAN DENSITY: THE CHOICES ARE WIDE OPEN

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ABSTRACT

Rapid urbanization, especially in developing countries, means that the worldwide tradition of living in low-rise housing is giving way to life in urban apartments. This implies huge environmental and sociocultural changes. For sustainability, dense cities offer some advantages, including efficient land use and transport systems. But there are also many possible negatives of such urbanization, and particularly for lower income groups.

A widespread model is high-rise urban "superblocks". The reasoning is often said to be the need to house many people in very compact cities. This argument is not strictly true. Equally high population densities can be achieved in several ways, including quite low-rise, with equal energy efficiency as well as environmental and social qualities. We explore these choices and assess options for sustainable living in future urban residential areas.

Life cycle analysis is often applied to individual buildings but less often to urban development seen as a whole. We suggest some important "new" considerations need to be taken into account in deciding which urban forms to choose. In particular, high-rise as compared to low-dense options have implications as regards embodied energy, recurrent costs, flexibility and post use, which have to date been little discussed in the research literature.

Keywords: Urban Density, Sustainable Living, Urban Block, Residential, Low Dense, Energy Efficiency.

1. INTRODUCTION

City planning goals include all three areas of environmental, economic and social sustainability. Recognised "eco-city" objectives include improved urban microclimate, reduced heat island, low carbon footprint, mixed use, walkability, diversity and social cohesion. Resilience – the quality of adaptability and robustness over time – is a key goal that applies to all three areas.

Cities have often evolved on the basis of economic factors linked to local resources, industry or favourable hub location for trade. Growth has often been at the expense of local environments and often, ultimately, of living quality too. What is new, we argue, is not urban forms as such, but the relatively new perspective of sustainability, both global and local. This new understanding demands that we consider (and design) cities and urban form in integrated ways that address all three of the above areas. Methods of evaluation must therefore also be holistic, such as that provided by the Sustainability Value Map [1].

There are various competing paradigms of urban form: low-dense European typologies, "garden cities", modernist zoning, and dense high-rise. Historically these have been championed mainly on grounds of functional efficiency and/or conviviality; that is, mainly on *economic* and *social* criteria, not *ecological*. In this paper we discuss how today's essential focus on the third area – ecology, including resource flows, energy use, climate emissions and ecological footprint – sheds new light on the suitability of options such as high-rise and low-dense.

2. URBAN PARADIGMS: DENSITY

The particular focus of our current research [2] is cities in hot climate developing countries. This is where most growth is occurring, where new urban millions are fast acquiring cars and energy amenities, and also where needs amongst the poorest groups are most pressing. However, an almost universal paradigm seems to be that of high-rise urban solutions. Is this necessarily best, or most sustainable?

Densities are illustrated with examples from studies in Ningbo, China, with comparison to studies elsewhere. Some of the issues discussed are well known, for example regarding energy efficiency and heat island effect. So too are principles for design – both of buildings and of cities – which is in ecological terms more sustainable. These solutions may not even cost significantly more, but are seldom applied in the rush for development; coupled with a rather unquestioned belief in the high-rise model. In addition there comes the priority still given to private car transport, which has colossal impacts on both the ecological and social characteristics of cities.

Previously, we have studied three residential block typologies in Ningbo [3], identifying the trend of mid- to high-rise superblocks, as many other cities. Top-down, large scale master planning of residential blocks is widespread. The lack of climatic and energy design and lack of analysis of how residential blocks are shaping social qualities in our cities are main concerns of our study.

Many studies such as [4] and [5] provide detailed insights into how various typologies perform – whether in energy, economic or social terms. In China, cities are increasingly high-rise with large gated superblocks. But this choice is crucial to issues of sustainable living, urban energy and microclimate. We have explored density comparisons from various sources (Table 1) showing typical differences in average building height and Floor Area Ratio (FAR) of various typologies, as well as Surface Coverage (SC). The superblocks are common in China and often offer very limited mixed use. The high-rise blocks cover less of the surface; but whilst their FAR and hence population density is up to twice that of older, traditional neighborhoods, it is not more than that of low-dense ones such as typical European city blocks.

Table 1 Urban Density Comparisons
(Source: the authors [3], for Europe [4] and for Jinan [6])

Urban Typology	SC	FAR	Average 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	1.5-3.5	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

3. CITIES IN DEVELOPING COUNTRIES

The megacities of hot climate developing countries, where air conditioning is spreading very rapidly, are experiencing increasing urban heat island effects. Crowded conditions and lack of energy amenities may, in a warming world, lead to very poor living conditions and increasing mortality. And whereas *high quality* high-rise may provide satisfactory living conditions, *low cost* high-rise may often lead to little better than "vertical slums".

In particular for lower income groups, low-rise may offer advantages both in terms of ecology, costs and community. In eco-technical terms, low-rise buildings allow for simpler materials and passive climatic solutions, which are a key to economic eco-design. In economic terms they can be low cost. As evidenced both by traditional city neighborhoods and recent successful European eco-districts, they can offer variety, user satisfaction and social cohesion.

Whilst high-rise may be necessary in some city centers, land use is not the real issue since high densities may be achieved in quite low-rise. Importantly, this is not about "going back" to outdated models; rather, there is good reason to revisit and refine low-rise concepts in the new light of sustainability. Some of these are briefly outlined below.

4. CASE STUDIES: URBAN BLOCKS, NINGBO

In a typical urban area of Ningbo of around 1.5km^2, comprising mainly residential blocks, we can note a variety of urban layouts (Figure 1 and Table 2).

Figure 1 Study area of Yinzhou District, South Ningbo. Highlighted blocks indicate current occupancy below 70%.

Table 2 Urban Block details and typologies
(Source: the authors)

block	Status	Occupancy Level	Typology
A	Completed	Very low	Commercial + mixed use (no residential)
B	Under Construction	n/a	Commercial + mixed use (no residential)
C	Mostly completed	Occupied	Public Services
D	Under Construction	n/a	Proposed residential
E	Completed (from earlier date, ca 1990)	Fully Occupied	Residential + commerce on street edge
F	Vacant (continuous development from E)	n/a	n/a (possibly reserved for residential)
G	Under Completion (last phase)	Not yet occupied	Public Services and Commercial
H	Completed ca. 2005	Most occupied	Residential + commercial on street edge
I	Completed	Occupied	Local Library
J	Completed in 2012	Low	Residential + commercial on street edge
K	Completed in 2012	Very Low	High-end residential

All except block E are recent blocks. Most incorporate a few retail and mixed-use amenities such as shops, banks and food outlets. At present many have low occupancy due to rapid growth. Blocks E and H are two distinctive typologies of low-rise and high-rise respectively (Figure 2), with similar surface coverage of 0.23 and 0.17 (Table 1). The 6-floor block (E) has a fairly dense grid pattern with only a few internal green spaces. The newer high-rise block (H) has residential towers grouped around large green spaces. Both have some commercial units along the main street edges.

In the 1990s there were few cars; available surface areas in block E are now largely filled by cars. The newer block H, on the contrary, has very extensive underground parking. According to our preliminary LCA study, the resources footprint of this is almost as large as that of the buildings themselves. The hidden cost of these infrastructures is also considerable as part of embodied energy and carbon for such development scenario.

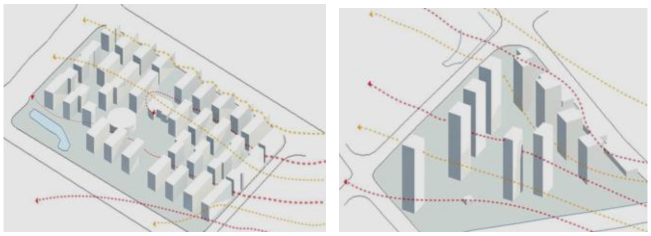

Figure 2 Block E (left) and block H (right) showing height differences, densities, and indicative summer wind flow.

Table 3 below compares the spatial layout, density and some performance features of these two blocks.

Table 3 Comparison of Blocks E and H

	Spatial Layout	Density	Performance
E	One main communal space; minimal green spaces between the units; surface parking (very limited).	FAR 1.2; SC 0.23 Compact building layout of 10m unit width and 17m between units.	Cross ventilation for all units; with low energy consumption, 1-2 AC (air conditioning) units per apartment.
H	Public and private communal spaces, major green spaces, underground and surface parking (for most not all units).	FAR 2.6; SC 0.17 High-rise and clustered layout, 25m deep blocks with 25-150m between units.	Mix of 1-sided and 2-sided ventilation; some poor daylighting; higher level of energy consumption, 2-4 AC units per apartment.

5. DISCUSSION

Powerful arguments can be found both for and against the “compact city” idea, which has been widespread in recent years. Whilst it enables efficient public transport, it also means a “compact” concentration of “negatives” – such as pollution, heat island, noise and congestion. However, it is in particular with regard to aspects such as energy and climate, that new arguments appear which are in favour of low-dense options; hence our argument that we need to revisit these. Holistic urban design, including a complete life cycle view, provides some powerful arguments about the relative benefits of low-dense and high-rise. Let us consider the following points:

5.1. An equally high *overall population density* (FAR or dph) is achievable with low-rise; typical blocks in cities like Paris have a FAR of over 3,0 and even 4,0 – higher than the super blocks in Ningbo and many similar cities.

5.2. As regards thermal energy efficiency, the *overall building form* or surface-volume ratio in high-rise is in general no more compact than low-dense.

5.3. *Building services and shafts*, especially for ventilation, lifts and stairs, tend to take up excessive amounts of costly space in very high-rise buildings.

5.4. As regards creating a favorable urban microclimate, high-rise provides more ground level green space as well as cleaner air and more air movement available in high buildings; however many countries show good microclimate solutions in low-rise traditional typologies, in both hot-dry and hot-humid climates.

5.5. *Solar protection*, one of the keys to low energy design in hot climates, is more difficult in high-rise where more of the facades are exposed.

5.6. *Embodied energy*, an increasing part of the overall life cycle picture, must almost inevitably be higher in high-rise due to the need for energy/carbon intensive materials such as reinforced concrete (RC) and steel. In low-rise, simpler materials can be used.

5.7. As is shown in the LSE-Eifer study and others, the *operational energy* efficiency can be just as good in low-dense as in high-rise typologies.

5.8. *Recurrent embodied energy* for ongoing high-rise maintenance (especially façade maintenance) is probably also more onerous and expensive than in low-rise.

5.9. *Ventilation* in high-rise is tending towards apartments with one-sided ventilation (and poor daylighting), with AC, hence increased energy use for mechanical rather than natural ventilation - and increased energy for lighting.

5.10. The energy/carbon impacts of *materials transport* and *on-site construction*, although quite minor in the LCA balance, are higher in general with high-rise buildings.

5.11. *Post use impacts* are probably higher with high-rise due to complicated demolition and recycling or disposal of more complex and polluting construction materials and technical components.

5.12. High-rise offers less *flexibility or “generality”* as a building type, hence less resilience to future modification and adaptation - another key sustainability factor.

The above list does not pretend to be exhaustive, but it underlines how low-rise may offer advantages in terms of the “new” sustainability agenda of environment, energy and climate emissions. More research is certainly needed on the relative merits of low-dense versus high-rise options.

6. FURTHER DISCUSSION ON TRANSPORT

A note must be added on the issue of urban transport or urban mobility. In developing countries, acquisition of a private car is a seemingly unstoppable ambition or is considered as a matter of status. In addition, in hot climates they make a large contribution to the heat island effect. Transport is recognized as perhaps the toughest challenge in designing sustainable cities [7]. In life cycle analyses (LCA) of buildings, if transport to and from the buildings is included, as in Norwegian LCA systems, it forms the major part of the total energy and climate impacts [8]. This again highlights the new perspective that the sustainability agenda brings to urban planning.

Whatever the urban density, transport is the key to energy and GHG reductions. Whilst the "compact city" optimizes transport hubs and public transit, it often overlooks the key eco-design goal of walkable cities. Where cars are given priority, vast areas of city land are occupied by roads and underground parking: and congestion (inefficient mobility, the opposite of the goal) is inevitable. In walkable developments, such as the acclaimed Vauban eco-district in Freiburg, Germany, inhabitants possess cars, but do not need to use them much [9]. Therefore, traffic occupies much less space (and causes less pollution, noise, and danger). A walkable city *cannot be* a car city.

In other words, high urban density *only* makes sense if there is low car use. Very low densities on the other hand – the "suburban sprawl" paradigm – is obviously at the other extreme, necessitating high transport emissions.

Figure 3 Vauban housing model, Freiburg, Germany (left);
Figure 4 High rise model of Ningbo block H, China (right)

7. CONCLUSIONS

New considerations relating to sustainability – energy and climate in particular – demand that we reconsider future paradigms of urban form. We have argued that high-rise may for many reasons often be less favorable than low-dense urban forms, especially in energy/climate terms.

Whereas high-rise is often seen as necessary in order to achieve high population densities, studies show, perhaps surprisingly, that equally high population densities can in fact be achieved with low-rise typologies.

There are social, spatial and economic issues as well. Typical high-rise blocks create gated communities, are a poor environment for children, and are unsuitable for user participation and management. Debate as to parameters for sustainable cities is ongoing [10]; but all of the above may be key factors; especially in developing country cities, which by definition comprise many low cost areas. This is where the human needs are greatest. In low-income projects, high-rise construction quality is also likely to be quite poor, which may also argue against high-rise as an appropriate model.

Traditional settlements in many cultures were low-dense, from Mediterranean towns to North African *medinas* or Chinese *hutong*. Low-dense urban development was a popular concept in recent decades, not least in the Nordic countries, due to the social qualities it offers; environmental concerns now offer new reasons.

The science of life cycle studies gives us a new way of seeing things. It is within this perspective that choices of urban density take on new dimensions, which we have outlined here. This paper does not pretend to offer answers so much as questions. However, many of the above points are relatively "new" considerations that argue for renewed interest in low-dense type urban solutions.

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